Journal of High Energy Physics, Gravitation and Cosmology, 2026, 12(4), 2042-2062
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

Tri-Vortex Coupling and Layered Field Topology

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How to cite this paper: Butto, N. (2026) Tri-Vortex Coupling and Layered Field Topology. *Journal of High Energy Physics, Gravitation and Cosmology*, **12**, 2042-2062.
https://doi.org/10.4236/jhepgc.2026.124101

Received: March 26, 2026
Accepted: September 13, 2026
Published: September 16, 2026

Abstract

Across diverse physical systems—from nuclear matter to cosmic plasmas—stable structures exhibit recurring patterns of bipolar organization, layered morphology, and counter-rotating flow, despite operating under vastly different force laws and energy scales. This work proposes that such recurrence reflects a universal interaction topology rather than a universal force. Building on a vortex-based description of interacting flows, we identify the tri-vortex monopole as the minimal stable interaction unit in a continuous medium. Each vortex is shown to possess an intrinsic four-arm spiral architecture imposed by symmetry and circulation conservation in a bipolar environment. When three vortices—two of like polarity and one of opposite polarity—interact, their spiral arms cannot connect arbitrarily. Topological closure, phase coherence, and energy minimization force the system to organize into a double-loop structure: an internal coupling circuit formed by three direct arm connections and an external return circuit formed by four additional arm pathways that link the top and bottom vortices with the lateral vortices. The redistribution of the six resulting degrees of freedom of binary polarity yields exactly seven distinct global configurations, corresponding to a hierarchy of seven stable interaction layers. This layer count follows combinatorially from the six binary variables, independent of any specific force or material substrate. The tri-vortex monopole and its seven-layer hierarchy thus constitute a geometric attractor for interacting flows, providing a unified topological foundation for layered structure formation across scales and disciplines. Subsequent papers will demonstrate how this universal topology is realized in specific physical contexts, including nuclear binding, biological growth fields, and astrophysical plasma structures.

Keywords

Universal Interaction Topology, Tri-Vortex Monopole, Coupled Vortex

Systems, Layered Field Structures, Spiral Arm Topology, Bipolar Symmetry, Topological Interaction Models, Continuous Media, Emergent Geometry, Double-Loop Coupling

1. Introduction

Many natural systems—ranging from microscopic to astronomical scales—exhibit recurring structural features such as bipolar organization, layered morphology, and counter-rotating flow patterns. These similarities persist despite the systems being governed by fundamentally different force laws, material properties, and energy scales. Such recurrence raises a foundational question: are these structures imposed by specific physical interactions, or do they reflect deeper geometric and topological constraints that transcend particular domains?

Traditional physical theories explain structure formation primarily through force-specific mechanisms. Nuclear systems are modeled using quantum chromodynamics, biological form through genetic regulation and biochemical signaling, and astrophysical objects through gravitation and magnetohydrodynamics. While highly successful within their respective domains, these approaches typically treat geometry as a consequence rather than as a primary organizing principle. As a result, structurally similar configurations observed across disciplines are often interpreted as analogies rather than as manifestations of a shared underlying framework.

An alternative viewpoint has progressively emerged in several areas of physics and biology, emphasizing the role of geometry, topology, and conservation laws in organizing matter. In fluid dynamics, vortices represent long-lived, topologically protected structures that dominate flow organization and energy transport [1] [2]. In plasma physics, helical flux tubes and bipolar outflows arise naturally from constraints imposed by circulation, helicity, and magnetic reconnection [3]-[5]. In biological systems, growth and form are increasingly understood as being guided by spatial fields—mechanical, chemical, and bioelectric—that constrain development along preferred geometries rather than encoding explicit shapes [6]-[9].

Across these contexts, structure formation is governed less by local forces alone and more by global interaction topologies that constrain how matter can organize.

Over the past years, the author has developed a vortex-based framework in which particles, fields, and composite systems are described as organized circulatory structures embedded in a continuous medium. These studies have addressed diverse problems, including internal particle structure, composite binding, and emergent layered morphologies. A recurring outcome of this work is the appearance of a common geometric pattern underlying otherwise disparate phenomena. The present article extracts this pattern from its specific realizations and formulates it as a stand-alone foundational structure, independent of any particular force or material substrate.

The central object introduced here is the tri-vortex monopole: a minimal, stable interaction topology formed by the coupling of three vortices—two of like polarity and one of opposite polarity—within a bipolar configuration. Unlike pairwise vortex interactions, which tend either toward indefinite orbiting or mutual annihilation [10] [11], the tri-vortex arrangement allows for stable coupling while preserving non-zero net flux. Importantly, this monopole is topological rather than electromagnetic in nature; it represents a directed organization of circulation and interaction pathways rather than a new fundamental charge.

A key element of the present framework is the internal structure of each vortex. Rather than being treated as featureless rotational objects, vortices are shown to possess an intrinsic spiral-arm architecture, imposed by symmetry and circulation conservation in a bipolar environment. Spiral instabilities in rotating systems are well documented in fluid dynamics and astrophysics, where azimuthal modes organize flow into discrete arms that serve as preferred channels for momentum and energy transport [2] [12] [13]. In symmetric bipolar configurations, the lowest non-degenerate spiral mode compatible with reflection and rotational symmetry corresponds to a four-arm structure, which emerges as a stable compromise between shear minimization and angular-momentum redistribution.

When tri-vortex coupling occurs, these spiral arms cannot connect arbitrarily. Constraints of topological closure, phase coherence, and energy minimization force the system to organize into a double-loop interaction structure, consisting of an internal coupling circuit and an external return circuit. Similar internal-external loop architectures are known to arise in vortex dynamics, magnetic flux-tube systems, and self-organized flow networks [3] [14] [15]. The redistribution of the remaining spiral arms into compatible coupling families leads naturally to the emergence of a hierarchy of seven stable interaction layers.

Crucially, the number, ordering, and relative structure of these layers arise as geometric consequences of the tri-vortex configuration and four-arm symmetry. They do not depend on the specific physical forces acting within the system. Different domains populate the same topology with different dynamics, but the underlying interaction architecture remains invariant. This distinction between topology and physical implementation is central to the present work.

The purpose of this article is, therefore, deliberately foundational. We aim to:

1) Define the internal spiral structure of a vortex in a bipolar interaction environment.

2) Introduce the tri-vortex monopole as the minimal stable interaction topology.

3) Derive the emergence of a seven-layer interaction hierarchy from topological and energetic constraints alone.

4) Establish the universality of this interaction topology independently of any specific physical domain.

No reference is made in this paper to nuclear, biological, or astrophysical systems except in a strictly contextual sense. Those applications will be developed in subsequent works, where the present topology will be shown to manifest as layered binding structures, growth fields, and plasma morphologies under domain-specific dynamics.

By isolating the universal interaction topology from its physical realizations, this study provides a geometric foundation upon which diverse structural phenomena can be understood within a single, coherent framework.

2. Structure of a Vortex and the Four-Arm Spiral Architecture

2.1. Vortices as Organized Interaction Structures

In a continuous medium capable of sustaining circulation, vortices may be treated as long-lived, structurally organized flow configurations rather than merely idealized rotational singularities. In the simplest axisymmetric description, a vortex is characterized by its circulation,

$$\Gamma = \oint \boldsymbol{v} \cdot \mathrm{d}\boldsymbol{l},$$

where $\boldsymbol{v}$ is the velocity field and Γ is conserved in the absence of dissipation. However, studies in fluid dynamics, plasma physics, and rotating media indicate that perfectly axisymmetric configurations are generically sensitive to perturbation [5]-[12]. Under such perturbations, organized spiral channels may emerge and act as preferred routes for momentum transport, energy redistribution, and interaction with the surrounding medium.

Purely circular flow is inefficient at mediating exchange with neighboring structures. The development of spiral organization may therefore be interpreted as a natural mechanism by which a rotating system redistributes shear and angular momentum while preserving coherent circulation [15] [16].

2.2. Spiral Arms as Azimuthal Instability Modes

The emergence of spiral structure can be described by decomposing perturbations of an underlying axisymmetric flow into azimuthal Fourier modes. A small disturbance may be written as

$$\delta\Psi(r,\theta,t) \propto \mathrm{e}^{im\theta},$$

where θ is the azimuthal angle and $m \in \mathbb{Z}$ is the azimuthal mode number. The integer m determines the angular symmetry of the perturbation and corresponds to the number of repeating angular structures around the rotation axis.

The cases $m = 1$, $m = 2$, and $m = 3$ correspond, respectively, to lopsided, dipolar or bar-like, and three-lobed distortions, whereas $m \geq 4$ yields higher-order spiral symmetries. Within the present framework, the vortex is embedded in a bipolar interaction environment that is assumed to preserve reflection symmetry about an equatorial plane together with inversion along a principal axis. Under these conditions, the lower modes are restricted: $m = 1$ breaks inversion symmetry, $m = 2$ reduces to an effectively dipolar deformation rather than a genuine multi-arm spiral, and $m = 3$ is incompatible with the assumed inversion symmetry because of their odd-fold angular structure.

Accordingly, the lowest-order non-degenerate azimuthal mode consistent with both rotational order and the assumed bipolar symmetry is $m = 4$. In this sense, the four-arm spiral is adopted here as the minimal symmetry-compatible spiral architecture of a rotating bipolar system. Whether it is also the dynamically preferred mode in a specific medium depends on the detailed governing equations and must be assessed separately (**Figure 1**).

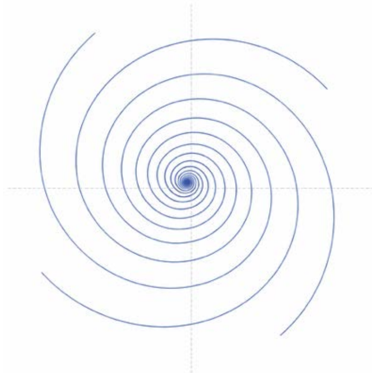

Figure 1. Four-arm spiral vortex ($m = 4$), the minimal stable configuration combining rotational symmetry, bipolar balance, and internal structural organization.

2.3. Physical Interpretation of the Four Spiral Arms

Within the present model, each vortex embedded in a bipolar interaction environment is therefore described by an intrinsic four-arm spiral architecture. These spiral arms originate near the vortex core and extend helically outward, carry interaction flux in the form of circulation, momentum, or field coupling, define preferred attachment channels for coupling with other vortices, and preserve topological continuity of the organized flow.

The arms are not treated as material filaments but as geometric flow channels determined by the global organization of the velocity and vorticity fields. Comparable multi-arm spiral structures are widely observed in rotating disks and self-organized flows, where they arise as stable compromises between angular-momentum transport and symmetry preservation [13] [17] [18].

2.4. Symmetry-Induced Arm Overlap in Bipolar Configurations

When vortices participate in a coherent bipolar configuration, their spiral arms do not remain independent. In the present framework, vortices of like polarity are assumed to share compatible radial-flux orientation and helical handedness, making phase alignment energetically favorable. As a result, corresponding spiral arms tend to overlap under common rotation.

This produces three immediate consequences. First, arms belonging to vortices of like polarity tend to align in phase. Second, overlapping arms no longer behave as distinguishable coupling channels. Third, the number of independent interaction pathways is reduced by symmetry. This reduction is a geometric consequence of shared rotation and does not depend on the microscopic nature of the medium. It plays a central role in determining how many coupling pathways remain available once multiple vortices interact.

2.5. Role of Spiral Arms in Inter-Vortex Coupling

Within the present model, spiral arms provide the admissible conduits for inter-vortex coupling. Any viable coupling pathway must satisfy three simultaneous requirements: topological closure, so that open-ended interaction lines are excluded; phase coherence, so that connected arms retain compatible pitch and rotational phase; and energetic economy, so that the chosen configuration lowers the total interaction cost, often represented as an effective tension along the spiral paths [19].

Because not all arms can satisfy these requirements simultaneously, only a subset can participate in short, direct internal couplings. The remaining arms must reorganize into larger outer or return pathways. This redistribution mechanism prepares the transition from a single-vortex structure to a composite layered organization (**Figure 2**).

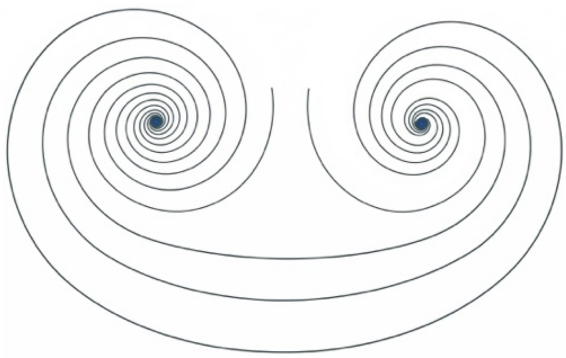

Figure 2. Bipolar symmetry and arm overlap. Two vortices in a coherent bipolar arrangement rotate about a shared axis. Corresponding spiral arms partially overlap because of phase alignment and common rotation, reducing the number of independent coupling channels.

2.6. Transition to Tri-Vortex Coupling

The four-arm spiral architecture establishes the interaction grammar of vortices. In the next section, we show that when three vortices—two of like polarity and one of opposite polarity—interact within a bipolar arrangement, the constraints described above force the system into a tri-vortex monopole configuration. This configuration constitutes the minimal stable interaction topology and provides the foundation for the emergence of layered field structures (**Figure 3**).

3. Tri-Vortex Coupling and Monopole-Like Interaction Topology

3.1. Why Two Vortices Are Insufficient

The interaction of two vortices in a continuous medium is fundamentally unstable as a binding configuration. Classical vortex dynamics shows that:

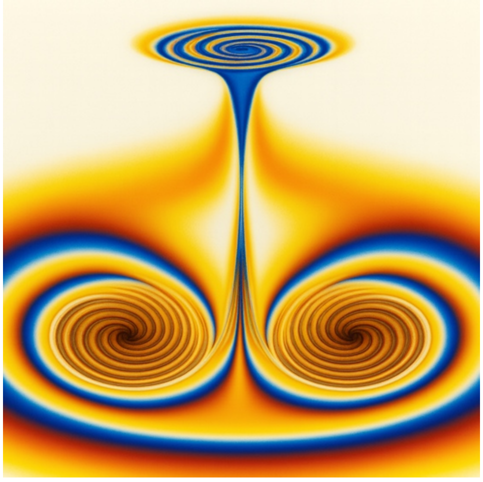

Figure 3. Tri-vortex interaction topology formed by two like-polarity vortices and one opposite-polarity vortex. Under four-arm spiral coupling constraints, the system reorganizes into a minimal stable monopole-like configuration with an internal high-coherence loop and an external return loop, ensuring phase locking, topological closure, and energetic stability.

- vortices of identical circulation tend to orbit indefinitely without forming a bound state.
- vortices of opposite circulation attract and annihilate or collapse into a transient dipole [10] [11].

In neither case does a stable, localized interaction structure emerge. Two-vortex systems lack the degrees of freedom necessary to simultaneously satisfy circulation conservation, phase coherence, and global energy minimization.

This limitation implies that pairwise interactions alone cannot serve as the primitive building block of stable composite structures.

3.2. The Tri-Vortex Configuration as the Minimal Stable Interaction Unit

A qualitatively new regime emerges when three vortices interact simultaneously. Consider a configuration consisting of:

- two vortices of identical polarity,
- one vortex of opposite polarity,

arranged within a bipolar interaction geometry.

Let the individual circulations be

$$\Gamma_1 = \Gamma_2 = +\Gamma, \Gamma_3 = -\Gamma,$$

so that the total circulation satisfies

$$\Gamma_{\text{tot}} = \Gamma_1 + \Gamma_2 + \Gamma_3 = +\Gamma \neq 0.$$

This non-zero net circulation defines a monopole-like interaction core, while internal circulation balance prevents collapse. Importantly, this monopole character is topological, not electromagnetic: it represents directed organization of flow and interaction pathways rather than a new conserved charge.

Such tri-vortex configurations are known in fluid dynamics to exhibit enhanced stability relative to vortex pairs, owing to the redistribution of angular momentum among multiple interaction channels [20] [21].

3.3. Spiral-Arm-Mediated Coupling in the Tri-Vortex System

As established in Section 2, each vortex possesses an intrinsic four-arm spiral architecture. When three vortices couple:

- not all spiral arms can connect directly without violating phase or closure constraints,
- coupling must occur through selective arm engagement.

The interaction, therefore, reorganizes into two complementary coupling circuits:

1) Internal Coupling Loop

A subset of spiral arms forms a short, high-coherence circuit linking the three vortex cores. This loop establishes phase locking and defines the primary interaction skeleton.

2) External Return Loop

Remaining spiral arms reorganize into a longer circuit encircling the system, ensuring topological closure and global stability.

This double-loop architecture is not imposed but arises naturally from the constraints outlined in Section 2. Similar internal-external loop structures are well known in magnetohydrodynamic flux-tube systems and helicity-conserving flows [3] [22].

3.4. Energetic Interpretation and Stability

The stability of the tri-vortex monopole can be expressed through a generic interaction energy functional,

$$E_{\text{tot}} = \sum_k \left(\sigma L_k + E_{\text{phase}}^{(k)} + E_{\text{twist}}^{(k)} \right),$$

where:

- L_k is the length of the coupling channel k,
- σ is an effective interaction tension,
- E_{phase} penalizes phase mismatch,
- E_{twist} penalizes excessive torsion and curvature.

The internal loop minimizes L_k and phase mismatch, while the external loop minimizes total twist and enforces closure. No alternative configuration yields a lower energy state under the same topological constraints.

Thus, the tri-vortex monopole represents a local minimum of the interaction energy, stabilized by topology rather than by force strength.

3.5. Relation to Previous Vortex-Based Studies

The tri-vortex monopole topology identified here is not introduced ad hoc. Variants of this same interaction structure have appeared implicitly in several vortex-based studies by the author, where it was embedded within specific physical realizations.

In particular:

- vortex models of elementary particles revealed composite structures stabilized by internal circulation loops and external return paths,
- multi-vortex configurations exhibited monopole-like flow organization and layered morphologies,
- coupled vortex systems consistently reorganized into double-loop architectures under stability constraints.

These prior works demonstrated that stable composite structures emerge only when three or more vortical elements interact, and that layered organization is a natural consequence of spiral-arm redistribution and phase locking [23]-[27].

In the present article, those domain-specific results are abstracted into a general interaction topology, independent of any particular physical interpretation.

3.6. From Tri-Vortex Coupling to Layered Interaction Hierarchies

Once the tri-vortex monopole is established, the emergence of discrete interaction layers becomes unavoidable. The four spiral arms of each vortex generate more potential coupling pathways than can be accommodated within the internal loop. The excess arms must therefore reorganize into outer coupling families.

As a result:

- a small number of tightly bound inner layers forms around the internal loop,
- additional, more extended layers form through the external loop and cross-coupling between spiral arms.

The precise layer count follows directly from:

- four spiral arms per vortex,
- bipolar symmetry,
- tri-vortex coupling constraints.

In the following section, we demonstrate how these constraints lead systematically to a seven-layer interaction hierarchy, entirely from geometric and topological considerations.

3.7. Interaction of Two Tri-Vortex Monopole-Like Units: Six-Vortex System and Proposed Golden-Ratio Scaling

When two tri-vortex monopole-like units interact, the result is a six-vortex composite system (see **Figure 4**). A physically motivated example is a bound proton-neutron pair, if each nucleon is interpreted within the present framework as a confined monopole-like vortex complex of opposite effective polarity [24]. In such a composite, the spiral arms of the two three-vortex units interlace and reorganize subject to topological closure, phase compatibility, and reduction of the total interaction energy.

3.7.1. Binary Polarity Description

Each vortex is assigned a binary polarity $\sigma_i = \pm 1$. Centrifugal, outward-dominant vortices are assigned $\sigma_i = +1$, whereas centripetal, inward-dominant vortices are

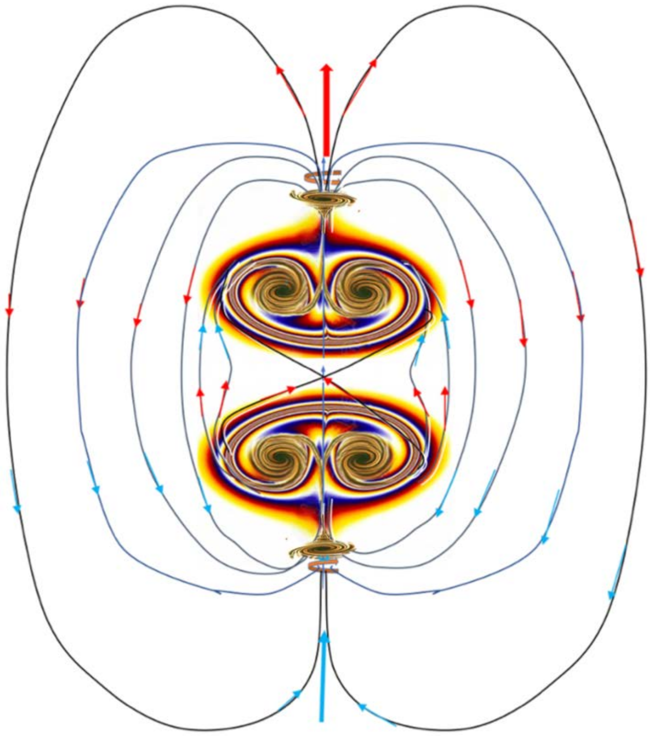

Figure 4. Universal energy model composed of two coupled poles, each formed by a tri-vortex unit (two like-polarity vortices and one opposite). The bipolar arrangement establishes a balanced flow system in which inward and outward fluxes are distributed through internal coupling loops and external return pathways, giving rise to a layered interaction hierarchy and global topological stability. Source [24].

assigned $\sigma_i = -1$. For the six-vortex composite, the total polarity is

$$P = \sum_{i=1}^{6} \sigma_i .$$

Because each σ_i can take only the values ±1, the total polarity can assume only seven values,

$$P \in \{-6, -4, -2, 0, +2, +4, +6\}.$$

These define seven coarse-grained sectors of total polarity. This sevenfold combinatorial structure provides the macroscopic polarity classification used later in the hierarchical description. By itself, however, it does not yet determine the real-space geometry of the interaction layers.

3.7.2. Internal and External Coupling Families

As the two tri-vortex units approach, only a subset of their spiral arms can engage directly without violating phase and closure constraints. In the present topology, the coupling reorganizes into an inner family and an outer family.

A compact internal family is formed by three short, high-coherence coupling lines linking phase-compatible vortices across the interaction core. These inner connections define the most strongly bound part of the six-vortex composite. The remaining admissible arm connections reorganize into four larger return pathways that complete global closure and redistribute angular momentum over a wider radius.

Taken together, these three internal and four external pathways provide a natural geometric analogue of the seven allowed sectors of total polarity in the six-vortex binary description. The correspondence is structural rather than strictly one-to-one: the pathways belong to the real-space coupling topology, whereas the seven sectors arise from coarse-graining in polarity space.

3.7.3. Proposed Self-Similar Radial Scaling

Because the spiral arms lengthen and unwind away from the core, successive coupling families need not be equally spaced in radius. If the six-vortex composite is assumed to adopt a self-similar morphology that balances radial field decay against the increasing path length and torsional cost of outer loops, then the radii of successive layers are expected to follow approximately a constant ratio,

$$\frac{r_{n+1}}{r_n} \approx q.$$

In the present model, the golden ratio

$$\phi = \frac{1+\sqrt{5}}{2} \approx 1.618$$

is proposed as the natural candidate for this scaling factor, so that

$$r_n = r_1 \phi^{n-1}.$$

This choice is motivated by the well-known role of ϕ in self-similar spiral organization and by its ability to relate compact inner couplings to more extended outer return pathways within a single scale-invariant morphology. On this basis, the first three radii (r_1, r_2, r_3) may be associated with the compact internal coupling family, whereas (r_4, r_5, r_6, r_7) represent the more extended external family.

At the present stage, this golden-ratio spacing should be understood as a model hypothesis motivated by self-similar organization. A full variational derivation from an explicit interaction-energy functional remains an important task for future work.

3.7.4. Transition to the Seven-Layer Hierarchy

The six-vortex composite, therefore, combines two complementary descriptions. In polarity space, six binary degrees of freedom define seven allowed sectors of total polarity. In real space, the coupling topology separates into a compact inner family and a more extended outer family. The seven-layer hierarchy introduced in the next section is obtained by representing these seven coarse-grained polarity sectors through seven interaction layers arranged around the composite core.

In this interpretation, the three innermost layers correspond to the most coherent internal couplings, whereas the four outer layers correspond to progressively larger return pathways. Their relative spacing is modeled by the self-similar scaling ansatz given above.

4. Polarity, Flow Asymmetry, and the Emergence of the Seven-Layer Interaction Hierarchy

4.1. Polarity as a Dynamical Property of Vortical Flow

Within the universal interaction topology developed in the preceding sections, polarity is not treated as an intrinsic label but as an emergent dynamical property of vortical flow. It arises from the relative dominance of inward versus outward radial components within an organized rotating structure.

A vortex is said to possess negative polarity when its internal organization is dominated by centripetal flow, such that trajectories spiral from the periphery toward the core. Conversely, a vortex is said to possess positive polarity when centrifugal flow dominates, with trajectories emerging from the core and spiraling outward into the surrounding medium.

Both polarities may sustain rotation and associated circulatory effects. The distinction lies not in the existence of rotation itself, but in the direction of net flux exchange with the environment. In this sense, polarity reflects flow asymmetry rather than electric charge or material composition.

4.2. Polarity in the Tri-Vortex Monopole-Like Configuration

When three vortices interact to form a tri-vortex monopole-like unit, polarity becomes a collective property of the coupled system. As discussed in Section 3, the minimal stable interaction topology consists of two vortices of one polarity and a third of the opposite polarity arranged within a bipolar geometry.

This asymmetry is essential. If all three vortices shared the same dominant flow direction, the system would tend either toward runaway expansion or toward collapse. Stability requires a balance between outward-projected flux and inward-absorbed flux, enforced by the coexistence of centrifugal and centripetal vortices.

Within this tri-vortex configuration, positive-polarity vortices provide outward-propagating interaction channels, whereas negative-polarity vortices provide inward-absorbing sinks. Their coupling yields a directed yet closed interaction topology characterized by a preferred axis and a non-zero internal flux, while still preserving global closure. For this reason, the resulting structure is described as monopole-like in a topological sense.

4.3. Selective Engagement of Spiral Arms

Each vortex contributes four spiral arms, as established in Section 2. Once polarity asymmetry is introduced, however, these arms are no longer functionally equivalent.

Spiral arms associated with centrifugal vortices preferentially act as emissive channels, projecting interaction outward. Spiral arms associated with centripetal vortices preferentially act as absorptive channels, drawing interaction inward. When vortices of opposite polarity interact, only certain arm pairings can satisfy the requirements of phase coherence, topological closure, and energetic economy simultaneously.

As a consequence, only a subset of spiral arms participates in the formation of the internal coupling circuit, whereas the remaining arms are redirected into outer or return circuits. This selective engagement of spiral arms is the basic mechanism underlying the emergence of a layered interaction hierarchy.

4.4. Formation of the Inner Interaction Layers

The first stage of organization gives rise to a small number of inner interaction layers associated with the most direct and energetically favorable couplings between emissive and absorptive spiral arms.

These inner layers form close to the interaction core, exhibit the highest degree of phase coherence, and define the structural skeleton of the coupled system. They are therefore responsible for the strongest binding and the greatest dynamical stability. Because only a limited number of spiral arms can be accommodated in this inner circuit without violating phase or closure constraints, the number of such inner layers is restricted by geometry.

4.5. Redistribution into Outer Layers

The remaining spiral arms cannot terminate freely. Topological continuity requires that they be incorporated into admissible return pathways, while energetic considerations disfavor forcing them into an already saturated internal circuit. As a result, these arms reorganize into more extended outer coupling families at larger radii.

These outer layers are less tightly bound than the inner ones, but they play an essential structural role. They act as return paths, ensuring global closure, redistributing angular momentum, reducing shear, and stabilizing the inner structure against collapse or runaway expansion. The coexistence of compact inner layers and more extended outer layers defines the double-loop architecture introduced in Sections 2 and 3, consisting of an internal coupling circuit and an external return circuit. This structure is similar to that of the interaction between a proton and a neutron.

4.6. The Seven-Layer Hierarchy

When two tri-vortex monopole-like units interact, the resulting composite system contains six vortices, each assigned a binary polarity variable

$$\sigma_i \in \{-1,+1\}, i = 1,\cdots,6.$$

As discussed in Section 3.7, the total polarity of the six-vortex system is

$$P = \sum_{i=1}^{6} \sigma_i ,$$

and can therefore assume only the seven values

$$P \in \{-6,-4,-2,0,+2,+4,+6\}.$$

These seven values define seven coarse-grained polarity sectors of the composite system.

At the geometric level, the same coupling constraints described above reorganize the spiral arms into two distinct families: a compact internal family associated with the most coherent core couplings, and a more extended external family associated with return pathways and global closure. In the present topology, this organization is represented by three inner layers and four outer layers.

The seven interaction layers should therefore be understood as the geometric expression of an underlying seven-sector polarity organization. In this sense, the number seven is not introduced as a symbolic postulate, but emerges from the conjunction of six binary polarity degrees of freedom, selective arm engagement, and topological closure within the six-vortex composite.

4.7. Proposed Golden-Ratio Scaling of Layer Radii

The successive interaction layers need not be equally spaced in radius. Because outer loops are longer and less tightly bound than inner ones, a self-similar radial organization is naturally suggested. If the layered structure is assumed to balance radial field decay, increasing path length, and topological continuity, then the sequence of layer radii may be approximated by a geometric progression,

$$\frac{r_{n+1}}{r_n} \approx q.$$

Within the present framework, the golden ratio

$$\phi = \frac{1+\sqrt{5}}{2} \approx 1.618$$

is proposed as a natural candidate for this scaling factor, so that

$$r_n = r_1 \phi^{n-1}.$$

Under this ansatz, the first three radii (r_1, r_2, r_3) correspond to the compact inner layers, whereas (r_4, r_5, r_6, r_7) describe the progressively more extended outer layers. At the present stage, this golden-ratio spacing should be understood as a model hypothesis motivated by self-similar organization. A complete derivation from an explicit interaction-energy functional remains an important task for future work.

4.8. Apparent Neutrality and Far-Field Cancellation

An important consequence of this layered organization is that a system may possess rich internal structure, including rotation, circulation, and multi-layer coupling, while exhibiting approximately neutral behavior in the far field.

This occurs when outward-directed flux from centrifugal vortices is balanced by inward-directed flux from centripetal vortices, when the outer return pathways close locally, and when no net long-range interaction channel remains open. Neutrality, in this framework, is therefore interpreted not as the absence of internal dynamics, but as the topological cancellation of large-scale flow.

4.9. Generality of the Layered Topology

Because the seven-layer hierarchy is constructed from geometric and topological ingredients—four-arm spiral architecture, polarity asymmetry, selective coupling, and six-vortex organization—it may be viewed as a general interaction template rather than a mechanism tied to a single physical medium.

Different realizations of this template may occur in different systems depending on the nature of the medium, the governing dynamical laws, and the forces that populate the topology. In this sense, the present model proposes that layered vortex organization expresses a general structural principle, while its specific physical manifestation remains system-dependent.

4.10. Transition to Three-Dimensional Topological Lifting

Thus far, the interaction topology has been described primarily in terms of coupled spiral structures and radial layer organization. In the next section, this hierarchy is extended into a three-dimensional volumetric form, where the interaction layers are represented as nested shells or lobes. This topological lifting preserves the underlying interaction grammar while allowing distinct physical realizations in three-dimensional space.

5. Three-Dimensional Topological Lifting of the Interaction Field

5.1. From Planar Interaction Topology to Volumetric Organization

The interaction topology developed in Sections 2 - 4 has been described primarily in terms of coupled spiral structures and layered organization within a plane orthogonal to a preferred axis. This planar representation is sufficient to make the coupling logic explicit, but any physical realization of the system must ultimately be embedded in three dimensions. The extension of circulation-preserving planar structures into volumetric fields is a familiar problem in topology, fluid mechanics, and helicity-preserving flow theory [28]-[31].

In the present framework, the three-dimensional structure is obtained not by introducing new interaction rules, but by lifting the existing planar topology into three dimensions while preserving its key invariants. These include circulation conservation [19] [29], polarity asymmetry defined by inward versus outward flow dominance [25] [27], topological closure of the coupling pathways [32] [33], and the hierarchical distinction between compact inner couplings and more extended outer return families [34] [35].

The resulting volumetric structure is therefore interpreted as a geometric embedding of the planar interaction topology rather than as a separate dynamical regime [30] [31].

5.2. Axial Extension and Bipolar Symmetry

The tri-vortex monopole-like unit defined in Section 3 establishes a preferred axis through the imbalance between inward- and outward-directed flow channels. Under three-dimensional lifting, this axis becomes the organizing spine of the interaction field. Around it, the flow reorganizes above and below a central plane in a manner consistent with the bipolar symmetry already introduced in the planar description.

This symmetry is preserved through reflection across the central plane, generating two mirror-related volumetric regions. Each region inherits the same internal interaction logic: spiral arms extend helically around the preferred axis while remaining subject to phase compatibility and closure constraints. In this way, the planar spiral channels described in Section 2 acquire a three-dimensional interpretation as helical surfaces or flow sheets, and the planar layers described in Section 4 acquire the form of nested volumetric regions [31] [33].

The three-dimensional field may therefore be viewed as the axial continuation of the same interaction grammar already established in two dimensions.

5.3. Volumetric Interpretation of the Interaction Layers

After lifting into three dimensions, the seven interaction layers are no longer represented as concentric planar regions, but as nested volumetric domains of the lifted vector field. These domains are separated by transition surfaces across which the dominant coupling pathways change character [29] [34].

The inner layers form compact, high-coherence volumetric regions surrounding the interaction core. They correspond to the most direct couplings between inward- and outward-directed flow channels and define the structural nucleus of the configuration [19] [33].

The outer layers form progressively larger shells or lobes enclosing the inner core. These more extended regions act as return pathways for the redistributed flux, participate in angular-momentum balance, and contribute to the stabilization of the overall configuration [29] [35].

If the self-similar radial ansatz introduced in Section 4.7 is retained under three-dimensional lifting, then the characteristic radii of these nested volumetric layers satisfy

$$\frac{r_{n+1}}{r_n} \approx \phi, \phi = \frac{1+\sqrt{5}}{2}.$$

Accordingly, the volumetric shells may be modeled as a self-similar hierarchy in which each successive layer is scaled approximately by the golden ratio. At the present stage, this scaling should be understood as part of the proposed model architecture rather than as a fully derived consequence of the three-dimensional lifting itself.

5.4. Preservation of the Double-Loop Architecture

An essential requirement of the three-dimensional embedding is the preservation of the double-loop interaction structure identified in Sections 3 and 4. In volumetric form, the internal coupling circuit is represented by a closed circulation localized near the preferred axis, whereas the external return circuit becomes a broader toroidal or shell-like flow enveloping the inner structure.

This interpretation preserves the distinction between compact high-coherence couplings and more extended return pathways. Because the lifting is assumed to be topologically smooth, the interaction architecture retains the same basic loop organization as in the planar case [19] [32] [34].

In the simplest version of the lifted topology considered here, no additional independent coupling loops are introduced. Dimensional extension changes the geometric realization of the interaction field, but not the fundamental coupling grammar inherited from the planar topology [29] [31].

5.5. Stability and Energetic Interpretation in Three Dimensions

The energetic picture introduced in Section 3 extends naturally to the lifted configuration. The total interaction energy may again be represented schematically as

$$E_{\text{tot}} = \sum_k \left(\sigma L_k + E_{\text{phase}}^{(k)} + E_{\text{twist}}^{(k)} \right),$$

where L_k now denotes the length of three-dimensional coupling pathways, while the phase and twist terms account for mismatch, curvature, and torsional cost in the volumetric embedding [32] [33].

Within the present model, the seven-layer lifted configuration is interpreted as a favorable organization because it preserves short, coherent inner couplings while allowing the remaining interaction channels to close through more extended outer pathways. Alternative rearrangements that merge layers, suppress return circuits, or force additional couplings through the inner region would generally be expected to increase path length, phase mismatch, or torsional strain.

For this reason, the lifted seven-layer structure may be regarded as a candidate local minimum of the effective interaction energy within the topological class considered here. A full proof of this claim would require a more explicit energy functional and remains a task for future work.

If the golden-ratio scaling proposed in Section 4.7 is maintained, then the same self-similar spacing may be carried over to the volumetric shells. In that case, the lifted configuration combines topological closure with approximate scale invariance in its radial organization.

5.6. Apparent Shape Diversity within a Single Topological Family

Although the underlying topology is held fixed, its three-dimensional manifestations may vary with boundary conditions, medium properties, or excitation state. Such variations may include elongation or compression along the preferred axis, differential expansion of outer shells, or partial attenuation of specific layers. These modifications alter the geometry of the embedding without necessarily changing the topology of the interaction structure itself [30] [35].

Apparent shape diversity should therefore be interpreted as variation within a single topological family rather than as evidence for different underlying interaction architectures [29] [31]. The same coupling grammar may thus admit multiple geometric realizations while preserving its core invariants.

5.7. Implications of Three-Dimensional Lifting

The three-dimensional lifting developed here shows that the interaction topology introduced in the preceding sections admits a natural volumetric realization. In this lifted form, monopole-like tri-vortex organization is preserved, layered coupling hierarchies remain meaningful, and polarity continues to function as a descriptor of inward versus outward flow balance in three-dimensional space.

More broadly, the lifting procedure indicates that complex three-dimensional morphologies may arise from a single invariant interaction template. If the self-similar radial ansatz is retained, the nested shells provide a quantitative signature of the topology that may, in principle, be sought in different physical realizations.

In later applications, this lifted topology may serve as a common structural template onto which different media, forces, or field interpretations are mapped, while preserving the same underlying geometric organization.

6. Conclusions

In this work, we proposed a universal interaction topology for coupled vortical structures in a continuous medium. Rather than treating vortices as featureless rotational singularities, the present framework models them as organized flow entities endowed with internal spiral architecture. Within this setting, a tri-vortex monopole-like unit emerges as the smallest interaction topology capable of combining non-zero net circulation, phase locking, and topological closure.

The analysis further suggests that, under the assumed bipolar symmetry, the lowest-order non-degenerate azimuthal mode compatible with structured inter-vortex coupling is the four-arm configuration, $m = 4$. In this sense, the four-arm spiral architecture provides the basic interaction grammar of the model, specifying the admissible channels through which vortices may couple, overlap, and redistribute flow.

When vortices of mixed polarity interact, the simultaneous requirements of phase compatibility, closure, and energetic economy lead naturally to a double-loop organization composed of a compact internal coupling family and a more extended external return family. When two tri-vortex monopole-like units are combined, the resulting six-vortex system admits six binary polarity variables and therefore seven possible values of the total polarity. These seven coarse-grained polarity sectors provide the combinatorial basis for the sevenfold hierarchical organization developed in the article. In the geometric representation adopted here, this seven-sector structure is expressed as a hierarchy of three inner and four outer interaction layers.

Within the present model, polarity is interpreted as a dynamical property of flow asymmetry, determined by the relative dominance of inward versus outward radial flux, rather than as an intrinsic charge-like attribute. Apparent neutrality is correspondingly reinterpreted as large-scale cancellation of balanced inward and outward flow pathways, rather than as the absence of internal structure or dynamics.

The extension of the planar interaction topology into three dimensions shows that the same coupling grammar may be embedded in a volumetric field without introducing new topological rules. Under such lifting, the planar interaction layers acquire the form of nested shells or lobes organized around a preferred axis, while circulation, polarity asymmetry, closure, and hierarchical differentiation are preserved. In this way, the three-dimensional realization remains a geometric continuation of the same underlying topology.

A further element of the framework is the proposal that the radial organization of the layers may follow a self-similar scaling law. In the present formulation, the golden ratio,

$$\phi = \frac{1+\sqrt{5}}{2},$$

is introduced as a natural candidate for the spacing factor between successive layers. This scaling should presently be regarded as a model hypothesis motivated by self-similar organization and by the balance between compact inner couplings and more extended outer return pathways. A full derivation from an explicit interaction-energy functional remains for future work.

Taken together, these results suggest that the tri-vortex monopole-like unit and its associated layered hierarchy may be understood as a general interaction template for organized flows in continuous media. The framework provides a unified geometric language for describing how complex layered structures can emerge from a small number of topological and symmetry constraints, without requiring separate structural rules for each physical realization.

Future work will be needed to connect this general topology to specific dynamical systems and to determine how the proposed interaction template is populated by particular media, forces, and boundary conditions. In that broader context, the present framework may serve as a common geometric core for comparing diverse phenomena that exhibit coupled vortical organization across different scales.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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