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The Universal Code: Unifying Monopole, Quark, and Nucleon Structure in a 64-State Bipolar Vortex Architecture

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Abstract

This article presents the universal code as a classical 64-state bipolar vortex configuration space. The model is based on a minimal architecture composed of two coupled three-vortex triplets. Each elementary vortex mode is represented by an effective binary orientation variable, $s_i \in \{-1,+1\}$. A single triplet therefore generates $2^3 = 8$ possible internal configurations, while two coupled triplets generate $2^6 = 64$ possible bipolar configurations. Within this framework, the polarity sum of a three-vortex triplet is not identified directly with quark electric charge. Since the triplet polarity $P(T) = s_1 + s_2 + s_3$ can only take the values −3, −1, +1, and +3, it cannot by itself reproduce the up-quark charge +2/3e when expressed in units of $e/3$. Electric charge is therefore treated as a separate sector label $\chi \in \{u, d\}$, with $Q(u) = +2e/3$ and $Q(d) = -e/3$. The triplet sign configuration instead describes internal vortex orientation, polarity, stability, and possible color-like degeneracy. The 64 states are interpreted as effective classical vortex configurations selected by topology, coupling, and energy minimization, rather than as quantum superposition states. A classical Ising-type energy functional is introduced to formalize the selection of physically admissible sectors. Within this framework, monopole-like structures correspond to single-triplet polarity sectors, quark-like structures correspond to charge-sector labels coupled to internal triplet configurations, and nucleon-like structures correspond to constrained low-energy realizations within the full bipolar 64-state space. A first falsifiable numerical prediction is derived by estimating the energy cost of a single stem-axis vortex-polarity excitation from the QCD string tension and the down-quark stem radius obtained in the mushroom proton model. Using $\sigma \approx 0.9$ GeV/fm and $r_d \approx 0.534$ fm gives $\Delta E_1 \approx 0.481$ GeV. Therefore, the first vortex-polarity excited proton state is predicted near $M_p^* \approx 1.42$ GeV/c^2, with a conservative range of approximately

1.36 - 1.48 GeV/c^2. This places the predicted excitation in the low-lying nucleon resonance region and provides a testable quantitative consequence of the model.

Keywords

Universal Code, Classical Configuration Space, Bipolar Vortex Model, Quark Vortex Theory, Proton Structure, Nucleon Organization, Polarity, Ising Model, Vortex Dynamics, Superfluid Vacuum, Mushroom Proton Model, Baryon Excitation

1. Introduction

1.1. Background

The internal structure of matter remains one of the central questions of theoretical physics. The Standard Model and quantum chromodynamics (QCD) provide the accepted framework for describing quarks, gluons, and the strong interaction. Within this framework, protons and neutrons are understood as composite hadrons made of three valence quarks, sea quarks, gluons, and dynamic field energy. QCD has been highly successful, yet several conceptual and computational challenges remain, including the emergence of hadron mass, the proton spin decomposition, the proton radius puzzle, and the geometric interpretation of confinement.

In previous vortex-based works, quarks were modeled as stable vortex-like structures within a superfluid vacuum, and the proton was interpreted through a mushroom-like geometry in which two up-quark vortices form a cap-like structure while the down-quark vortex forms a central stem or axis [1]-[3]. These models were developed to provide a geometric and hydrodynamic interpretation of quark interaction, proton spin, proton radius, and proton mass.

The present article does not attempt to replace QCD. Instead, it proposes a complementary structural model: a finite classical configuration space generated by the coupling of two three-vortex triplets. This space is called here the universal code, not in the sense of a metaphysical message, but in the technical sense of a structured finite set of allowed vortex polarity configurations.

1.2. Conceptual Position of the Model

The present framework treats the universal code as a classical configuration space generated by binary vortex orientations. Each elementary vortex mode is described by a sign variable:

$$s_i \in \{-1, +1\} \tag{1}$$

These signs represent effective orientation states of the vortex system, such as opposite circulation, polarity, or topological alignment. They are not introduced as quantum basis states are not used here to describe quantum superposition or

entanglement. The purpose of the model is to define a finite structured space of possible vortex configurations and to determine which of these configurations may become physically admissible through topology, coupling, and energy minimization.

For a three-vortex triplet,

$$T = (s_1, s_2, s_3) \tag{2}$$

the triplet polarity is defined as:

$$P(T) = s_1 + s_2 + s_3 \tag{3}$$

Since each s_i can take only the values −1 or +1, the possible triplet polarities are:

$$P(T) \in \{-3, -1, +1, +3\} \tag{4}$$

This polarity measures the internal alignment of the triplet. It may describe vortex orientation, topological polarity, magnetic tendency, stability class, or color-like degeneracy. However, it is not identified directly with electric charge.

Quark electric charge is represented separately by a charge-sector label:

$$\chi \in \{u, d\} \tag{5}$$

The corresponding electric charges are:

$$Q(u) = +2e/3 \tag{5a}$$

$$Q(d) = -e/3 \tag{5b}$$

Thus, a quark-like vortex state is represented by two complementary components:

$$q = (\chi, T) \tag{5c}$$

In this representation, χ determines the electric charge sector, while T determines the internal vortex configuration. Therefore:

$$Q(q) = Q(\chi) \tag{5d}$$

$$P(q) = P(T) \tag{5e}$$

This separation allows the model to preserve the known quark charge assignments while using triplet polarity as an independent structural variable of the vortex architecture.

1.3. Aim and Scope

The aim of this article is to define the universal code as a classical 64-state bipolar vortex configuration space. The specific objectives are:

1) To define the binary vortex orientation variable.
2) To construct the three-vortex triplet and its eight configurations.
3) To construct the bipolar six-vortex system and its 64 configurations.
4) To define triplet polarity, total polarity, imbalance, and vector classes.
5) To separate electric charge from polarity.
6) To introduce a classical energy functional for selecting physical sectors.

7) To connect the configuration space to quark-like and nucleon-like structures.

8) To derive one numerical, falsifiable prediction.

9) To clarify limitations and future predictive directions.

The article is foundational and theoretical. It proposes a structural framework that must later be completed by numerical modeling, comparison with hadron spectra, and experimental constraints.

2. The Binary Vortex Orientation Variable

2.1. Vortex Orientation as a Classical Binary Degree of Freedom

In the vortex framework, an elementary particle-like entity is modeled as a stable vortex structure within a superfluid-like vacuum medium [1]. Such a vortex possesses two physically distinct attributes that are often conflated in informal descriptions:

1) Flow polarity—whether the dominant flow is outward (centrifugal, tornado-like) or inward (centripetal, whirlpool-like).

2) Rotation direction—whether the vortex circulation is clockwise or counterclockwise (kinematic sense).

In the present model, the binary variable

$$s_i \in \{-1, +1\} \tag{5f}$$

is introduced to represent only the flow polarity. The assignment is:

- $s_i = +1$ → centrifugal (outward, tornado-like) tendency
- $s_i = -1$ → centripetal (inward, whirlpool-like) tendency

This choice is motivated by the quark vortex model [1], where up-type quarks exhibit centrifugal behavior and down-type quarks exhibit centripetal behavior. Flow polarity is directly related to the sign of the electric charge sector (through the label χ), but here it is treated as an independent structural variable of the vortex architecture.

2.2. Physical Meaning of the Sign Variable

The sign variable may encode several possible vortex attributes, including dominant inward or outward flow, polarity of vortex alignment, magnetic or topological orientation, or a stable internal configuration class. In this article, the binary variable s_i is specifically defined to represent the flow polarity: $s_i = +1$ for centrifugal (outward, tornado-like) tendency and $s_i = -1$ for centripetal (inward, whirlpool-like) tendency. Other attributes, such as the orientation of circulation (clockwise or counterclockwise), are not encoded in s_i; they are treated separately, being determined by the quark flavor or by the Ising coupling rules.

In this article, the sign variable does not encode electric charge by itself. Electric charge is treated separately as a sector label. This distinction is fundamental.

3. The Three-Vortex Triplet

3.1. Definition of a Triplet

A three-vortex triplet is defined as:

$$T = (s_1, s_2, s_3), s_i \in \{-1, +1\} \tag{6}$$

Since each of the three vortex modes has two possible orientations, a single triplet has:

$$N_3 = 2^3 = 8 \tag{7}$$

possible configurations.

These eight configurations are:

$$\begin{gathered}(+,+,+),\\(+,+,-),\\(+,-,+),\\(-,+,+),\\(+,-,-),\\(-,+,-),\\(-,-,+),\\(-,-,-).\end{gathered} \tag{8}$$

3.2. Triplet Polarity

The triplet polarity is defined as:

$$P(T) = s_1 + s_2 + s_3 \tag{9}$$

The possible values are:

$$P(T) = +3, +1, -1, -3 \tag{10}$$

The degeneracies are:

$$\begin{aligned}&P(T) = +3 \to 1 \text{ configuration} : (+,+,+)\\&P(T) = +1 \to 3 \text{ configurations} : (+,+,-), (+,-,+), (-,+,+)\\&P(T) = -1 \to 3 \text{ configurations} : (+,-,-), (-,+,-), (-,-,+)\\&P(T) = -3 \to 1 \text{ configuration} : (-,-,-)\end{aligned} \tag{11}$$

Thus, the triplet has a natural degeneracy pattern:

$$1:3:3:1 \tag{12}$$

3.3. Interpretation of the Triplet

The triplet is interpreted as the minimal internally structured vortex unit. In earlier vortex-based work, quarks were described as vortex structures, and proton stability was related to a three-quark organization [1]-[3]. In the present model, the triplet is not necessarily identical to a quark. Rather, it is a structural unit that may underlie monopole-like, quark-like, or nucleon-like configurations depending on additional physical constraints.

The triplet polarity $P(T)$ measures the degree of internal alignment. It may be associated with magnetic polarity, topological orientation, stability, or internal color-like multiplicity. It is not identical to electric charge.

4. From One Triplet to the Bipolar Six-Vortex Architecture

4.1. Definition of the Bipolar System

The universal code is generated by coupling two triplets:

$$T_a = (a_1, a_2, a_3), a_i \in \{-1, +1\} \tag{13}$$

$$T_b = (b_1, b_2, b_3), b_i \in \{-1, +1\} \tag{14}$$

The full bipolar configuration is:

$$S = (a_1, a_2, a_3; b_1, b_2, b_3) \tag{15}$$

The semicolon separates the two triplets.

Since the system contains six binary variables, the number of total configurations is:

$$N_6 = 2^6 = 64 \tag{16}$$

The complete classical configuration space is:

$$\Omega_{64} = \{S = (a_1, a_2, a_3; b_1, b_2, b_3) \mid a_i, b_i \in \{-1, +1\}\} \tag{17}$$

Therefore:

$$|\Omega_{64}| = 64 \tag{18}$$

This is the mathematical origin of the universal code.

4.2. Why the Space Is Structured

The 64-state space is not an arbitrary set of six binary signs. It inherits structure from the bipolar triplet architecture:

1) The six variables are divided into two triplets.
2) Each triplet has its own polarity.
3) The two triplets may be coupled pairwise.
4) The total configuration has a global polarity.
5) The difference between the two triplets defines a bipolar imbalance.
6) The system can be coarse-grained into 16 vector classes.

Thus, Ω_{64} is a structured polarity space, not a random binary list.

4.3. Hierarchical Construction

The hierarchy of the model is:

superfluid vacuum

→ vortex formation
→ binary vortex orientation
→ three-vortex triplet
→ eight triplet configurations
→ two coupled triplets
→ 64 bipolar configurations
→ constrained physical sectors
→ stable particle-like realizations. (19)

This hierarchy connects the finite combinatorial model to the broader vortex program.

5. Polarity, Imbalance, and Vector Classes

5.1. Triplet Polarities

For the upper or first triplet:

$$P_a = a_1 + a_2 + a_3 \tag{20}$$

For the lower or second triplet:

$$P_b = b_1 + b_2 + b_3 \tag{21}$$

Each triplet polarity can take four values:

$$P_a, P_b \in \{-3, -1, +1, +3\} \tag{22}$$

5.2. Total Polarity

The total polarity of the bipolar configuration is:

$$P = P_a + P_b \tag{23}$$

Equivalently:

$$P = a_1 + a_2 + a_3 + b_1 + b_2 + b_3 \tag{24}$$

The possible values are:

$$P \in \{-6, -4, -2, 0, +2, +4, +6\} \tag{25}$$

The degeneracies are binomial:

$$\begin{aligned} P = +6 &\to 1 \text{ configuration} \\ P = +4 &\to 6 \text{ configurations} \\ P = +2 &\to 15 \text{ configurations} \\ P = 0 &\to 20 \text{ configurations} \\ P = -2 &\to 15 \text{ configurations} \\ P = -4 &\to 6 \text{ configurations} \\ P = -6 &\to 1 \text{ configuration} \end{aligned} \tag{26}$$

The degeneracy sum is:

$$1 + 6 + 15 + 20 + 15 + 6 + 1 = 64 \tag{27}$$

5.3. Bipolar Imbalance

The imbalance between the two triplets is defined as:

$$\Delta = P_a - P_b \tag{28}$$

The pair (P, Δ) provides a useful coarse-grained description of each configuration. P measures total polarity, while Δ measures asymmetry between the two poles.

5.4. Vector-Class Representation

Each configuration S can be mapped to a two-dimensional class vector:

$$V(S) = (\Delta, P) \tag{29}$$

Because P_a and P_b each have four possible values, there are:

$$4 \times 4 = 16 \tag{30}$$

coarse-grained vector classes.

The degeneracy of a class is:

$$g(P_a, P_b) = g(P_a)\, g(P_b) \tag{31}$$

where:

$$g(+3) = 1, g(+1) = 3, g(-1) = 3, g(-3) = 1. \tag{32}$$

The 16 vector classes summarize the internal organization of the 64 configurations.

The vector classes are used here as a coarse-graining tool. They do not yet define particles by themselves. Their role is to organize the 64 configurations into polarity-imbalance families that may later be connected to excited states, magnetic responses, or stem-cap asymmetries. In the present work, the physical selection is not made by the vector class alone, but by the energy functional $E(S)$ and the imposed proton-like or neutron-like constraints.

5.5. Physical Meaning of the Vector Classes

The vector classes are structural sectors. A physical particle-like state must be selected from these sectors by additional constraints.

The vector classes can be grouped as follows:

Pole classes: highly aligned configurations with maximal polarity.

Diagonal classes: asymmetric configurations with one strongly polarized triplet and one mixed triplet.

Inner axial classes: balanced or weakly polarized configurations with higher degeneracy.

These classes may later be related to nucleon stability, excited states, magnetic response, or vortex imbalance.

6. Relation between Triplet Polarity and Electric Charge

6.1. Why the Direct Charge Mapping Fails

A direct identification:

$$Q \propto P(T) \tag{33}$$

is mathematically impossible for quarks.

The triplet polarity can only be:

$$P(T) \in \{-3, -1, +1, +3\} \tag{34}$$

But the Standard Model quark charges are:

$$Q(u) = +2e/3 \tag{35}$$

$$Q(d) = -e/3 \tag{36}$$

In units of $e/3$:

$$Q(u) = +2 \tag{37}$$

$$Q(d) = -1 \tag{38}$$

Since +2 is not included in {−3, −1, +1, +3}, triplet polarity cannot directly represent electric charge.

6.2. Charge-Sector Label

To correct this, the model introduces a charge-sector label:

$$\chi \in \{u, d\} \tag{39}$$

The charge function is:

$$Q(\chi) = +2e/3, \chi = u \tag{40}$$

$$Q(\chi) = -e/3, \chi = d \tag{41}$$

A quark-like vortex state is therefore represented as:

$$q = (\chi, T) \tag{42}$$

where χ determines electric charge and T determines internal vortex configuration.

6.3. Internal Polarity of a Quark-Like State

For a quark-like state:

$$q = (\chi, T) \tag{43}$$

the electric charge is:

$$Q(q) = Q(\chi) \tag{44}$$

The internal polarity is:

$$P(q) = P(T) \tag{45}$$

Thus:

$$\text{electric charge} \neq \text{triplet polarity} \tag{46}$$

This is the central correction of the revised model.

6.4. Color-Like Degeneracy

Although triplet polarity is not electric charge, the triplet structure may still be relevant to color-like internal multiplicity.

The polarity class $P(T) = +1$ contains three configurations:

$$(+,+,-),(+,-,+),(-,+,+) \tag{47}$$

The polarity class $P(T) = -1$ also contains three configurations:

$$(+,-,-),(-,+,-),(-,-,+) \tag{48}$$

This threefold degeneracy may provide a structural analogy to the three color degrees of freedom in QCD. However, this article does not claim that these sign

configurations are identical to QCD color. It only proposes that the triplet architecture naturally contains threefold internal multiplicities that may be explored in future work.

7. Classical Energy Functional and Selection Principle

7.1. Need for an Energy Principle

The 64-state configuration space contains all possible sign arrangements. However, nature does not realize all formal possibilities equally. Physical states must be selected by stability, topology, composition, and energy.

Therefore, the model introduces a classical energy functional:

$$E:\Omega_{64}\to\mathbb{R} \tag{49}$$

The physical sector is defined as the subset of configurations satisfying the relevant constraints:

$$\Omega_{\text{phys}}\subset\Omega_{64} \tag{50}$$

Stable physical configurations are those that minimize $E(S)$ within Ω_{phys}.

7.2. Ising-Type Energy Functional

A minimal classical energy functional is:

$$E(S)=-\sum_i h_i s_i-\sum_{i<j}J_{ij}s_i s_j \tag{51}$$

where:

$$s_i\in\{-1,+1\},i=1,\cdots,6 \tag{52}$$

The coefficients h_i represent local bias terms. The couplings J_{ij} represent interaction strengths between vortex orientations.

Because the system contains two triplets, the energy may be decomposed as:

$$E(S)=E_a+E_b+E_{ab} \tag{53}$$

For the first triplet:

$$E_a=-\sum_i h_{i^a}a_i-\sum_{i<j}J_{ij^a}a_i a_j \tag{54}$$

For the second triplet:

$$E_b=-\sum_i h_{i^b}b_i-\sum_{i<j}J_{ij^b}b_i b_j \tag{55}$$

For the coupling between triplets:

$$E_{ab}=-\sum_i K_i a_i b_i-\sum_{i\neq j}K_{ij}a_i b_j \tag{56}$$

Thus:

$$\begin{aligned}E(S)=&-\sum_i h_{i^a}a_i-\sum_i h_{i^b}b_i-\sum_{i<j}J_{ij^a}a_i a_j-\sum_{i<j}J_{ij^b}b_i b_j\\&-\sum_i K_i a_i b_i-\sum_{i\neq j}K_{ij}a_i b_j\end{aligned} \tag{57}$$

This is a classical Ising-type energy model.

At the present stage, the full set of Ising parameters h_i, J_{ij}, and K_{ij} are not yet derived from first principles. The present article fixes only one effective exci-

tation scale using the QCD string tension and the down-quark stem radius. A full future study should determine these parameters by a combination of vortex dynamics, hadron masses, and baryon resonance data.

7.3. Stable Sector

The stable sector is:

$$\Omega_{\text{stable}} = \left\{ S \in \Omega_{\text{phys}} \mid E(S) \text{ is locally or globally minimized} \right\} \tag{58}$$

A proton-like stable state is:

$$S_p = \arg\min E(S), S \in \Omega_p \tag{59}$$

A neutron-like stable state is:

$$S_n = \arg\min E(S), S \in \Omega_n \tag{60}$$

Here Ω_p and Ω_n are the proton-like and neutron-like constrained sectors.

7.4. Degeneracy Lifting

The polarity observables classify configurations, but they do not uniquely determine physical states. Two configurations may share the same P and Δ values but have different detailed sign arrangements. If the coupling constants J_{ij} and K_{ij} are position-dependent, then:

$$E(S_1) \neq E(S_1), \text{ even if } V(S_1) = V(S_2) \tag{61}$$

This provides a mechanism for degeneracy lifting.

Therefore, the 64-state space should not be interpreted as predicting 64 equally real particles. It is a structured possibility space. Physical states are selected by energy minimization and constraints.

8. Connection to Monopoles, Quarks, and Nucleons

8.1. Monopole-Like Sector

A monopole-like structure may be represented by a single triplet:

$$M = T = (s_1, s_2, s_3) \tag{62}$$

Its polarity is:

$$P_m = s_1 + s_2 + s_3 \tag{63}$$

In this case, triplet polarity may be interpreted as magnetic or topological polarity. This interpretation is more natural than electric charge because magnetic polarity can be associated with orientation and circulation.

8.2. Quark-Like Sector

A quark-like state is represented as:

$$q = (\chi, T) \tag{64}$$

where:

$$\chi \in \{u, d\} \tag{65}$$

The electric charge is determined by χ:

$$Q(u) = +2e/3 \tag{66}$$

$$Q(d) = -e/3 \tag{67}$$

The triplet T determines internal vortex orientation:

$$T = (s_1, s_2, s_3) \tag{68}$$

Therefore, quark-like states possess two layers:

1) charge sector χ,

2) internal vortex state T.

This avoids the earlier mistake of reducing electric charge to a sign sum.

8.3. Proton-Like Sector

The proton has valence content:

$$p = uud \tag{69}$$

Its electric charge is:

$$Q(p) = Q(u) + Q(u) + Q(d) \tag{70}$$

Substituting:

$$Q(p) = +2e/3 + 2e/3 - e/3 = +e \tag{71}$$

In the present model, the proton-like sector is not defined by the total polarity alone. It is defined by:

$$\Omega_p = \{S \in \Omega_{64} \mid S \text{ satisfies proton-like charge-sector, topology, and energy constraints}\} \tag{72}$$

A stable proton-like state is selected by:

$$S_p = \arg\min E(S), S \in \Omega_p \tag{73}$$

8.4. Neutron-Like Sector

The neutron has valence content:

$$n = udd \tag{74}$$

Its electric charge is:

$$Q(n) = Q(u) + Q(d) + Q(d) \tag{75}$$

Substituting:

$$Q(n) = +2e/3 - e/3 - e/3 = 0 \tag{76}$$

The neutron-like sector is:

$$\Omega_n = \{S \in \Omega_{64} \mid S \text{ satisfies neutron-like charge-sector, topology, and energy constraints}\} \tag{77}$$

The stable neutron-like state is:

$$S_n = \arg\min E(S), S \in \Omega_n \tag{78}$$

8.5. Proton-Neutron Difference

The proton and neutron differ in charge-sector composition, but they may also differ in internal vortex polarity, imbalance, and energy.

Possible structural differences include:

$$P(S_p) \neq P(S_n) \tag{79}$$

$$\Delta(S_p) \neq \Delta(S_n) \tag{80}$$

$$E(S_p) \neq E(S_n) \tag{81}$$

Future work should test whether the small neutron-proton mass difference can be modeled as:

$$\Delta E_{np} = E(S_n) - E(S_p) \tag{82}$$

Empirically, the neutron-proton mass difference is approximately:

$$\Delta m_{np} c^2 \approx 1.293 \text{ MeV} \tag{83}$$

A successful quantitative version of the model should reproduce this scale or explain why additional electromagnetic and QCD contributions are required.

9. Relation to the Mushroom Proton Model

9.1. Geometric Interpretation

In the mushroom proton model, the proton is interpreted as a geometric vortex structure in which the two up quarks form a cap-like rotating structure and the down quark forms a central stem or axis [2] [3]. This geometry provides a physical motivation for dividing the nucleon into two coupled sectors.

The bipolar six-vortex model can be interpreted as a coarse-grained sign architecture underlying such a geometry. One triplet may represent cap-related vortex orientations, while the other may represent stem-axis or complementary vortex orientations.

Thus:

$$T_a \rightarrow \text{cap-related vortex sector} \tag{84}$$

$$T_b \rightarrow \text{stem-axis or complementary vortex sector} \tag{85}$$

This mapping is not yet unique, but it provides a bridge between the abstract 64-state configuration space and the proposed proton geometry.

9.2. Projection into Physical Space

To relate the six-sign vector to physical geometry, define a projection:

$$\Pi : \Omega_{64} \rightarrow \mathbb{R}^3 \tag{86}$$

A simple symmetric projection may be:

$$r_x = a_1 + b_1 \tag{87}$$

$$r_y = a_2 + b_2 \tag{88}$$

$$r_z = a_3 + b_3 \tag{89}$$

Thus:

$$r(S) = (r_x, r_y, r_z) \tag{90}$$

This projection is only an example. Other projections may be more suitable for the mushroom geometry, especially if the cap lies primarily in the *x*-*y* plane and the stem aligns with the *z*-axis.

For example, one may assign:

$$\begin{aligned} &\text{cap plane}: (a_1, a_2, b_1, b_2), \\ &\text{stem axis}: (a_3, b_3). \end{aligned} \tag{91}$$

Then a stem-cap asymmetry can be measured by:

$$A_{sc} = |a_3 + b_3| - \frac{1}{2}|a_1 + a_2 + b_1 + b_2| \tag{92}$$

This kind of projection may help connect the abstract code to geometric proton models.

9.3. Volume and Density Constraints

The proton mass model provides estimated geometric quantities such as cap volume, stem volume, and total proton volume [3]. These quantities can constrain the energy functional by requiring that stable configurations correspond to geometries compatible with observed proton mass and density.

A future model may impose:

$$V(S_p) \approx V_p \tag{93}$$

$$\rho(S_p) \approx \rho_p \tag{94}$$

$$E(S_p) \approx M_p c^2 \tag{95}$$

where V_p, ρ_p, and M_p are the proton volume, density, and mass used in the mushroom model.

This would turn the 64-state framework from a classification system into a numerical model.

10. Quantitative Prediction and Falsifiability

10.1. Need for a Numerical Test

A configuration-space model becomes scientifically meaningful only if it produces at least one numerical prediction that can be compared with known or future data. The 64-state bipolar vortex space by itself is a classification scheme. To become predictive, the model must assign an energy scale to changes in vortex orientation and then compute the energy difference between stable and excited configurations.

In the present model, the first numerical test is derived from the energy cost of a single polarity-flip excitation in the bipolar vortex structure.

10.2. Energy Scale from QCD String Tension

The strong interaction between confined quarks is commonly characterized by the QCD string tension. A standard phenomenological value is approximately:

$$\sigma \approx 0.9\ \text{GeV/fm} \tag{96}$$

In the vortex interpretation, this string-tension scale is interpreted as the energy required to deform or reorient a confined vortex connection over a characteristic hadronic length.

From the mushroom proton model, the down-quark stem radius was estimated as:

$$r_d \approx 5.34\times10^{-16}\ \text{m} = 0.534\ \text{fm} \tag{97}$$

This length is used here as the effective scale for a single stem-axis vortex polarity reorientation. Therefore, the energy cost of one elementary polarity-flip excitation is estimated as:

$$\Delta E_1 = \sigma r_d \tag{98}$$

Substituting:

$$\Delta E_1 = \left(0.9\ \text{GeV/fm}\right)\left(0.534\ \text{fm}\right) \tag{99}$$

Thus:

$$\Delta E_1 \approx 0.481\ \text{GeV} = 481\ \text{MeV} \tag{100}$$

This value is not fitted to the nucleon excitation spectrum. It is obtained from the QCD string-tension scale and the down-quark stem radius previously derived in the mushroom proton model.

10.3. Prediction of the First Vortex-Polarity Excited Proton State

If the proton ground state corresponds to the lowest-energy configuration S_p in the 64-state space, then the first vortex-polarity excitation corresponds to the lowest configuration obtained by flipping one effective stem-axis polarity relation. The mass of this excited state is predicted to be:

$$M_p^* c^2 \approx M_p c^2 + \Delta E_1 \tag{101}$$

Using the proton rest energy:

$$M_p c^2 \approx 938.27\ \text{MeV} \tag{102}$$

one obtains:

$$M_p^* c^2 \approx 938.27\ \text{MeV} + 480.6\ \text{MeV} \tag{103}$$

Therefore:

$$M_p^* c^2 \approx 1418.9\ \text{MeV} \tag{104}$$

The model therefore predicts a first vortex-polarity excited proton state near:

$$M_p^* \approx 1.42\ \text{GeV}/c \tag{105}$$

This value lies close to the known low-lying nucleon excitation region, especially the Roper resonance N(1440). The present model does not claim identity

with the Roper resonance at this stage; rather, it predicts that the first vortex-polarity excitation should appear in the approximate 1.4 - 1.45 GeV mass range.

10.4. Falsifiability Criterion

The prediction may be stated in falsifiable form:

If the bipolar vortex configuration-space model is correct, the first stem-axis vortex-polarity excitation of the proton should occur near 1.42 GeV/c^2, within the uncertainty associated with the effective stem radius and the QCD string-tension scale.

A conservative uncertainty range may be estimated by allowing:

$$\sigma = 0.85 - 0.95\,\mathrm{GeV/fm} \tag{106}$$

and:

$$r_d = 0.50 - 0.57\,\mathrm{fm} \tag{107}$$

Then:

$$\Delta E_1 \approx 0.425 - 0.542\,\mathrm{GeV} \tag{108}$$

Therefore:

$$M_p^* \approx 1.36 - 1.48\,\mathrm{GeV}/c \tag{109}$$

The model is challenged if no low-lying nucleon excitation or resonance-like structure exists in this range, or if future high-precision baryon spectroscopy excludes a vortex-polarity excitation in this interval. The prediction is considered falsified if a dedicated search at the relevant mass scale finds no evidence of an excited state with the expected properties, or if the observed excitation energy lies outside the 1.36 - 1.48 GeV range.

10.5. Interpretation

This prediction gives physical meaning to the 64-state space. The ground-state proton is interpreted as the lowest-energy constrained configuration. Excited baryon states correspond to higher-energy configurations generated by polarity flips, imbalance changes, or altered stem-cap coupling.

The key point is that the 64-state model does not merely classify possible signs. It predicts that the first nontrivial polarity excitation should require an energy of approximately:

$$\Delta E_1 \approx 481\,\mathrm{MeV} \tag{110}$$

This provides a direct numerical bridge between the vortex configuration space, the mushroom proton geometry, and the observed baryon excitation scale.

10.6. Future Extension

Once the Ising parameters h_i, J_{ij}, and K_{ij} are fully determined, the complete 64-state energy spectrum can be computed. The present article provides the first calibration step by deriving one excitation scale from the QCD string tension and

the previously calculated down-quark stem radius. Future work should compute the full ordering of the 64 configurations and compare it with the known nucleon and Δ-baryon resonance spectrum.

11. Discussion

11.1. Main Contribution

The main contribution of this article is the reformulation of the universal code as a classical 64-state configuration space generated by a bipolar six-vortex system.

The model consists of two coupled tri-vortex units, each containing three vortices. Assigning a binary orientation to each of the six vortices produces 2^6 = 64 possible bipolar configurations. The framework further introduces polarity observables for each tri-vortex unit, the total system polarity, the bipolar imbalance, 16 vector classes, a classical energy-based selection principle, and an initial quantitative prediction for the excitation spectrum.

Together, these elements provide a coherent and finite configuration framework for organizing and comparing vortex-based particle models.

11.2. Importance of the Charge Correction

The separation of electric charge from triplet polarity is essential. Without this correction, the model fails mathematically because a three-sign polarity sum cannot generate the up-quark charge.

The corrected representation is:

$$q = (\chi, T) \tag{111}$$

where χ determines electric charge and T determines internal vortex structure.

This makes the model compatible with the known quark charges while preserving the internal polarity architecture.

11.3. Why the Model Is Classical

The model is classical because it uses discrete sign configurations and a diagonal Ising-type energy functional. It does not include quantum tunneling, superposition, or entanglement.

Therefore, the correct terminology is:

configuration space, state set, polarity class, energy functional, selection sector.

The terms Hilbert space, quantum code, and superposition should not be used unless a future version introduces noncommuting operators and tunneling terms.

11.4. Relation to QCD

The model does not replace QCD. QCD remains the accepted theory of the strong interaction. The present model is an effective structural framework intended to provide a geometric and combinatorial interpretation of internal organization.

The correct relationship is complementary:

QCD describes the fundamental gauge dynamics.

The vortex model proposes a geometric interpretation of internal structure.
The 64-state code organizes possible polarity configurations.
The energy functional selects physically relevant sectors.

11.5. Relation to Modern Vortex Literature

The present model belongs to a broader family of approaches in which vortices, flux tubes, topological defects, and superfluid analogies are used to explore particle and nuclear matter. Modern studies of color superconductivity, dense quark matter, vortex stability, vorticity in the quark-gluon plasma, and linked-vortex descriptions of baryonic matter show that vortex concepts remain relevant in contemporary high-energy and nuclear theory [4]-[28].

The present article differs from these approaches because it does not begin with a full QCD field solution. Instead, it proposes a finite effective configuration space that may serve as a coarse-grained description of internal vortex polarity. Therefore, the model should be understood as phenomenological and structural, not as a complete derivation from QCD.

11.6. Limitations

The model has several limitations:

1) The binary variables are not arbitrary postulates, but effective labels of two stable vortex-orientation sectors. They represent a coarse-grained reduction of a more complete continuous vortex dynamics. In the present article, this reduction is assumed phenomenologically and justified by the existence of opposite circulation or polarity states. A full derivation from vortex-field equations remains a necessary next step.

2) The complete set of Ising coupling constants is not yet derived from first-principles vortex-field equations. However, their scale is constrained by known hadronic physics. In particular, the QCD string tension,

$$\sigma \approx 0.9\,\mathrm{GeV/fm}$$

combined with the down-quark stem radius,

$$r_d \approx 0.534\,\mathrm{fm}$$

gives a first effective coupling scale:

$$J_0 \approx \sigma r_d \approx 0.481\,\mathrm{GeV}$$

Thus, the couplings are not arbitrary. The present model fixes a physically motivated energy scale, while a future complete treatment should determine the full coupling matrix from vortex dynamics or baryon spectroscopy.

3) The threefold degeneracy of the mixed triplet classes may provide a structural analogy to QCD color, but it is not identified with color charge itself. In the present model, the triplet configurations

$$P(T) = +1 \to 3 \text{ states}, P(T) = -1 \to 3 \text{ states}$$

show that a three-vortex architecture naturally generates threefold internal mul-

tiplicities. This resembles the threefold structure of color degrees of freedom, but a full equivalence would require a derivation of SU(3) color symmetry from the vortex configuration space. Therefore, the present article treats this relation as a possible direction for future development, not as an established result.

4) The proton and neutron sectors are presently defined by charge-sector composition and energy selection. The proton sector is constrained by the valence assignment uud, while the neutron sector is constrained by *udd*:

$$\Omega_p = \{S \in \Omega_{64} \mid \chi(S) = uud\}$$

$$\Omega_n = \{S \in \Omega_{64} \mid \chi(S) = udd\}$$

The physically realized proton and neutron are then selected as the lowest-energy configurations within these sectors:

$$S_p = \arg\min E(S), S \in \Omega_p$$

$$S_n = \arg\min E(S), S \in \Omega_n$$

A future development of the model should make these constraint functions more explicit by adding topological, geometric, and symmetry conditions related to the mushroom proton structure.

5) The present model provides a structural basis for organizing the hadron spectrum, but a complete numerical reproduction of all hadron masses is beyond the scope of this article. The 64-state bipolar vortex configuration space offers a first framework for classifying nucleon-like ground and excited states. In particular, the model derives a first quantitative excitation scale, predicting a low-lying proton excitation near 1.42 GeV/c^2. Future work should extend this method to the full baryon and meson spectrum by computing the complete 64-state energy ordering and comparing it with known hadron resonances.

6) The projection from the six-sign configuration space to physical geometry is defined phenomenologically by the mushroom proton structure. In the present model, the cap-related variables are associated mainly with the x-y plane, while the stem-related variables are associated mainly with the z-axis. Thus, a simple geometric projection can be written as:

$$r_x = a_1 + b_1$$

$$r_y = a_2 + b_2$$

$$r_z = a_3 + b_3$$

This projection is not claimed to be unique. It is the simplest symmetry-respecting map connecting the six-sign space to a three-dimensional stem-cap geometry. Future work should refine this projection by deriving it from the detailed vortex field geometry and by comparing the resulting spatial distributions with proton form-factor data.

7) The present article derives one first excitation scale, $\Delta E_1 \approx 0.481$ GeV, as an initial quantitative calibration of the 64-state vortex configuration space. This is sufficient to produce a testable prediction for the first vortex-polarity excited proton state near $M_p^* \approx 1.42$ GeV/c^2. A full future calculation must determine all 64

configuration energies and compare them with baryon spectroscopy.

8) These limitations do not invalidate the framework, but they define the work required before the model can be considered fully predictive.

12. Conclusions

This article has presented a formulation of the universal code as a classical 64-state bipolar vortex configuration space.

The model begins with a binary vortex orientation variable $s_i \in \{-1,+1\}$. A three-vortex triplet generates $2^3 = 8$ configurations. Two coupled triplets generate $2^6 = 64$ configurations. This 64-state structure is interpreted as a classical configuration space, not as a quantum Hilbert space.

There is a clear separation between electric charge and triplet polarity. The triplet polarity $P(T) = s_1 + s_2 + s_3$ can only take the values −3, −1, +1, and +3. Therefore, it cannot directly reproduce the up-quark charge $+2/3e$. Electric charge is instead represented by a sector label $\chi \in \{u,d\}$, while the triplet configuration T represents internal vortex orientation and polarity.

A classical Ising-type energy functional is introduced to select physical sectors from the full configuration space. Proton-like and neutron-like states are interpreted as constrained low-energy configurations rather than as direct realizations of all 64 states. The model also connects naturally with the mushroom proton geometry by interpreting the two triplets as cap-like and stem-like vortex sectors.

The present article adds a first falsifiable numerical consequence. Using the QCD string tension $\sigma \approx 0.9$ GeV/fm and the mushroom-model down-quark stem radius $r_d \approx 0.534$ fm, the energy of a single stem-axis vortex-polarity excitation is estimated as $\Delta E_1 \approx 0.481$ GeV. This leads to a predicted first vortex-polarity excited proton state near $M_p^* \approx 1.42$ GeV/c^2, with a conservative range of 1.36 - 1.48 GeV/c^2.

The theory remains incomplete, but it now has a clearer mathematical foundation and one quantitative testable direction. Its future development requires explicit coupling constants, degeneracy lifting, numerical energy minimization, and comparison with measurable quantities such as the proton-neutron mass difference, nucleon magnetic moments, and excited baryon spectra.

In its corrected form, the universal code should be understood as a structured classical polarity space that organizes possible vortex configurations and provides a foundation for future quantitative work in vortex-based particle modeling.

Conflicts of Interest

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

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Appendix A. Degeneracy of Total Polarity Classes

For six binary variables:

$$s_i \in \{-1,+1\}, i = 1,\cdots,6 \tag{A1}$$

Define total polarity:

$$P = \sum_{i=1}^{6} s_i \tag{A2}$$

Let n_- be the number of negative signs. Then:

$$P = 6 - n_- \tag{A3}$$

Therefore:

$$n_- = (6 - P)/2 \tag{A4}$$

The degeneracy is:

$$g(P) = C(6, n_-) \tag{A5}$$

This yields:

$$\begin{aligned} &P = +6, \quad n_- = 0, \quad g = 1 \\ &P = +4, \quad n_- = 1, \quad g = 6 \\ &P = +2, \quad n_- = 2, \quad g = 15 \\ &P = 0, \quad\ n_- = 3, \quad g = 20 \\ &P = -2, \quad n_- = 4, \quad g = 15 \\ &P = -4, \quad n_- = 5, \quad g = 6 \\ &P = -6, \quad n_- = 6, \quad g = 1 \end{aligned} \tag{A6}$$

Thus:

$$\sum g(P) = 64 \tag{A7}$$

Appendix B. Degeneracy of Triplet Polarity Classes

For a triplet:

$$T = (s_1, s_2, s_3) \tag{B1}$$

The triplet polarity is:

$$P(T) = s_1 + s_2 + s_3 \tag{B2}$$

The values and degeneracies are:

$$\begin{aligned} P(T) &= +3 \rightarrow g = 1 \\ P(T) &= +1 \rightarrow g = 3 \\ P(T) &= -3 \rightarrow g = 1 \end{aligned} \tag{B3}$$

Thus:

$$\sum g\left(P(T)\right) = 8 \tag{B4}$$

Appendix C. Degeneracy of the 16 Vector Classes

For the bipolar system:

$$P_a \in \{-3,-1,+1,+3\} \tag{C1}$$

$$P_b \in \{-3,-1,+1,+3\} \tag{C2}$$

The vector class is:

$$V = (\Delta, P) \tag{C3}$$

where:

$$\Delta = P_a - P_b \tag{C4}$$

$$P = P_a + P_b \tag{C5}$$

The degeneracy of each class is:

$$g(P_a, P_b) = g(P_a)\, g(P_b) \tag{C6}$$

The total degeneracy is:

$$\sum g(P_a, P_b) = (1+3+3+1)^2 = 8^2 = 64 \tag{C7}$$

Appendix D. Corrected Energy Scale from QCD String Tension

The relevant confinement scale is the QCD string tension:

$$\sigma \approx 0.9\ \text{GeV/fm} \tag{D1}$$

In SI units:

$$1\ \text{GeV} = 1.602\times10^{-10}\ \text{J} \tag{D2}$$

and:

$$1\ \text{fm} = 10^{-15}\ \text{m} \tag{D3}$$

Therefore:

$$\sigma \approx \left(0.9\times1.602\times10^{-10}\ \text{J}\right)\Big/\left(10^{-15}\ \text{m}\right) \tag{D4}$$

Thus:

$$\sigma \approx 1.44\times10^{5}\ \text{N} \tag{D5}$$

This corrects the earlier use of 1.44×10^3 N. The correct force equivalent of 0.9 GeV/fm is approximately 1.44×10^5 N.

For a displacement of 1 fm, the energy is:

$$E_{conf} = \sigma r = \left(0.9\ \text{GeV/fm}\right)\left(1\ \text{fm}\right) \tag{D6}$$

Therefore:

$$E_{conf} = 0.9\ \text{GeV} \tag{D7}$$

For the down-quark stem radius used in the mushroom proton model:

$$r_d \approx 0.534\ \text{fm} \tag{D8}$$

the corresponding polarity-flip energy is:

$$\Delta E_1 = \sigma r_d \tag{D9}$$

Substituting:

$$\Delta E_1 = \left(0.9\ \text{GeV/fm}\right)\left(0.534\ \text{fm}\right) \tag{D10}$$

Thus:

$$\Delta E_1 \approx 0.481\ \text{GeV} \tag{D11}$$

This is the energy scale used in Section 10 to predict the first vortex-polarity excitation of the proton.