Q10 – Scalar Transport and Coherent Phase Evolution in Scalar–Conformal NUVO Systems

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Abstract

The preceding papers in the Q-series established the existence of admissible closure states and their transport behavior within the scalar–conformal NUVO framework. In particular, Q8 formulated the continuous transport of closure structures along well-defined worldlines, while Q9 demonstrated that coherence arises as a compatibility condition on exchange interactions along such paths.

In the present work, we introduce a derived scalar quantity—phase—as the cumulative geometric measure associated with transport of closure states through the scalar field. This phase is not postulated as a wave property, nor introduced through operator formalism, but emerges directly from consistency requirements on transport and exchange along admissible trajectories.

We show that local phase gradients encode transport direction and rate, and that coherence is equivalent to a path-compatibility condition on phase accumulation. Closed transport loops impose a phase closure condition, yielding discrete admissible structures consistent with the quantization results of Q7 [1]. Scalar geometry enters explicitly through modulation of phase accumulation, linking curvature to coherence.

No probabilistic assumptions, wave ontology, or operator structures are introduced. Phase is interpreted strictly as a geometric bookkeeping quantity associated with transport consistency. The results establish the minimal structure required for a full transport law, developed in the subsequent paper, and provide the necessary foundation for the emergence of Schrödinger-type dynamics as a limiting description.

Notation and Conventions

- $\mathcal{M}$ denotes the spacetime manifold.
- η denotes the reference Lorentzian metric (typically Minkowski in a global chart).
- g denotes the physical metric.
- The scalar field $\Lambda : \mathcal{M} \to \mathbb{R}_{>0}$ is the NUVO modulation field.
- The physical metric is scalar–conformal:

$$g_{\mu\nu} = \Lambda^2 \, \eta_{\mu\nu}.$$

[*]Bibliography is provisional. Cross-references to companion NUVO-series papers (M-, SR-, Q-, QB-, QM-series) will be updated with Zenodo DOIs in subsequent versions.

- $\Lambda_0 > 0$ denotes the baseline scalar availability level supported by the intrinsic delivery structure of the underlying field. In the absence of localized structural occupation the scalar field satisfies $\Lambda(x) = \Lambda_0$.
- The dimensionless scalar diagnostic is

$$\lambda(x) := \frac{\Lambda(x)}{\Lambda_0}.$$

- The scalar field represents the *locally available structural capacity* of the underlying delivery field. Localized structures may reduce this availability through occupation or transport, but the intrinsic delivery baseline Λ_0 remains fixed.
- Greek indices $\mu, \nu, \ldots$ range over spacetime coordinates $0, 1, 2, 3$.
- We use the Einstein summation convention unless explicitly stated otherwise.

Remark 0.1. *Unless otherwise stated, the background signature is* $(-, +, +, +)$.

This manuscript is mathematical in scope. It establishes definitions, structural identities, and variational consequences within a scalar–conformal setting. Sector reductions and correspondence limits are recorded only when explicitly stated as additional assumptions and are not used as premises in derivations.No claim of full dynamical equivalence to general relativity, quantum mechanics, or classical field theories is made at the level of the present foundational development. Where later papers compare limiting behavior, those comparisons are presented as correspondence targets rather than as identity statements.The NUVO program is organized as a sequence of internally consistent mathematical papers. Foundational papers (M-series) fix the scalar–conformal geometry, variational structure, and notation. Subsequent papers treat sectoral reductions (gravity, exchange, quantization, and bound-state structure) as controlled specializations of the foundational framework.**Scalar ontology.** The scalar field Λ represents the *locally available structural capacity* of an underlying delivery field permeating spacetime. The baseline level Λ_0 denotes the availability supported by this intrinsic delivery structure in the absence of structural occupation. Localized structures or transport processes may reduce the available capacity relative to this baseline, but the intrinsic delivery baseline itself is not altered. Consequently the scalar field measures the *available portion* of structural capacity rather than the intrinsic production of the underlying field.

1 Introduction

1.1 Position within the Q-Series

The Q-series develops the exchange and closure sector of the scalar–conformal NUVO framework, building from admissible closure conditions to transport and interaction structure. In Q7, closure conditions were shown to yield discrete admissible configurations, establishing the foundation for quantized structure without recourse to external postulates. Q8 [2] extended this framework by introducing the transport of closure states along continuous worldlines, while Q9 demonstrated that coherence arises from compatibility of exchange interaction along such transport paths.

The present paper continues this development by introducing a derived quantity—phase—that encodes the cumulative effect of transport and exchange along admissible trajectories. This construction represents a necessary intermediate step between transport structure (Q8–Q9) and the full transport law developed in subsequent work.

As in the preceding Q-series papers, the present analysis is carried out entirely within the exchange sector. The quantities introduced below describe transport-consistent exchange structure along admissible closure trajectories and should not be interpreted as support-sector delivery variables, anchor-sustaining intake, or primitive dynamical forces.

1.2 Scope and Objectives

The primary objective of this paper is to establish phase as a geometric quantity arising from transport, rather than as a postulated wave property. Specifically, we aim to:

- Define an incremental phase associated with transport of closure states under exchange interaction;
- Show that phase accumulates along transport paths and depends on both trajectory and scalar geometry;
- Demonstrate that local phase gradients encode transport direction and rate;
- Establish coherence as a consistency condition on phase accumulation across admissible paths;
- Derive a phase closure condition for closed transport loops, connecting directly to the discrete closure results of Q7.

Throughout, no wave-based assumptions are introduced, and no operator formalism is employed. The construction is entirely geometric and deterministic, based solely on transport and exchange structure already developed in the series.

1.3 Interpretive Framework

In conventional quantum formulations, phase is typically introduced as an intrinsic component of a wavefunction [3, 4]. In contrast, the present framework treats phase as a derived quantity that arises from the requirement of consistent transport of closure structures through the scalar field.

Under this interpretation, phase serves as a bookkeeping measure of cumulative transport and exchange effects. Its gradient reflects the local direction and rate of admissible transport, while differences in phase between paths encode compatibility conditions. Coherence is thus not an interference phenomenon, but a statement that multiple transport paths yield consistent phase accumulation.

This perspective removes the need for probabilistic interpretation at the level of fundamental structure. No assumptions are made regarding measurement, probability amplitudes, or statistical interpretation. Such concepts, if introduced, arise only as secondary interpretations of the underlying geometric and transport-consistent framework.

Finally, it is emphasized that the present work does not attempt to construct a dynamical wave equation. Rather, it establishes the minimal structure required for such a construction. The emergence of a full transport law, and its correspondence to known dynamical equations, is deferred to subsequent papers in the series.

2 Transport Structure from Prior Results

2.1 Closure Transport and Worldline Structure

In Q8, the transport of admissible closure states was formulated as a continuous process along well-defined trajectories in scalar–conformal NUVO space. Each closure structure is associated with a persistent anchor whose motion defines a continuous worldline

$$\gamma : \tau \mapsto x^{\mu}(\tau),$$

parameterized by an intrinsic transport parameter τ.

Transport along γ is not arbitrary but constrained by closure admissibility and scalar geometry. The anchor remains a coherent structure under transport, and its trajectory represents the evolution of a closure state through the scalar field.

This worldline description provides the geometric backbone for all subsequent constructions. In particular, all quantities introduced in the present paper will be defined relative to transport along such admissible trajectories.

2.2 Exchange Interaction Along Transport Paths

In Q9, it was shown that transport is accompanied by continuous exchange interaction between the closure structure and the surrounding scalar environment. This interaction is not a discrete event but a distributed process along the trajectory γ.

Let γ be a transport path connecting two points x_1 and x_2. Along this path, the closure structure experiences a locally defined exchange interaction characterized by a scalar rate function

$$\mathcal{E}(x) \quad \text{for } x \in \gamma,$$

which encodes the interaction between the transported structure and the ambient scalar field.

The cumulative effect of exchange along the path is therefore expressed as a path-integrated quantity of the form

$$\int_{\gamma} \mathcal{E}(x)\, d\tau,$$

which depends explicitly on both the trajectory and the scalar geometry through which the transport occurs.

This exchange interaction modifies the effective transport behavior of the closure state and will serve as a key input in the definition of phase in the subsequent section.

2.3 Capacity Distribution Along Trajectories

The exchange interaction is governed by the local distribution of scalar capacity along the transport path. As established in prior work, the scalar field $\lambda(x)$ determines the local availability of capacity, and thus modulates the interaction between transported structures and the environment.

Accordingly, the exchange rate $\mathcal{E}(x)$ may be understood as a function of both the local scalar field and its variation, i.e.

$$\mathcal{E}(x) = \mathcal{E}\big(\lambda(x), \nabla\lambda(x), \dots\big).$$

This dependence ensures that transport is sensitive to scalar geometry. Regions of varying λ induce corresponding variations in exchange interaction, thereby influencing the cumulative transport behavior along γ.

It is emphasized that the present framework does not assign independent dynamical status to $\mathcal{E}(x)$; rather, it is a derived quantity reflecting the interaction of closure transport with scalar geometry.

2.4 Summary of Transport Structure

The preceding results establish three key elements that will be used in the construction of phase:

- Transport occurs along admissible worldlines γ defined by closure persistence;
- Exchange interaction is continuously distributed along these paths and accumulates as a path-dependent quantity;
- The scalar field $\lambda(x)$ modulates exchange interaction through local capacity availability.

Together, these elements define a transport framework in which all relevant quantities are path-dependent and geometrically determined. The introduction of phase in the next section will be based entirely on these transport and exchange properties.

3 Emergence of Phase from Transport

Origin in closure compatibility under transport. The phase quantity introduced here arises as a representation of closure compatibility under transport. As established in Q2 [5], admissible configurations satisfy a scalar-modulated return condition over cycles. When such closure structures are transported, continuous exchange with the scalar geometry produces a distributed accumulation of transport content.

The phase construction introduced below provides the minimal scalar representation of this accumulated transport, encoding the recurrence of compatibility conditions along admissible trajectories.

3.1 Necessity and Uniqueness of a Phase-Like Quantity

The transport structure recalled in Section 2 imposes three minimal requirements on any scalar quantity intended to compare admissible transport histories:

- it must accumulate along transport paths;
- it must be local in the sense that its infinitesimal increment depends only on the local transport state and scalar geometry;
- it must support comparison between distinct admissible paths joining the same endpoints, and in particular closed-loop compatibility conditions.

A scalar quantity satisfying these requirements must arise from a local increment of the form

$$d\chi = F(x)\, d\tau,$$

where $F(x)$ is a scalar rate determined by the local transport and exchange structure. Any dependence on higher path history beyond the local state would violate locality, while any non-additive assignment would fail to support cumulative comparison across concatenated path segments.

Since the exchange interaction rate $\mathcal{E}(x)$ is precisely the local scalar quantity already available from the transport structure of Section 2, the minimal admissible construction is therefore

$$d\chi \propto \mathcal{E}(x)\, d\tau.$$

Up to an overall normalization constant, this construction is unique. We therefore identify the corresponding scalar quantity with phase and write

$$d\phi := \kappa\, \mathcal{E}(x)\, d\tau.$$

Thus phase is not introduced here as an additional primitive object. Rather, it is the unique scalar bookkeeping quantity, up to normalization, that accumulates locally along admissible transport paths and supports comparison of transport histories.

3.2 Incremental Phase Definition

Given the transport structure established in Section 2 and the uniqueness argument above, we now define the scalar quantity ϕ associated with the cumulative effect of transport along an admissible trajectory.

Let γ be a transport path parameterized by τ. We define an incremental phase $d\phi$ along γ as a scalar measure of the local transport and exchange interaction:

$$d\phi := \kappa\, \mathcal{E}(x)\, d\tau,$$

where $\mathcal{E}(x)$ is the exchange interaction rate introduced in Section 2, and κ is a normalization constant to be determined by global consistency conditions.

This definition assigns a scalar increment to each infinitesimal segment of the transport path, reflecting the cumulative influence of exchange interaction on the transported closure structure.

3.3 Accumulation Along Transport Paths

The total phase accumulated along a transport path γ from x_1 to x_2 is defined as the path integral

$$\phi[\gamma] := \int_\gamma d\phi = \kappa \int_\gamma \mathcal{E}(x)\, d\tau.$$

This construction makes explicit that phase is a path-dependent quantity. Different admissible trajectories connecting the same endpoints may, in general, yield different accumulated phase.

Accordingly, phase does not represent a local field defined independently at each point, but rather a cumulative quantity associated with transport between points.

3.4 Dependence on Scalar Geometry

Since the exchange rate $\mathcal{E}(x)$ depends on the scalar field $\lambda(x)$ and its variation, the accumulated phase is sensitive to the underlying scalar geometry. Explicitly, one may write

$$\mathcal{E}(x) = \mathcal{E}\big(\lambda(x), \nabla\lambda(x), \dots\big),$$

so that

$$\phi[\gamma] = \kappa \int_\gamma \mathcal{E}\big(\lambda(x), \nabla\lambda(x), \dots\big)\, d\tau.$$

Regions of varying scalar capacity therefore induce corresponding variations in phase accumulation. In this sense, phase encodes not only the transport path, but also the geometric structure through which the transport occurs.

3.5 Phase as a Derived Transport Quantity

The phase ϕ introduced here is not an independent dynamical variable, nor is it associated with an underlying wave structure. It is a derived scalar quantity that records the cumulative effect of transport and exchange along admissible trajectories.

Its role is therefore purely geometric: it provides a consistent measure of transport history that can be compared across different paths. All subsequent uses of phase in this framework will rely only on this transport-derived definition.

3.6 Normalization and Global Consistency

The constant κ sets the scale of phase accumulation and is not fixed by local considerations alone. However, it is not arbitrary. Its normalization is constrained by the global closure structure developed in the earlier Q-series.

In particular, Q4 [6] identified a closure-action scale associated with a complete coherent return cycle, and Q5 [7] showed that exchange-mediated transport is naturally measured relative to that same action scale. Accordingly, phase accumulation must be normalized so that one full coherence-compatible action increment corresponds to one full phase cycle in the chosen representation.

This means that κ is fixed by comparison between the exchange-integrated transport along a path and the closure-action scale already derived in the series. Equivalently, κ converts local exchange accumulation into phase measured in units of coherent closure.

Thus κ is determined up to representational convention by the requirement that phase accumulation be consistent with the closure-action structure established in Q4–Q5, rather than by an independent local postulate.

In particular, once a representation is chosen in which one full closure-action unit corresponds to one full phase cycle, κ becomes the corresponding global normalization constant linking local exchange transport to phase accumulation.

This normalization identifies phase accumulation as the transport action measured in units of the closure-action scale, thereby linking phase directly to the invariant exchange action associated with elementary closure cycles.

This establishes phase as a globally constrained quantity derived from local transport and exchange, with normalization anchored to the closure-action scale already present in the Q-series.

4 Phase Gradient and Effective Transport Direction

4.1 Local Phase Variation

Although the phase $\phi[\gamma]$ is defined as a path-dependent quantity, it is useful to consider its local variation in a neighborhood of a point x. For sufficiently small segments of admissible transport, the incremental phase $d\phi$ may be expressed in terms of local variations in position.

Accordingly, we define the local phase gradient through variation over nearby admissible path segments sharing the same local point x:

$$\nabla\phi(x).$$

This quantity characterizes how the accumulated phase varies under infinitesimal changes of admissible transport through a neighborhood of x. It should therefore be understood as a local differential representation of phase accumulation, even though the full phase remains path-dependent globally.

4.2 Relation to Transport Direction

Let γ be an admissible transport trajectory passing through a point x, with tangent vector

$$u^\mu = \frac{dx^\mu}{d\tau}.$$

The incremental phase along γ is given by

$$d\phi = \kappa\,\mathcal{E}(x)\,d\tau.$$

Expressing this in terms of spatial displacement, we obtain

$$d\phi = \nabla\phi(x) \cdot dx,$$

so that along the trajectory

$$\nabla\phi(x) \cdot u = \kappa\,\mathcal{E}(x).$$

This relation shows that the phase gradient is aligned with admissible transport directions, and that its projection along the trajectory encodes the local exchange-modulated transport rate.

4.3 Effective Transport Encoding

The phase gradient $\nabla\phi$ thus serves as a local encoding of transport structure. Specifically:

- Its direction identifies admissible transport directions;
- Its magnitude reflects the local rate of exchange-modulated transport;
- Its variation captures changes in transport behavior induced by scalar geometry.

Importantly, this interpretation does not assign independent dynamical status to $\nabla\phi$. It is a derived quantity that summarizes the local behavior of transport and exchange, rather than generating motion through an independent law.

4.4 Dependence on Scalar Geometry

Since the exchange rate $\mathcal{E}(x)$ depends on the scalar field $\lambda(x)$, the phase gradient inherits this dependence. Regions of varying scalar capacity therefore produce corresponding variations in $\nabla\phi$.

In particular, gradients of λ modify the local alignment and magnitude of $\nabla\phi$, thereby influencing admissible transport directions and coherence conditions.

4.5 Absence of Dynamical Interpretation

While the phase gradient provides a useful local characterization of transport, it is emphasized that no dynamical law is introduced at this stage. The relation

$$\nabla\phi(x) \cdot u = \kappa\,\mathcal{E}(x)$$

is purely kinematic, expressing consistency between accumulated phase and transport along admissible trajectories.

No identification is made between $\nabla\phi$ and any independent physical quantity such as momentum, nor is any operator structure introduced. Such interpretations, if adopted, arise only at the level of alternative mathematical representation in later developments.

5 Coherence as Transport Consistency

5.1 Definition of Coherence

Let x_1 and x_2 be two points in scalar–conformal NUVO space, and let γ_1 and γ_2 be two admissible transport paths connecting these points. Each path carries an associated accumulated phase,

$$\phi[\gamma_1], \quad \phi[\gamma_2],$$

as defined in Section 3.

We define the phase difference between the two paths as

$$\Delta\phi := \phi[\gamma_1] - \phi[\gamma_2].$$

The two transport paths are said to be *coherent* if their phase difference satisfies a compatibility condition of the form

$$\Delta\phi = \Phi_c,$$

where Φ_c is a characteristic coherence scale determined by the transport structure, exchange interaction, and scalar geometry.

Nevertheless, once the transport structure of a specific system is fixed, one may pass to a normalized representation in which the coherence increment is expressed relative to a standard phase cycle. Such a representation does not alter the underlying system-dependent coherence structure; it merely provides a convenient encoding of it.

5.2 Coherence Scale and Structural Compatibility

The coherence scale Φ_c represents the minimal phase difference for which transport along distinct admissible paths yields equivalent structural outcomes. That is, when

$$\Delta\phi = \Phi_c,$$

the transported closure structure arrives at x_2 in a configuration that is compatible across both paths.

In this sense, coherence expresses a condition of structural consistency rather than periodic closure. The value of Φ_c encodes the intrinsic relationship between transport, exchange, and geometry for the system under consideration.

For example, in bound systems such as hydrogen, the coherence scale may correspond to a non-integer cycle structure determined by the underlying scalar geometry, rather than to a simple integer multiple of a universal phase unit.

5.3 Path Compatibility Conditions

In general, different admissible paths between the same endpoints will accumulate different phase due to variations in exchange interaction and scalar geometry. Coherence therefore imposes a constraint on the set of admissible paths.

Specifically, a set of paths $\{\gamma_i\}$ is coherent if their phase differences are compatible with the coherence scale Φ_c. More generally, compatibility may be expressed as

$$\Delta\phi = m\,\Phi_c, \quad m \in \mathbb{Z},$$

which represents repeated coherence alignment over multiple transport cycles.

This condition defines a discrete equivalence relation on admissible transport paths, partitioning them into classes of mutually compatible trajectories.

5.4 Coherence as a Geometric Condition

The coherence condition is purely geometric in origin. It depends only on accumulated phase along transport paths, which is itself determined by exchange interaction and scalar geometry.

No assumption of wave superposition, oscillatory behavior, or probabilistic interpretation is required. Coherence arises solely from the requirement that transport-induced phase accumulation be structurally consistent across admissible paths.

5.5 Local and Global Aspects of Coherence

Coherence exhibits both local and global structure:

- **Local coherence** corresponds to smooth variation of phase across nearby transport paths, ensuring compatibility of transport in a local neighborhood;
- **Global coherence** corresponds to the existence of discrete phase alignments governed by the coherence scale Φ_c, including repeated alignments of the form $\Delta\phi = m\Phi_c$.

Local coherence governs the continuity of transport structure, while global coherence introduces discrete constraints on admissible transport configurations.

5.6 Distinction from Periodic Closure

It is important to distinguish coherence from periodic closure. The condition

$$\Delta\phi = m\,\Phi_c$$

defines structural compatibility, but does not imply that the phase itself is periodic with a universal period.

Periodic closure arises only when the coherence scale admits a representation in which Φ_c corresponds to a fixed cycle, such as 2π, or when repeated coherence alignment produces an effective periodicity.

Thus, conventional periodic conditions of the form $\Delta\phi = 2\pi n$ are not fundamental, but emerge only in specific representations or limiting regimes.

The coherence scale Φ_c is not freely chosen but is determined by the underlying closure-action structure and scalar geometry of the system. It therefore reflects intrinsic transport compatibility rather than an externally imposed parameter.

5.7 Implications for Admissible Transport

The introduction of a coherence scale Φ_c restricts the set of admissible transport configurations. Only those sets of paths that satisfy the coherence condition are physically realizable as consistent transport processes.

As a result, coherence introduces a discrete structure into the otherwise continuous transport framework. This discrete structure will be shown in the next section to correspond to closure conditions for transport loops, providing the bridge to quantized admissible states.

6 Closed Transport Loops and Phase Closure

6.1 Phase Accumulation Along Closed Paths

Consider a closed admissible transport path γ such that

$$\gamma : x \to x,$$

i.e., the trajectory begins and ends at the same point in scalar– conformal NUVO space.

The total accumulated phase along γ is given by

$$\phi[\gamma] = \oint_\gamma d\phi = \kappa \oint_\gamma \mathcal{E}(x)\, d\tau.$$

This quantity represents the cumulative transport and exchange effect experienced by a closure structure after completing one full cycle along the path.

6.2 Closure Condition from Transport Consistency

Relation to the scalar-modulated closure functional. The phase closure condition introduced here is not an independent postulate, but a reformulation of the scalar-modulated return condition established in Q2,

$$k \oint_\gamma \lambda_{\text{eff}}(x, u)\, ds = L_\gamma.$$

The accumulated phase

$$\phi[\gamma] = \kappa \oint_\gamma \mathcal{E}(x)\, d\tau$$

provides a normalized measure of exchange-modulated transport along the cycle. The requirement

$$\phi[\gamma] = m\, \Phi_c$$

therefore represents the same closure compatibility condition expressed in terms of transport-accumulated phase rather than scalar-modulated arc length.

Thus the phase closure condition is equivalent to the Q2 closure functional under the identification of phase with normalized transport action.

For a closed transport loop to represent an admissible process, the closure structure must return to a configuration that is compatible with its initial state. This imposes a consistency condition on the accumulated phase.

Specifically, closure requires that the total phase accumulated along the loop be compatible with the coherence structure introduced in Section 5. That is, there exists an integer $m \in \mathbb{Z}$ such that

$$\phi[\gamma] = m\, \Phi_c,$$

where Φ_c is the coherence scale.

This condition expresses the requirement that transport around the loop produces an integer number of coherence-aligned phase increments, ensuring structural compatibility upon return to the initial point.

6.3 Discrete Structure from Loop Closure

The closure condition

$$\oint_\gamma d\phi = m\,\Phi_c$$

introduces a discrete structure into the space of admissible closed transport paths. Not all closed trajectories satisfy this condition; only those for which the accumulated phase aligns with integer multiples of the coherence scale are admissible.

This discrete selection of admissible loops corresponds directly to the quantized closure structures identified in Q7. In that context, admissible states arise from closure conditions on transport, and the present formulation shows that these conditions can be expressed in terms of phase accumulation.

6.4 Normalization of Phase Scale

The normalization constant κ introduced in Section 3 is not arbitrary, but is constrained by the requirement that closure conditions be satisfied for physically admissible transport loops.

Specifically, κ sets the conversion between exchange-integrated transport along a path and the coherence scale Φ_c. The relation

$$\kappa \oint_\gamma \mathcal{E}(x)\,d\tau = m\,\Phi_c$$

determines κ up to a universal scaling, once the coherence structure of the system is fixed.

In this sense, κ and Φ_c are not independent free inputs: κ sets the conversion from local exchange accumulation to phase, while Φ_c records the system-dependent coherence increment with which that normalized phase must be compared.

6.5 Dependence on Scalar Geometry

Since the exchange rate $\mathcal{E}(x)$ depends on the scalar field $\lambda(x)$, the accumulated phase along a closed loop is sensitive to the geometry of the path.

In particular, variations in λ along γ modify the value of the loop integral

$$\oint_\gamma \mathcal{E}(x)\,d\tau,$$

and thus influence whether the closure condition is satisfied.

This demonstrates that quantized closure is not imposed externally, but emerges from the interaction between transport, exchange, and scalar geometry.

6.6 Emergence of Effective Periodicity

The closure condition

$$\phi[\gamma] = m\,\Phi_c$$

does not, in general, imply that phase is periodic with a universal period. However, in cases where the coherence scale admits a normalized representation, repeated closure cycles may produce an effective periodicity.

In such representations, one may define a normalized phase variable $\tilde{\phi}$ for which the coherence scale corresponds to a fixed cycle. In that case, the closure condition may take the form

$$\tilde{\phi}[\gamma] = 2\pi n,$$

for some integer n.

It is emphasized that this periodic form is not fundamental, but arises as a consequence of normalization. The underlying closure condition remains expressed in terms of the coherence scale Φ_c.

6.7 Connection to Quantized Admissible States

The discrete set of admissible closed transport loops determined by

$$\oint_\gamma d\phi = m\,\Phi_c$$

corresponds to the set of quantized admissible states identified in Q7. Each admissible state may be associated with a class of closed transport paths satisfying the phase closure condition.

This establishes a direct correspondence between phase-based closure and the quantized structure of closure states, providing a geometric foundation for discrete spectra without invoking wave or operator formalism.

7 Scalar Geometry Contribution to Phase Evolution

7.1 Role of the Scalar Field

The scalar field $\lambda(x)$ determines the local geometric structure of NUVO space through the conformal metric. As established in prior work, λ governs the local availability of capacity and thus modulates the interaction between transported closure structures and the surrounding environment.

Since the exchange rate $\mathcal{E}(x)$ depends on $\lambda(x)$ and its variation, the incremental phase defined in Section 3 inherits this dependence. Explicitly,

$$d\phi = \kappa\,\mathcal{E}\big(\lambda(x), \nabla\lambda(x), \dots\big)\,d\tau.$$

Thus, phase accumulation along a transport path is directly influenced by the scalar geometry.

7.2 Geometric Modulation of Phase Accumulation

Let γ be an admissible transport path. The accumulated phase along γ may be expressed as

$$\phi[\gamma] = \kappa \int_\gamma \mathcal{E}\big(\lambda(x), \nabla\lambda(x), \dots\big)\,d\tau.$$

Variations in λ along the path therefore induce corresponding variations in phase accumulation. Regions of increasing or decreasing scalar capacity modify the rate at which phase is accumulated, altering the total phase associated with the trajectory.

In this sense, λ acts as a geometric modulator of transport, affecting both the magnitude and distribution of phase along admissible paths.

7.3 Curvature Effects on Transport Consistency

The dependence of $\mathcal{E}(x)$ on $\nabla\lambda(x)$ implies that spatial variation of the scalar field introduces curvature-dependent effects into phase accumulation.

Two transport paths connecting the same endpoints but traversing different regions of scalar geometry will, in general, accumulate different phase. Consequently, coherence conditions depend not only on the endpoints of transport, but also on the geometric structure of the paths.

This establishes a direct connection between scalar curvature and transport consistency: variations in λ influence whether two paths satisfy the coherence condition introduced in Section 5.

7.4 Geometric Modulation of Coherence Scale

Since coherence is defined in terms of accumulated phase, the coherence scale Φ_c inherits dependence on scalar geometry. In particular, the effective value of Φ_c for a given system reflects the integrated influence of λ along admissible transport paths.

This implies that coherence is not a purely local property, but a global characteristic determined by the interplay of transport, exchange, and scalar geometry. Systems with different geometric configurations may therefore exhibit distinct coherence scales.

7.5 Sensitivity of Closure Conditions to Geometry

The closure condition

$$\oint_{\gamma} d\phi = m\,\Phi_c$$

depends explicitly on the scalar field through the exchange rate $\mathcal{E}(x)$. As a result, the set of admissible closed transport loops is sensitive to the geometric structure of λ.

Changes in scalar geometry may shift the value of the loop integral, thereby altering which transport paths satisfy the closure condition. This provides a geometric mechanism for modifying the discrete spectrum of admissible closure states.

7.6 Interpretation as Geometric Control of Transport

The results above show that scalar geometry plays an active role in determining transport behavior. Rather than serving as a passive background, the scalar field $\lambda(x)$ controls the accumulation of phase, the compatibility of transport paths, and the admissibility of closed loops.

This control is entirely geometric: it arises from the dependence of exchange interaction on the scalar field and its variation, and does not require the introduction of additional dynamical assumptions.

7.7 Preparation for Transport Law

The dependence of phase accumulation on $\lambda(x)$ and its variation indicates that transport behavior is governed by a structured relationship between geometry and exchange.

While the present paper treats phase as a derived quantity, the results suggest the existence of a more complete description in which transport, exchange, and scalar geometry are unified within a single evolution framework.

The development of this full transport law, incorporating the geometric dependence identified here, is the subject of the subsequent paper in the series.

8 Interpretive Clarifications (Non-Dynamical)

8.1 Absence of Wave Ontology

The phase ϕ introduced in this work is not associated with an underlying wave or oscillatory entity. It is defined purely as a cumulative measure of transport and exchange along admissible trajectories.

No assumption is made regarding the existence of a wavefunction, nor is any oscillatory or periodic behavior imposed at the level of fundamental structure. Any wave-like interpretation that may arise in subsequent developments is therefore secondary and representational, rather than fundamental.

8.2 Absence of Probabilistic Interpretation

The present framework does not introduce probability as a primitive concept. Phase and coherence are defined entirely in terms of deterministic transport and geometric consistency.

Quantities such as phase accumulation, coherence scale, and closure conditions arise from transport structure and scalar geometry, without reference to statistical interpretation or measurement postulates.

Any probabilistic interpretation, if adopted, must therefore be understood as an emergent or effective description rather than a fundamental aspect of the theory.

8.3 Phase as a Geometric Bookkeeping Quantity

The phase ϕ serves as a bookkeeping quantity that records the cumulative effect of transport and exchange along admissible paths. It does not generate motion, nor does it represent an independent physical field.

Its utility lies in providing a consistent scalar measure that can be compared across different transport paths, enabling the definition of coherence and closure conditions.

8.4 Distinction from Conventional Formalisms

In conventional quantum formulations, phase is typically introduced as a component of a complex amplitude, and is directly associated with operator-based dynamics and wave evolution.

In contrast, the present construction does not rely on operator formalism or predefined dynamical equations. The phase arises independently of any such structure and is defined solely through transport and exchange.

Alternative mathematical representations, including operator-based formalisms, may be constructed to encode the structures developed here. However, such representations are not unique and do not constitute the foundational description.

8.5 Separation of Structure and Representation

It is important to distinguish between the structural content of the theory and the mathematical representations used to describe it. The present work establishes a transport-based geometric structure from which phase, coherence, and closure emerge.

Different mathematical formalisms may be used to represent this structure, including those that resemble conventional quantum mechanics. Such representations are secondary and must be understood as encodings of the underlying transport-consistent framework, rather than as fundamental definitions.

8.6 Scope of the Present Construction

The present paper establishes the geometric and transport-based structure necessary to define phase and coherence. It does not attempt to construct a full dynamical law governing the evolution of these quantities.

In particular, no second-order evolution equation is introduced. The development of a complete transport law, incorporating the geometric dependencies identified here, is deferred to subsequent work.

9 Transition to Full Transport Law

9.1 Limitations of the Present Construction

The preceding sections establish phase as a transport-derived quantity and coherence as a condition of path compatibility. These results provide a consistent geometric framework for describing admissible transport and closure structure.

However, the present construction remains kinematic in nature. Phase is defined through accumulation along transport paths, and coherence is expressed as a compatibility condition, but no law governing the evolution of transport itself has been introduced.

In particular, the framework does not yet specify how transport paths are determined, how phase evolves under changing conditions, or how closure structures respond dynamically to variations in scalar geometry.

9.2 Need for a Unified Transport Description

The dependence of phase on exchange interaction and scalar geometry, as developed in Sections 3 and 7, indicates that transport behavior is not arbitrary but governed by an underlying structure linking geometry, exchange, and admissibility.

This suggests the existence of a unified transport law in which:

- transport trajectories,
- exchange interaction, and
- scalar geometry

are coupled within a single descriptive framework.

Such a law must reproduce the kinematic relations derived here while providing a rule for the evolution of transport and phase in general settings.

9.3 Toward a Second-Order Transport Structure

The phase construction developed in this paper is inherently first-order, defined through incremental accumulation along a path. A complete description of transport is expected to require a higher-order structure that determines how phase and transport evolve together.

In particular, the dependence of phase accumulation on the spatial variation of $\lambda(x)$ suggests that second-order relations involving geometric variation will play a central role in the full transport law.

The identification and formulation of this higher-order structure is the next step in the development of the Q-series.

9.4 Preview of Subsequent Development

The subsequent paper [8] will introduce a full transport law that unifies phase, exchange, and scalar geometry within a single framework. This development will extend the present kinematic construction to a dynamical description, in which the evolution of transport and phase is governed by a well-defined equation.

Within that framework, it will be shown that familiar dynamical structures [3] may emerge as limiting representations of the underlying transport law. Such representations are not assumed at the outset, but arise naturally from the geometric and transport-consistent structure established in the present work.

10 Summary

In this paper, we have established phase as a derived quantity arising from the transport of closure structures in scalar–conformal NUVO space. Building on the transport framework developed in Q8 and the coherence structure introduced in Q9, phase was defined as the cumulative effect of exchange interaction along admissible transport paths.

The key results of this work are as follows:

- Phase was introduced as a path-dependent scalar quantity derived from transport and exchange, without invoking wave assumptions or operator formalism;
- The phase construction was shown to be unique up to normalization among scalar bookkeeping quantities that accumulate locally along admissible transport paths and support path comparison and loop closure;
- The local phase gradient was shown to encode transport direction and rate, providing a geometric characterization of admissible transport;
- Coherence was defined as a condition of path compatibility, governed by a system-dependent coherence scale Φ_c, rather than by a universal periodic condition;
- Closed transport loops were shown to impose a phase closure condition of the form $\oint d\phi = m\Phi_c$, yielding a discrete set of admissible configurations consistent with the closure structure derived in Q7;
- The normalization of phase was shown to be globally anchored to the closure-action structure established in Q4–Q5, so that the present phase formalism introduces no new independent scale;
- The scalar field $\lambda(x)$ was shown to modulate phase accumulation, coherence, and closure, establishing geometry as an active component of transport behavior.

These results demonstrate that discrete structure emerges naturally from transport consistency and scalar geometry, without requiring probabilistic interpretation, wave ontology, or externally imposed quantization conditions.

The construction presented here is entirely kinematic, providing the minimal geometric framework required to define phase and coherence. No dynamical law governing the evolution of transport has been assumed.

This work therefore serves as a bridge between the transport and coherence structure developed in earlier papers and the full transport law to be introduced subsequently. In that development, it will be shown that familiar dynamical representations arise as limiting forms of the underlying transport-consistent framework established here.

A Phase Definition from Exchange Rate

A.1 Incremental Phase Structure

In Section 3, the incremental phase was introduced as

$$d\phi := \kappa\, \mathcal{E}(x)\, d\tau,$$

where $\mathcal{E}(x)$ denotes the local exchange interaction rate along an admissible transport path γ, and κ is a normalization constant.

This definition assigns a scalar increment to each infinitesimal segment of transport, providing a cumulative measure of exchange-modulated transport along the path.

A.2 Dimensional Consistency

The phase ϕ is dimensionless by construction. Therefore, the product $\kappa\, \mathcal{E}(x)\, d\tau$ must also be dimensionless.

Let $[\mathcal{E}]$ denote the dimensional scale associated with the exchange rate and $[d\tau]$ the parameterization of transport. Then κ must carry dimensions such that

$$[\kappa] = \frac{1}{[\mathcal{E}]\,[d\tau]}.$$

This ensures that phase accumulation is a pure scalar quantity, independent of the choice of parameterization.

A.3 Reparameterization Invariance

The definition of phase must be independent of the specific choice of transport parameter τ. Consider a reparameterization

$$\tau \to \tau'(\tau),$$

with corresponding transformation

$$d\tau = \frac{d\tau}{d\tau'}\, d\tau'.$$

For $d\phi$ to remain invariant under this transformation, the exchange rate must transform as

$$\mathcal{E}'(x) = \mathcal{E}(x)\, \frac{d\tau}{d\tau'}.$$

Under this transformation,

$$d\phi = \kappa\, \mathcal{E}'(x)\, d\tau' = \kappa\, \mathcal{E}(x)\, d\tau,$$

so that the accumulated phase

$$\phi[\gamma] = \int_\gamma d\phi$$

is invariant under reparameterization.

This establishes that phase depends only on the geometric path and exchange structure, and not on the choice of parameterization.

A.4 Normalization Freedom and Global Constraint

The constant κ is not fixed by local considerations alone. It represents the global scaling factor relating exchange-integrated transport to phase accumulation, and its normalization must be anchored to the closure-action scale already established earlier in the Q-series.

The value of κ is constrained by closure conditions on admissible loops. Specifically, for any closed transport path γ,

$$\kappa \oint_{\gamma} \mathcal{E}(x)\, d\tau = m\, \Phi_c, \quad m \in \mathbb{Z},$$

where Φ_c is the coherence scale.

This condition determines κ up to representational convention once the coherence structure of the system is specified and the closure-action scale is chosen as the transport normalization standard.

A.5 Interpretation

The incremental phase definition

$$d\phi := \kappa\, \mathcal{E}(x)\, d\tau$$

should be interpreted as a minimal geometric construction that assigns a scalar measure to transport along admissible paths.

It does not introduce additional dynamics, nor does it assume any particular representation of phase. Rather, it provides a consistent framework for comparing transport processes and defining coherence and closure conditions.

This definition forms the basis for all subsequent constructions involving phase within the NUVO framework.

B Path Dependence and Integrability Conditions

B.1 Path Dependence of Phase Accumulation

The phase $\phi[\gamma]$ defined in Section 3 is, in general, a path-dependent quantity. For two admissible transport paths γ_1 and γ_2 connecting the same endpoints x_1 and x_2, the accumulated phase satisfies

$$\phi[\gamma_1] \neq \phi[\gamma_2]$$

in general.

This path dependence arises from the variation of the exchange rate $\mathcal{E}(x)$ along different trajectories, as well as from the underlying scalar geometry through its dependence on $\lambda(x)$ and its gradients.

B.2 Integrability Condition

A special case arises when the phase becomes path-independent. In this case, the accumulated phase between two points depends only on the endpoints and not on the specific path taken.

This occurs if and only if the incremental phase $d\phi$ is an exact differential, i.e., there exists a scalar function $\phi(x)$ such that

$$d\phi = \nabla\phi(x) \cdot dx$$

globally, and

$$\phi[\gamma] = \phi(x_2) - \phi(x_1)$$

for all admissible paths γ connecting x_1 and x_2.

Equivalently, path independence requires that the integral of $d\phi$ around any closed loop vanish:

$$\oint_\gamma d\phi = 0$$

for all closed admissible paths γ.

B.3 Non-Integrable Structure in General

In the general NUVO setting, the presence of spatial variation in $\lambda(x)$ and the corresponding dependence of $\mathcal{E}(x)$ on $\nabla\lambda(x)$ imply that $d\phi$ is not an exact differential.

Consequently,

$$\oint_\gamma d\phi \neq 0$$

for generic closed paths.

This non-vanishing loop integral reflects the intrinsic path dependence of phase accumulation and is a direct consequence of the coupling between transport and scalar geometry.

B.4 Relation to Coherence and Closure

The non-integrable nature of phase accumulation is essential for the existence of nontrivial coherence and closure conditions.

If $d\phi$ were globally exact, then all closed-loop integrals would vanish, and no discrete closure conditions would arise. In that case, coherence would be trivial, and no discrete structure would emerge from transport.

In contrast, the non-integrable structure allows for nonzero loop integrals, which may satisfy the closure condition

$$\oint_\gamma d\phi = m\,\Phi_c.$$

Thus, the existence of discrete admissible states is directly tied to the path dependence of phase.

B.5 Geometric Interpretation

The failure of $d\phi$ to be globally integrable may be interpreted as a geometric property of the scalar–conformal structure. Variations in $\lambda(x)$ induce a nontrivial transport geometry in which phase accumulation depends on the path taken through the scalar field.

This structure is analogous to geometric situations in which path dependence encodes information about the underlying geometry, though no specific formalism is assumed here.

B.6 Local Integrability and Approximate Behavior

Although phase is generally path-dependent, there may exist local regions in which $\lambda(x)$ varies slowly. In such regions, $\mathcal{E}(x)$ may be approximated as locally uniform, and the incremental phase may behave approximately as an exact differential.

In this limit,

$$\oint_\gamma d\phi \approx 0$$

for sufficiently small loops, and phase becomes approximately path-independent.

This local integrability provides a regime in which transport may be treated as effectively conservative, even though the global structure remains non-integrable.

B.7 Summary

Phase accumulation in scalar–conformal NUVO space is, in general, path-dependent due to the coupling between transport and scalar geometry. This non-integrable structure is essential for the emergence of nontrivial coherence and discrete closure conditions.

Path-independent phase arises only as a special limiting case, while the general framework requires a path-dependent description to capture the full structure of transport and closure.

C Relation to Holonomy Structure (Preview)

C.1 Loop-Based Phase Accumulation

As established in Section 6 and Appendix B, the accumulated phase along a closed transport path γ is given by

$$\phi[\gamma] = \oint_\gamma d\phi,$$

and, in general, this quantity does not vanish. Instead, it satisfies the closure condition

$$\phi[\gamma] = m\,\Phi_c,$$

for admissible loops.

This establishes that closed transport paths carry an intrinsic scalar measure associated with phase accumulation.

C.2 Path-Dependent Transport and Loop Invariants

The existence of nonzero loop integrals implies that phase accumulation encodes information about the path taken through scalar–conformal NUVO space. In particular, two paths connecting the same endpoints may produce different accumulated phase, while closed loops yield nontrivial scalar values.

This suggests that phase accumulation along closed paths defines a class of loop-dependent invariants associated with transport and exchange.

These invariants depend on the scalar field $\lambda(x)$ and its variation, and thus reflect the geometric structure of the underlying space.

C.3 Relation to Transport Geometry

The loop-dependent phase accumulation may be interpreted as a measure of the geometric structure encountered during transport. In particular, the failure of phase to be path-independent indicates that transport is influenced by a nontrivial geometric environment.

From this perspective, the quantity

$$\oint_\gamma d\phi$$

captures the cumulative geometric effect experienced by a transported closure structure as it traverses a closed path.

C.4 Preview of Holonomy Interpretation

In more developed geometric frameworks, quantities defined by accumulation around closed loops are often associated with holonomy [9, 10], i.e., the failure of a transported quantity to return to its original state after parallel transport along a closed path.

While no such formalism is assumed in the present work, the phase closure condition introduced here exhibits an analogous structure: the accumulated phase around a loop reflects the underlying geometry and determines admissibility through discrete closure conditions.

C.5 Distinction from Formal Holonomy Structures

It is important to emphasize that the present construction does not introduce connections, parallel transport operators, or gauge fields. The phase ϕ is defined directly through transport and exchange, and its loop accumulation arises from this definition.

Any correspondence with more formal holonomy structures should be understood as an interpretation or potential reformulation of the present results, rather than as a foundational assumption.

C.6 Role in Subsequent Development

The identification of loop-dependent phase accumulation as a geometric invariant suggests that deeper structural descriptions may be possible in which transport, phase, and geometry are unified within a more formal framework.

Such developments are not required for the present construction, but may provide useful alternative representations of the transport structure derived here. In particular, they may clarify the relation between phase accumulation, closure conditions, and the emergence of discrete spectra in later formulations.

C.7 Summary

Closed-loop phase accumulation provides a scalar measure of the geometric structure encountered during transport. While analogous to holonomy in more formal settings, this interpretation is not assumed here, but arises naturally from the path-dependent phase construction developed in the main text.

D Connection to Q7 Closure Conditions

D.1 Closure Conditions in Q7

In Q7, admissible bound states were shown to arise from closure conditions on transport and exchange. These conditions select a discrete set of configurations for which a transported closure structure returns to a compatible state after completing an admissible cycle.

The resulting discrete structure was obtained without reference to phase or wave-based arguments, and was expressed directly in terms of closure consistency within the exchange sector.

D.2 Phase-Based Reformulation of Closure

In the present work, closure conditions have been reformulated in terms of accumulated phase along closed transport paths. Specifically, for a closed admissible path γ, the closure condition takes the form

$$\oint_\gamma d\phi = m\,\Phi_c, \quad m \in \mathbb{Z},$$

where Φ_c is the coherence scale defined in Section 5.

The normalization entering this phase-based condition is inherited from the closure-action structure developed in Q4–Q5. Thus the present reformulation does not introduce a new phase scale independent of the earlier action analysis; it repackages the same closure content in phase language.

D.3 Equivalence of Closure Conditions

The phase-based closure condition introduced above is not an additional assumption, but a reformulation of the closure structure established in Q7.

To see this, note that the accumulated phase

$$\phi[\gamma] = \kappa \oint_\gamma \mathcal{E}(x)\, d\tau$$

is directly proportional to the total exchange-modulated transport along the closed path. The requirement that this quantity correspond to an integer multiple of the coherence scale is equivalent to the requirement that the closure structure returns to a compatible state.

Thus, the discrete admissibility condition of Q7 is reproduced precisely by the phase closure condition in the present formulation.

D.4 Interpretation of the Coherence Scale

The coherence scale Φ_c introduced in this paper corresponds to the minimal phase increment required for structural compatibility of transport. In the Q7 framework, this scale is determined by the underlying exchange and geometric structure of the system.

Importantly, Φ_c is not assumed to be a universal constant. Its value depends on the specific transport and exchange configuration under consideration. As a result, the discrete structure of admissible states reflects system-dependent coherence properties.

D.5 Discrete Structure from Transport Consistency

The equivalence established above shows that the discrete set of admissible states arises from transport consistency conditions, whether expressed in terms of closure structure (Q7) or phase accumulation (Q10).

This demonstrates that quantization is not imposed externally, but emerges from the requirement that transport and exchange remain self-consistent over closed cycles.

D.6 Relation to Repeated Coherence Alignment

The condition

$$\oint_\gamma d\phi = m\,\Phi_c$$

may be interpreted as the accumulation of m successive coherence alignments along the closed path. Each increment of Φ_c corresponds to a minimal compatibility condition, and closure occurs when these increments combine to produce a fully consistent cycle.

This interpretation provides a direct link between the local coherence structure introduced in Section 5 and the global closure conditions of Q7.

D.7 Summary

The phase-based formulation developed in this paper is fully consistent with the closure conditions established in Q7. Rather than introducing new assumptions, it provides an alternative representation of the same underlying structure.

This establishes a direct correspondence between transport-based closure and phase accumulation, completing the connection between the Q7 and Q10 formulations.

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