# Spherepop Calculus and Amplitwistor Computation: A Geometric–Thermodynamic Foundation for AI

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**Abstract**

We introduce *Spherepop Calculus* (SPC), a foundational computational formalism in which the primitives of computation are *geometric collapse*, *merge*, and the dynamics of a background plenum endowed with scalar, vector, and entropy fields. Computation is interpreted as geometric evolution, not symbolic rewriting. We show that classical paradigms including lambda calculus, functional programming, logical inference, neural architectures, and tensor contraction formalisms arise as *coordinate projections* or *degenerations* of SPC, rather than independent foundations.

We then develop a complex–analytic representation of SPC via *amplitwistors*, in which collapse corresponds to holomorphic scattering, merge to contour gluing, and global computation to amplitwistor integration constrained by thermodynamic flow. The result is a unified computational substrate that is geometric, thermodynamic, holomorphic, and inherently nonlocal. SPC thus provides a principled foundation for AI that subsumes and geometrically explains neural, logical, and tensor–based reasoning systems.

# Introduction

Foundations of computation have historically relied on symbolic formalisms such as lambda calculus and Turing machines, later complemented by vector–based and tensor–based methods in machine learning. These approaches introduce computational primitives (terms, weights, embeddings) that are external to the dynamics they describe. In each case, computation is implemented by *syntactic* or *algebraic* manipulation, rather than derived from geometric or physical principles.

This work begins instead from geometry. We propose *Spherepop Calculus* (SPC), where the fundamental operations are *collapse* ("pop") and *merge* of geometric regions ("spheres") in a dynamical plenum. Semantics is intrinsic: a term denotes a geometric configuration, and computation corresponds to geometric evolution driven by thermodynamic constraints.

Our first objective is to show that classical computational paradigms arise as restricted viewpoints on SPC. Neural and tensor–based systems are obtained by local linearization and flattening of boundary curvature. Logical deduction appears as thresholded collapse. Lambda calculus and functional programming are recovered when geometric semantics degenerate to purely syntactic abstraction and application.

Our second objective is to lift computation into complex geometry using *amplitwistors*, generalizing twistor methods in mathematical physics.[1] Under this representation, collapse becomes holomorphic scattering; merge becomes composite interaction; computation becomes contour integration in amplitwistor space; and inference emerges as thermodynamic modification of holomorphic structure rather than symbolic deduction or tensor contraction.

The paper proceeds by defining SPC, establishing its operational and geometric semantics, demonstrating confluence and computational adequacy, and then embedding functional and tensor paradigms as degenerate projections. The amplitwistor formulation is then developed to yield a geometric–thermodynamic foundation for AI.

# 1 Motivation

Modern AI formalisms rely on representational scaffolding. Tensors communicate by contractive products along arbitrary index sets; graphs are constructed to express relational structure between symbols; and logical systems manipulate terms without spatial semantics. Each of these formalisms deliberately avoids, or postpones, geometry. Yet their effectiveness in deep learning reveals a latent geometric content: internal vector representations behave as though they encode angles, distances, and flows, but the geometry remains implicit and ungoverned.

This implicit geometry manifests in awkward inductive biases. Neural networks must be regularized to approximate locality; graph neural networks impose relational structure externally; attention mechanisms reconstruct spatial association by means of dot products in a latent embedding space. These constructions achieve geometric effects by indirect means. They rely on explicit scaffolding because there is no native geometric primitive.

Spherepop calculus eliminates the scaffolding by placing geometry at the basis of computation. Spheres, pops, and flows are the fundamental operators, and all subsequent computational phenomena are derived from these primitives. No indexing convention, no synthetic tensor product, and no extrinsic graph is required.

# 2 Spherepop as Primitive Geometry

Let $P$ denote a plenum manifold supporting a scalar potential $\Phi$, vector flow $v$, and entropy density $S$.[2] A *sphere* is a compact submanifold $S \subset P$ with boundary $\partial S$ and embedding $i_S : S \hookrightarrow P$. A *pop* is a boundary-respecting morphism $\pi : (S, \partial S) \to (P, i_S(S))$ whose differential $D\pi$ induces a first-order flow $v_\pi$. Intuitively, a pop collapses the internal configuration of $S$ and radiates geometric effects outward along the boundary.

We emphasize that spheres and pops are not metaphors, but primitive constructors. The existence of nested spheres corresponds to hierarchical scopes; their interaction and dissolution constitute computation. Classical computational constructs—functions, applications,

[1] For accessible geometric insight into twistor constructions and complex structure, see T. Needham's expository work on complex geometry [1].

[2] Derived from the RSVP triad.

substitution—arise as shadows of these geometric operations. In particular, SPC recovers dependent type theory as a normal-order limit of geometric evaluation.

### 2.1 Spheres as Computational Regions

A sphere $S \subset P$ is a computational region whose internal state is not given by a symbol assignment, but by its geometric configuration: its embedding $i_S$, its induced metric, and its phase structure. The computational significance of $S$ depends on the normal bundle $N_{S/P}$ and on the entropy gradient $\nabla_S S$, which together determine how information flows across its boundary. Whereas conventional representations encode data in a fixed vector space, SPC treats data as an instance of geometry.

The nesting relation between spheres induces a partial order: $S \prec S'$ if and only if $S \subset S'$ as submanifolds of $P$. This induces a hierarchical evaluation strategy analogous to call-by-value or call-by-name in lambda calculus; however, the order is not imposed syntactically, but follows from the geometry of the plenum.

### 2.2 Boundary and Coherence

Let $\partial S$ denote the boundary of a sphere $S$. A pop must preserve boundary coherence:

$$\pi|\_\partial S = i_S|\_\partial S, \tag{1}$$

ensuring that geometric information leaving $S$ enters the plenum without tearing. This condition generates a coherence constraint between nested spheres: if $S \subset S'$, then the pop on $S'$ constrains pops on $S$, and vice versa. The resulting structure is analogous to a higher categorical boundary condition rather than a syntactic typing rule.

### 2.3 Flows and Transport

Given a pop $\pi$, the induced flow $v_\pi$ propagates curvature and phase into the plenum. We interpret $v_\pi$ as a computational transport: information leaves the interior of $S$ by exerting geometric influence on its surroundings. Unlike symbolic systems, where output must be encoded explicitly, Spherepop transports information by natural geometric evolution.

## 3 The Pop Derivative

The primitive computational action of SPC is not arithmetic but collapse. A pop induces a measurable change in local structure. Let $\mathcal{F}(S)$ denote the internal configuration of $S$. The *pop derivative* is defined by:

$$D_{\text{pop}}\mathcal{F}(S) = \lim_{\epsilon \to 0} \frac{\mathcal{F}(\text{pop}_\epsilon(S)) - \mathcal{F}(S)}{\epsilon}. \tag{2}$$

Geometrically, the pop derivative measures the first-order effect of collapse on observables of $S$. Computationally, it measures how information is transported from the interior to the exterior.

This contrasts with symbolic differentiation, where variables are abstract. In SPC, differentiation arises from geometric variation. Subsequent sections relate the pop derivative to the RSVP vector field and to thermodynamic structure.

### 3.1 Boundary Measure

If $\mu$ is a boundary measure on $\partial S$, then a pop induces a reweighting of $\mu$:

$$d\mu' = \lambda_\pi \, d\mu, \tag{3}$$

where $\lambda_\pi$ encodes the entropy released by collapse. Informationally, this expresses a conservation principle: collapse reduces internal complexity but increases boundary expressivity.

This provides a physical semantics for the *activation phenomena* of machine learning: high-dimensional patterns that appear "activated" in neural networks correspond to changes in boundary measure induced by collapse.

## 4 The Merge Product

Computation in SPC is the composite effect of multiple collapses. Let $S_1, S_2$ denote spheres with compatible boundaries. Define the merge product:

$$S_1 \diamond S_2 = \overline{\mathrm{pop}(S_1 \cup S_2)}. \tag{4}$$

In other words, we merge $S_1, S_2$ by forming their union and collapsing the combined region into the plenum. This operator defines the algebraic structure of SPC: composition is collapse, and the unit is the empty sphere.

[Associativity] If $S_1, S_2, S_3$ have mutually coherent boundaries, then $(S_1 \diamond S_2) \diamond S_3 = S_1 \diamond (S_2 \diamond S_3)$.

*Sketch.* Boundary coherence ensures that the induced flows are compatible, and collapse is determined up to homotopy by boundary. Hence the two-step collapses are homotopic, and the resulting submanifolds coincide up to equivalence. □

Thus SPC forms a monoidal category whose objects are spheres and whose morphisms are pops. The merge product defines horizontal composition. As we will show, this category admits a functor to a derived category of RSVP fields, endowing computation with physical content.

## 5 Derived Geometry

The plenum $P$ supports scalar, vector, and entropy fields $(\Phi, v, S)$, giving it the structure of a smooth manifold with thermodynamic state. Spheres inherit the induced structure by pullback. Pops generate variations in this structure, subject to conservation laws derived from RSVP.

Let $\mathcal{M}$ be the derived moduli space of spheres in $P$. Then SPC calculations take place in $\mathbf{D}(\mathcal{M})$, a derived category whose objects encode collapse histories. Each pop contributes a morphism in $\mathbf{D}(\mathcal{M})$, and the merge product lifts to a derived tensor product.

### 5.1 Shifted Symplectic Structure

Spherepop is naturally equipped with a shifted symplectic form $\omega[-1]$ characteristic of derived field theories. The pop derivative induces a Hamiltonian flow on $\mathbf{D}(\mathcal{M})$, ensuring that computation follows a physically meaningful trajectory in moduli space. This gives SPC a rigorous geometric semantics analogous to the role Hamiltonian structure plays in classical mechanics.

## 6 The Spherepop Calculus

We now formalize SPC as a computational calculus. The constructors introduced above admit a syntactic presentation analogous to term construction in lambda calculus or primitive recursive functions. Their semantics, however, is inherently geometric.

### 6.1 Syntax

Let $\mathcal{S}$ denote the class of spheres in $P$. We write $|\mathcal{S}|$ for the underlying set of all spheres (including the empty sphere). The syntax of SPC is given by the following grammar:

$$t ::= S \mid \mathrm{pop}(t) \mid t_1 \diamond t_2 \mid t[\Phi, v, S], \tag{5}$$

where $S \in \mathcal{S}$ is a geometric region, $\mathrm{pop}(t)$ denotes collapse (Sec. 2), $t_1 \diamond t_2$ is the merge product (Sec. 3), and $t[\Phi, v, S]$ denotes evaluation with respect to the ambient RSVP fields. The substitution $t[\Phi, v, S]$ marks the extension of $t$ into the plenum geometry.

Note that $t$ is not a symbolic expression, but a formal reference to geometric structure. Unlike symbolic calculi, where syntax precedes interpretation, SPC syntax inherits its meaning from geometry.

### 6.2 Operational Semantics

Evaluation is effected by geometric evolution. Let $t$ denote the semantic value of $t$; then:

$$S = S, \tag{6}$$

$$\mathrm{pop}(t) = \mathrm{pop}(t), \tag{7}$$

$$t_1 \diamond t_2 = \mathrm{pop}(t_1 \cup t_2), \tag{8}$$

$$t[\Phi, v, S] = (t, \Phi, v, S), \tag{9}$$

where $(t, \Phi, v, S)$ denotes the geometric configuration obtained by gluing the RSVP fields to the sphere structure of $t$. This is not a valuation but a geometric embedding; evaluation produces a physical configuration, not a symbolic value.

### 6.3 Typing

A typing judgment $\Gamma \vdash t : \tau$ assigns $t$ a geometric type $\tau$. Types correspond to geometric moduli:

$$\tau ::= \mathbf{Sphere} \mid \mathbf{Pop} \mid \mathbf{Merge} \mid \mathbf{RSVP}. \tag{10}$$

Typing rules follow directly from the constructors:

$$[]\Gamma \vdash S : \textbf{Sphere} \qquad []\Gamma \vdash \mathrm{pop}(t) : \textbf{Pop}\Gamma \vdash t : \textbf{Sphere} \tag{11}$$

$$[]\Gamma \vdash t_1 \diamond t_2 : \textbf{Merge}\Gamma \vdash t_1 : \textbf{Sphere}\Gamma \vdash t_2 : \textbf{Sphere} \tag{12}$$

$$[]\Gamma \vdash t[\Phi, v, S] : \textbf{RSVP}\Gamma \vdash t : \textbf{Sphere}. \tag{13}$$

Typing ensures that evaluation is geometrically coherent. In contrast with symbolic calculi, where typing is syntactic, here types encode physical admissibility. The RSVP fields enforce thermodynamic constraints determining whether a pop is permissible.

### 6.4 Normal Form

Evaluation terminates when no further collapse is possible. A term $t$ is in *normal form* if $\mathrm{pop}(t) = t$ up to homotopy. Informally, all collapsible geometry has been discharged into the plenum. In practice, normal forms represent boundary configurations with no remaining internal structure.

[Confluence] If $t \Rightarrow t'$ and $t \Rightarrow t''$ by two distinct evaluation sequences, then there exists a common $u$ such that $t' \Rightarrow u$ and $t'' \Rightarrow u$.

*Sketch.* Since $\diamond$ forms an associative product and collapse is determined by boundary geometry, distinct evaluation orders differ only by homotopy of intermediate submanifolds. Therefore computation is confluent up to geometric equivalence, and normal forms are unique up to homotopy. □

Confluence implies that Spherepop admits a consistent notion of semantic equivalence: two terms are equal if their geometric realizations are homotopic. This guarantees well-definedness of computation independent of evaluation strategy.

### 6.5 Computational Adequacy

Let $NF(t)$ denote the normal form of $t$. The calculus is computationally adequate if $NF(t)$ captures the final geometric state of computation. Adequacy follows immediately from confluence: every evaluation path converges to an equivalent normal form.

[Adequacy] For all $t$, $t = NF(t)$.

Thus evaluation in SPC yields a unique geometric outcome. This constitutes the computational semantics of Spherepop calculus.

## 7 Geometric Semantics

The Spherepop calculus admits a semantic interpretation in terms of derived geometry on the plenum. In contrast with symbolic calculi, whose semantics are given by valuation mappings from expressions to sets, SPC interprets computation as geometric evolution constrained by RSVP fields $(\Phi, v, S)$. Every term $t$ evaluates to a geometric configuration, and the meaning of $t$ is precisely this configuration.

### 7.1 Semantic Function

Define the semantic function

$$\mathcal{J} : \mathbf{SPC} \to \mathbf{DG}(P) \tag{14}$$

from the syntactic category **SPC** into the derived geometric category $\mathbf{DG}(P)$ whose objects are geometric configurations of spheres, boundary conditions, and RSVP fields, and whose morphisms are pop-induced transformations. Following the evaluation rules of Sec. 6, we set

$$\mathcal{J}(\mathrm{pop}(t)) = \mathrm{pop}(\mathcal{J}(t)), \qquad (16)$$

$$\mathrm{J}(\mathrm{t}_1 \diamond t_2) = \mathrm{pop}(\mathcal{J}(t_1) \cup \mathcal{J}(t_2)),$$

$$\mathcal{J}(t[\Phi, v, S]) = (\mathcal{J}(t), \Phi, v, S).$$

$$\mathcal{J}(S) = (S, i_S^{\Phi, i_S^{v, i_S^{S), \mathcal{J}(\mathrm{pop}(t))=\mathrm{pop}(\mathcal{J}(t)), \mathcal{J}(t_1 \diamond t_2)=\mathrm{pop}(\mathcal{J}(t_1)\cup\mathcal{J}(t_2)), \mathcal{J}(t[\Phi,v,S])=(\mathcal{J}(t),\Phi,v,S).}}}$$

Thus semantics is evaluation; nothing is interpreted symbolically. The semantic value of $t$ is its geometric realization.

### 7.2 Derived Category

Let $\mathcal{M}$ denote the moduli space of spheres in $P$. Pops generate a family of morphisms in $\mathcal{M}$; their compositions form the hom-sets. The geometric semantics of SPC is naturally cast in the derived category

$$\mathbf{D}(\mathcal{M}), \tag{17}$$

whose objects are spheres with collapse history and whose morphisms are homotopy classes of pop-induced flows. The enrichment by RSVP fields encodes thermodynamic structure, and the induced Hamiltonian flow provides a canonical dynamical semantics.

### 7.3 Hamiltonian Semantics

The pop derivative (Sec. 2) induces a Hamiltonian vector field on $\mathbf{D}(\mathcal{M})$:

$$X_{\mathrm{pop}} = \iota_{D_{\mathrm{pop}}} \omega[-1], \tag{18}$$

where $\omega[-1]$ is the shifted symplectic form associated with the RSVP fields. Hamilton's equations govern the geometric evolution of collapse:

$$\dot{t} = X_{\mathrm{pop}}(t), \tag{19}$$

expressing computation as a symplectic flow. Thus computational dynamics obey conservation constraints and thermodynamic principles.

### 7.4 Thermodynamics and Entropy

The RSVP entropy $S$ determines the dissipation of collapse. Let $\Delta S(\text{pop})$ denote the entropy released during collapse. Boundary coherence implies that

$$\Delta S(\text{pop}) = \int_{\partial S} \langle v_\pi, n \rangle \, d\mu, \tag{20}$$

where $n$ is the outward normal and $\mu$ is boundary measure. Thus computation respects thermodynamic balance: internal complexity is reduced while boundary expressivity increases. Computation is therefore irreducibly thermodynamic.

### 7.5 Functoriality

Since merge is associative and pop is compatible with RSVP fields, the semantic function $\mathcal{J}$ is a monoidal functor:

$$\mathcal{J}(t_1 \diamond t_2) \simeq \mathcal{J}(t_1) \otimes \mathcal{J}(t_2), \tag{21}$$

where $\otimes$ is derived tensor product in $\mathbf{D}(\mathcal{M})$. Functoriality ensures that computational composition corresponds to geometric composition.

### 7.6 Equivalence Up To Homotopy

Confluence (Sec. 4) implies that any two evaluation sequences of $t$ produce homotopy-equivalent geometric configurations. Thus semantic equality is homotopy equivalence:

$$t_1 = t_2 \qquad \text{iff} \qquad \mathcal{J}(t_1) \simeq \mathcal{J}(t_2). \tag{22}$$

This makes SPC a homotopy-complete model of computation. Its meaning is geometric, not symbolic.

## 8 Computation as Geometry

In conventional formal systems, computation is an extrinsic process: expressions transform other expressions, and meaning is assigned after the fact by a semantic map. In SPC, computation is intrinsic: the act of evaluation is geometric evolution. The relevant quantities are curvature, entropy flow, and boundary structure. This section develops the computational interpretation of collapse and merge.

### 8.1 Activation as Boundary Curvature Change

Let $\kappa(\partial S)$ denote the mean curvature of the sphere boundary induced by the embedding $i_S$. A pop modifies boundary curvature by collapsing internal geometry into the surrounding plenum. Define the activation operator

$$\text{Act}(S) = \Delta\kappa(\partial S) = \kappa(\partial S') - \kappa(\partial S), \tag{23}$$

where $S' = \mathrm{pop}(S)$. This differential measures the extent to which collapse increases boundary expressivity. In neural networks a similar quantity is encoded by nonlinear activation functions; here it arises geometrically.

The activation of $t$ is thus neither a symbolic operation nor a nonlinear transformation on embedding vectors, but a change in geometric response at the boundary. Activation is a curvature phenomenon.

## 8.2 Propagation as Derived Transport

Let $v_\pi$ be the vector field generated by pop $\pi$, as in Sec. 2. Then the propagation of information is given by the solution $\gamma(t)$ of

$$\dot{\gamma}(t) = v_\pi(\gamma(t)). \tag{24}$$

Thus propagation is Hamiltonian transport in $\mathbf{D}(\mathcal{M})$. Importantly, no symbolic routing is required. Information flows because geometry evolves.

## 8.3 Composition as Colimit

Let $\mathcal{J}$ be the semantic functor of Sec. 5. The semantic value of merge is the derived colimit in $\mathbf{D}(\mathcal{M})$:

$$\mathcal{J}(t_1 \diamond t_2) \simeq \mathrm{colim}\{\mathcal{J}(t_1), \mathcal{J}(t_2)\}. \tag{25}$$

Thus computational composition in SPC corresponds to forming the colimit of geometric configurations, rather than composing symbolic functions. All composition is geometric colimit.

## 8.4 Hierarchical Control

Nested spheres induce hierarchical control flows. A sphere $S$ embedded in $S'$ inherits boundary conditions from $S'$ and imposes constraints on $S'$. This bidirectional coupling is not present in symbolic control structures, which are unidirectional. Instead, control arises from geometry: subregions influence enclosing regions by emitting curvature; enclosing regions influence subregions by shaping allowable pops. Computation is hierarchical because geometry is nested.

## 8.5 Learning as Curvature Minimization

If $\Phi$ and $S$ denote RSVP scalar and entropy fields, then their interaction defines an energy functional

$$\mathcal{E}(S) = \int_S \Phi \, d\mathrm{vol} - \int_{\partial S} S \, d\mu. \tag{26}$$

A collapse decreases internal energy while increasing boundary entropy, hence $\mathcal{E}$ is driven toward extremal states. Learning corresponds to minimizing $\mathcal{E}$ over collapse histories, subject to admissible pop operations.

[Gradient Flow] Let $t$ be a term and let $\gamma(s)$ denote its collapse history. Then $\gamma$ follows a gradient-like descent:

$$\frac{d}{ds}\mathcal{E}(\gamma(s)) \leq 0, \tag{27}$$

with equality only at normal form.

*Sketch.* Collapse reduces internal complexity and increases boundary entropy. These changes strictly decrease $\mathcal{E}$ unless the boundary is already maximally expressive. Thus normal forms correspond to critical points of $\mathcal{E}$. □

Learning in SPC is therefore the geometric process of minimizing an RSVP energy functional. The result is a curvature configuration, not a weight assignment.

### 8.6 Computation as Thermodynamic Evolution

Since pop operations are Hamiltonian flows constrained by entropy, SPC inherits the thermodynamic interpretation of RSVP. A computation is an irreversible evolution in the derived moduli space driven by entropy release. Symbolic systems encode irreversibility by arbitrary directionality (e.g., program counter); Spherepop obtains it physically. Computation is literally the dissipation of internal complexity into geometric boundary structure.

## 9 Neural and Logical Computation as Geometric Shadows

We now show that many standard computational formalisms arise as shadows of Spherepop calculus when geometric structure is projected onto fixed coordinate systems, discrete index sets, or thresholded relations. These representations inherit computational power from derived geometry, but sacrifice geometric semantics. In this sense, conventional neural and logical systems may be understood as extrinsic coordinatizations of collapse phenomena.

### 9.1 Linearization and Coordinate Projection

Let $S \subset P$ be a sphere with boundary $\partial S$ and let $\{e_i\}$ denote a choice of local coordinate frame along $\partial S$. Evaluation of a term $t$ at the boundary induces a coordinate representation:

$$x_i = \langle n, e_i \rangle, \tag{28}$$

where $n$ is the outward normal of $\partial S$. These coordinates form a vector $x = (x_i)$, which serves as a local linear shadow of boundary structure. We emphasize that this coordinate arises by choice, not by intrinsic computational necessity. The internal geometry is discarded in favor of a linear chart.

## 9.2 Neural Computation as Local Pop Approximation

A neural layer consists of an affine-linear transformation followed by a nonlinear activation. In SPC, collapse induces curvature change at the boundary (§6.1). Linearization of the pop around a coordinate chart yields

$$x' = Wx + b, \tag{29}$$

where $W$ and $b$ capture the first-order dependence of boundary curvature on ambient RSVP fields. The nonlinear activation is similarly obtained by thresholding the curvature differential, e.g., $\mathrm{Act}(S) = \Delta\kappa(\partial S)$. Thus a neural layer is a first-order Taylor approximation of collapse.

[Neural Shadow] Every neural layer is the shadow of a Spherepop collapse in a local coordinate chart, obtained by linearization of boundary curvature and thresholding of geometric response.

Thus neural computation expresses collapse phenomena extrinsically. We call this the *neural shadow* of SPC.

## 9.3 Message Passing and Graph Structure

Graph neural networks propagate messages along edges of a graph. In SPC, geometry induces adjacency by boundary proximity: two points share an "edge" if their boundaries interact under collapse. Define adjacency

$$A_{uv} = \mathbf{1}\{\partial S_u \cap \partial S_v \neq \emptyset\}. \tag{30}$$

Then pop propagation becomes message passing:

$$x'_u = \sum_v A_{uv} f(x_v), \tag{31}$$

which recovers graph convolution as the projection of Hamiltonian transport into adjacency space. Again, graph structure is a coordinate artifact of geometric interaction.

## 9.4 Logical Inference as Thresholded Collapse

Let $S_A, S_B$ represent spheres associated with logical predicates $A, B$. If collapses of $S_A$ and $S_B$ jointly activate curvature at the boundary of $S_C$, then we obtain a logical implication:

$$(A \wedge B) \Rightarrow C. \tag{32}$$

Thresholding curvature defines Boolean truth:

$$C = \mathbf{1}\{\mathrm{Act}(S_C) > \tau\}. \tag{33}$$

Thus logical inference is the discretization of collapse-mediated interaction. Its syntactic form obscures the geometric mechanism.

## 9.5 Probabilistic Inference as Boundary Measure

Let $\mu(\partial S)$ be the boundary measure induced by RSVP entropy. Collapse updates $\mu$, generating posterior distributions:

$$\mu'(\partial S) = \frac{1}{Z}\exp(-\mathcal{E}(S)). \tag{34}$$

Thus Bayesian update is recovered as a Gibbs-type reweighting of boundary measure. Probabilistic inference is a thermodynamic shadow of geometric evolution.

## 9.6 Combinatorial Computation as Degenerate Geometry

When all spheres are degenerate and collapse is trivial, SPC reduces to a combinatorial calculus on a discrete set of symbols. This recovers conventional symbolic computation:

$$\text{collapse trivial} \quad \Longrightarrow \quad \mathbf{SPC} \simeq \mathbf{Symb}. \tag{35}$$

Hence symbolic computation arises as the extreme case in which geometric semantics vanish.

## 9.7 Summary

Neural, logical, and probabilistic formalisms appear as coordinate projections of Spherepop into particular representational spaces: local vector spaces, adjacency graphs, or Boolean domains. Collapse is the intrinsic phenomenon; layers, message passing, and logical implication are extrinsic shadows. Computation is geometric; neural and logical systems describe its projections.

# 10 Equivalence to Lambda Calculus and Functional Paradigms

Classical theories of computation rely on symbolic formalisms, the most canonical being lambda calculus. We now show that SPC contains lambda abstraction and application as special cases of geometric embedding and collapse. Consequently, functional programming paradigms appear as syntactic shadows of geometric evaluation.

## 10.1 Lambda Abstraction as Geometric Scope

Let $\lambda x.\, t$ denote a lambda term with bound variable $x$. In SPC, abstraction corresponds to introducing a sub-sphere whose boundary isolates the scope of the variable. Let $S_x$ denote a sphere encoding the scope of $x$ and let $S_t$ encode the geometry of $t$. Then lambda abstraction is represented by the nested sphere

$$\Lambda_x(t) := S_x \prec S_t, \tag{36}$$

where nesting expresses dependency of $t$ on $x$. The boundary of $S_x$ plays the role of the abstraction boundary.

## 10.2 Application as Collapse and Merge

Application $(\lambda x.\, t)\ u$ substitutes $u$ for $x$ in $t$. In SPC, substitution is executed by collapsing the $S_u$ sphere into the abstraction sphere $S_x$ and then merging with $S_t$:

$$\mathrm{App}(t, u) := \mathrm{pop}(S_x \diamond S_u) \diamond S_t. \tag{37}$$

Operationally, application is the geometric process of replacing the scope of $x$ with the geometry of $u$. Collapse performs substitution; merge performs evaluation.

[Beta Reduction] Let $t, u$ be terms, and assume $x$ is bound in $t$. Then evaluation of $(\lambda x.\, t)\ u$ by SPC yields a term homotopic to $t[u/x]$, the standard beta-reduced form.

*Sketch.* Collapse of $S_u$ into $S_x$ substitutes internal geometry; merge into $S_t$ propagates effects into the body of $t$. Confluence ensures uniqueness up to homotopy. □

Thus beta-reduction corresponds to geometric collapse, and eta- and alpha-equivalences correspond to homotopies of sphere boundaries.

## 10.3 Higher-Order Functions

Since spheres may contain sub-spheres, and collapses may operate on regions containing collapses, SPC directly supports higher-order computation. A higher-order function $F : (A \to B) \to C$ is represented by a sphere $S_F$ whose boundary admits pop operations on sub-spheres corresponding to functions of type $A \to B$. Evaluation of $F$ on such a function amounts to collapse within $S_F$.

## 10.4 Functional Paradigms as Geometric Evaluation

Let **LC** denote the category of lambda terms up to beta equivalence. The mapping

$$\mathcal{L} : \mathbf{LC} \to \mathbf{SPC} \tag{38}$$

embedding lambda calculus into Spherepop identifies abstraction with nested spheres and application with collapse and merge. Thus functional programming paradigms—including higher-order functions, closures, and currying—arise as syntactic presentations of geometric evaluation.

## 10.5 Universality

Lambda calculus is known to be Turing complete. Since SPC contains lambda calculus via the embedding $\mathcal{L}$, it is computationally universal:

$$\mathbf{LC} \hookrightarrow \mathbf{SPC} \quad \Longrightarrow \quad \mathbf{SPC} \text{ is Turing complete.} \tag{39}$$

Conversely, **SPC** extends lambda calculus by giving it geometric semantics, higher-dimensional structure, and thermodynamic interpretation.

### 10.6 Geometric Generalization

As symbolic calculi capture only the degenerate case in which geometric semantics are suppressed, lambda calculus appears as the zero-dimensional shadow of SPC. In this view, functional programming corresponds to collapse restricted to purely syntactic constructors. The geometric model is strictly stronger: it subsumes functional paradigms and provides additional structure unavailable in symbolic formalisms.

### 10.7 Summary

Spherepop calculus strictly extends lambda calculus: it contains abstraction and application as geometric primitives, recovers beta-reduction as collapse, and supports higher-order functions intrinsically. Functional programming is thus the syntactic shadow of geometric computation.

## 11 Tensor Logic as Flat Boundary Projection

Having established that SPC subsumes classical computation (§8) and that neural and logical systems appear as geometric shadows (§7), we now show that Tensor Logic arises when Spherepop is restricted to flat boundary geometry and evaluated through local linear projections. In this regime, collapse becomes tensor contraction, and merge becomes Einstein summation.

### 11.1 Preliminaries

Tensor Logic (TL) models reasoning in terms of tensor contractions among embedding vectors. Its central operations are projection, einsum, and threshold. We interpret these as flattened forms of collapse and merge over boundary charts on $\partial S$. The semantics of SPC therefore induces Tensor Logic by geometric degeneration: TL is the projection of Spherepop onto linear boundary coordinates with vanishing curvature and suppressed interior.

### 11.2 Flat Boundary Condition

Let $S \subset P$ be a sphere with boundary $\partial S$ and curvature $\kappa(\partial S)$ (Sec. 6). If $\kappa(\partial S) = 0$ for all $S$ participating in a computation, then boundary geometry is flat, and collapse simplifies to selection and contraction of coordinates. Formally,

$$\kappa(\partial S) = 0 \quad \Longrightarrow \quad \mathrm{pop}(S) = \mathrm{Proj}(\partial S), \tag{40}$$

where Proj denotes projection onto a fixed boundary chart. Thus Tensor Logic corresponds to zero-curvature evaluation.

## 11.3 Merge as Einstein Summation

Under flat boundary conditions, merge induces contraction:

$$\mathcal{J}(t_1 \diamond t_2) \simeq \sum_{i,j} T^{(1)}_{i\ell} T^{(2)}_{\ell j}, \tag{41}$$

recovering the familiar Einstein summation rule. The summation index $\ell$ corresponds to the internal region collapsed by pop. In general geometry, contraction is replaced by geometric merge; the tensor operation is merely the flat projection.

## 11.4 Linearization of Collapse

Let $\mathrm{Act}(S) = \Delta\kappa(\partial S)$ be the activation of collapse (Sec. 6.1). Under flat boundary conditions and local linearization,

$$\mathrm{Act}(S) \approx Wx, \tag{42}$$

with $x$ the boundary coordinate of the incoming sphere and $W$ the Jacobian of pop. Thresholding yields Boolean or piecewise-linear activation, reproducing the Tensor Logic interpretation of nonlinear reasoning in embedding space.

## 11.5 Semantic Equivalence

Let **TL** denote the category of Tensor Logic expressions up to the usual equivalence relations. Then Spherepop induces a functor

$$\mathcal{T} : \mathbf{SPC} \to \mathbf{TL} \tag{43}$$

by restricting to flat boundaries and linear charts. Moreover, collapse and merge reduce to contraction and einsum, giving an equivalence

$$\mathbf{SPC}\big|\_\kappa = 0 \simeq \mathbf{TL}. \tag{44}$$

Thus Tensor Logic is not a foundational theory; it is the zero-curvature projection of Spherepop.

## 11.6 Domingos as Local Linear Shadow

In Domingos' formulation, reasoning is expressed through linear operations in embedding space with logical structure encoded by tensor transformations. This corresponds precisely to the local linearization of collapse at flat boundaries. As such, the Tensor Logic account of reasoning appears as the geometrically flattened restriction of SPC: reasoning in embedding space is the twistor projection of collapse.

## 11.7 Algebraic Equivalence Under Boundary Flattening

Let $\mathcal{J}$ be the semantic functor of Sec. 7. We restrict $\mathcal{J}$ to flat boundaries by imposing the constraint $\kappa(\partial S) = 0$ on all spheres $S$. Algebraically, collapse becomes linear projection, and merge becomes bipartite tensor contraction. Let

$$\mathcal{J}_0 := \mathcal{J}\big|_{\kappa=0}. \tag{45}$$

Then $\mathcal{J}_0$ induces a functor $\mathcal{J}_0 : \mathbf{SPC} \to \mathbf{TL}$ such that

$$\mathcal{J}_0(t_1 \diamond t_2) = \mathcal{J}_0(t_1) \, \oplus \, \mathcal{J}_0(t_2), \tag{46}$$

where $\oplus$ denotes the tensor connective of Tensor Logic.

[Algebraic Equivalence] Under flat boundary conditions, collapse and merge induce the algebra of tensor connectives in Tensor Logic.

## 11.8 Categorical Correspondence via Monoidal Restriction

Let **SPC** be the monoidal category generated by spheres and collapse with monoidal product $\diamond$. Let **TL** be the monoidal category whose objects are embedding tensors and whose arrows are tensor contractions. The flattening functor $\mathcal{T}$ of Sec. 9 induces a monoidal functor

$$\mathcal{T} : \mathbf{SPC} \to \mathbf{TL} \tag{47}$$

with

$$\mathcal{T}(t_1 \diamond t_2) = \mathcal{T}(t_1) \otimes \mathcal{T}(t_2). \tag{48}$$

Hence Tensor Logic is the monoidal reflection of Spherepop under curvature suppression.

[Monoidal Equivalence] If all collapses are flat and boundary curvature vanishes, then $\mathcal{T}$ induces a monoidal equivalence

$$\mathbf{SPC}\big|\_\kappa = 0 \simeq \mathbf{TL}.$$

## 11.9 Computational Equivalence Through Local Linearization

Tensor Logic represents computation by manipulating embeddings through tensor contractions and threshold operations. Under local linearization of collapse (Sec. 6),

$$\mathrm{pop}(S) \approx Wx + b, \tag{49}$$

and merge induces tensor multiplication. Let $\mathrm{TL}(t)$ denote the Tensor Logic interpretation of $t$. Then local linearization yields

$$\mathrm{TL}(t) = \mathcal{J}_0(t)[W, b]. \tag{50}$$

Thus every Tensor Logic computation is the local linearization of a Spherepop evaluation.

[Computational Equivalence] Every Tensor Logic computation is executable as the first-order linear approximation of a Spherepop collapse.

### 11.10 Model-Theoretic Interpretation

Tensor Logic inherits a model-theoretic semantics based on embeddings and projections. Spherepop inherits a geometric semantics based on collapse and boundary curvature. Under flat boundary conditions, the semantic equations coincide:

$$\mathcal{J}_0(t) = \mathrm{TL}(t). \tag{51}$$

Thus Tensor Logic may be regarded as the model theory of zero-curvature Spherepop. Model-theoretic entailment corresponds to the evaluation of derived collapse under projection.

Model-theoretic validity in Tensor Logic coincides with semantic validity of SPC under flat boundary evaluation.

### 11.11 Operational Collapse vs. Einsum

The operational semantics of SPC interprets computation as the geometric act of collapse. Tensor Logic interprets computation as einsum over embeddings. Under curvature suppression,

$$\mathrm{pop}(t_1 \diamond t_2) = \mathrm{einsum}(t_1, t_2), \tag{52}$$

making einsum the degenerate operational rule of collapse. Consequently, Tensor Logic is not a novel algebraic foundation, but a special operational regime of Spherepop.

### 11.12 Summary

Tensor Logic emerges from Spherepop when curvature is suppressed, interior geometry is collapsed to zero thickness, and merge is linearized to tensor contraction. Einsum and projection are special cases of geometric merge and collapse. Reasoning in Tensor Logic represents the flat boundary shadow of geometric computation.

## 12 Amplitwistors and Geometric Computation

Tensor representations flatten geometric structure into local linear coordinates. In contrast, twistor geometry provides a holomorphic representation in which null directions of spacetime are encoded as points of a complex projective space. Amplitwistors extend this idea to scattering amplitudes, providing a nonlocal representation of interactions. In this section we show that Spherepop calculus admits an amplitwistor interpretation in which collapse becomes a nonlocal update over twistor fields.

### 12.1 Twistor Background

Let $(M, g)$ be a four-dimensional Lorentzian manifold. The (projective) twistor space $PT$ is the complex manifold parameterizing null geodesics in $M$. Each point of $PT$ corresponds to a null direction in $M$, and each null geodesic corresponds to a complex projective line in $PT$. This construction transforms local geometric structure on $M$ into holomorphic data on $PT$, enabling computation on a nonlocal complex manifold.

## 12.2 Amplitwistors

Amplitwistors extend the twistor description to scattering theory, encoding momenta and polarization data in complex geometry. In the amplitwistor formalism, scattering amplitudes are computed by integrating holomorphic differential forms over complex submanifolds of an amplitwistor space. The resulting formalism provides a nonlocal, coordinate-free representation of multi-particle interaction.

## 12.3 Spherepop in Twistor Coordinates

Let $S \subset P$ be a sphere encoding local geometry. Under twistorization, the geometry of $S$ is encoded as a complex locus $Z_S \subset PT$. Collapse corresponds to modifying the complex structure on the locus, and merge corresponds to composing such modifications:

$$\mathcal{J}(t) \mapsto F(Z_S). \tag{53}$$

Thus Spherepop computations can be performed directly in twistor space by manipulating complex loci.

## 12.4 Nonlocality

The twistor representation makes explicit the nonlocal structure implicit in Spherepop collapse: the effect of collapse on $P$ may propagate along null directions in $PT$. This provides a natural interpretation of nonlocal computational effects, which do not require explicit message passing or symbolic communication. In twistor space, computation is inherently nonlocal.

## 12.5 Holomorphic Collapse

Pop operations act by modifying complex structure on $PT$. Let $D_{\text{pop}}$ be the collapse derivative of Sec. 2. Then

$$D_{\text{pop}} \mapsto \bar{\partial}\text{-operator on } PT, \tag{54}$$

identifying collapse with a holomorphic differential operator. Thus Spherepop inherits a holomorphic semantics in amplitwistor space.

## 12.6 Comparison with Tensor Logic

Tensor Logic linearizes geometric computation in local coordinates, disregarding nonlocality and complex structure. Amplitwistor coordinates, in contrast, preserve the global geometry of collapse and provide a natural arena for nonlocal computation. Rather than reducing computation to tensor contraction, amplitwistors lift it to holomorphic geometry. Tensor Logic is a flattening; amplitwistors are a lifting.

## 12.7 Summary

Amplitwistors provide a complex-analytic representation in which Spherepop collapse is expressed as a holomorphic differential operator. Computation becomes nonlocal by construction, and geometric structure is preserved. In contrast to Tensor Logic, amplitwistors respect the manifold geometry underlying SPC.

# 13 Collapse as Twistor Scattering

Spherepop collapse acts locally on $P$ but propagates globally in $PT$. This resemblance to scattering—local interaction yielding global correlations—is made precise in amplitwistor geometry. In this section we interpret pop as a twistor scattering operation modifying holomorphic data along complex contours.

## 13.1 Scattering Interpretation

Consider a collapse $\mathrm{pop}(S)$ in $P$. Under the twistor mapping of Sec. 12, $S$ maps to a locus $Z_S \subset PT$. Collapse modifies near-boundary geometry, hence modifies $Z_S$. Let $\Delta Z_S$ denote the resulting change in complex structure. The geometric change induced by collapse resembles the insertion of a vertex operator or interaction term in scattering theory.

$$\mathrm{pop}(S) \longmapsto Z_S \mapsto Z_S + \Delta Z_S. \tag{55}$$

Thus collapse generates a twistor scattering event.

## 13.2 Holomorphic Scattering Operator

Let $\mathcal{A}$ denote the amplitwistor scattering operator acting on complex loci. Then pop induces an operator

$$\mathcal{A}_{\mathrm{pop}} : Z_S \to Z'_S, \tag{56}$$

which modifies complex structure by holomorphic deformation. In local coordinates this corresponds to insertion of an operator $\mathcal{O}_{\mathrm{pop}}$ acting on a holomorphic differential form on $PT$.

## 13.3 Contour Deformation

Scattering amplitudes are computed by integrating holomorphic forms over contours in amplitwistor space. Collapse induces deformation of these contours, thus modifying amplitudes:

$$\int_\Gamma \Omega \quad \mapsto \quad \int_{\Gamma'} \Omega. \tag{57}$$

Hence collapse corresponds to contour modification in twistor space, in analogy with the deformation of scattering contours in QFT.

### 13.4 Merge as Composite Scattering

Merge $\diamond$ combines geometric regions in $P$; in amplitwistor geometry this becomes gluing of the corresponding complex loci:

$$Z_{t_1 \diamond t_2} = \mathrm{Glue}(Z_{t_1}, Z_{t_2}). \tag{58}$$

If collapse corresponds to scattering, merge corresponds to composition of scattering processes. A composite pop sequence represents a multi-vertex twistor interaction.

### 13.5 Holomorphic Action Functional

Let $\Omega$ be the holomorphic volume form on amplitwistor space. Define the action

$$\mathcal{S}[Z_S] = \int_{Z_S} \Omega. \tag{59}$$

Collapse transforms $Z_S$ and thus changes $\mathcal{S}$. The result is a twistor scattering amplitude for collapse. This gives Spherepop an amplitwistor action principle.

### 13.6 Summary

Collapse in $P$ induces scattering in $PT$: pop acts as a holomorphic operator, merge corresponds to composite interactions, and geometric evaluation becomes contour deformation. Pop is scattering.

## 14 Amplitwistor Integration and Global Interactions

Having interpreted collapse as a scattering process in amplitwistor space (Sec. 13), we now integrate these local scattering events to obtain global computational behavior. In traditional scattering theory, amplitudes are obtained by integrating local interaction data over contours in a complex manifold. The analogous construction in SPC integrates collapse histories over amplitwistor space to produce global geometric inference.

### 14.1 Collapse Histories

Let $\gamma$ be a collapse history for a term $t$. Under the amplitwistor representation of Sec. 12, $\gamma$ maps to a family of complex loci $\{Z_{\gamma(s)}\}_{s \in [0,1]}$. Collapse generates a trajectory in amplitwistor space, and global computation corresponds to integrating holomorphic data along this trajectory.

### 14.2 Global Amplitwistor Integral

Let $\Omega$ be the holomorphic measure in amplitwistor space and let $Z_\gamma$ denote the twistor locus associated with collapse history $\gamma$. Define the global computation

$$\mathcal{I}(t) = \int_{Z_\gamma} \Omega, \tag{60}$$

where the integral runs over all collapse-induced loci of $t$. Hence evaluation of a term in SPC corresponds to a holomorphic integral in amplitwistor space.

## 14.3 Nonlocality

Unlike conventional symbolic evaluation, the integral $\mathcal{I}(t)$ depends on the global geometry of $Z_\gamma$. This encodes nonlocal correlations, as collapse of a local region in $P$ may propagate along null directions in $PT$. In this sense, computation in the amplitwistor representation is inherently nonlocal, independent of any explicit message passing mechanism.

## 14.4 Composite Interaction

Merge composes two regions in $P$ into a single computational unit. Under amplitwistor integration this becomes contour gluing:

$$\int_{Z_{\gamma_1 \diamond \gamma_2}} \Omega = \int_{Z_{\gamma_1}} \Omega \circ \int_{Z_{\gamma_2}} \Omega. \tag{61}$$

Thus the algebra of merge operations corresponds to the algebra of composite contour integrals, making merge a global interaction rule.

## 14.5 Scattering Amplitudes as Computation

The integral $\mathcal{I}(t)$ resembles a scattering amplitude obtained by integrating interaction data over complex contours in amplitwistor space. In SPC, collapse produces such interaction data; global computation is therefore equivalent to evaluating a scattering amplitude. Pop computes by scattering.

## 14.6 Holomorphic Inference

The global amplitwistor integral provides a principle of inference:

$$t_1 = t_2 \iff \mathcal{I}(t_1) = \mathcal{I}(t_2). \tag{62}$$

Two terms are equivalent if their amplitwistor integrals coincide. In contrast to Tensor Logic, which relies on algebraic equalities of linear operators, SPC inherits a holomorphic criterion for computational equivalence.

## 14.7 Summary

Global computation in Spherepop is the amplitwistor integral of collapse histories. Merge becomes global gluing, collapse becomes scattering, and equivalence is determined by equality of holomorphic integrals. Inference is holomorphic, not linear-algebraic.

# 15 Twistor–RSVP Coupling

The amplitwistor interpretation of Spherepop provides a complex manifold representation of collapse. The RSVP framework introduces a scalar field $\Phi$, a vector field $v$, and an entropy field $S$ on the plenum $P$. We now couple these representations by lifting RSVP fields to twistor space and interpreting collapse as a coupled holomorphic–thermodynamic evolution. This yields a twistorized form of the plenum in which computation is expressed through amplitwistor geometry.

## 15.1 RSVP Fields

Let $P$ be the plenum manifold and $(\Phi, v, S)$ the RSVP fields. The scalar field $\Phi$ encodes potential, the vector field $v$ encodes flow, and the entropy field $S$ encodes thermodynamic structure. These fields evolve according to plenum dynamics, which are not assumed to arise from a metric variation or from Einstein equations. The plenum $P$ carries collapse-induced dynamics determined by thermodynamic constraints.

## 15.2 Twistor Lift

Let $\pi : PT \to P$ denote the twistor fibration. The RSVP fields admit a twistor lift:

$$\Phi^\sharp = \pi^{\Phi,} \qquad v^\sharp = \pi^{v,} \qquad S^\sharp = \pi^{S.} \tag{63}$$

Thus the RSVP fields define holomorphic data on twistor space, making collapse a holomorphic–thermodynamic evolution.

## 15.3 Coupled Collapse

Collapse modifies boundary geometry $S \subset P$, hence modifies the lifted RSVP fields:

$$(\Phi^\sharp, v^\sharp, S^\sharp) \mapsto (\Phi^\sharp + \Delta\Phi^\sharp,\ v^\sharp + \Delta v^\sharp,\ S^\sharp + \Delta S^\sharp). \tag{64}$$

These modifications in $PT$ correspond to transformed thermodynamic conditions in $P$. Collapse therefore couples amplitwistor geometry to plenum thermodynamics.

## 15.4 Twistor–Lamphrodynamic Semantics

Let $\mathcal{A}$ be the amplitwistor scattering operator of Sec. 13. Define the twistor–lamphrodynamic operator

$$\mathcal{L} := \mathcal{A} \circ (\text{lift RSVP}). \tag{65}$$

Then the semantic value of $t$ in twistor space is

$$\mathcal{J}(t) = \mathcal{L}(Z_t), \tag{66}$$

where $Z_t$ is the amplitwistor locus for term $t$. Thus SPC evaluation becomes a lamphrodynamically constrained scattering process on twistor space.

### 15.5 Thermodynamic Curvature

The RSVP entropy $S$ modulates curvature in $P$. Under the twistor lift, $S^\sharp$ modulates complex geometry in $PT$, influencing the holomorphic structure of collapse. This yields a curvature representation coupling thermodynamic and complex-analytic data. The result is a twistor-thermodynamic geometry that governs computation.

### 15.6 Comparison with Tensor Logic

Tensor Logic encodes computational transformations by linear operators on embedding vectors. Twistor–RSVP coupling encodes computational transformations by thermodynamically constrained holomorphic operators. Tensor Logic discards both thermodynamics and geometry, replacing collapse by linear algebra. Twistor–RSVP restores the full geometric–thermodynamic semantics of computation.

### 15.7 Summary

Collapse in Spherepop induces thermodynamic evolution of RSVP fields. Its twistor representation induces holomorphic evolution of lifted RSVP fields in amplitwistor space. Computation therefore acquires a twistor–thermodynamic semantics in which collapse is a coupled holomorphic–lamphrodynamic process. Tensor Logic corresponds to the degenerate, zero-curvature projection of this geometry.

## 16 Hierarchical Twistor–RSVP Computation

The coupling developed in Sec. 15 defines computation as a thermodynamically constrained holomorphic scattering process in amplitwistor space. In this section we introduce a hierarchical structure based on nested spheres, which induces hierarchical twistor–RSVP evolution. Computation propagates across scales of the plenum and across layers of amplitwistor geometry.

### 16.1 Nested Spheres and Multiscale Collapse

Let $S \subset S' \subset P$ be nested spheres representing multiscale regions of the plenum. Under twistorization, these map to nested loci $Z_S \subset Z_{S'} \subset PT$. Collapse of $S$ modifies $Z_S$ and subsequently modifies $Z_{S'}$ due to their containment relation. Thus collapse induces multiscale twistor interactions.

### 16.2 Hierarchical Lamphrodynamic Evolution

The RSVP fields $(\Phi, v, S)$ govern local evolution in $P$. Hierarchically nested spheres induce hierarchical lamphrodynamic constraints:

$$(\Phi, v, S)_{S'} \mapsto (\Phi, v, S)_S \mapsto (\Phi, v, S)_{\mathrm{int}}, \tag{67}$$

where the subscript indicates restriction to nested regions. Collapse propagates thermodynamic constraints across scales, inducing hierarchical computational behavior.

### 16.3 Twistor Hierarchy

The twistor lift $\pi$ applies to each level of the hierarchy, producing a hierarchy in $PT$:

$$Z_{\text{global}} \supset Z_{\text{regional}} \supset Z_{\text{local}}. \tag{68}$$

Collapse at one level modifies the lifted entropy and complex structure at finer or coarser levels. Thus computation is both local and global in twistor space.

### 16.4 Hierarchical Scattering

Let $\mathcal{A}$ denote the twistor scattering operator. Nested collapse yields

$$\mathcal{A}_S \circ \mathcal{A}_{S'} \circ \mathcal{A}_{\text{global}}, \tag{69}$$

representing a chain of twistor interactions. Computation is thus a hierarchical scattering process governed by RSVP thermodynamics.

### 16.5 Multiscale Integration

The global amplitwistor integral of Sec. 14 decomposes into nested contributions:

$$\mathcal{I}(t) = \int_{Z_{\text{global}}} \Omega = \int_{Z_{\text{regional}}} \Omega = \int_{Z_{\text{local}}} \Omega, \tag{70}$$

yielding a multiscale holomorphic inference principle. Local collapse participates in global inference by way of the twistor hierarchy.

### 16.6 Summary

Nested spheres induce hierarchical lamphrodynamic constraints, which lift to hierarchical twistor geometry. Collapse propagates across scales, producing multiscale scattering events and global holomorphic inference. Computation is therefore hierarchical in both the plenum and twistor space.

## 17 Holomorphic Entropy and Nonlocal Inference

Entropy in RSVP induces lamphrodynamic relaxation in the plenum. Under the twistor lift, entropy becomes a holomorphic field in amplitwistor space. We now show that collapse induces holomorphic entropy flow, producing nonlocal inference by complex propagation rather than local message passing or symbolic deduction.

### 17.1 Holomorphic Entropy Field

Let $S^\sharp = \pi^S$ be the lifted entropy field. Collapse alters $S^\sharp$ along complex loci $Z_S$, inducing a holomorphic entropy flow

$$\bar{\partial} S^\sharp = \Delta S^\sharp \,. \tag{71}$$

This identifies collapse with entropy-driven evolution in twistor space.

### 17.2 Nonlocality

The modification of $S^\sharp$ along $Z_S$ propagates in $PT$ along null complex directions, making inference nonlocal by construction. This differs fundamentally from Tensor Logic, which relies on local embedding coordinates and linear contraction.

### 17.3 Holomorphic Inference

Inference between regions $S_A$ and $S_B$ occurs when collapse of $S_A$ modifies $S^\sharp$ at $S_B$. The resulting inference relation is given by

$$S_A \rightsquigarrow S_B \quad \Longleftrightarrow \quad \Delta S^\sharp(Z_{S_A}) \longrightarrow \Delta S^\sharp(Z_{S_B}). \tag{72}$$

Thus inference arises through holomorphic entropy flow, not symbolic deduction.

### 17.4 Complex-Analytic Learning

Learning in SPC (Sec. 6.5) minimizes plenum energy. Under the twistor lift, learning corresponds to modifying $S^\sharp$ to reduce holomorphic variation. Collapse (learning) therefore drives the system toward holomorphic equilibrium states in amplitwistor space.

### 17.5 Summary

Entropy couples collapse to a holomorphic differential operator, producing nonlocal inference through complex propagation. Learning minimizes entropy variation, driving the system toward holomorphic equilibrium. Inference is holomorphic and nonlocal.

## 18 Toward a Unifying Computational Physics

We conclude that Spherepop calculus, when interpreted in amplitwistor coordinates and coupled to RSVP fields, yields a computational physics based on thermodynamically constrained holomorphic scattering.

Tensor Logic and lambda calculus arise as degenerate shadows of this geometry, and neural and logical systems appear as coordinate projections. Computation is geometric, thermodynamic, and holomorphic by construction.

### 18.1 Unification

Spherepop unifies:

1. geometric collapse and merge,
2. thermodynamic entropy flow,
3. holomorphic scattering,
4. hierarchical inference,
5. functional abstraction,
6. tensor contraction as degeneration.

Computation arises from geometric first principles, not symbolic construction.

### 18.2 Future Directions

Future work includes:

1. rigorous construction of amplitwistor–RSVP scattering theory,
2. categorical semantics of holomorphic collapse,
3. computational completeness of twistor–RSVP evolution,
4. coupling with physical twistor theories,
5. experimental consequences for geometric machine learning.

### 18.3 Conclusion

Spherepop calculus defines computation as geometric collapse and thermodynamic evolution, and amplitwistors provide a complex-analytic representation of this computation. Tensor Logic emerges only as the flat, linearized projection of this geometry. Computational physics is therefore geometric and amplitwistor-based rather than syntactically tensor-based.

## A Formal Specification of Spherepop Calculus

### A.1 Syntax

Let $\mathcal{S}$ be the class of admissible spheres in the plenum $P$. Spherepop terms are expressions of the form

$$t ::= S \mid \mathrm{pop}(t) \mid t_1 \diamond t_2 \mid t[\Phi, v, S],$$

where $S \in \mathcal{S}$, $\mathrm{pop}(t)$ denotes collapse, $t_1 \diamond t_2$ denotes merge, and $t[\Phi, v, S]$ denotes evaluation relative to the ambient fields $(\Phi, v, S)$.

## A.2 Types

Spherepop types are given by

$$\tau ::= \textbf{Sphere} \mid \textbf{Pop} \mid \textbf{Merge} \mid \textbf{RSVP}.$$

Typing judgments $\Gamma \vdash t : \tau$ satisfy

$$\frac{}{\Gamma \vdash S : \textbf{Sphere}}, \qquad \frac{\Gamma \vdash t : \textbf{Sphere}}{\Gamma \vdash \mathrm{pop}(t) : \textbf{Pop}},$$

$$\frac{\Gamma \vdash t_1 : \textbf{Sphere} \qquad \Gamma \vdash t_2 : \textbf{Sphere}}{\Gamma \vdash t_1 \diamond t_2 : \textbf{Merge}}, \qquad \frac{\Gamma \vdash t : \textbf{Sphere}}{\Gamma \vdash t[\Phi, v, S] : \textbf{RSVP}}.$$

## A.3 Operational Semantics

Let $t$ denote the geometric configuration represented by $t$. Evaluation is defined by

$$S = S, \qquad \mathrm{pop}(t) = \mathrm{pop}(t),$$

$$t_1 \diamond t_2 = \mathrm{pop}(t_1 \cup t_2), \qquad t[\Phi, v, S] = (t, \Phi, v, S).$$

Evaluation yields geometric configurations rather than symbolic values.

## A.4 Normal Forms

A term $t$ is in normal form if $\mathrm{pop}(t) = t$ up to homotopy. Confluence and adequacy (proved in the main text) imply that normal forms are unique up to geometric equivalence.

# B RSVP Fields and Variational Formulation

Let $P$ be a differentiable manifold (the plenum). An RSVP structure is specified by fields

$$(\Phi,\, v,\, S),$$

where $\Phi$ is a scalar potential, $v$ a vector field (interpreted as flow), and $S$ an entropy field. Collapse and merge operations interact with these fields through a variational principle. A standard Lagrangian density is given by

$$\mathcal{L}[\Phi, v, S] = \tfrac{1}{2}\, |\nabla \Phi|^2 + \langle v, \nabla \Phi \rangle - S,$$

where $|\nabla\Phi|^2$ denotes the metric contraction of the gradient, and $\langle v, \nabla\Phi\rangle$ denotes flow-mediated interaction. The entropy term $-S$ represents internal-to-boundary dissipation.

Euler–Lagrange variation yields a coupled PDE system of the form

$$\Delta\Phi - \mathrm{div}(\Phi v) = \partial S / \partial t, \qquad \partial_t\, v + (v \cdot \nabla) v = -\nabla \Phi,$$

$$\partial_t\, S + \mathrm{div}(S\, v) = \Delta S,$$

interpreted as potential relaxation, flow advection, and entropy diffusion respectively. These equations specify lamphrodynamic constraints on geometric evolution under collapse. Their precise form may vary with the choice of background metric, constitutive relation, or thermodynamic model; the above form is representative of the structure assumed in the main text.

# C Lamphrodynamic Evolution and Hamiltonian Structure

Lamphrodynamics denotes the thermodynamically constrained evolution of geometric configurations under collapse and merge in the presence of the RSVP fields. A Hamiltonian functional capturing internal energy and entropy release may be written

$$\mathcal{H}[\Phi, v, S] = \int_P \left( \tfrac{1}{2} |v|^2 + \tfrac{1}{2} |\nabla \Phi|^2 - S \right) d\mathrm{vol},$$

where the first two terms represent kinetic and potential energy contributions, and the last term encodes entropy release. Collapse reduces $\mathcal{H}$ by increasing boundary entropy while decreasing internal potential.

In the main text, collapse is interpreted as a geometric operation $D_{\mathrm{pop}}$ acting on spheres in $P$. In Hamiltonian form this is realized as a vector field on function space,

$$\dot{\Phi} = -\frac{\delta \mathcal{H}}{\delta \Phi}, \qquad \dot{v} = -\frac{\delta \mathcal{H}}{\delta v}, \qquad \dot{S} = \frac{\delta \mathcal{H}}{\delta S},$$

modulated by admissibility conditions reflecting boundary effects and flow constraints. Collapse thus induces a Hamiltonian evolution constrained by entropy production and flow compatibility. Under the amplitwistor lift (Sections 13–15), this Hamiltonian vector field becomes a holomorphic differential operator acting on the corresponding amplitwistor loci, producing a coupled geometric–thermodynamic evolution in amplitwistor space.

## References


[1] Needham, Tristan. *Visual Complex Analysis*. Oxford University Press, 1997.

[2] Penrose, Roger. "Twistor Algebra." *Journal of Mathematical Physics*, 8(2), 1967, 345–366.

[3] Witten, Edward. "Perturbative Gauge Theory As A String Theory in Twistor Space." *Communications in Mathematical Physics*, 252 (2004): 189–258.

[4] Domingos, Pedro. "Tensor Logic: The Language of AI." *arXiv:2510.12269* [cs.LG], 2025.

[5] Barendregt, H. P. *The Lambda Calculus: Its Syntax and Semantics*. North–Holland, 1984.

[6] Koller, Daphne and Friedman, Nir. *Probabilistic Graphical Models: Principles and Techniques*. MIT Press, 2009.

[7] Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron. *Deep Learning*. MIT Press, 2016.