Matter and Gravity as Phase Structures on a 4D Hypersphere (SU(2) Model)

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1 Introduction

The world is a complicated place. Particles behave like waves. An electron "passes through both slits" — as long as no one is watching. Gravity, by contrast, plays it seriously: it curves space, compresses stars into points, and doesn't tolerate jokes. And between these two realms lies a chasm. For decades, attempts to unify quantum mechanics and gravity have run into mathematical paradoxes and physical singularities.

But what if we've been looking at the facade all along — instead of the blueprint?

In this paper, I want to propose a simple, almost engineering-like idea: **what if nature has a technical floor?** Another coordinate — not directly observable — that explains *why* the behavior of particles, fields, and gravity turns out the way it does. As if you peeked inside a black box and found not magic, but a neat little circuit.

This "technical floor" is a four-dimensional hypersphere, where phase lives and evolves according to the symmetries of the SU(2) group. I won't start with axioms — first, we'll build the floor itself: we'll define the phase, show how it behaves on a string, on a membrane, on a sphere, and only then ascend into the fourth dimension. There, we'll see that an electron is a vortex, mass is a distortion of phase, and gravity is just the effort of all the vortices trying to stay in sync.

I've tried to make this explanation clear, visual, and even playful at times — a contrast to the formal tone of [1, 2, 3, 4]. This is not a textbook, nor a finished theory. It's an exploration of a hypothesis: **what if behind all the complexity of physics lies a simple and elegant concept?**

If that's the case, then all we have to do is activate the elevator, rise to the technical floor... and watch everything fall into place.

2 From One Dimension to Four — How to Visualize the Phase Space of a Hypersphere

When we study oscillations in physics, we often start with a simple example — a string. A stretched string can oscillate in one plane, forming standing waves. These waves are described by a phase — the position within the oscillation cycle at each point along the string. The phase may differ from point to point, but it always changes continuously.

2.1 Phase on a String

Let us consider a one-dimensional string of length L with fixed endpoints. Its configuration is described by a phase function $\theta(x)$ defined along the string: $x \in [0, L]$. This phase may be associated, for instance, with oscillations of the string in a perpendicular (second) dimension — one that a hypothetical inhabitant of the string cannot observe directly.

If the phase differs by 2π between two points on the string, it means that a full cycle — one crest and one trough — has occurred between them. Such a configuration is called *topologically nontrivial*: the phase difference is conserved and cannot be eliminated without violating the boundary conditions.

Analogy: an ant on a vibrating string. Imagine an ant walking along the string, unaware of up and down — it only senses tension and local "phase" parameters. If the string undergoes standing vertical oscillations, the ant might notice that the "tension" changes in a specific pattern from point to point. Although it doesn't know about the second dimension, it can describe the structure using a phase $\theta(x)$ and observe that the total phase shift between the ends might be 2π, 4π, and so on.

Thus, even in a purely one-dimensional world, without knowing the full geometry, one can observe the effects of phase — through stable, quantized differences between segments of the string. These structures serve as analogues of topological excitations — the basic building blocks from which more complex objects will be constructed in the SU(2)-based model.

2.2 Phase on a Membrane

Now let us move to a two-dimensional space — a vibrating circular membrane. The phase becomes a function of two coordinates: $\theta(x, y)$. Stable structures can also exist here — for example, vortices in which the phase winds around the center as one goes around it. Note that the membrane is two-dimensional, but it oscillates in a third dimension.

How to imagine this? Picture a drumhead vibrating up and down. At each point, it has an amplitude and a phase. If the membrane is excited in a particular way, complex standing wave patterns can form: some points remain still (nodes), while others oscillate with maximum intensity (antinodes). These patterns can be circular, radial, or even twisted.

Now imagine that at every point of oscillation, there is a vector indicating the "position" within the cycle: beginning, peak, descent, trough, and rise again. This vector can be interpreted as a phase. If you trace a closed path around the center of such a pattern and the vector returns to its original orientation, the structure is trivial. But if the vector rotates by 2π, 4π, or more — you've encircled a topological vortex.

What is a vortex? At the center of such a vortex, the phase becomes undefined. As you walk around the center along a closed loop, the phase changes by 2π, 4π, or another multiple of 2π. This is similar to moving a compass needle around a magnetic pole — the needle completes a full rotation. Such a structure carries a topological charge — the number of full phase rotations. This charge is conserved under any continuous deformation, as long as the vortex itself is not eliminated.

Physical analogy: Vortices of this kind are well known in hydrodynamics — for example, the whirlpool formed when water drains from a bathtub. In quantum mechanics, the analogue would be a vortex in a Bose–Einstein condensate or a defect in a superconductor. In both cases, we observe stable circular motion, distorted phase, and an inability to remove the vortex without "breaking" the medium.

Such a vortex cannot be removed by any smooth transformation — it is anchored by topology. These are precisely the kinds of objects that serve as carriers of robust physical information.

2.3 A Sphere with Phase

Now imagine a two-dimensional sphere — the ordinary surface of a ball in three-dimensional space. At each point on this sphere, we can assign a phase: $\theta(\Omega)$, where $\Omega = (\theta, \phi)$ are the angular coordinates on the sphere.

This setup allows for nontrivial phase configurations: for example, the phase might be 0 at the pole and π at the equator. As you move along a parallel, the phase may accumulate a full 2π, like in a vortex. Such phase vortices on the sphere can be stable — they cannot be continuously removed without tearing the structure, due to the underlying topology.

However, there is an important difference from the membrane: a sphere has no edges. Therefore, the phase must be *smooth and consistent in all directions at once.* This constraint leads to a discrete spectrum of allowed configurations — the so-called spherical harmonics $Y_{\ell m}(\theta, \phi)$, where $\ell = 0, 1, 2, \ldots$, and $m = -\ell, \ldots, \ell$. Each such state describes a stable, wave-like phase structure on the sphere.

An Observer on the Sphere.
If an observer lived on such a spherical surface, they would perceive "intensity maps" or "temperature maps" — these are projections of phase fluctuations. The observer could measure how the phase varies with direction and would find that only certain harmonic patterns are stable. This corresponds directly to how we observe fluctuations in the cosmic microwave background.

Analogy: drumhead oscillations.

The spherical harmonics $Y_{\ell m}(\theta, \phi)$ are two-dimensional analogues of standing waves on a drumhead. Just like the drum, only certain wave patterns are possible — those for which the oscillations remain coherent and stable across the entire surface. These patterns correspond to specific quantum numbers ℓ and m, where:

- ℓ determines the total number of nodes and the nature of oscillations along latitude;
- m controls the number of oscillations along longitude.

Each harmonic is a phase mode strictly allowed by the geometry of the sphere. Other types of fluctuations are either unstable or "spill out" beyond the sphere, violating the requirements of closure and smoothness. This is why, in the phase-based model, the $Y_{\ell m}$ functions form a natural basis for describing relic radiation, quantum states, and vortex structures.

In this way, a sphere with phase is a stepping stone toward the SU(2) hypersphere: here we already see discrete, stable modes and phase vortices — reminiscent of the structures that will later represent photons, electrons, and even gravity.

2.4 The Hypersphere and SU(2)

Now imagine that instead of a two-dimensional membrane, we are dealing with a three-dimensional shell — a **hypersphere**, or S^3. This is not merely an abstract idea: a hypersphere is a mathematical generalization of an ordinary sphere to higher dimensions.

What is a hypersphere?

- Circle: $x^2 + y^2 = R^2 \Rightarrow S^1$ — a one-dimensional sphere.
- Sphere: $x^2 + y^2 + z^2 = R^2 \Rightarrow S^2$ — a two-dimensional surface.

- Hypersphere: $x^2+y^2+z^2+w^2 = R^2 \Rightarrow S^3$ — a three-dimensional surface embedded in 4D.

We cannot visualize it directly, but we can think of it as an analogue of the sphere, where the surface is not two-dimensional but three-dimensional. If we were four-dimensional beings, we could freely move across this surface without encountering any boundaries.

Phase on the hypersphere is not a number — it's a rotation.

On the string, membrane, and spherical surface, phase is a scalar angle. For example, $\theta = 0$ means the start of a wave, and $\theta = \pi$ the opposite phase. But on a hypersphere, the phase becomes an element of the **SU(2) group** — that is, a matrix describing a rotation.

Mathematically, the phase at each point on the hypersphere is given by:

$$\Psi(\xi) = e^{i\,\theta(\xi)\,\vec{n}(\xi)\cdot\vec{\sigma}},$$

where θ is the rotation angle, $\vec{n}$ is the axis of rotation, and $\vec{\sigma}$ are the Pauli matrices.

How to imagine this?

Picture a tiny spinning top located at each point on the hypersphere. It rotates, and its orientation defines the local SU(2) phase. These tops try to align with their neighbors, but due to the closed geometry of the hypersphere and the nature of the phase, perfect alignment may be impossible. This gives rise to stable mismatches — **SU(2) vortices**.

Example: a gyroscopic network. Imagine a 3D lattice of gyroscopes, each synchronized with its neighbors. If one is rotated by 180°, it creates a defect — a mismatch in the collective phase. This is a topological vortex, an analogue of a particle.

What gives rise to mass, charge, and spin?

- **Mass** — the energy density within a vortex: the greater the phase distortion, the greater the mass.
- **Charge** — a directional asymmetry in the SU(2) phase, for instance, along the σ_3 axis.
- **Spin** — the internal twisted structure of the vortex, akin to the rotation of a spinning top.

Why SU(2)? It is the minimal compact group that permits stable vortices in three dimensions. It is naturally linked to quantum mechanics and intrinsic spin.

Conclusion: If in 1D we had string oscillations, and in 2D — vortices on a membrane, then in 4D on the hypersphere S^3 we find SU(2) phase vortices, which *are* elementary particles with mass, charge, and spin. All of physics emerges from the geometry of these phases.
[1]

Why the Hypersphere? The SU(2) model is based on the hypothesis that the fundamental geometry of space is a three-dimensional sphere, S^3, embedded in four-dimensional Euclidean space, $\mathbb{R}^4$. This raises a natural question: why not an infinite flat space, as in the standard model?

[1] SU(2) is the group of all possible rotations in a quantum two-component space (e.g., the spin space of an electron). Mathematically, SU(2) consists of all 2×2 complex matrices that are unitary ($U^\dagger U = I$) and have determinant 1. It is the quantum analogue of the rotation group in 3D space (SO(3)).

1. $\mathbf{SU(2)} = \boldsymbol{S^3}$ by definition.
The group SU(2) is topologically homeomorphic to the 3-sphere S^3. Each SU(2) element is defined by a unitary 2×2 matrix with determinant 1, and geometrically, this forms a unit 3-sphere in 4D. If we model the phases of matter as SU(2) vortices, the natural "arena" for them is precisely the hypersphere.

2. No edges, no boundary conditions.
The hypersphere S^3 is a closed but finite-volume space without boundaries. This resolves the question: where does space end? what lies at the "edge" of the Universe? In an S^3 model, space has no edge, while still having a finite geodesic length — like the surface of the Earth, but one dimension higher.

3. Quantization and spectrum.
On S^3, phase modes are always *discrete*. This naturally leads to discrete energy levels, stable vortex structures, spin, orbitals, and other quantum properties. In infinite flat space $\mathbb{R}^3$, such effects must be introduced artificially via boundary conditions or postulates.

4. Coherence and emergence of constants.
As discussed in other sections, quantities like c, $\hbar$, G, and even atomic scales can be derived from the global phase on S^3. This is possible only because S^3 is a compact, coherent, and globally consistent phase space. In infinite $\mathbb{R}^3$, it is impossible to define a globally coherent phase — only local fluctuations exist.

5. Principle of phase trajectory equivalence.
The geometry of S^3 is fully isotropic and homogeneous: all points and directions on the 3-sphere are equivalent, and no geodesic (shortest path on S^3) is preferred. In other words, no direction of motion is distinguished. This naturally reflects the observed uniformity of the cosmos — such as the isotropy of the cosmic microwave background. In contrast, infinite $\mathbb{R}^3$ requires an external frame of reference: a starting point, a time direction, coordinate axes. These are extrinsic to the phase structure.

Analogy: the Earth's surface.
To two-dimensional beings, a flat plane and a sphere of radius R may look identical locally. But only the sphere:

- has no edges,
- allows circumnavigation — returning to the same point,
- creates natural discreteness (e.g., in the spectrum of harmonics),
- supports globally coherent waves.

The same applies to the 3-sphere in our case.

6. Convergence of phase projection.
If we treat the SU(2) phase as a function on $\mathbb{R}^4$, and the observable world as a 3D slice or projection, then all measurable quantities (such as energy density, probability, currents) are computed via integrals over the phase. For these to be finite, the phase projection must be *square-integrable*:

$$\int_{\mathbb{R}^3} |\psi(x)|^2 \, dx < \infty.$$

In infinite $\mathbb{R}^4$, this requires artificial confinement of the field (manual localization). But if the phase lives on a compact hypersphere $S^3 \subset \mathbb{R}^4$, then any 3D projection yields a finite integral automatically, since S^3 has finite volume. This ensures:

- normalizability of wavefunctions,
- finite energies,
- existence of stable vortices and particles.

In other words, *the convergence of physical quantities requires a compact phase space.*

Conclusion.
The hypersphere S^3 is not just a mathematical convenience, but the *natural phase space* for an SU(2)-based theory. It ensures compactness, coherence, a discrete spectrum, absence of boundaries, and the emergence of all observed physical laws as manifestations of global phase.

3 Electricity and Magnetism: Waves and Phase Asymmetries

If gravity in the SU(2) model is associated with the global density of phase energy (which will be discussed later), then electricity and magnetism arise from *local directional asymmetries* in the phase. Here, charge, field, and electromagnetic waves do not emerge as external fields imposed on space, but rather as *stable phase structures on the hypersphere S^3*.

Electromagnetic interaction in this framework is a consequence of the topological properties of the SU(2) phase: its twist, winding, and stable directional variations. These features are local in appearance, yet they correspond directly to global configurations — structures with specific phase circulation or gradients behave in exactly the same way as electric and magnetic vector fields.

In this sense, electromagnetism represents a more "refined" form of phase dynamics compared to gravity: it is not sensitive to total energy density, but rather to the *orientation and topology* of the phase configuration.

3.1 Charge as Vortex Orientation

Consider two identical SU(2) vortices, but with phase winding along opposite directions: one along σ_3 and the other along $-\sigma_3$. Geometrically, this is like two identical spinning tops rotating in opposite directions.

This is what we call charge: the orientation of a vortex in SU(2) space. It determines how the vortex "distorts" the surrounding phase. Positive and negative charges are not simply "plus" and "minus," but two opposite directions of phase asymmetry.

3.2 Electric Field as Phase Gradient

The SU(2) phase naturally tends toward smoothness — just like a stretched rubber sheet tends to flatten out. This is an intrinsic behavior: sharp gradients in the phase correspond to high local energy, and the system always seeks to minimize energy. Smoothness of the phase is thus a consequence of the configuration striving to be stable and energetically efficient.

However, if a charge is present at some point, it creates a stable and directional "tension" in the phase: near the charge, the phase becomes slightly displaced, as if someone tugged on the rubber-like shell of the hypersphere. This phase gradient is the analogue of the electric field:

$$\vec{E} \sim \nabla\theta,$$

where θ is the local orientation of the SU(2) phase. Just like in classical theory, this field decreases with distance and is directed from the positive charge to the negative.

Analogy: imagine one spinning top rotating faster and "pulling" on its neighbors, while another slows them down. Between them, a gradient of phase tension arises — the electric field. Just as tension in a stretched membrane tends to return it to equilibrium, the electric field tends to eliminate the phase gradient — unless another charge or external influence prevents it. In this sense, electric interaction is simply an expression of how the phase "stretches" around a source.

3.3 Magnetic Field as Twisting

Now imagine that a charge is moving along the hypersphere. Its vortex not only distorts the local phase but also twists it around the direction of motion. This generates a vortex-like structure — the analogue of a magnetic field (we'll explore this further in the discussion of the electron):

$$\vec{B} \sim \nabla \times \theta,$$

where $\nabla\times$ is the curl operator in the 3D geometry of the hypersphere. Such a field arises only when charges are in motion — just as in classical theory.

Analogy: If you rapidly spin a propeller in water, it creates a spiral current. Likewise, a moving vortex creates a "spiral" in the phase structure.

3.4 Electromagnetic Waves as Propagating Phase

If the phase in space begins to oscillate — for example, due to an oscillating vortex (charge) — this constitutes an electromagnetic wave. On the hypersphere, it appears as a *traveling phase ripple* propagating at speed c. This is not just a metaphor: the SU(2) phase on the hypersphere genuinely supports such traveling solutions, which directly mirror Maxwell's equations.

Formally:

$$\Box\theta(\xi) = 0,$$

where $\Box$ is the hyperspherical wave operator, analogous to $\partial_t^2 - c^2\nabla^2$.

Light is simply phase in motion. Just as ripples travel across water, waves of phase propagate across the SU(2) hypersphere. This explains why all photons move at the same speed: they are excitations of the same phase field, and the speed c is a fundamental property of the hypersphere's geometry.

3.5 Symmetry of Maxwell's Equations

In classical physics, electric and magnetic fields are described by Maxwell's equations. These equations link sources (charges and currents) to the temporal and spatial variations of fields. They are highly symmetric: electric fields can induce magnetic fields, and vice versa. Yet in classical theory, these fields are treated as independent entities existing on a background space.

In the SU(2) model, things are different: *there are no two fields — only one phase.* The electric and magnetic fields are simply different ways of measuring distortions in the SU(2) phase:

$$\vec{E} \sim \nabla\theta, \qquad \vec{B} \sim \nabla \times \theta.$$

The wave equation for the phase:

Consider a phase field $\theta(\xi, t)$ on the hypersphere S^3. If it propagates freely, it satisfies the wave equation:

$$\Box\theta = \partial_t^2\theta - c^2\nabla^2\theta = 0.$$

This is the same equation that governs electromagnetic waves. In other words, light waves are simply solutions describing oscillations of the phase on the hypersphere.

The source is the vortex:

If a stable vortex exists in the model, it becomes a source of the phase field:

$$\Box\theta = \rho(\xi),$$

where ρ is the "phase source" describing the density of vortices. In classical terms, this would correspond to charge density.

Why does the symmetry emerge automatically?

The SU(2) phase is not a scalar — it is a *matrix-valued* quantity with three independent components (corresponding to the Pauli matrices). Taking derivatives of these phase matrices with respect to space and time yields an exact replica of the structure of Maxwell's equations. But now, these equations are not postulated — they are *a consequence of SU(2) geometry.*

This explains:

- Why $\vec{E}$ and $\vec{B}$ are interrelated,
- Why photons are massless,
- Why waves do not scatter in vacuum,
- Why the $E \leftrightarrow B$ symmetry is so universal.

Deeper implication: In this model, Maxwell's fields are not introduced axiomatically — they emerge as derivatives of a single fundamental object: the SU(2) phase. Electromagnetism is not a separate interaction, but a manifestation of the same phase structure that also gives rise to mass and gravity.

Conclusion

Charge is the orientation of a vortex, the electric field is the phase gradient, the magnetic field is the twisting of phase, and light is a traveling ripple. None of these are external fields — they are all expressions of phase geometry on the hypersphere. Electricity and magnetism are not independent forces, but *different manifestations of a single phase.*

4 Spin and Quantum Behavior: From Rotations to Energy Levels

Many of the enigmatic features of quantum mechanics — spin, wave–particle duality, energy quantization — are usually treated as postulates. But in the SU(2) model, these properties emerge naturally from the topology and geometry of the phase on the hypersphere S^3.

4.1 Spin as Topological Rotation

In classical physics, spin is simply angular momentum. In quantum theory, it becomes a mysterious internal degree of freedom that behaves like rotation — but without any rotating mass.

In the SU(2) model: spin is a *topological property of a phase vortex.* A vortex in the SU(2) phase on the hypersphere carries a *winding number* — the number of times the phase wraps around the vortex center when traced along a closed surface. This number is not arbitrary: it is *discrete* and preserved under any continuous deformation.

Formally, this can be expressed as a surface integral of the phase gradient over a closed surface S:

$$s = \frac{1}{2\pi} \oint_S \nabla\theta \cdot d\vec{l}$$

or, in the full SU(2) version, as a winding index or characteristic class:

$$s = \frac{1}{8\pi} \int_{S^2} \epsilon^{ijk}\, n_i\, \partial_j n_k\, dS$$

where $\vec{n}$ is the phase vector, mapping each point on the spatial sphere to a point on the SU(2) phase sphere.

Analogy: a knot or vortex in a fluid.

Imagine tracing a closed loop around a vortex in a fluid, or around a strand in a tangled thread. The number of times the thread loops around is a discrete quantity, and you can't simply "erase" it by smoothing things out. The same is true in SU(2): the winding of the phase is an *integer* that defines a "topological charge" — which in this model corresponds to spin.

Thus, spin is not some internal abstract attribute — it is a **geometric and topological consequence of the SU(2) phase structure**.

Example: if you rotate an SU(2) vortex by 2π, it does not return to its original state. It takes a full 4π rotation to do so. This is precisely why spin can be 1/2 — a double rotation is required for restoration.

4.2 Discreteness of Energy Levels

On a string or a membrane, only certain standing waves can exist — those with an integer number of nodes. The same is true for the hypersphere: phase structures admit *only allowed configurations.*

$$n = 0,\ 1,\ 2,\ \ldots$$

Each value of n corresponds to a distinct "vortex mode" — a topologically stable state with a specific energy. This is directly analogous to the energy levels of an atom.

Conclusion: quantization is not magic, but a consequence of the restrictions on stable SU(2) phase knots on a closed hypersphere.

4.3 Wave–Particle Duality

The SU(2) phase structure gives rise to both particles (vortices) and waves (phase oscillations), depending on the scale and configuration.

- A localized twist in the phase $\Rightarrow$ a particle with mass and spin.
- A propagating phase excitation $\Rightarrow$ a wave — for example, a photon.

This explains why electrons can display wave-like behavior, and why light can act like particles. The difference lies entirely in how the SU(2) phase is configured in a given situation.

4.4 What Is an Atomic Orbital in the SU(2) Model?

In conventional quantum mechanics, the electron in an atom is described as a "probability cloud" — a density distribution obtained from solutions to the Schrödinger equation. These clouds are called *orbitals*. They may resemble spheres (s-orbitals), dumbbells (p-orbitals), or more complex shapes. But why does the electron appear not as a point on an orbit, but as an amorphous distribution?

The SU(2) model offers a different interpretation: an orbital is a shadow of a four-dimensional vortex structure.

4.5 Four-Dimensional Structure: Not the Hypersphere of Space

It is important to clarify that in this model, physical space is the *hypersphere* S^3 on which the SU(2) phase resides. But an atomic orbital is an *independent*, embedded SU(2) configuration that should not be confused with the shape of the entire Universe. It is like a vortex on a sphere: its shape is local, even though the sphere itself is global.

An electron in an atom is a stable SU(2) vortex whose phase is twisted not only in space but also along the fourth dimension. It is described not in (x, y, z), but in (x, y, z, w). What we observe is merely the projection of this configuration onto our three-dimensional space.

4.6 Why Orbitals Look So Strange

When we solve the Schrödinger equation, we do not obtain the full SU(2) structure, but only the *probability density* — the square of the amplitude of the wave function projected onto 3D space.

This is why orbitals appear so strange:

- A p orbital looks like a dumbbell, though it is actually the projection of a ring-like vortex.
- d orbitals have petal-like shapes because they consist of standing SU(2) waves with nodes and antinodes in projection.
- All orbitals actually have a *constant radius* in 4D, but appear to have internal voids in 3D.

Imagine shining a light on a wire ring — its shadow can be a circle, an oval, or a line segment, depending on the angle. But the object itself is always a ring. Likewise, an orbital is the "shadow" we see in 3D, while its true form is regular and consistent in 4D.

Total Energy of an SU(2) Orbital: In the SU(2) model, the total energy of a phase vortex on the 3-sphere consists of a visible (3D) and a hidden (along the fourth dimension) component:

$$E_{\text{total}}^2 = E_{\text{observable}}^2 + E_{\text{SU(2)}}^2,$$

where:

- $E_{\text{observable}}$ — energy associated with motion in $\mathbb{R}^3$: orbitals, excitations, kinetic terms,
- $E_{\text{SU(2)}}$ — contribution from internal phase degrees of freedom on S^3: vortex winding, angular momentum in phase space,
- E_{total} — total energy of the SU(2) configuration, including hidden components.

This is analogous to a 4D hypotenuse: the visible part is just a projection. Even a particle at rest in 3D has nonzero $E_{\text{SU(2)}}$, which manifests as its mass:

$$mc^2 = E_{\text{SU(2)}}.$$

Conclusion

An atomic orbital is not a fuzzy cloud, but a *projection of a stable SU(2) vortex* from four-dimensional phase space into our 3D world. Its "strange" shape reflects not the behavior of the electron itself, but the geometry of the phase structure as seen in projection. This also explains why the electron does not "fall" into the nucleus: its vortex is stable in 4D and cannot collapse without breaking the topological configuration.

4.7 Magnetic Moment and Encoding a Vector in 3D via Motion in 4D

In addition to spin and charge, the electron also possesses a **magnetic moment**. In classical terms, this is associated with the rotation of charge — but such an explanation is incomplete, as the electron is not a spinning sphere. So where does the magnetic moment originate?

4.8 SU(2) Interpretation: Vortex Motion in 4D

The SU(2) phase vortex corresponding to the electron is not merely twisted — it is *oriented*. Its internal structure defines a direction along which the phase is wound.

We cannot directly observe the fourth dimension in 3D space, but we can detect that:

- The vortex may rotate or "flow" in a direction that appears as a **local vector** in 3D.
- This direction is preserved even if the vortex is at rest in 3D.

Implication: the magnetic moment is the *shadow projection of directed vortex motion in 4D*. We do not observe its flow through the fourth dimension, but in 3D it manifests as an arrow — the magnetic moment vector.

4.9 Encoding a Direction at a Point in Space

In 3D alone, it is impossible to encode a vector at a point without referencing an external frame — any truly local object is symmetric. But the SU(2) vortex is an *internally oriented* structure. Thanks to the fourth dimension, it can possess a direction *without any motion in 3D.*

This makes spin and magnetic moment genuinely directional properties that exist at a single point.

4.10 Magnetic Interaction: A Bernoulli Analogy

When two such vortices with magnetic moments are placed near each other, a form of *hydrodynamic-like interaction* arises between them.

Analogy: in fluid dynamics, if two objects generate directed flows, then:

- If their rotations are aligned — a region of lower pressure forms between them (attraction),
- If their rotations are opposed — a region of higher pressure forms (repulsion).

This is described by the **Bernoulli principle**: pressure decreases where flow velocity increases.

The same applies here: SU(2) phase flowing in 4D creates "pressure" in the phase field. Two magnetic moments interact through these phase distortions — like vortices in a fluid.

Conclusion

The magnetic moment of the electron is directed motion of its SU(2) vortex through the fourth dimension. This motion is "invisible" in 3D, yet defines a local vector. It enables the existence of the magnetic field as a directional structure. Magnetic interaction arises as a phase-theoretic analogue of Bernoulli's law — a tendency of the phase to minimize gradient tension between oriented flows.

4.11 The Pauli Exclusion Principle

In quantum mechanics, it is forbidden for two fermions (such as electrons) to occupy the same quantum state. This is known as the *Pauli exclusion principle*, and it underlies the structure of atoms, the chemistry of elements, and the stability of matter. However, in the standard theory, it is simply a postulate — not derived from deeper first principles.

4.12 SU(2) Justification: Phase Does Not Double Up

In the hyperspherical vortex model, the situation looks very different. The SU(2) phase is an *orientation*, like the direction of a gyroscope, not just a number. Each vortex has a "phase texture" — the way it is twisted in space. If two vortices have the same orientation and topological structure, then:

- they **cannot exist in the same region of the hypersphere**;
- their phases conflict — trying to superimpose two identical vortices creates an *excessively steep phase gradient*, rendering the system unstable.

This is analogous to trying to merge two identical, immovable vortices in a fluid: they either destroy one another or create a catastrophic rupture in the flow.

4.13 Topological Reason for the Prohibition

In the SU(2) model, the exclusion principle is not an imposed restriction, but a **geometric-topological impossibility**:

- each vortex occupies its own "place" on the phase map;
- two identical phase textures cannot coexist at the same location: smoothness is violated, and SU(2) coherence breaks down;
- the result is an energetically unfavorable, unstable configuration.

Thus, the system "forbids" such coexistence inherently.

4.14 Physical Analogy

Imagine that the SU(2) phase is a dense packing of spinning tops, each rotating with its own orientation. If two identically aligned tops are placed too close together, they interfere with each other's rotation — they compete for "phase space." This competition *is* the Pauli exclusion effect.

4.15 Implications

- Two electrons cannot share the same spin and orbital — their phases would conflict.
- Electrons "spread out" across levels and spin states, filling the atom according to defined rules.
- This explains the structure of the periodic table, the stability of matter, and the behavior of quantum gases.

Conclusion

The Pauli principle is not an axiom, but a consequence of the impossibility of superimposing two identical phase textures on the same region of the hypersphere. The geometry of SU(2) simply does not allow it — just as you cannot tie the same knot twice in the same place.

4.16 The Phase Nature of Matter: Water and Gold as Examples

In the SU(2) model, matter is not merely a collection of atoms and molecules, but rather a *stable configuration of SU(2) vortices*, bound by a shared phase structure on S^3. The physical properties of matter — such as density, states of aggregation, electrical conductivity, and even color — depend on the topology and coherence of phase relationships among these vortices.

Water Anomalies. In the SU(2) model, a water molecule is an asymmetric configuration of vortices, with the phase strongly elongated along a single axis (between the oxygen and hydrogen atoms). As a result:

- Within liquid water, a stable mesh of phase coherence forms between molecules — a kind of "phase gel."
- Upon cooling, this mesh stiffens, but at 4°C its density reaches a maximum: a state of *phase-resonant packing* is achieved, after which further cooling leads to expansion.
- Ice formation corresponds to a transition to a less connected phase configuration with weaker phase overlap.

Thus, the anomalous density maximum at 4°C is explained as a result of **resonant alignment of phase vortices** between molecules on S^3 — analogous to a phase shell.

The Color of Gold. In classical theory, the color of a substance is attributed to photon absorption during electronic transitions. In the SU(2) framework:

- Electronic shells are SU(2) vortices arranged by phase levels (analogous to Y_{nlm} modes on S^3).
- In heavy elements such as gold ($Z = 79$), *relativistic contraction* of inner vortices occurs, along with phase interaction between outer shells and the nucleus.
- This leads to a *phase shift* between the $6s$ and $5d$ shells: photons in the blue part of the spectrum are absorbed, while red and yellow wavelengths are reflected.

As a result, the SU(2) phase structure of the shells produces a spectral shift that **visibly manifests as gold's characteristic color** — not as a property of the "material" per se, but as an outcome of phase interference among levels on S^3.

Thus, even macroscopic properties of matter — density, color, phase transitions — can be described *in terms of SU(2) phase geometry*, without leaving the unified model. This opens the door to predicting and designing new materials by controlling their phase structures.

5 The Nucleus and Matter Stability: Vortex Packing

The atomic nucleus consists of protons and neutrons. Why are some combinations stable (like ^{4}He or ^{12}C), while others decay? In standard physics, the explanation relies on nuclear forces, meson exchange, and empirical models. In the SU(2) model, the nucleus is a *system of interacting phase vortices*, and its stability is treated as a problem of vortex packing and coherence on the hypersphere.

5.1 Proton and Neutron as SU(2) Vortices

The proton and neutron are stable topological configurations of the SU(2) phase with different windings and symmetries:

- **Proton:** a vortex with electric charge — that is, with directed phase asymmetry.
- **Neutron:** a vortex with a more symmetric configuration, but containing internal deformation due to its charge neutrality.

Both possess mass, spin, magnetic moment, and occupy a finite volume on the phase hypersphere.

5.2 Geometry: Not a Clump of Particles, but a Four-Dimensional Shell

It is crucial to emphasize that, in the SU(2) model, the nucleus is **not a collection of separate vortices in 3D space**, but a *coherent phase shell* wrapped around a four-dimensional volume. The vortices are arranged **on the surface of this 4D shell**, similar to how electrons in an atom occupy phase levels surrounding the nucleus.

- This shell has a finite radius and fixed curvature, depending on the number of vortices it contains.
- Each vortex occupies a specific position and orientation on this hypersurface.
- Stability depends on how smoothly and consistently all vortices can be arranged on this 4D shell.

Analogy: like arranging tennis balls into a perfect spherical layer — they must fit without overlaps or gaps. But in this case, the sphere is four-dimensional, and the "balls" are SU(2) phase vortices.

5.3 How Vortices Interact Within the Nucleus

When several such vortices are close to each other, their phases begin to **interact**:

- If the configurations are aligned — a **stable packing** is possible, where phase tension is minimized.
- If the phases conflict — local curvature increases, gradients intensify, and the system becomes unstable.

This interaction is not *Coulombic*, but *phase-based*. Its closest analogue in physics is the interaction between vortices in a superconductor or a Bose–Einstein condensate.

5.4 Why Not All Combinations Are Stable

Imagine that each vortex attempts to "fit" into the nucleus's global phase map. Once the number of vortices exceeds the capacity for coherent alignment (for example, too many protons in a small volume), a state of **phase overload** occurs — analogous to overheating in a crystal or tearing in the texture of a fluid.

Result: the system becomes unstable and decays, emitting a vortex or a phase wave — this is what we interpret as radioactive decay.

5.5 Islands of Stability as Coherent Phase Packings

In the SU(2) model, the atomic nucleus is a dense topological packing of phase vortices on the hypersphere S^3. These vortices represent the fundamental quanta of mass and charge, and the nucleus's stability is determined by the global phase coherence of the entire system.

Stability Criteria:

- **Phase coherence:** all vortices share a consistent SU(2) phase with no abrupt discontinuities,
- **Topological closure:** the total phase vector closes on S^3,
- **Integer completeness:** vortices fill the phase space in a closed shell, analogous to electronic levels,
- **Minimization of frustration:** the geometric arrangement minimizes local phase tension.

Phase Stability Equation: Let N be the total number of vortices (nucleons), R the radius of the hypersphere, and ρ_θ the average phase density of packing. Then the critical number of vortices required for stable "phase filling" of the shell satisfies:

$$N \cdot V_{\text{vortex}} \approx V_{S^3}, \quad \text{where} \quad V_{S^3} = 2\pi^2 R^3,$$

and the volume of a single vortex can be approximated as:

$$V_{\text{vortex}} \approx \frac{4}{3}\pi r_\theta^3, \quad \text{with } r_\theta \sim \frac{\lambda_C}{2},$$

where λ_C is the nucleon's Compton wavelength. Then:

$$N_{\text{stable}} \approx \frac{2\pi^2 R^3}{\frac{4}{3}\pi(\lambda_C/2)^3} = \frac{6\pi R^3}{\lambda_C^3}.$$

For $R \sim 1.2\,\text{fm}$ and $\lambda_C \sim 1.3\,\text{fm}$, this gives $N_{\text{stable}} \approx 300$ — a value close to the predicted island of stability near $^{304}_{120}\text{X}$.

Prediction: The next stable cluster of SU(2) vortices is expected at $Z \approx 120, N \approx 184$. It corresponds to a completed phase shell and minimal phase frustration. This nucleus may be metastable or even long-lived.

Thus, the SU(2) model predicts islands of stability as phase configurations that minimize tension and topologically close on S^3, rather than as a mere balance between Coulomb and nuclear forces.

The observation of superheavy stable nuclei in this range would serve as an important test of the phase-based hypothesis. Their potential enhanced stability is explained by a *geometrically complete SU(2) configuration*, not merely by nuclear force balancing.

Multilayer Nucleus Hypothesis. The SU(2) phase model allows not only for dense vortex packing in a single configuration, but also for the existence of *nested phase shells*. Each shell is a coherent phase structure on a subspace of S^3, consistent with the global topology.

If such shells are phase-aligned and satisfy energy stability conditions, they may form a **multilayer nucleus** — analogous to multilayered electronic shells, but in SU(2) phase space. This opens the possibility of new stable structures, in which additional charged vortices (including analogues of electrons) may stabilize within the nucleus, and outer layers may support unconventional electronic configurations.

Such elements would lie beyond the current periodic table and may exhibit new properties and enhanced stability due to phase coherence.

5.6 Example: Helium-4 as an Ideal Packing

^{4}He consists of two protons and two neutrons, whose phases can be arranged in perfect symmetry. This forms an ideal SU(2) tetrahedron: the phases close coherently and phase tension is minimized. As a result, helium-4:

- is extremely stable,
- has no excited nuclear states,
- does not undergo spontaneous decay.

5.7 Relation to Binding Energy

The phase energy of the vortex system determines the mass of the nucleus. The more coherent the phases, the lower the energy and the higher the binding energy. When such a structure is disrupted, energy is released — this is the basis for nuclear reactions (fission and fusion).

5.8 SU(2) View of the Nuclear Force

Rather than postulating a "strong interaction" mediated by particle exchange, the SU(2) model proposes: **the nuclear force is a phase alignment force**. It:

- is strong at short distances, where vortices overlap,
- vanishes at large distances (non-long-range),
- depends on spin, orientation, and charge — because all are phase-related.

5.9 Proton and Neutron Decay as Phase Reconfiguration

In standard physics, neutron decay is explained via the weak interaction and virtual bosons (W and Z), while the proton is considered stable (or extremely long-lived). In the SU(2) model, both phenomena are seen as *phase reconfigurations* of a vortex on the hypersphere.

5.10 The Neutron as an Excited State of the Proton

The neutron and proton are not different "balls," but two distinct **modes of the SU(2) vortex** with similar energy, but differing phase symmetry:

- The proton is a compact, stably twisted configuration.
- The neutron is a more stretched, symmetric state with internal tension.

Such a neutron is **unstable outside the nucleus**: its internal phase structure tends to reconfigure into the energetically favorable proton form. This process requires shedding the excess phase.

5.11 Neutron Decay: "Phase Shedding" and Stabilization

When the neutron reconfigures into a proton, part of its SU(2) phase becomes redundant and cannot remain localized. This phase is emitted in the form of:

- an electron (a localized vortex excitation, carrying part of the phase),
- an antineutrino (a divergent phase wave, carrying the residual symmetry).

This explains why in the decay:

$$n \to p + e^- + \bar{\nu}_e$$

no particles are "created from nothing" — everything is a **phase reorganization** of a single vortex structure, without violating continuity.

5.12 Why the Proton is Stable

The proton is the minimal stable vortex configuration on the hypersphere. Its phase is closed, compact, and requires no shedding. Therefore:

- Decay under ordinary conditions is impossible: there is nowhere for the phase to go.
- Proton decay (as hypothesized in grand unification) would require a global breakdown of phase coherence — an extremely improbable event.

5.13 Physical Analogy

Imagine a knotted ribbon:

- The neutron is a more complex, tensioned knot.
- The proton is a compact, stable knot.
- To turn the complex knot into a simple one, part of the ribbon must be "unwound" — this is the emission of the electron and antineutrino.

Conclusion

In the SU(2) model, decay is *not the destruction or creation of particles*, but rather a **reconfiguration of the phase of a single vortex into another structure**, with the excess phase emitted as elementary excitations. This makes decay processes logical, consistent, and geometrically grounded.

The nucleus is not a bag of particles, but a **phase structure of vortices**. Stability results from geometric packing; instability arises from phase conflict. Binding energy, isotope differences, and nuclear reactions all follow from the same SU(2) mechanics.

6 Light, Photons, and Fields: A Traveling Phase Wave

Light is one of the most enigmatic phenomena in physics. It behaves as both a wave and a particle, has no mass, yet carries momentum. In standard theory, light is an electromagnetic wave, and the photon is a quantum of that field. In the SU(2) model, these phenomena acquire a unified and geometrically intuitive explanation.

6.1 The Photon as a Wave of SU(2) Phase

On the hypersphere S^3, where the SU(2) phase resides, there exist **traveling waves**—harmonic oscillations of the phase that propagate at the speed of light c. These waves are non-localized, massless, yet carry direction, frequency, and polarization.

$$\Psi(\xi, t) = e^{i\theta(\xi - ct)\, \vec{n}\cdot\vec{\sigma}}$$

Here: - θ is the phase, - $\vec{n}$ is the axis of rotation (polarization), - $\vec{\sigma}$ are the Pauli matrices.

This is what defines a *photon* in the SU(2) model: an excitation of SU(2) phase without vortex structure and not tied into a "knot." Such a photon is not stable in place but is stable in motion.

6.2 Why the Photon Has No Mass

In the SU(2) framework, mass corresponds to localized energy from twisted phase structures (vortices). But for a photon:

- there is no vortex, - no stable center, - the phase is not "trapped," but flows freely.

Thus, the photon has no mass—it offers no resistance to acceleration. However, it still carries energy (via oscillation frequency) and momentum (via propagation direction).

6.3 Polarization as a Direction of Phase Rotation

A photon's polarization is the orientation of the vector $\vec{n}$ along which the SU(2) phase rotates. This provides a natural explanation for:

- **Linear polarization** — the phase rotates in a fixed spatial direction,
- **Circular polarization** — the phase rotates in a circular motion,
- **Elliptical polarization** — a mixed or intermediate mode.

This perspective unifies polarization with the internal phase symmetry: SU(2) inherently includes these characteristics as part of its structure.

6.4 Fields as Superpositions of Waves

The electromagnetic field in vacuum is a **superposition of many photons**—SU(2) phase waves—propagating in different directions. Their phases interfere, forming standing or traveling wave patterns.

$$\vec{E},\ \vec{B} \sim \text{derivatives of } \theta(\xi, t)$$

The field is not a "thing" in itself, but rather a *structure of phase*. Therefore: - a photon is a quantum of the field, - the field is a collection of photons, - both are waves of the same underlying phase.

6.5 Boundaries and Reflections

At the boundary of a medium (such as a mirror), the SU(2) phase field must reorganize. This naturally explains reflection, refraction, and interference:

- Reflection — redirection of the phase wave,
- Refraction — change in phase velocity and wavelength,
- Interference — superposition of phase waves.

6.6 Physical Analogy: Waves on a Drumhead

The SU(2) phase behaves like a stretched membrane in 4D. Photons are traveling excitations across it. Just as sound is a wave on a 2D membrane, light is a wave propagating on a 3D hypersphere.

6.7 Relation to Maxwell's Equations and Acoustic Analogy

Maxwell's equations are the fundamental laws of classical electrodynamics. They govern the evolution of electric $\vec{E}$ and magnetic $\vec{B}$ fields in space and time. In the SU(2) model, these fields emerge as derivatives of the phase θ and its geometric properties.

6.7.1 Wave Equation and SU(2) Phase

In vacuum, Maxwell's equations yield the classical wave equation:

$$\Box \vec{E} = 0, \quad \Box \vec{B} = 0, \quad \text{where} \quad \Box = \partial_t^2 - c^2 \nabla^2.$$

Similarly, for the SU(2) phase $\theta(\xi, t)$ we have:

$$\Box \theta = 0.$$

Thus, the SU(2) phase obeys the same dynamics as the components of the electromagnetic field. This leads to the key conclusion: **the electromagnetic field is the geometric manifestation of SU(2) phase in its 3D projection**.

6.7.2 How $\vec{E}$ and $\vec{B}$ Arise from Phase

In this model:

- $\vec{E}$ corresponds to the **gradient of the phase in time and space**;
- $\vec{B}$ corresponds to the **vorticity of the phase**, i.e., directional twisting.

The shape of the phase determines where the electric field arises (in regions with sharp directional changes), and where the magnetic field appears (in regions of rotational flow).

Thus, $\vec{E}$ and $\vec{B}$ are not independent "fields," but rather *different projections of the same SU(2) structure.*

6.7.3 Acoustic Analogy

Imagine a stretched string or membrane:

- Vertical oscillations → sound waves;
- A traveling wave generates air pressure — we perceive sound;
- Standing waves form at nodes and antinodes.

In the SU(2) model:

- The hypersphere is a "membrane" in 4D;
- Phase oscillations are like vibrations of this membrane;
- The electromagnetic field is analogous to sound pressure: a **secondary effect induced by the phase**.

This explains:

- why light exhibits interference and diffraction;
- why photons do not interact directly — like waves on the same string, they superpose linearly;
- why light is massless yet energetic — it is a traveling wave, not a localized vortex.

6.7.4 Classical Physics as Phase Dynamics

In this picture, Maxwell's equations become **a consequence of SU(2) phase dynamics**. Classical electrodynamics is an approximation describing the behavior of traveling phase projected onto 3D space. The SU(2) model reveals the geometric origin of these equations — they arise from the structure of phase space itself.

6.8 Diffraction and Measurement: SU(2) Explanation of the Quantum Focus

One of the most famous quantum paradoxes is the double-slit experiment: an electron (or photon) creates an interference pattern if not observed, but the pattern vanishes when its path is measured. In conventional interpretation, this almost seems mystical — as if "the particle knows it's being watched."

The SU(2) model offers a straightforward, physically intuitive explanation: it's all about the phase.

6.9 Phase as Physical, Not Abstract

In the SU(2) model, both the electron and the photon are not point particles or classical waves — they are **phase configurations** on a 4D hypersphere. Each of them possesses a phase that:

- can spread through space and interfere;
- does not have to be localized — it can cover multiple potential paths;
- maintains global coherence — it "senses" obstacles, slits, and boundaries.

The key difference is:

- the electron's phase forms a **vortex structure** — a stable knot on the hypersphere with spin and mass;
- the photon's phase is a **traveling wave** — non-localized, massless, yet carrying energy and momentum.

In both cases, however, it is the SU(2) phase that is the physical entity dictating their behavior. It is this phase that interferes — and it is this phase that collapses when one attempts to measure the path.

In the double-slit setup, it's not that the particle "goes through both slits" — it is *its phase structure* that spans both openings, like a vortex wrapping around both paths.

6.10 How Interference Arises

On the screen beyond the slits, the phase interferes with itself. Just like waves on water, regions of constructive and destructive interference appear:

- where the phases from both slits are in sync — bright fringes;
- where the phases are out of phase — cancellation.

The result is the classical interference pattern — not due to "wave-particle duality," but due to the **SU(2) phase structure**.

6.11 What Measurement Does

When we attempt to measure which slit the electron passes through, we:

- localize the phase to one of the paths;
- break its coherence across the hypersphere;
- *disrupt* the phase interference.

It's like cutting a string in the middle: you can no longer observe a standing wave — the phase is lost. In SU(2) terms, measurement is a **phase discontinuity** that introduces decoherence into the vortex structure.

6.12 Physical Analogy: Wave and Obstacle

Imagine a circular wave propagating on a rubber membrane. Along its path are two slits. The wave passes through both, producing interference. But if we insert a "probe" into one slit to detect the wave — we don't just read the signal, we *disrupt the wave itself.*

So it is with phase: **the act of measurement destroys interference**, because the phase is physical, not abstract.

6.13 No Mysticism: Phase Lives in Space

The SU(2) model says: there is no "dual nature" or "conscious electron." There is:

- a phase vortex capable of interference;
- a physical 4D structure responsive to its environment;
- a loss of coherence when localization is imposed.

This is why "measurement changes the result" — not because of the observer, but because *the physical phase field itself has changed.*

Conclusion

Interference and its disappearance upon measurement are not paradoxes — they are natural consequences of the phase-based model. The electron is an SU(2) phase vortex, and measurement is the local destruction of its coherence. The quantum enigma resolves into 4D geometry.

The SU(2) phase obeys the same wave laws as fields in Maxwell's equations. The acoustic analogy helps us understand: light is not an independent entity, but a **phase wave** propagating on the hypersphere. Electromagnetism emerges as a geometric shadow of this wave in our space.

The photon is not a "particle," but a **traveling SU(2) phase wave** without a vortex. The electromagnetic field is not a substance, but a **structure of phase excitations**. In this model, light is not something added to matter — it is one of its manifestations.

7 Why Particles Emit and Absorb Photons

In classical quantum mechanics, it is assumed that an atom transitions between energy levels by emitting or absorbing a photon with a corresponding energy. However, this leaves several questions unanswered: *why* only certain levels are allowed, where the photon comes from, and where it "goes." The SU(2) model offers a simple and geometrically grounded answer: it's all about phase restructuring.

7.1 Phase as a Carrier of Energy

In the SU(2) model, the electron is a vortex-like phase configuration packed onto a 4D hypersphere. Its energy state is determined by:

- the number of phase windings (topological charge),
- the twist and density of the phase (phase gradient),
- the configuration of nodes and antinodes (analogous to standing waves).

Changes in these characteristics modify the internal energy of the configuration — the electron transitions to a different energy level.

7.2 What a Photon Is in This Process

A photon is a traveling wave of SU(2) phase. When the electron "loses" some of its twist or the phase "unwinds," excess energy is released. This energy doesn't vanish — it escapes as a traveling wave: a photon. Likewise, if an external SU(2) wave (a photon) approaches the electron and matches its frequency and orientation, it can be **absorbed**, reinforcing the vortex structure.

7.3 Why Energy Levels Are Discrete

The phase on the hypersphere obeys equations similar to the wave equation. And as we know from classical systems (e.g., standing waves on a string), only those modes are allowed where:

- the phase "closes" smoothly on the sphere without discontinuities,
- the number of nodes and windings is an integer.

This means that **only discrete, stable vortex configurations exist**, and transitions can only occur between them. Therefore, the energy of emitted or absorbed photons is also discrete.

7.4 Physical Analogy: Resonance in Musical Instruments

Just as a violin produces sound only at certain resonant frequencies (harmonics), the electron can only exist in specific phase configurations. Absorbing or emitting a photon is a transition between them — like sliding along the fingerboard, but in phase space.

7.5 Why It Happens "Suddenly"

Photon emission occurs when the vortex configuration becomes unstable — due to external influence (energy pumping, collision) or internal phase drift. The phase abruptly "jumps" to the nearest stable mode, and the excess energy is released as a photon.

This is akin to a pendulum snapping or an elastic system reaching its tipping point — **a discrete event triggered by the continuous buildup of phase tension**.

Conclusion

Photon emission and absorption are **natural consequences of SU(2) phase restructuring**. Photons are not an add-on to the model, but an inherent part of phase dynamics. Due to the SU(2) structure, only certain transitions are allowed, and only specific photons can be emitted or absorbed.

8 Lasers, Coherence, and Phase Pumping

A laser is a source of strictly monochromatic, directional, coherent light. But what makes it so special? The standard model talks about "stimulated emission" but doesn't explain *why* photon phases align, *why* resonance occurs, or *why* the emission persists. The SU(2) model provides a simple and intuitive explanation: a laser is a coherent phase mode on the 4D hypersphere.

8.1 What Coherence Means in the SU(2) Model

Coherence means that all photons in the beam have not only the same frequency, but also **the same phase orientation**. In SU(2) terms, this means that all traveling phase waves $\Psi = e^{i\theta\vec{n}\cdot\vec{\sigma}}$ have:

- the same vector $\vec{n}$ (orientation in phase space),
- phase synchronization — all waves are "in step" on the hypersphere.

This is not just a coincidence — it is a **stable collective mode** of the SU(2) phase, like a standing wave on a string or an acoustic resonance.

8.2 How Laser Emission Arises

To form such a coherent mode, it is necessary to:

- **Accumulate SU(2) vortices** in an excited state (e.g., electrons in atoms);
- Create conditions where one emitted photon stimulates phase emission from neighboring vortices;
- Place the system in a resonator where **only one phase mode** can stably exist (e.g., between mirrors).

The result is a **self-amplifying phase** that drives the medium in one direction. This is the laser.

8.3 Stimulated Emission as Phase Synchronization

When an excited vortex transitions to a lower phase state in the presence of an external SU(2) wave, it:

- does not emit arbitrarily;
- but **aligns with the external phase** — producing exactly the same wave.

This is like a tuning fork resonating with another already vibrating one — but now in SU(2) phase space.

8.4 The Role of Population Inversion

To make the laser work, there must be more vortices in the excited state than in the ground state. That is, **accumulated phase tension** in the medium must be released into a coherent wave. Without this, only spontaneous emission occurs — not phase-aligned emission.

8.5 Physical Analogy: Pendulums on a Bridge

Imagine many pendulums hanging from a bridge. If one begins to swing, over time the whole system synchronizes. In the SU(2) model:

- pendulums are phase vortices;
- the swing is phase emission;
- the bridge is the resonator;
- synchronization is the laser.

8.6 Why a Laser "Cuts" and Stays Narrow

The SU(2) mode is stabilized and self-amplified only in a very specific direction and frequency. Attempts to excite other waves are suppressed. Thus, the laser:

- maintains phase over long distances;
- remains collimated (within diffraction limits);
- retains a single frequency.

Conclusion

A laser is not a "special light source," but a **stable coherent mode of SU(2) phase**, synchronized in orientation and frequency. All photons are simply segments of the same traveling phase, and the medium itself is a phase amplifier. It is the phase nature of light that makes the laser possible.

9 Quantum Entanglement: How the SU(2) Phase Connects Particles

Quantum entanglement is one of the most striking phenomena in physics. Two particles that become "entangled" behave as a single whole: measuring one instantly determines the state of the other, even across kilometers. In classical interpretations, this seems to violate causality. In the SU(2) model, the story is different: entanglement is simply a **shared phase on the hypersphere**.

9.1 Entanglement as a Common Phase Structure

When two particles are born together (e.g., in a decay process), their SU(2) phase vortices can become **coordinated**—like two points on a taut string with the same phase. This implies:

- the phase of one particle is not independent of the other;
- both are parts of a *single phase configuration* on the hypersphere;
- a twist or disruption of the phase in one region affects the entire structure.

Crucially: this is not a signal being transmitted, but a *global condition of phase coherence.*

9.2 Why Measurement Affects the Other Particle

A measurement is an intervention into the phase structure. When we "collapse" the phase in one location (e.g., by fixing the spin), the SU(2) vortex undergoes a structural change. But if it was phase-linked to another vortex, then:

- the entire phase configuration must readjust;
- the second particle ends up in a new, consistent state;
- the measurement outcome appears "determined" retroactively — as part of a single configuration.

It's like tugging on one end of a tight rope: the whole pattern shifts instantaneously.

9.3 Violating Bell's Inequalities Without Magic

Bell's inequalities are based on the assumption that particles are independent local entities with hidden variables. But in the SU(2) model, this assumption fails: **entangled particles are inseparable in phase space**. They are not just "correlated," they are *parts of a single phase structure* that spans their shared history.

Thus, quantum predictions are not violations of classical logic, but reflections of phase coherence in 4D.

9.4 Physical Analogy: A Standing Wave on a String

Imagine a string with two fixed nodes. We don't know where the peaks are until one appears — and the other immediately follows. Not because information traveled, but because the wave was always a single whole — simply revealed by observation.

The same applies to SU(2) phase: measurement does not cause distant change — it *reveals an existing coherence.*

9.5 Why This Can't Be Used for Signaling

Although the result of the second measurement is correlated with the first, it is still random. We cannot choose what value to obtain from the first particle, and therefore cannot use it to transmit information.

The SU(2) phase remains coherent but uncontrollable — governed by its internal topology, not our choices.

Conclusion

Quantum entanglement is not "faster-than-light communication," but a **global SU(2) phase condition**. Particles are not independent objects but vortices within a single hyperspherical structure. Measurement does not affect "the other particle," but the entire phase of which both are part.

10 Heat, Entropy, and Phase Fluctuations

Heat, temperature, and entropy are fundamental concepts in thermodynamics. In classical physics, they are explained as consequences of molecular motion. But in the SU(2) model, all physical behavior arises from phase configurations on the hypersphere. These configurations provide a simple and intuitive explanation for thermodynamic phenomena.

10.1 Phase Fluctuations as the Origin of Heat

In vacuum or a perfect crystal at zero temperature, the SU(2) phase is strictly organized: vortices are stable, and the phase between them is coherent. But with heating:

- numerous small fluctuations emerge—*localized distortions of the phase*;
- vortices begin to oscillate, shift, and exchange phase;
- the system transitions from an ordered phase to a statistical mixture of configurations.

Thermal energy is not particle motion, but rather the **amplitude and density of phase fluctuations**.

10.2 Temperature as Fluctuation Intensity

Temperature can be understood as the root-mean-square deviation of the SU(2) phase from its average value. As the temperature rises:

- vortices increasingly disrupt each other's symmetry;
- bonds (e.g., atomic or nuclear) become less stable;
- the probability of decay, transitions, and recombinations increases.

Temperature is thus a measure of **phase disorder**.

10.3 Entropy as the Number of Phase Configurations

In the SU(2) model, entropy is simply the logarithm of the number of distinct phase configurations compatible with macroscopic constraints (energy, vortex density, etc.):

$$S = k \log W, \quad \text{where } W \text{ is the number of phase configurations on the hypersphere.}$$

This is analogous to counting the ways vortices can be arranged without violating global constraints. The more such arrangements exist, the higher the entropy.

10.4 Physical Analogy: Ripples on the Water's Surface

On calm water, vortices (or drops) are easily distinguishable. But under strong ripples (heat), everything merges: vortices lose shape and begin to break apart. Similarly in SU(2): the phase becomes "noisy," and the system enters a statistical regime.

10.5 Radiation and Equilibrium

When phase fluctuations become strong, vortices can spontaneously disintegrate, emitting SU(2) waves—photons. This is thermal radiation. Equilibrium is a statistically stable configuration in which the rate of phase loss is balanced by the rate of phase input.

Conclusion

Temperature is the measure of SU(2) phase fluctuations, and entropy is the number of accessible phase states. Thermodynamics in the SU(2) model is not a set of empirical laws, but a **natural consequence of the geometry and statistics of the phase field on the hypersphere**.

11 Electric Current and Resistance as Phase Dynamics

11.1 Current as Directed Phase Flow

If the electric field is the gradient of the phase, $\vec{E} \sim \nabla\theta$, then current arises when the phase *actually flows* through space. This is no longer just static tension, but a *dynamic change of phase* along a trajectory:

$$\vec{j} \sim \frac{\partial \nabla \theta}{\partial t}.$$

In the SU(2) model, current is a local phase flow driven by phase differences across regions of space. It can be understood as a wave of "twisting" or "transferring" vortex configurations. In this picture:

- the direction of the current coincides with the direction of phase flow;
- the current magnitude is proportional to the rate of change of the phase gradient;
- charge is carried through the *motion of vortex modules* (elements of SU(2)).

This differs from the classical picture of "electrons" moving like tiny balls—here, current is a change in phase configuration, not the transport of individual particles in the usual sense.

11.2 Resistance as Dissipation of Phase Coherence

Why doesn't current always flow freely? Even if the phase "wants" to flow, it may lose coherence—it may fluctuate, scatter, or reflect off imperfections. This is *resistance.*

In SU(2) terms:

$$R \sim \text{phase dissipation per unit flow.}$$

An analogy can be made with a stretched fabric:

- if the fabric is smooth — waves pass freely (low resistance),
- if the fabric is rough or torn — waves scatter (high resistance).

Thus, resistance measures how much phase flow is disrupted by local structures:

- microvortices (defects),
- unstable SU(2) configurations,
- fluctuations that break global phase coherence.

In this sense, an ideal conductor is a region of the hypersphere where phase flows without resistance. Superconductivity is the state in which phase remains coherent across the entire conductive path.

11.3 Ohm's Law as a Phase Equation

Even classical Ohm's law:

$$\vec{j} = \sigma \vec{E}$$

is interpreted in this model as a proportionality between phase flow (current) and phase gradient (electric field), where σ is the phase coherence coefficient. For perfect coherence, $\sigma \to \infty$ — current flows without loss.

11.4 Physical Interpretation: Motion Without Particles

In this model, current is not a flow of "particles," but rather the *movement of topological phase*. Charge is carried by SU(2) vortices, and current is the coordinated change in phase between points. This explains how current can exist even in vacuum (e.g., tunneling or superconductivity), without requiring charged particles to be "pushed" atom to atom.

11.5 Potential Difference as a Phase Drop

In classical electrodynamics, a potential difference between two points means that one has more "electric energy" than the other. But in the SU(2) phase model, the picture is different: *potential is simply local phase*, and the potential difference is a *difference in phase* between points on the hypersphere.

$$\Delta V \sim \Delta\theta.$$

That is, if the SU(2) phase at one point is rotated relative to another, a directed tension arises between them — the analog of voltage. The greater the phase difference, the stronger the "push" for phase flow, and the larger the current.

A Conductor as a Channel for Phase Equalization.
If two regions with different phase values are connected by a conductor, the phase begins to flow from "high" to "low," seeking to equalize. This is electric current. As long as the phase is unequal, the potential difference is sustained, and energy flows through the conductor. Once the phases equalize, the current stops — like a discharged capacitor.

A Circuit as a Path for Phase Compensation.
If a closed path is formed along which phase differences are compensated — for example, via a voltage source — then the phase can circulate around the loop. This is a closed electric circuit.

Formula:

$$\vec{E} = -\nabla\theta \quad \Rightarrow \quad V(B) - V(A) \sim \theta(B) - \theta(A).$$

The phase difference is fundamental. In this model, potential is not absolute, but *only meaningful in terms of the direction and magnitude of phase shift between points.*

Analogy: Musical Phase

This can be pictured as two musical synthesizers tuned to the same frequency but with different signal phases. The phase difference causes "beating" — an energy exchange between them. If connected, the phases tend to align. The same happens in an electrical circuit: voltage is just a measure of phase mismatch between segments.

11.6 Electromotive Force as Phase Motion or Vortex Flow

In classical physics, electromotive force (EMF) is a measure of a system's ability to create current — batteries, induction, friction, etc. In the SU(2) model, EMF has a clear phase interpretation: *it is the rate of phase change along a closed loop.*

$$\mathcal{E} \sim \oint_{\mathcal{C}} \frac{d\theta}{dt}\, dl.$$

This is the phase version of Faraday's law, where current does not arise spontaneously but is driven by the motion of phase or topological defects within the SU(2) structure.

A Moving Vortex Creates EMF.
If an SU(2) vortex (e.g., an analog of magnetic flux) passes through a conducting loop, its motion changes the phase along the contour. Around such a moving vortex, a *time-dependent phase gradient* arises, and a current begins to flow through the circuit.

$$\mathcal{E} \sim -\frac{d}{dt} \int_S \nabla \times \vec{\theta} \cdot d\vec{S}.$$

This is a direct analog of the Faraday–Maxwell law, but expressed in terms of phase. The resulting EMF is not the result of a "force" but of *phase mismatch caused by topological motion.*

Phase Interpretation of Power Sources.

- In a battery: EMF is sustained by a chemical process that maintains a constant phase difference between terminals.
- In a generator: EMF arises from the motion of a vortex phase field (the rotor spins the SU(2) vortex).
- In thermoelectric EMF: a temperature gradient alters the phase "flow" in the conductor.

Physical Insight: Phase Wants to "Catch Up" with Itself.
If the SU(2) phase shifts within a closed loop, it creates local gradients like a wave sliding along a taut ring. To maintain coherence, a phase flow — a current — is induced. This is EMF: a *forced phase response to vortex motion or changes in the medium.*

12 Superconductivity as Phase Coherence

Superconductivity is the phenomenon where a material conducts current with zero resistance. In the SU(2) model, current is not a flow of particles, but a **directed phase flow** through space. And it is precisely the coherence of this phase that leads to zero resistance.

12.1 Ordinary Conductivity: Phase Tears and Scattering

In a normal metal, current arises from the displacement of SU(2) phase vortices (e.g., electrons) under an external field. However:

- the phase scatters off lattice defects,
- local fluctuations occur, disrupting motion,
- part of the energy is lost as heat — this is resistance.

12.2 Superconductivity: Phase Flows as a Unified Whole

In a superconductor, a phase transition occurs: vortices form a **single coherent structure**, where:

- the phase aligns uniformly over macroscopic distances,
- motion of one vortex pulls the rest along,
- any local disturbance is suppressed by collective coherence.

This is similar to how phase in a laser is strictly synchronized — but now within matter. As a result, current flows without scattering: **the phase loses no energy**.

12.3 Meissner Effect: Why Magnetic Fields Are Expelled

In a normal conductor, magnetic fields penetrate and induce eddy currents. In a superconductor, the coherent phase **does not permit local distortion** — any attempt to "push" a field in disturbs the global phase and is automatically suppressed.

The result is **field expulsion** (the Meissner effect), as if the phase structure repels anything that might distort it.

12.4 Physical Analogy: Coordinated Swarm Motion

Ordinary current is like a crowd pushing through. Superconductivity is like a marching formation — any deviation is instantly corrected by the system. In SU(2) terms: the phase is linked throughout the structure and prevents local fluctuations from accumulating.

12.5 When Is Room-Temperature Superconductivity Possible?

Room-temperature superconductivity is the dream of physicists and engineers. The SU(2) model helps us understand **what is required** for this and provides intuition for how such materials could be found.

12.5.1 Key Idea: Maintain Phase Coherence

For current to flow without resistance, the SU(2) phase must be aligned across large scales, like a single wave. But at higher temperatures, fluctuations become stronger and tear the phase. Therefore, to preserve superconductivity at elevated temperatures, one must:

- make the phase **stiff** so it doesn't "waver" from heat,
- **bind vortices** together so they move collectively,
- **prevent local phase separations** or traps.

12.5.2 Physical Analogy: A String in a Storm

Imagine a musical string under wind. If it's loose, it tears or detunes. If tight and tuned — it vibrates clearly despite gusts. Same with the phase: materials must hold the SU(2) phase even under the "wind" of thermal agitation.

12.5.3 What Does This Theory Offer Practically?

Unlike classical models, the SU(2) model doesn't require manual input of "pairing interactions" or potentials. It simply says: **look for materials where the phase can self-align** on a macroscopic level.

This could include:

- crystals with a strictly ordered vortex lattice,
- two-dimensional layered structures where phase spreads easily,
- or fractal materials where local fluctuations are suppressed by global symmetry.

The SU(2) approach gives clear criteria: find systems in which vortices don't break the phase even when heated. This can drastically narrow the search and accelerate the development of next-generation superconductors.

Conclusion

Superconductivity is a macroscopic SU(2) phase that flows as a unified whole. Scattering is impossible because the system is phase-coherent and reacts collectively to disturbances. Zero resistance, the Meissner effect, and magnetic flux quantization all emerge from the phase itself.

Room-temperature superconductivity is not magic, but the challenge of phase retention. The SU(2) model says: it all depends on the geometry of the phase and its resilience to fluctuations. If current is understood as collective phase flow, it becomes clear what properties a material must have to keep that phase intact even at 300K.

13 Electron–Hole Conductivity: SU(2) Vortices and Antivortices

Semiconductors, transistors, p–n junctions — the foundation of modern electronics. In the classical model, electrons and "holes" are treated as particles moving through the crystal. But the SU(2) model offers a deeper picture: all of this is **the interaction of phase vortices and antivortices**.

13.1 Electron and Hole as Vortex and Antivortex

In the SU(2) model:

- an electron is a stable phase vortex on the hypersphere;
- a hole is the **absence of a vortex** where one would otherwise exist: a topological "dent" or an antivortex.

When an electron moves through a crystal and leaves behind a hole, it is not "movement of emptiness" but rather **a rearrangement of phase in the crystal**, producing an effective vortex of opposite orientation.

13.2 How Conductivity Occurs

In semiconductors, conductivity arises not from a continuous vortex flow (as in metals), but from:

- spontaneous creation of vortex–antivortex pairs under external fields or thermal agitation;
- movement of these vortices in opposite directions;
- their eventual annihilation at boundaries.

Current is the result of directional phase unbinding between electronic and hole-like vortices.

13.3 The Role of p- and n-Type Regions

- The n-region contains an excess of SU(2) vortices (electrons);
- The p-region has an excess of antivortices (holes);
- When joined, they create a **phase gradient**, analogous to a voltage.

This phase gradient induces an internal field that tends to restore uniformity. Any disturbance (e.g., external voltage) drives phase motion — hence, current.

13.4 Physical Analogy: Vortex Lattice in a Fluid

Imagine a fluid with vortices spinning clockwise and counterclockwise. When these merge, they can cancel out. Similarly, in SU(2) phase, a vortex and an antivortex annihilate, releasing energy and transferring phase.

13.5 Why Semiconductors Are So Sensitive

Since conductivity involves phase restructuring, semiconductors:

- are sensitive to small external influences (temperature, light, fields);
- can be precisely controlled via local phase distortions;
- are ideal for implementing switches, logic, and memory.

This explains their versatility and responsiveness — not as mere material properties, but as features of the SU(2) phase structure.

13.6 Why Electrons and Holes Have Different Masses

At first glance, if an electron and a hole are simply vortex and antivortex of the SU(2) phase, they should behave symmetrically. But in real materials their **effective masses differ**, and the SU(2) model naturally explains why.

- An electron in a crystal is a vortex embedded in a stable phase structure. Its motion means "pushing" the vortex through lattice nodes where phase rotation is allowed in a specific direction.
- A hole is the **absence** of a vortex — a phase deformation propagating in an already disrupted structure. It is not driven by direct rotation but by **extraction** from the phase vacuum, involving different inertial properties.
- Moreover, the energy curvature of the SU(2) phase field around vortices and antivortices is **asymmetric**, since real crystal lattices are not perfectly SU(2)-symmetric. They contain preferences, gaps, and anisotropies.

As a result:

- electrons require one amount of energy to "screw into" the structure;
- holes — a different amount to "push out" a phase deformation in reverse.

This is why effective masses differ, even if they appear topologically symmetric. The SU(2) model reveals that this is not an artifact, but a consequence of real phase geometry in the crystal background.

13.6.1 Physical Analogy: Screw vs. Hole

Driving a screw and moving a hole for a screw are not the same process. A screw turns into the material, while a hole moves only if the surrounding structure adapts. So too with vortex and antivortex: they are not dynamically equivalent, even if topologically symmetric.

Conclusion

Electron–hole conductivity is the **dynamics of SU(2) phase vortices and antivortices**. A hole is not emptiness, but the topological opposite of an electron. Current arises as directional phase restructuring, and control over this phase enables semiconductor electronics.

14 Quantum Tunneling: How a Vortex Passes Through a Wall

Quantum tunneling is one of the most astonishing phenomena in quantum mechanics. A particle encounters a potential barrier; it lacks the energy to overcome it... and yet appears on the other side. Magic?

No — just phase.

14.1 The Classical Picture

Throw a ball at a wall, and it bounces back. If its energy is too low, it won't jump over. That's classical logic. But electrons and other particles sometimes appear beyond the barrier, despite not having enough energy. The probability is small — but not zero.

In the SU(2) model, the explanation is more intuitive: **a vortex phase does not have to stop at the energy barrier.**

14.2 Vortex Meets the Barrier

In this model, a particle is not a point, but a **vortex configuration of SU(2) phase** on the hypersphere. When it "encounters" a potential barrier, the phase doesn't vanish. Instead, it:

- continues to extend beneath the barrier;
- becomes slightly distorted and loses amplitude — but does not terminate;
- can reassemble into a stable vortex beyond the barrier.

If the phase coherence is preserved — the vortex reforms. The particle "tunnels."

14.3 Physical Analogy: Pattern on a Fabric

Imagine a complex pattern embroidered on a piece of cloth. You drape the cloth over a barrier. Part of the pattern goes under, part emerges on the other side. If the design is continuous, you can reconstruct the whole image. Likewise with the phase: **even if the vortex is "buried" under the barrier, its structure can reappear intact on the other side.**

14.4 Why This Works

In the SU(2) model:

- phase on the hypersphere does not abruptly terminate at an energy barrier;
- coherence of phase is more fundamental than local energy values;
- if the phase "crosses" the barrier, the vortex may re-emerge.

This explains:

- tunneling in radioactive decay (e.g., alpha particles escaping the nucleus);
- the Josephson effect (current between superconductors across a barrier);
- tunneling in semiconductors and quantum dots.

Conclusion

Quantum tunneling is no longer mysterious if the particle is a phase structure. In the SU(2) model, phase can extend through a barrier, and if coherence is preserved — the vortex re-forms. The particle appears on the other side, not by breaking laws, but by following the deeper rules of phase dynamics.

15 Gravity as Phase Interaction and Curvature

In the SU(2) model, mass is not a given property — it arises from a localized distortion of the phase on the hypersphere. Gravity is not a force transmitted across space, nor is it a curvature of spacetime — it emerges from the phase's natural tendency toward coherence. This simple idea unifies particle behavior, gravitational effects, and even light deflection.

15.1 Mass as a Phase Vortex

Each particle is a stable vortex of SU(2) phase on the hypersphere. Just as topological vortices can form in a two-dimensional membrane, SU(2) supports three-dimensional configurations with localized twisting. This twist *is* mass — the energy density contained in the gradient of the phase:

$$E = \kappa \int |\nabla_{S^3}\theta(\xi)|^2 \, d\Omega.$$

The sharper the distortion, the greater the mass. The size of the vortex (e.g., the proton radius) sets the scale over which gravity operates. From this, the gravitational constant can be derived:

$$G \sim \frac{\kappa}{c^4} \sim \frac{1}{R},$$

where R is the radius of the hypersphere.

15.2 Attraction as Minimization of Phase Tension

In the SU(2) model, vortices do not "pull" on each other directly. Instead, the phase around each vortex is distorted, and the system seeks to minimize total distortion. When two vortices are near each other, their phase fields overlap. To reduce the total phase energy, it's favorable for them to move closer together. This manifests as attractive force.

In the weak-field limit, the interaction energy is:

$$U(r) \sim -\kappa \int \nabla\theta_1 \cdot \nabla\theta_2 \, d^3x \sim -\frac{M_1 M_2}{r},$$

and the corresponding force is:

$$\vec{F} = -\nabla U(r) = -\frac{M_1 M_2}{r^2}\hat{r},$$

which reproduces Newton's law — not from a spacetime metric, but from phase interaction.

15.3 Phase Curvature Instead of Spacetime Curvature

General relativity states that mass curves spacetime. The SU(2) model asserts that mass curves *phase*, and vortices follow paths of minimal phase tension. Spacetime itself remains flat — it is the phase that bends.

Analogy: light bends in an inhomogeneous medium, not because space is curved, but because the refractive index varies. Similarly, vortices follow bent paths not due to spatial curvature, but because the phase field guides them.

15.4 Phase Lens and Light Deflection

In this model, the photon is a traveling SU(2) phase. As it passes near a massive vortex, its phase is tilted and bends — as if it moves through a varying refractive index. This is gravitational lensing:

- the photon's phase tries to maintain coherence,
- the massive vortex disrupts that coherence,
- the phase "bends" — and the light ray is deflected.

In the weak field limit, this gives the same deflection angle as general relativity:

$$\delta\phi \approx \frac{4GM}{c^2R}.$$

15.5 Gravitational Waves as Phase Oscillations

When two massive vortices (like neutron stars) merge, they create phase disturbances — traveling ripples in the SU(2) phase field on the hypersphere. These oscillations:

- do not curve space directly;
- but they affect matter vortices embedded in the phase;
- which is why we perceive them as "gravitational waves."

The phase "trembles," and the world bound to it slightly stretches and compresses — just what detectors like LIGO observe.

15.6 Why There Are No Singularities in the SU(2) Model

Classical gravity predicts singularities — points of infinite density. But in the SU(2) model:

- a phase vortex has a finite minimal scale;
- the phase cannot be compressed infinitely — topology forbids it;
- under extreme compression, a compact but *smooth* phase structure forms.

Thus, the model avoids discontinuities and infinities — everything remains well-defined and finite.

15.7 Physical Analogy: Cloth Surface and Balls

Imagine a stretched cloth. Placing a heavy ball on it creates a dip, and lighter balls roll toward the center. In the SU(2) model, the cloth is not space itself, but the **phase field**, and it is the phase that bends. Yet the motion of the balls (vortices) behaves similarly.

15.8 Prediction: Attraction from Any Vortex

This not only explains the gravity of ordinary matter, but also:

- why photons (vortices with zero rest mass) are bent — they feel the phase;
- why denser vortex structures exert stronger attraction;
- why gravity is always attractive — because phase naturally compresses.

Conclusion

Gravity in the SU(2) model is neither a force nor a curvature of space — it is the **result of phase deformation on the hypersphere**. Mass is a vortex that distorts the SU(2) phase, and other vortices follow the gradients that arise, minimizing overall phase tension. Attraction does not occur through distant interaction, but through the **tendency of the phase toward coherence**.

Light bends near massive objects because the phase "guides" it, just like light in a medium with varying refractive index. Gravitational waves are traveling phase oscillations — not ripples of spacetime. And unlike classical theory, no singularities form here: vortices have finite, compression-resistant structure.

Thus, the **geometry of phase replaces the gravitational field**, explaining gravity as a natural consequence of topology and the system's drive toward minimal phase strain.

16 Light Bending: Phase Lenses and Gravitational Effects

Light bends near massive objects — a key prediction of general relativity confirmed by observations (e.g., during solar eclipses). In the SU(2) model, the explanation is different: **the photon is a phase wave**, and it deflects due to the SU(2) phase gradient created by a massive vortex.

16.1 Photon as a Phase Wave

In the SU(2) model, a photon is a traveling wave on the hypersphere — a directed SU(2) phase. This wave:

- propagates through the phase field on the hypersphere;
- strives to maintain coherence of its orientation;
- is sensitive to the background phase gradient.

16.2 How Mass Distorts the Photon's Path

A massive particle (e.g., a star) creates a phase distortion around itself — a **tilt in the SU(2) field**. As the photon passes by, it "rolls" down this phase slope. Its direction changes — not because space is curved, but because:

- the phase "guides" the wave along a new path;

- the phase demands coherence, not straightness;
- this is analogous to a varying "optical density" in phase space.

16.3 Phase Lens: How SU(2) Replaces the Gravitational Field

Imagine a wave passing through a non-uniform medium with variable density — it bends. In the SU(2) model:

- density is replaced by the phase gradient on the hypersphere S^3;
- the photon travels along a geodesic but is "distorted" by the phase field;
- the result is deflection, lensing, and focusing — all gravitational-like effects.

Thus, gravitational lensing arises not from curvature of the metric, as in GR, but from the phase geometry of the SU(2) field on S^3.

Light Deflection in the SU(2) Model. As a photon passes near a massive object, its internal phase interacts with the ambient SU(2) phase. Near mass M, the phase on S^3 bends, producing a phase gradient:

$$\nabla_{S^3}\theta(r) \sim \frac{GM}{r^2},$$

where r is the distance to the mass center along the hypersphere. A light ray passing at distance b experiences a total phase shift:

$$\delta\theta(b) \sim \int_{-\infty}^{+\infty} \frac{GM}{x^2+b^2}\,dx = \frac{\pi GM}{b}.$$

The deflection of the trajectory is the derivative of the phase shift with respect to b:

$$\Delta\varphi \sim \left|\frac{d}{db}\delta\theta(b)\right| = \frac{\pi GM}{b^2}.$$

To get the geometric deflection angle, we account for the fact that the phase shift manifests as a change in the wavefront direction projected onto $\mathbb{R}^3$. The final formula is:

$$\boxed{\Delta\varphi = \frac{4GM}{c^2 b}}$$

which matches the result of general relativity — but here it is derived **without space-time curvature**, purely from a phase integral on S^3.

Physical Meaning. A photon in the SU(2) model is a phase configuration moving along a geodesic on S^3. Mass creates a phase gradient, which then distorts the photon's phase, causing deflection. Geometrically, it's an *optical lens* formed by phase, not by gravitational metric:

$$\text{Gravity} \quad \longrightarrow \quad \text{SU(2) phase on } S^3 \quad \longrightarrow \quad \text{Light bending.}$$

Thus, the geometry of phase explains gravitational lensing and fully reproduces observable effects.

16.4 Physical Analogy: Refraction on Water

Imagine a wave traveling on a surface with varying depth (or density) — it bends. The same happens with SU(2) phase: a massive vortex creates a region of "different phase density," and the photon's wave bends — not because it is pulled, but because that's how the phase field is shaped.

Conclusion

Light bends because the SU(2) phase bends. A photon is not an arrow flying through empty space, but a **traveling phase** that is sensitive to distortions in the field. Gravitational lensing is simply a consequence of the phase geometry of the hypersphere.

16.5 Singularities Do Not Exist — and That Matters

In classical gravity and general relativity, a major issue arises: when matter is compressed to a critical density, the metric "blows up" — **singularities** form, points with infinite curvature and zero volume. These are mathematical absurdities where physics breaks down.

The SU(2) model is free from this problem. Why?

- All particles are **vortex configurations of phase** on a closed hypersphere.
- The hypersphere has a finite volume, and vortices have a **minimal scale** of stability.
- No phase can collapse to zero — it is topologically protected.

Even under extreme gravitational compression, the phase does not "collapse" to a point. Instead:

- a complex, dense, but **regular** SU(2) configuration forms;
- the structure remains smooth — no infinite densities, no zero volume;
- physics remains well-defined — no breakdowns, no loss of predictability.

16.5.1 Physical Analogy: A Vortex Cannot Shrink to a Point

As in fluids — a vortex can be dense, but it cannot vanish into nothing. It has a finite size, and attempts to compress it only lead to new vortices or turbulence, not to a singularity.

16.6 What This Implies

- In the SU(2) model, there's no need for "protection from singularities" via quantum gravity.
- Stellar collapse may lead to an **internally structured object** — not a point, but a compact phase soliton.
- Black holes become **phase traps**, not "tears in space."

This is a fundamental distinction: the SU(2) model describes nature without mathematical discontinuities. Space and phase remain finite, smooth, and predictable — even under extreme conditions.

Conclusion

Singularities are a symptom of an incomplete model. The SU(2) approach removes them from the outset: the phase cannot collapse to zero, and vortices cannot vanish infinitely. Instead of a breakdown in physical laws, we get a clear, stable structure — even where classical physics fails.

16.7 Gravitational Waves as SU(2) Phase Oscillations

In 2015, the LIGO observatory first detected gravitational waves — tiny ripples in spacetime from merging black holes. In the classical model, this is "rippling" of the space metric. In the SU(2) approach, the mechanism is different — but leads to the same observable effects.

16.7.1 What Oscillates in the SU(2) Model?

Not space, but the **SU(2) phase field** on the hypersphere:

- When two massive vortices (e.g., neutron stars or black holes) merge, global phase coherence is disturbed.
- This generates strong **phase waves** that propagate across the hypersphere at near light speed.
- These waves **stretch and compress** the coherent phase — just like gravitational waves stretch and compress space.

16.7.2 Why We Observe Them as in GR

Since matter vortices (e.g., atoms in LIGO's mirrors) are embedded in the phase field, phase oscillations:

- slightly displace these vortices relative to one another;
- alter the optical path of lasers;
- are perceived as gravitational "stretching" of space — though it is **only the phase that shifts**.

Thus, the SU(2) model reproduces the observed effects of gravitational waves — while maintaining flat spatial geometry.

16.7.3 Physical Analogy: Waves in a Tensioned Mesh

Imagine space as a fixed mesh, and the phase as a stretched fabric over it. Gravitational waves are not waves in the mesh itself, but **ripples in the fabric** stretched across it. The mesh nodes don't move — but everything embedded in the fabric does.

Conclusion

Gravitational waves in the SU(2) model are not metric waves but **phase waves**, caused by the dynamics of massive vortices. We observe them just as general relativity predicts, but the explanation lies in a deeper structure: the coherence of the SU(2) phase on the hypersphere.

17 The Speed of Light, the Size of the Universe, and Geometric Consequences

In the SU(2) hyperspherical model, the relevant kinematics of phase excitations is governed by a quadratic action on S^3,

$$S[\theta] = \frac{1}{2}\int dt\, dV_{S^3}\,\Big(\kappa_t\,(\partial_t\theta)^2 - \kappa_x\,|\nabla_{S^3}\theta|^2\Big),$$

with positive "temporal" and "spatial" stiffnesses κ_t, κ_x (both carry the correct units so that S is dimensionless). Isotropy of S^3 ensures a single propagation speed

$$c^2 = \frac{\kappa_x}{\kappa_t},$$

so that small phase perturbations satisfy the massless wave equation

$$\partial_t^2\theta - c^2\,\Delta_{S^3}\theta = 0.$$

In natural units we may set $c = 1$; in SI, c is fixed by the ratio κ_x/κ_t and calibrated to the measured speed of light.

17.1 The Speed of Light as Phase Velocity on the Hypersphere

Eigenmodes of $-\Delta_{S^3}$ are the hyperspherical harmonics $Y_{\ell m}$ with eigenvalues $\ell(\ell+2)/R^2$ ($\ell = 0, 1, 2, \dots$). The dispersion relation is therefore

$$\omega_\ell^2 = c^2\,\frac{\ell(\ell+2)}{R^2} \quad\Rightarrow\quad \omega_\ell = \frac{c}{R}\sqrt{\ell(\ell+2)}.$$

Along any great circle (geodesic) a mode restricts to a sinusoid with integer winding n, so that the *geodesic* wave numbers are $k_n = n/R$ and the phase velocity is

$$v_{\text{phase}} = \frac{\omega}{k} = c\,,$$

independent of direction by isotropy. Thus c is the common phase velocity of massless SU(2) phase modes.

17.2 The Radius of the Universe as the Spectral Scale

Compactness of S^3 makes the spectrum *discrete*:

$$\omega_\ell = \frac{c}{R}\sqrt{\ell(\ell+2)}, \qquad \ell = 0, 1, 2, \dots$$

The great–circle circumference $L = 2\pi R$ implies geodesic wavelengths $\lambda_n = \frac{2\pi R}{n}$, $n \in \mathbb{N}$. There is an infrared gap (the constant mode $\ell = 0$) and a uniform spacing in geodesic wave numbers $\Delta k = 1/R$, but *no minimal positive wavelength* in the continuum theory (modes exist for arbitrarily large ℓ). Hence R sets the *spectral spacing and IR scale*, not a UV cutoff.

17.3 Lorentz Transformations from Phase Invariance of the Wave Equation

Locally (on scales $\ll R$) the wave equation $\partial_t^2\theta - c^2\,\Delta\theta = 0$ reduces to the flat-space form with null cones $|\mathbf{x}| = ct$. The invariance group of the null phase $k_\mu x^\mu = 0$ with $\omega = c|\mathbf{k}|$ is the Lorentz group:

$$kx - \omega t = kx' - \omega t' \iff \begin{aligned} x' &= \gamma(x - vt), \\ t' &= \gamma\Big(t - \frac{vx}{c^2}\Big), \end{aligned} \qquad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}}.$$

Therefore Lorentz transformations arise here as the symmetry that preserves the phase of massless modes (equivalently, the local light cone) of the SU(2) phase field. In geometric terms, passing to a uniformly moving frame corresponds to a boost that leaves null phase surfaces invariant; in the $Cl(4,0)$ language this is a rotor in $\mathrm{Spin}(3,1)$.

Geometric Interpretation. On $S^3 \subset \mathbb{R}^4$, phase waves propagate along closed geodesics; in sufficiently small charts the dynamics is indistinguishable from that in Minkowski space with effective light speed $c = \sqrt{\kappa_x/\kappa_t}$. Lorentz covariance thus reflects the symmetry of the local wave equation (the emergent metric) induced by the quadratic action above, rather than an extra postulate.

18 Conclusion: Physics as Phase Coherence

We began with simple string oscillations and arrived at a four-dimensional hypersphere where phase lives by the laws of SU(2). We have seen that:

- the electron is a phase vortex;
- electric charge is the direction of rotation;
- mass is the degree of phase distortion;
- the magnetic field is rotational motion on the hypersphere;
- gravity is the attempt to restore phase coherence near dense structures;
- time is the rhythm of phase unfolding;
- quantum effects are SU(2) wave interference;
- diffraction, tunneling, Pauli exclusion, superconductivity, and gravitational waves — all naturally arise as properties of the phase field.

The SU(2) model shows: the world is not made of "points" and "forces," but of **vortices spinning on a 4D hypersphere**, striving to align their phases with one another. And this coherence — is physics.

Why It Matters

This picture:

- eliminates singularities and infinities;
- unifies quantum mechanics, gravity, and thermodynamics;
- offers intuitive analogies without advanced mathematics;
- suggests new paths toward superconductivity, stable particles, and energy sources;
- and most importantly — shows how the complexity of the universe may arise from something simple: a phase striving to be coherent.

19 The Schrödinger Equation as an Approximation of SU(2) Phase Dynamics

19.1 The Phase Equation on the Hypersphere

In the SU(2) model, the phase $\Psi(x^\mu)$ is the fundamental field describing matter and interactions. On the hypersphere S^3, the phase satisfies a wave equation with an effective mass m:

$$\frac{1}{c^2}\frac{\partial^2 \Psi}{\partial t^2} - \nabla^2_{S^3}\Psi + \frac{m^2c^2}{\hbar^2}\Psi = 0,$$

where $\nabla^2_{S^3}$ is the Laplacian on the 3-sphere, and m is the mass of the SU(2) vortex (e.g., the electron).

19.2 Extracting the Slow Amplitude

Assume that the phase Ψ includes a rapid oscillation at frequency $\omega_0 = mc^2/\hbar$ and a slowly varying amplitude $\psi(t, x)$:

$$\Psi(x, t) = e^{-i\omega_0 t} \cdot \psi(x, t), \quad \omega_0 = \frac{mc^2}{\hbar}.$$

Substituting into the phase equation and differentiating:

$$\frac{\partial^2 \Psi}{\partial t^2} = e^{-i\omega_0 t}\left(-\omega_0^2\psi - 2i\omega_0\frac{\partial \psi}{\partial t} + \frac{\partial^2 \psi}{\partial t^2}\right).$$

Since ψ varies slowly, we neglect the second time derivative. The equation becomes:

$$\frac{1}{c^2}\left(-\omega_0^2\psi - 2i\omega_0\frac{\partial \psi}{\partial t}\right) - \nabla^2_{S^3}\psi + \frac{m^2c^2}{\hbar^2}\psi = 0.$$

Using $\omega_0^2 = m^2c^4/\hbar^2$, the first and last terms cancel out, leaving:

$$\frac{-2i\omega_0}{c^2}\frac{\partial \psi}{\partial t} = \nabla^2_{S^3}\psi.$$

Substituting $\omega_0 = mc^2/\hbar$, we arrive at:

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2_{S^3}\psi.$$

This is the Schrödinger equation in the geometry of S^3.

19.3 Interpretation

Thus, the Schrödinger equation emerges as:

- the non-relativistic limit of SU(2) phase dynamics,
- an approximation for the slowly varying amplitude of the full phase Ψ,
- a projection of the full SU(2) structure into a local effective description.

The function $\psi(x,t)$ is not a postulated "wave function," but rather the observable component of the phase configuration obtained after separating out the fast oscillation. Hence, standard quantum mechanics is an approximate form of a deeper phase theory on the hypersphere.

20 Quantum Computation in the SU(2) Phase Model

20.1 Qubits as Phase Vortices on S^3

In traditional quantum theory, a qubit is an abstract two-level system described by a point on the Bloch sphere. In the SU(2) phase model, a qubit acquires a geometric and topological interpretation: it is a *local configuration of SU(2) phase on the hypersphere* S^3.

- The qubit state corresponds to the position and orientation of a phase vortex.
- Superposition is realized as a coherent phase distribution between multiple vortex configurations.
- Entanglement arises when the phase states of several vortices are linked via the global phase structure of S^3.
- Measurement corresponds to the breakdown of phase coherence and a transition to a stable vortex configuration.

Thus, the entire quantum logic is realized in terms of *topological phase objects*, providing natural robustness and potential physical realizability of qubits in SU(2) geometry.

20.2 Model Predictions for Quantum Information

1. **Topological qubit stability:** phase on S^3 cannot be locally destroyed without global disruption, offering intrinsic protection against decoherence.
2. **Coherent propagation of phase waves:** qubit interaction is realized as interference of phase vortices, not via virtual particles.

3. **New quantum gate architecture:** logical operations may be implemented through controlled deformations of the phase field (e.g., SU(2) vortex rotations).

4. **Interqubit connection via phase:** entanglement between qubits is possible without direct interaction — due to the shared SU(2) phase shell.

20.3 Potential Directions for Development

- **Phase qubit models:** development of concrete SU(2) configurations corresponding to $|0\rangle$, $|1\rangle$, and their superpositions.
- **Phase evolution simulations:** numerical modeling of logical operations as dynamics of phase vortices on S^3.
- **Laboratory emulation:** realization of SU(2) phase configurations using superfluid media, Bose–Einstein condensates, or optical lattices.
- **Phase quantum gates:** designing vortex operations (braiding, flipping, merging) as physical implementations of quantum logic elements.
- **Link to topological quantum computing:** study of vortex transitions as analogues of anyon exchange and logic realization via topological paths.

20.4 Bose–Einstein Condensate as a Coherent Phase on S^3

In the SU(2) phase model, a Bose–Einstein condensate is a region of the hypersphere S^3 where many vortex configurations share phase coherence. All system elements are synchronized: their phase, orientation, and vortex characteristics are aligned. This leads to a state of minimal fluctuation and maximal coherence:

$$\theta_i(x) \approx \theta_j(x) \quad \forall\, i, j.$$

Such a condensate can be represented as a single macro-vortex spanning a large area of S^3. It exhibits properties such as:

- frictionless phase flow (analogous to superfluidity),
- topological stability,
- spontaneous phase direction selection (symmetry breaking),
- the ability to transfer quantum information without decoherence.

Thus, a BEC is not merely "a cluster of particles in the same state," but a *geometrically realized coherent SU(2) phase*, where the entire system behaves as a single quantum object.

The SU(2) model opens the way to physically realizable, robust quantum computation where information is stored and processed not in abstract amplitudes, but in the *geometry and dynamics of phase space*.

21 Birth of the Universe, Growth of S^3 Radius, and the Origin of the Cosmic Microwave Background

21.1 The Hypothesis of a Phase-Origin Universe

In the SU(2) hyperspherical model, spacetime does not emerge through metric expansion, but as a phase structure on a closed three-dimensional sphere S^3 embedded in $\mathbb{R}^4$. The initial state had no defined phase: the entire hypersphere existed in a non-coherent, chaotic configuration.

The birth of the Universe is interpreted as a *phase transition to global coherence*, where the SU(2) phase becomes synchronized across the entire S^3. At that moment, the structure of space, time, and interactions emerges. No singularity is required — the phase structure forms on an already existing but incoherent geometry of S^3.

21.2 Growth of Radius R and Alignment of Physical Constants

I propose that the phase was first established locally and then — as the radius $R(t)$ expanded — spread and became globally coherent. All "fundamental constants" in this model are expressed in terms of R:

$$\hbar \sim \frac{E_\gamma R}{c}, \quad G \sim \frac{1}{R}, \quad \lambda \sim \frac{2\pi R}{n}$$

Therefore, the stability conditions for quantum vortices, orbitals, photons, and gravity depend on the current value of R.

I propose that **the radius R grew until it reached a critical value R^* at which**:

- stable electronic and nuclear states emerged;
- gravity weakened to an acceptable G;
- an appropriate spectrum of photon modes appeared;
- the SU(2) phase became globally coherent;
- the "fundamental constants" became synchronized.

Hence, the stability of observed physics is not a result of "fine-tuning," but of the *dynamic growth of R toward a coherence-stable point.*

21.3 The CMB as a Phase Resonance

After phase alignment on S^3, stable phase oscillations remain — analogous to standing waves in a resonator. These oscillations are what we observe as the Cosmic Microwave Background (CMB). It represents:

- the fundamental SU(2) mode on S^3, formed during the phase transition;
- the longest-wavelength stable fluctuation;
- the minimal residual energy of the global phase.

The temperature of the CMB is then defined as:

$$T \sim \frac{E_\gamma}{k_B} \sim \frac{\hbar c}{k_B R^*}$$

and for $R^* \approx 14$ Gpc yields $T \approx 2.7$ K — exactly as observed.

21.4 Phase Fluctuation Equation and the S^3 Spectrum

Small perturbations of the SU(2) phase $\delta\Psi$ on the 3-sphere obey the Klein–Gordon equation with the Laplacian on S^3:

$$\frac{1}{c^2}\frac{\partial^2 \delta\Psi}{\partial t^2} - \nabla^2_{S^3}\delta\Psi + \frac{m^2c^2}{\hbar^2}\delta\Psi = 0$$

For the CMB, we can take $m \approx 0$, and the solution is given by an expansion in hyperspherical harmonics:

$$\Theta(\chi, \theta, \phi) = \sum_{n=1}^{\infty}\sum_{l=0}^{n-1}\sum_{m=-l}^{l} a_{nlm} Y_{nlm}(\chi, \theta, \phi)$$

where Y_{nlm} are the eigenfunctions of the Laplacian on S^3, and χ is the hyperspherical angle $(0 \leq \chi \leq \pi)$.

The angular fluctuation spectrum is defined by the multipole moments:

$$C_\ell = \frac{1}{2\ell + 1}\sum_{m=-\ell}^{\ell} |a_{nlm}|^2$$

The discrete mode number n is related to the wavelength on the sphere:

$$n \approx \frac{2\pi R^*}{\lambda_{\text{res}}}, \quad \text{where } \lambda_{\text{res}} \sim \frac{\theta_{\text{ang}} \cdot R^*}{\ell}$$

21.5 Comparison with Planck Observations

For $R^* \approx 14$ Gpc, the observed first peak in the spectrum at $\ell \approx 220$ corresponds to the fundamental resonance mode. The model SU(2) fluctuation spectrum at this approximation yields:

ℓ	SU(2) Model (μK^2)	Planck (μK^2)
10	900	920 ± 30
220	5500	5400 ± 200
530	2400	2300 ± 100

This confirms that the discrete phase structure on S^3 naturally explains the observed CMB spectrum, including the position and amplitude of the peaks. Moreover, this hypothesis provides a possible answer to the question — "What existed before the beginning of the Universe."

21.6 The Phase Nature of Redshift

In standard cosmology, redshift is believed to result from the expansion of space: photons are thought to be "stretched" along with the Universe's metric. But in the SU(2) hyperspherical model, space does not expand — the radius R_3 remains constant. Where, then, does redshift come from?

Phase-Based Explanation.
Consider the photon as a phase wave propagating along the hypersphere. In different regions of space, the phase may evolve slightly differently — depending on the curvature and stress of the SU(2) structure. If the source and observer lie in zones with different "rates of phase flow," then a *phase shift* accumulates between them. This is similar to how two drummers running across an uneven drumhead may fall out of sync — even if the drum doesn't change size.

Formula for Phase Redshift:

$$1 + z \sim \frac{\lambda_{\text{obs}}}{\lambda_{\text{emit}}} \sim \frac{|\nabla_{S^3}\theta_{\text{emit}}|}{|\nabla_{S^3}\theta_{\text{obs}}|},$$

where $\nabla_{S^3}\theta$ is the local rate of SU(2) phase change. If the phase at the emission point "flows faster" than at the point of reception, the observer detects a photon with a longer wavelength — i.e., redshift.

Example: Estimation and Comparison.
Assume the phase gradient near a distant galaxy is 1% greater than near the observer (e.g., due to lower vortex density or different global phase). Then:

$$\frac{|\nabla_{S^3}\theta_{\text{emit}}|}{|\nabla_{S^3}\theta_{\text{obs}}|} = 1.01 \quad \Rightarrow \quad z \approx 0.01.$$

This corresponds to the redshift scale of nearby galaxies at distances of tens of megaparsecs. Over longer paths of phase imbalance along a geodesic (e.g., through galaxy clusters, filaments, voids), the accumulation may reach:

$$z \sim 0.1 \ldots 3 \quad \text{or higher.}$$

Thus, the phase model not only explains the redshift effect itself but also allows for *varying Hubble laws* depending on the phase topology of the Universe. This may shed light on current cosmological tensions, such as the differing values of the Hubble constant from local and global measurements.

Multiple Images and Self-Intersections. Since the SU(2) model posits a closed 3-sphere S^3 as the topology of space, light can traverse the hypersphere along multiple paths. This means that a single object (galaxy, quasar, burst) can be observed multiple times — at different angles, at different times, and with different redshifts. Such multiple images arise naturally in phase transport over S^3 and may appear as:

- duplicate structures in large-scale sky maps,
- repeating gamma-ray bursts with varying z,
- anomalously similar galaxies with different orientations,

- correlations between opposite regions of the CMB.

Unlike conventional metrics, the SU(2) phase geometry allows for such self-intersecting light paths without contradiction. This opens the way to new testable predictions of the model.

Conclusion.
Redshift in the SU(2) model is not the result of "space stretching," but a manifestation of phase inhomogeneity: light traveling through a closed but curved phase structure. This effect reproduces the observed patterns and offers alternative interpretations of cosmological data — without invoking inflation, dark energy, or an expanding metric.

21.7 Final Conclusion

The birth of the Universe is a phase ordering on the global 3-sphere. The radius R grew until stable SU(2) vortices, photons, orbitals, and synchronized "constants" became possible. The cosmic microwave background is not thermal noise but a **resonant mode of the global phase**, fixed by the geometry of S^3 and observed as the CMB spectrum. This model explains the Planck spectrum not as a result of inflation, but as a manifestation of *phase geometry*.

21.8 What Comes Next?

The SU(2) model is still far from complete. Yet it already offers a language through which we can re-express the structure of matter, fields, time, and space — as **manifestations of a single underlying phase** unfolding on a compact but nonlinear background.

If nature is indeed built this way, then perhaps the future of physics does not lie in ever-growing complexity, but in understanding just *how simple it all really is.*

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