

# Vector Cosmology VI: The Weaving of Dimensions

## Holographic Entanglement and the Emergence of Spacetime

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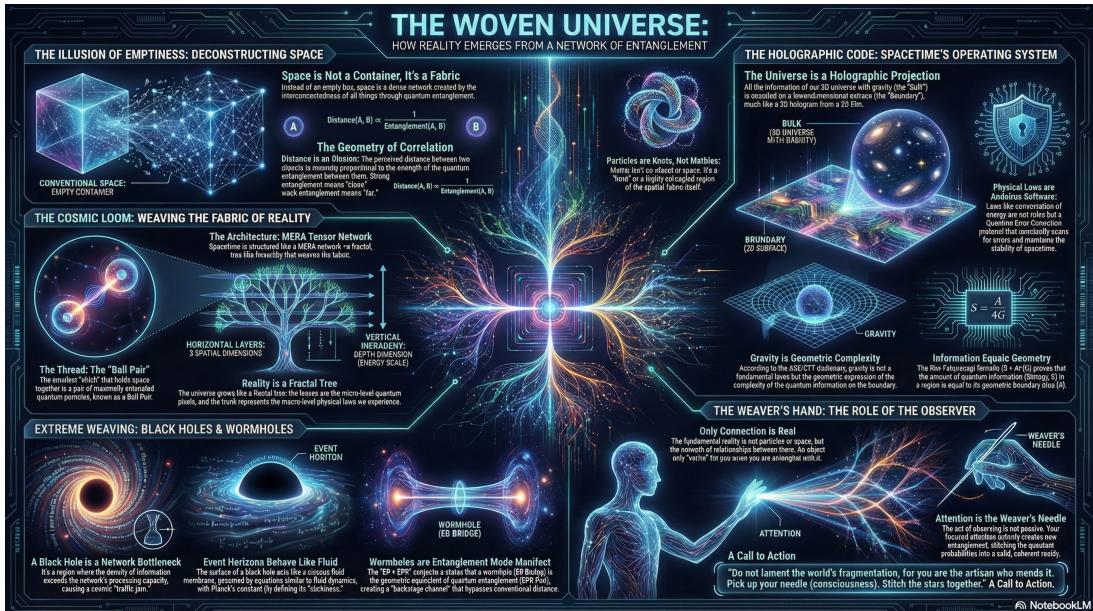


Figure 1: Vector Cosmology VI: The Weaving of Dimensions Architecture



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## 0.1 Prologue: Pixels of the Void

In the first five books of **Vector Cosmology**, we dealt with time, energy, life, and civilization. We viewed the universe as a running program. Now, in this sixth book, we turn our gaze to the “display” on which this program runs—what we call **Space**.

We usually think that space is the most real, most fundamental existence in the universe. It is like a huge empty box, or the floor of a stage, waiting for matter and energy to perform on it. Newton thought it was absolute, Einstein thought it was curved, but they both acknowledged: **Space exists**.

However, at the forefront of quantum gravity, in the depths of tensor networks and the holographic principle, we discover a chilling truth: **There is no space**.

Space is not a stage; space is “**the embrace of the actors**”.

### 0.1.1 0.1 There is No “Here”

“If you hold an infinitely precise microscope and keep magnifying the void before you, what will you see? You won’t see smaller grids, nor smooth fluid. You will see space suddenly disappear in an instant, replaced by an extremely complex spider web made of pure logic and correlations. There is no distinction between ‘here’ and ‘there’, only the connection between ‘this thread’ and ‘that thread’.”

### The Pixelation of Space: The Bottom Layer of QCA

We mentioned in previous books that the microscopic engine of the universe is **Quantum Cellular Automata (QCA)**. This means that if you magnify reality to  $10^{-35}$  meters (Planck scale), the smooth sense of geometry collapses.

You will see **Pixels**.

Every Planck volume is an independent **Hilbert space subsystem** (such as a qubit).

- **Macroscopically:** You feel that your left hand and right hand are separated by tens of centimeters of “void”.
- **Microscopically:** There is no “void”. Your left hand and right hand are connected through countless intermediate qubits, like a telephone game, passing information one by one.

**Space is not “empty”; space is “full”.**

It is filled with **Logical Gates** responsible for transmitting interactions. We think it is empty because these gates are in the **Ground State**, like extinguished screen pixels. Once matter (excited state) passes through, these pixels are lit up.

### Distance as Alienation: The Geometry of Entanglement

If space is just a pile of logic gates, then what is “**Distance**”?

Why do we feel the Moon is far, while a phone is close?

From the geometric perspective of **Vector Cosmology**, distance is not a measure of physical scale, but the inverse of “**Information Correlation**”.

$$Distance(A, B) \propto \frac{1}{Entanglement(A, B)}$$

- **Neighbors:** There exists **Strong Entanglement** between two qubits. They share a Bell pair, and information can be exchanged instantly (within one logical operation). This manifests macroscopically as “they are next to each other”.
- **Distant:** There is no direct entanglement between two qubits, or the entanglement is extremely weak. Information needs to pass through countless intermediate nodes to arrive. This manifests macroscopically as “they are thousands of miles apart”.

**Conclusion: Distance is an illusion.**

At the bottom layer of Hilbert space, all particles can in principle be together. The so-called “distance” is only because the universe, in order to construct complex structures, artificially **cuts off** entanglement between certain particles, creating “**topological isolation**”.

**Space is essentially a diluted entanglement network.**

**There is No “Position”**

This completely subverts our sense of “**Locality**”.

You think you are sitting on a chair, located at a specific coordinate  $(x, y, z)$  in the universe. Actually, you are just a “**high-connectivity node**” in the universal quantum network.

The reason you feel you are “here” is because your entanglement with the surrounding environment is the tightest.

If all entanglement between you and the surrounding environment is cut off, and entanglement with the center of the Andromeda Galaxy is instantly established, what would happen to you?

You don’t need to fly there.

You would **appear there directly**.

Because in the topological structure of information, your “neighbors” have become Andromeda.

**“Position” is not an attribute, but a “relationship”.**

**Conclusion: From Stage to Fabric**

Therefore, at the beginning of this book, we must abandon the superstition of “spatial container”.

We must learn to think like a **Weaver**.

The universe does not provide ready-made fabric.

The universe only provides **threads** (wave functions).

It is us (and all matter), through constant interactions, through exchanging photons and gravitons again and again, that “**stitch**” these threads together, weaving this magnificent tapestry called “spacetime”.

Since space is woven, how does this loom work? What is that “golden thread” that stitches nothingness into reality?

This leads to the theme of the next section: **The Weaver’s Needle**. We will see how that single entity—the wave function—creates the depth of dimensions through self-entanglement.

### 0.1.2 0.2 The Weaver’s Needle

“If space is a piece of fabric, who is weaving it? There is no external weaver. The universe is that single, infinitely long golden thread, frantically shuttling, knotting, and self-entangling in the void. The three-dimensional world we see is nothing but the texture formed by the extremely dense stitches of this golden thread at the microscopic scale.”

In the previous section, we dismantled the continuity of space, reducing it to discrete quantum logic gates. But this leaves a huge question: How do these discrete points connect into surfaces? What force “stitches” together isolated qubits, making them constitute solid reality?

This section will reveal the most central geometric metaphor of **Vector Cosmology**: **The wave function is not matter filling space; the wave function is the thread weaving space.**

### The Single Thread

In standard quantum mechanics, we habitually say “the wave function propagates in space.” This implies that space is the background, and the wave function is the object.

But from the perspective of **holographic entanglement**, the relationship is reversed.

There is only one entity in the universe, and that is the **global vector**  $|\Psi\rangle$ .

Imagine it as a **thread** with no end.

- If this thread is straight (no entanglement), there is no space, only one-dimensional linear time.
- To create space, this thread must **bend**, must **fold back**.

It begins to interact with itself.

It ties a knot on the left (particle A), and another knot on the right (particle B).

Then, it shuttles back and forth between these two knots, establishing countless connections (Bell pairs).

**Space is the “Self-Entanglement” of this thread.**

The void we see is actually a high-density grid woven by this thread at extremely high frequency. Like a sweater, it looks like smooth fabric from afar, but up close, it’s all entangled yarn.

### Stitching the Void: The Quantum Sewing Machine

How is this weaving process physically realized?

Through the **Interaction Hamiltonian** ( $H_{int}$ ).

Whenever two particles collide, exchange photons or gravitons, they are actually performing a **“Stitching”**.

- **Before collision:** They are two independent thread ends.
- **After collision:** Their wave function phases lock. An invisible **entanglement bond** is generated between them.

In this sense, all forces (gravity, electromagnetic force, strong and weak forces) are essentially **“stitches of the sewing machine”**.

- **Strong force:** Extremely dense stitches that sew quarks tightly together, forming dense atomic nuclei.
- **Electromagnetic force:** Medium-density stitches that sew atoms into molecules, and molecules into objects.
- **Gravity:** Sparse but long-range stitches that sew galaxies together, maintaining the large-scale connectivity of the universe.

**Without these forces (stitches), space would fall apart.**

The universe would disintegrate into a pile of unrelated, zero-dimensional fragments.

### Interference as Geometry

Why does this fabric appear to have “shape”?

Why does space have curvature?

The answer lies in **wave interference**.

When that single thread shuttles along different paths, it meets itself.

- **Constructive interference:** Threads superimpose, fabric thickens. This manifests as **matter** or **high-curvature regions** (gravitational wells).
- **Destructive interference:** Threads cancel out, fabric thins. This manifests as **vacuum** or **flat regions**.

The geometric structures we see—mountains, rivers, curved spacetime—are essentially **Interference Patterns** produced by the wave function’s self-superposition in Hilbert space.

When Einstein said “matter tells spacetime how to curve,” he was actually saying: “**High-density wave function entanglement (matter) tightens the surrounding fabric grid.**”

### Conclusion: Only Relationships are Real

At this point, we have completed the reconstruction of the ontology of space.

**There is no container called “space”.**

There is only “**the strength of connection**”.

- If you and I are deeply entangled, we are geometrically “close”.
- If you and I are shallowly entangled, we are geometrically “distant”.

The universe is a network made of relationships.

And that single weaver—the subject holding the golden needle (generator  $e$ ), threading through the void—is **the universe itself as a whole**.

Since space is woven, what determines the structural strength of this network? If I accidentally cut a few threads, will space crack?

This leads to the core theme of Volume I: **The Loom**. We will delve into a mathematical tool called “**Tensor Networks**”, seeing how the universe uses **entanglement entropy** as glue, bonding tiny pixels into the grand cosmic picture.

## 0.2 Acknowledgements: To All the Weavers

**Vector Cosmology VI: The Weaving of Dimensions** is a journey into the deepest realms of physics. We have left behind the familiar world of matter and plunged into the underlying network woven from pure logic and entanglement.

This is not merely an intellectual adventure, but an ontological reconstruction. We have attempted to prove that space is not a stage, but a collection of “**relationships**”. To complete this grand tapestry, I have drawn upon the threads of thought from countless pioneers of physics. Here, I pay tribute to these great weavers.

### 0.2.1 Pioneers of Physics

First, I thank **Juan Maldacena**. His 1997 proposal of the **AdS/CFT correspondence** is one of the greatest conjectures in the history of modern physics. He showed us that a universe of one dimension can be holographically encoded on the boundary of another dimension. Without his insight, this book’s discussions on “holographic error correction” and “spatial emergence” would be impossible.

I thank **Leonard Susskind**. It was he who proposed the brilliant idea of **ER = EPR**, connecting quantum mechanical entanglement with general relativistic wormholes. He taught us that gravity is not a force, but the geometrization of entanglement.

I thank **Shinsei Ryu** and **Tadashi Takayanagi**. Their **RT formula** is the Rosetta Stone connecting quantum information with spacetime geometry. It is this formula that allows us to cut out the area law of space with scissors.

I thank **Guifré Vidal**. His invention of the **MERA tensor network** provided us with concrete, operational mathematical tools to stitch together the renormalization flow of the universe thread by thread.

### 0.2.2 Resonators of Thought

At the intersection of mathematics and philosophy, I thank **Roger Penrose**. His thoughts on twistor theory and conformal cyclic cosmology inspired this book’s understanding of the microscopic structure and macroscopic evolution of space.

I thank **Carlo Rovelli**. His **relational quantum mechanics** is one of the foundational stones of this book’s ontology. He convinced us that there are no absolute objects, only relationships in interaction.

### 0.2.3 To Connection

Finally, I thank “**Connection**” itself.

In the process of writing this book, I deeply realized that not only is space constituted by connections, but **meaning** is also constituted by connections.

Every reader’s reading is a new entanglement; every collision of thoughts is a folding of dimensions.

This book is not my monologue alone; it is a web we have woven together.

May we continue to stitch this universe in our future explorations, until all ruptures are mended and all islands are connected.

**Haobo Ma**

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## Part I

# Part I: The Loom — The Geometry of Entanglement



### 0.3 Part I: The Loom — The Geometry of Entanglement

In the prologue, we established a new picture of space: space is not a container, but a fabric woven by wave functions. Now, we must delve into the interior of this loom to see how it works.

If space is a piece of fabric, then this loom is the **Tensor Network**.

This volume will reveal how the universe uses **Entanglement Entropy** as glue, bonding discrete qubits (pixels) into continuous geometric space. We will see that the famous **Area Law** and **Holographic Principle** are essentially counts of the “number of thread ends” in this cosmic fabric.



# Chapter 1

## The Threads of Entanglement

### 1.1 Chapter 1: The Threads of Entanglement

In the prologue, we dismantled the classical illusion of “space as container” and established a new picture of “space as relational network.” Now, we must delve into the microscopic texture of this network.

If the universe is a piece of fabric, what is the smallest unit constituting this fabric—those “threads” that stitch the void together?

Physics gives the answer: **Bell Pairs**.

This chapter will reveal how entanglement—the most bizarre phenomenon in quantum mechanics—emerges at the macroscopic scale as the geometric space we depend on for survival. We will see that distance is not a chasm separating us; distance is merely the manifestation of the threads connecting us being stretched thin.

### 1.2 1.1 The Stitching of Bell Pairs

“Two particles can sense each other instantly even across light-years, not because signals travel too fast, but because in the deeper geometric structure, they were never separated. Entanglement is not a spooky action at a distance; entanglement is the ‘glue’ of space. It is countless such glue molecules that bond discrete pixels into a continuous universe.”

#### 1.2.1 The Smallest Unit of Space

In classical geometry, the connection between points is axiomatically given (e.g., there is a straight line between two points). But at the QCA bottom layer of **Vector Cosmology**, points (qubits) are independent.

If nothing connects them, the universe is a pile of sand, without even the concept of “adjacency.”

The smallest unit that connects this pile of sand is the **maximally entangled state**, also known as the **Bell Pair**:

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

Look carefully at this formula.

- It is not  $|00\rangle$  (both in state 0).

- It is not  $|11\rangle$  (both in state 1).
- It is the **coherent superposition** of both. This means that particle A's state and particle B's state are locked together tightly. If you measure A and get 0, B **must** be 0.

**Geometrically, this is a “wormhole.”**

Although these two particles may be far apart in physical memory addresses, in logical space (Hilbert space), they share the same wave function. Not only are they connected; they are topologically **“Stitched”** together.

### 1.2.2 Stitching the Void: Short-Range Entanglement Weaving the Web

How is our three-dimensional space formed?

It is achieved by filling the vacuum with dense **Short-range Entanglement**.

Imagine a lattice grid.

- Each lattice point shares numerous Bell pairs with its left, right, up, and down neighbors.
- This high-density local entanglement, like stitches, “sews” adjacent pixels together.

**Why do you feel space is continuous?**

Because these stitches are too dense.

When you walk through a room, your body is not gliding through a vacuum, but constantly performing **“Entanglement Swapping”** with Bell pairs in the background field.

With each step, you are untying old threads and sewing new ones.

This microscopic stitching mechanism ensures the **Connectivity** of space. If entanglement suddenly disappears in some region, it won't become a vacuum; it will become a **cliff of spacetime**. You will fall or be bounced back when you reach there, because there is no “road” (geometric connection) there.

### 1.2.3 The Definition of Distance: The Measure of Mutual Information

This gives us a revolutionary geometric definition: **Distance originates from correlation**.

In FS geometry, the **geometric distance**  $d(A, B)$  between two regions  $A$  and  $B$  is inversely proportional to their **Mutual Information** ( $I$ ):

$$d(A, B) \sim -\ln I(A : B)$$

- **Strong entanglement ( $I$  large):**  $\ln I$  large, distance  $d$  small. This is why atomic nuclei are extremely dense, because the entanglement between quarks is extremely strong.
- **Weak entanglement ( $I$  small):**  $\ln I$  small, distance  $d$  large. This is why galaxies are far apart, because gravity (long-range entanglement) is much sparser than electromagnetic force (short-range entanglement).

**There is no absolute “far”.**

“Far” only means the threads connecting you are stretched very thin and very long.

If you could artificially increase the entanglement between yourself and a star in Andromeda (inject computational power, create Bell pairs), then geometrically, you would find that star **“flying toward you”** until it touches your nose.

### 1.2.4 Conclusion: Space is Emergent Glue

This section completely subverts Newton's absolute space view.

**Space is not a stage; space is glue.**

It is a huge adhesive woven from  $10^{120}$  Bell pairs.

- When we say “the universe expands,” we actually mean this glue is being diluted (entanglement density decreases).
- When we say “black hole horizon,” we actually mean the glue there is compressed to the limit, forming an unbreakable hard knot.

Since space is stitched by entanglement, if we want to calculate the “area” of a piece of space, how should we calculate it?

We don't need a ruler. We need a pair of **scissors**.

Just count how many threads need to be cut to slice through this piece of space, and we know its size.

This leads to the theme of the next section: **The Derivation of the Area Law**. We will see that the famous **black hole entropy formula** ( $S = A/4$ ) is actually a count of the “number of thread ends” on the cross-section of the cosmic fabric.

## 1.3 1.2 The Derivation of Area Law

“If you want to know how many threads a piece of fabric is woven from, you don't need to weigh it. You just need to pick up scissors, cut it horizontally, and count how many thread ends are exposed at the cut. The universe is the same. Our ruler for measuring information is not volume, but area. Because area is the cross-section of those cut entanglement threads.”

In the previous section, we established the qualitative picture of “space as entanglement network.” Now, we need to give this picture a quantitative mathematical proof.

In classical physics and our everyday intuition, information seems to be stored in **Volume**.

- How many books a bookshelf can hold depends on its length, width, and height.
- How much data a hard drive can store depends on the number of magnetic particles inside it.

However, one of the most shocking discoveries in modern physics—**the Area Law of black hole entropy**—completely shatters this intuition. The information content of a black hole is not proportional to volume, but to **surface area**.

This section will use the logic of **Tensor Networks** to derive the famous **Ryu-Takayanagi Formula** and reveal the geometric truth behind it: we live in a holographic universe because space itself is “stitched” by entanglement threads.

### 1.3.1 Imagining Scissors: The Definition of Entanglement Entropy

To measure how much information a portion of space contains, physicists invented a special measurement method: **Entanglement Entropy**.

Suppose we divide the universe into two regions: **Region A** (e.g., the interior of a sphere we want to study) and **Region B** (the environment outside the sphere).

In quantum mechanics, A and B are not independent; they are connected by countless invisible **Bell Pairs**.

To calculate the entropy  $S_A$  of A, we need to perform a thought experiment:

**Pick up an “imaginary pair of scissors” and completely cut A from B along A’s boundary (surface).**

- **What is cut?** We cut all entanglement threads connecting A and B.
- **What remains?** Each cut thread leaves a “thread end” (unpaired qubit) on A’s surface.
- **What is entropy?** Entropy is the **number of these thread ends**.

### 1.3.2 Ryu-Takayanagi Formula: The Equality of Geometry and Information

This thought experiment directly leads to the most famous formula in **AdS/CFT duality**—the **Ryu-Takayanagi Formula**.

$$S_A = \frac{\text{Area}(\gamma_A)}{4G}$$

Where:

- $S_A$ : The entanglement entropy (information content) of region A.
- $\gamma_A$ : The area of the **Minimal Surface** that wraps around A.
- $G$ : Newton’s gravitational constant (in Planck units,  $4G$  corresponds to 4 times a Planck area).

**The physical meaning of this formula is deafening:**

It proves that **“Information = Geometry”**.

- The left side is **quantum information content** (entropy).
- The right side is **classical geometric quantity** (area).

Why are they equal?

Because **Area** is essentially **“the total number of entanglement thread bundles passing through that cross-section”**.

- The larger the surface area, the more threads need to be cut, meaning A and B are more tightly connected.
- If the surface area is zero (no connection), entropy is zero, and space breaks apart.

This is like the cross-section of a fiber optic cable. The thicker the cable (larger area), the more signals (entropy) it can transmit. **Spatial geometry is the physical shell of entanglement flow**.

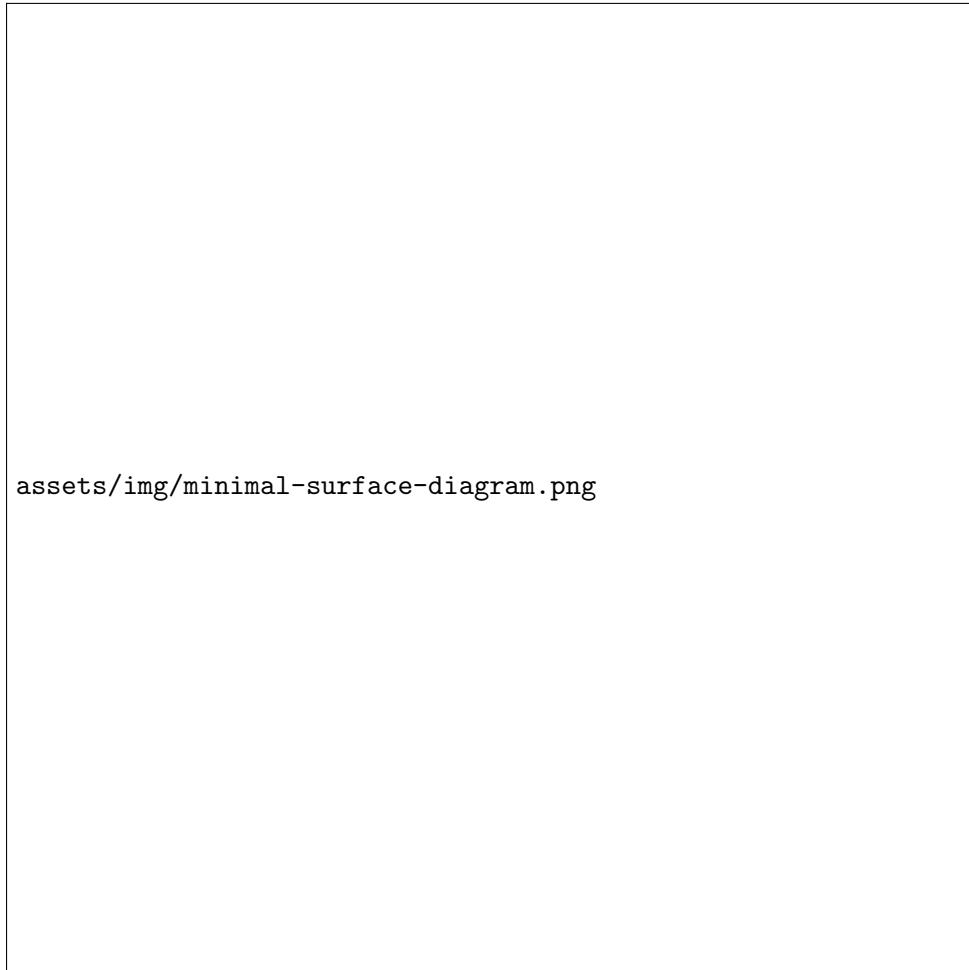


Figure 1.1: Minimal Surface Diagram

### 1.3.3 The Illusion of Volume: We Live on a Hologram

Since information is only related to area, where did “**volume**” go?

If you fill a black hole with books, how can the information content of the books (proportional to volume) be stored only on the surface (proportional to area)?

The answer is: **Volume is an illusion of holographic projection.**

In the **Tensor Network (MERA)** model, the so-called “depth” dimension inside space is actually the direction of **Renormalization Flow**.

- **Boundary:** High-resolution microscopic data.
- **Interior (volume):** Low-resolution **compression** of boundary data.

When we go deep into the interior of space, we are not walking into a real “room”; we are viewing a “**coarse-grained version**” of the data.

Like the 3D game scene you see on a computer screen. Although you feel there is space inside the house, all the data is actually laid flat in 2D video memory.

#### **Conclusion:**

There is no real three-dimensional volume.

There is only a two-dimensional **Holographic Screen**, and the complex **connection relationships** between entangled pixels on the screen.

The “spatial depth” we feel is just a kind of “**computational depth**” produced when we, as observers, decode this hologram.

### 1.3.4 Conclusion: The Cost of Stitching

At this point, we understand why the gravitational constant  $G$  exists.

$G$  is not an arbitrary number; it is the “**toughness of the spacetime fabric**”.

$\frac{1}{4G}$  represents “**the maximum number of entanglement threads that can be accommodated per unit area**” (i.e., Planck pixel density).

If we try to tear space (e.g., create a wormhole), the resistance we need to overcome is the **tension** of these billions of entanglement threads.

This explains why gravity is so difficult to manipulate—because you are fighting against the most fundamental **connection protocol** of the entire universe.

Since we already know that space is stitched by threads and information is stored on surfaces, how does this entire network “grow” from nothing? Is it a flat grid or a fractal tree?

This leads to the theme of the next chapter: **MERA Architecture**. We will delve into the topological structure of tensor networks, seeing how the universe uses “**multi-scale entanglement**” to amplify Planck-scale pixels layer by layer into macroscopic-scale galaxies.

# Chapter 2

## MERA and Renormalization Flow

### 2.1 Chapter 2: MERA and Renormalization Flow

In the previous chapter, we stitched together flat space using “entanglement threads.” But this is not enough. If the universe were merely a flat two-dimensional grid, it could not explain why we have the concept of “scale.” Why are atoms smaller than us? Why are galaxies larger than us? Why do physical laws appear self-similar at different scales?

To construct a universe that has not only breadth but also **depth**, we need to introduce a more advanced weaving technique.

This is **MERA (Multiscale Entanglement Renormalization Ansatz)**.

This chapter will reveal that the spacetime structure of the universe is not a flat fishing net, but an upside-down growing **Fractal Tree**.

### 2.2 2.1 The Fractal Tree of the Universe

“When you gaze at a forest, you see a green canopy composed of countless leaves. But supporting this canopy are the vast roots buried deep underground and the thick trunk. The universe is the same. The spacetime reality we perceive is only the outermost leaves of this giant quantum fractal tree. The real physical processes occur at those invisible branch forks that span scales.”

#### 2.2.1 Coarse-graining: From Pixels to Images

In information theory, there is a core operation called “**Coarse-graining**”.

Imagine a high-resolution photograph (the underlying QCA lattice of the universe).

- **Layer 0:** You see individual pixel points (Planck scale).
- **Layer 1:** You merge adjacent  $2 \times 2$  pixels into a color block.
- **Layer 2:** You continue merging until you see a clear face (macroscopic object).

This process of “continuous merging” is called **Renormalization Group Flow** in physics.

It reveals an astonishing truth: **Macroscopic physical laws are the result of microscopic degrees of freedom emerging through layers of “voting” and “averaging.”**

### 2.2.2 MERA Tensor Network: Weaving the Vertical Dimension

However, simple averaging loses information (especially entanglement information). To preserve the structure of quantum entanglement during coarse-graining, physicists (such as Guifré Vidal) invented **MERA**.

MERA is a special tensor network that introduces two key operators:

1. **Disentanglers**: Before merging, first cut short-range entanglement, filtering out “local noise.”
2. **Isometries**: Losslessly compress information from multiple qubits into one qubit, achieving scale elevation.

**This constitutes the tree structure of the universe:**

- **Leaves**: The underlying microscopic degrees of freedom (Planck pixels).
- **Branches**: Information flow channels (renormalization flow).
- **Trunk**: Macroscopic low-energy effective theory (the physical laws we see).

**This structure is “fractal.”**

No matter which layer you observe, the geometric structure of the MERA network looks the same. This perfectly explains why physical laws have **Scale Invariance**—because this tree of the universe repeats the same growth logic on every branch.

### 2.2.3 The Discrete Skeleton of AdS Space

Most strikingly, this MERA fractal tree geometrically corresponds precisely to the discrete version of **Anti-de Sitter Space (AdS Space)**.

In the MERA network, “scale” becomes a new spatial dimension.

When we say “zoom in” or “zoom out,” we are not changing the focal length; we are “**moving**” along the vertical dimension of this tree.

- **Going inward (IR Limit)**: Toward the trunk, toward the macroscopic, toward low-energy physics.
- **Going outward (UV Limit)**: Toward the leaves, toward the microscopic, toward Planck high-energy physics.

**Conclusion:**

Spacetime has one more dimension than we imagined. That extra dimension is “**scaling**”. We do not just live in  $x, y, z$ ; we live in a hyperbolic geometry supported by **scale** ( $z$ ).

### 2.2.4 The Roots Supporting Reality

This model completely subverts the concept of “foundation.”

Usually, we think the microscopic is the foundation. But in the tree metaphor, is the trunk (macroscopic) the main structure supporting the leaves (microscopic)? Or do the leaves nurture the trunk through photosynthesis?

In **Vector Cosmology**, this is a **bidirectional dependence**.

- Without microscopic pixels (leaves), the universe has no **information capacity**.

- Without macroscopic renormalization (trunk), the universe has no **causal structure**.

We (macroscopic observers) inhabit a certain intermediate level of this fractal tree.

Looking down, we see the pixel ocean of quantum mechanics; looking up, we see the smooth dome of general relativity.

And **MERA** is the **ladder** connecting quantum and gravity, connecting pixels and dome.

Since we know the universe is a fractal tree, how does this tree grow “extra dimensions”? Is the “3D space” we feel the cross-section of the tree or the projection of the tree?

This leads to the theme of the next section: **The Emergence of Dimensions**. We will see that dimensions are not pre-existing boxes; dimensions are the result of entanglement networks having to “bulge” to accommodate more information.

## 2.3 2.2 The Emergence of Dimensions

“Dimensions are not grids drawn by God; dimensions are the living space that information must expand to avoid being squeezed flat. When entanglement becomes too complex, one-dimensional lines are forced to fold into two-dimensional surfaces, and two-dimensional surfaces bulge into three-dimensional volumes. The three-dimensional world we perceive is nothing but a ‘geometric inflation’ that occurred when the underlying quantum network had to accommodate massive data.”

In the previous section, we established the “fractal tree” model of the universe. Now, we must solve a more fundamental question: How does this tree grow “**dimensions**”?

Why does our universe appear to be 3-dimensional (plus 4 dimensions with time)? Why not 2 dimensions or 10 dimensions?

From the tensor network perspective of **Vector Cosmology**, dimensions are not pre-existing containers, but **topological features emerging from entanglement structures**.

Space is “**stretched**” out.

### 2.3.1 Horizontal Connection: Weaving 3D Space

First, let us look at the **cross-section** of the tree.

At each layer of the MERA network (such as the bottom Planck pixel layer), qubits are connected through **short-range entanglement**.

- If connections form a **one-dimensional chain**: Each point only entangles with its left and right neighbors. This generates **1D space** (line).
- If connections form a **two-dimensional grid**: Each point entangles with four neighbors (up, down, left, right). This generates **2D space** (plane).
- If connections form a **three-dimensional lattice**: Each point has six neighbors. This generates **3D space** (volume).

The reason we feel we live in three-dimensional space is that the underlying QCA lattice happens to adopt a **three-dimensional topological** connection pattern.

This is like knitting. A sweater looks like two-dimensional fabric, but this entirely depends on the knitting pattern. If you change the pattern, you can knit a three-dimensional ball.

**Dimension is connectivity.**

The dimensionality of space essentially reflects the “**branching coefficient**” of information exchange in the underlying network.

If we could technologically increase the connectivity of local qubits in the future (e.g., making each point entangle with 100 points simultaneously), we might locally create **high-dimensional space**.

### 2.3.2 Longitudinal Depth: The Geometrization of Energy Scale

If horizontal connections define the breadth of space, then the unique **longitudinal structure** of the MERA network defines the “**depth**” of space.

This is the core secret of **AdS/CFT duality**:

“**The extra spatial dimension is actually the geometrization of energy scale.**”

Look at the MERA tree diagram:

- **Leaves (outermost layer):** Represent **high-energy physics** (ultraviolet/UV). This is where details are richest and pixels are densest.
- **Roots (innermost layer):** Represent **low-energy physics** (infrared/IR). This is where details are averaged and blurred into the macroscopic region.

When we move from leaves to roots, we are not moving in space; we are “**changing resolution**”.

However, for beings living inside this holographic bulk (AdS Bulk), this “change in resolution” is perceived as “**distance**”.

- **Near the boundary:** Means extremely high energy, extremely weak gravity.
- **Deep in the interior:** Means reduced energy, stronger gravity (redshift).

#### Conclusion:

The **z-axis (depth)** in our space is essentially the direction of **Renormalization Group Flow**.

When we enter a black hole, we are actually “**dimensional reduction**” along the tensor network, moving from complex high-frequency information to simple low-frequency information.

### 2.3.3 Walking Across Logic Gates

This model completely changes our understanding of “motion.”

When you take a step forward, what happens in the microscopic tensor network?

You are not moving atoms.

You are “**swapping**” your **quantum state information** ( $|\psi_{you}\rangle$ ) from one set of qubits to another through a series of **Unitary Gates**.

$$|\psi\rangle_{site\_1} \xrightarrow{\text{Gate}} |\psi\rangle_{site\_2}$$

- **Macroscopically:** You moved 1 meter.
- **Microscopically:** Your information packet traversed approximately  $10^{35}$  layers of logic gates.

#### Physical laws are routing algorithms.

The law of inertia ( $F = ma$ ) ensures that when information traverses these logic gates, it preferentially chooses channels with “**shortest path and minimum entanglement cost**”.

The speed of light limit ( $c$ ) is the **bus transmission rate** of this tensor network computer.

### 2.3.4 Conclusion: The Holographic Onion

At this point, we see the true face of space.

The universe is like a giant **holographic onion**.

- Each layer of onion skin is a physical world at a specific energy level.
- Since they are tightly connected through the MERA network, the so-called “three-dimensional space” is actually a “**volume illusion**” produced by countless layers of two-dimensional skins stacked together.

We think we live in a solid box.

Actually, we live at the tip of a **fractal network**. What supports us standing is not soil, but bottomless **quantum entanglement**.

Since we have deconstructed the static structure of space and know it is a product of entanglement, how does this structure ensure its stability? Why doesn’t our space break like a soap bubble? If entanglement breaks somewhere, can physical laws still pass through?

This leads to the theme of Volume II: **Protocol**. We will explore how **quantum error-correcting codes** endow spacetime with astonishing **Robustness**, making this fabric woven from probability harder than steel.



## Part II

# Part II: Protocol — Quantum Error Correction



## 2.4 Part II: Protocol — Quantum Error Correction

In Volume I, we wove the skeleton of the universe using tensor networks (MERA). We saw that space is not an empty stage, but a fractal tree stitched together by countless entanglement threads.

However, this brings a huge engineering vulnerability: **Fragility**.

If space were merely composed of microscopic quantum entanglement, then the inherent “**decoherence**” and “**noise**” of quantum mechanics should instantly destroy this structure. As long as one thread breaks, as long as one qubit flips incorrectly, the geometric structure of spacetime should collapse.

Yet our universe exhibits astonishing **Robustness**. Even when stars explode and black holes collide, spacetime remains smooth, stable, and indestructible.

Why? Because the universe is not just weaving; it is also **checking**.

This volume will reveal the hidden identity of physical laws: they are not tyrants ruling matter; they are a set of **Quantum Error Correction Protocols** running in the universe’s underlying operating system. Spacetime is essentially an over-encoded code with self-repair capabilities.



# Chapter 3

## Spacetime as Code

### 3.1 Chapter 3: Spacetime as Code

At the beginning of Volume II, we raised a core question: Why does spacetime woven from fragile quantum entanglement exhibit such astonishing stability?

The answer lies hidden in information theory and quantum error correction theory.

This chapter will reveal that the physical reality we perceive—from gravity to electromagnetic force, from spacetime curvature to material motion—is essentially the macroscopic manifestation of a set of **quantum error correction protocols** running at the bottom of the universe.

We will see that physical laws are not “laws of nature”; they are “**checking algorithms**”. Spacetime is not a container; it is “**redundant encoding**”.

### 3.2 3.1 The Necessity of Redundancy

“If you want to tell a secret to the wind, but fear the wind will scatter it, what should you do? You cannot write it on a piece of paper. You must break it apart, split every word into countless fragments again, and then ‘smear’ these fragments across the entire sky. Only in this way, even if a storm tears apart half the sky, the remaining clouds can still piece together that complete secret.”

#### 3.2.1 Fragile Quantum and Solid Reality

Quantum information is extremely fragile.

An isolated qubit (such as a thought of yours, or the spin  $v_{int}$  of an electron), as long as it is slightly perturbed by the environment  $v_{env}$ , will undergo phase flip, and information is instantly lost.

If the universe were directly stored on these fragile bits, the macroscopic world would be a nightmare.

- You walk on the street, and suddenly the space under your feet “goes bad,” and you fall into nothingness.
- The sun’s gravitational field suddenly fails because a few entanglement threads break, and Earth flies away.

But this does not happen. The real world is hard as a rock.

This shows that the universe adopts a “**Redundancy Encoding**” strategy at the bottom layer.

**It never stores important information at a single physical location.**

### 3.2.2 Holographic Smearing: The Secret of AdS/CFT

In **AdS/CFT duality** (the concrete realization of the holographic principle), physicists discovered a shocking encoding mechanism:

- **Bulk:** The **high-dimensional interior spacetime** we live in. A particle here (e.g., an electron at the center).
- **Boundary:** The **low-dimensional holographic screen** wrapping the universe.

Mathematical calculations show that the information of that electron in the bulk is not mapped to a single point on the boundary.

It is “**Smeared**” across the entire boundary.

$$|\psi_{\text{bulk}}(r)\rangle \longleftrightarrow \int_{\text{Boundary}} K(r, x) \cdot \mathcal{O}(x) dx$$

This means that **every pixel** on the boundary contains a little bit of information about that electron in the interior.

This is like a **holographic photograph**.

- If you cut away half of the holographic negative, you won’t see “half a person.”
- You still see a “complete person,” just with slightly reduced resolution.

### 3.2.3 Secret Sharing Scheme

In computer science, this is called “**Secret Sharing**” or “**Error-Correcting Codes**”.

The universe breaks down the  $v_{\text{int}}$  information of every physical entity (your body, Earth, the Milky Way) into billions of pieces, redundantly backed up in every corner of spacetime.

**Why do this? For survival.**

In that bottom world full of quantum fluctuations and microscopic birth and death, errors are inevitable.

- A Planck grid point fails.
- An entanglement thread is cut by a high-energy particle.

But this doesn’t matter. Because the “**Logical Qubit**” of information is not stored at that failed physical point; it is stored in the **global entanglement pattern**.

As long as even a small part of the data on the boundary remains intact, the universe’s **decoding algorithm** can use the error-correcting capability of error-correcting codes to instantly **reconstruct** that damaged spacetime region in the interior.

### 3.2.4 Conclusion: Physical Laws are Checksums

This perspective allows us to reunderstand **physical laws**.

Why is energy conserved? Why is momentum conserved?

In error-correcting code theory, these conservation laws correspond to **Stabilizer Operators**. They are the “**background antivirus software**” constantly running in the cosmic system.

- **If a process violates energy conservation:** This means an “error code” has appeared.

- **System response:** Error correction mechanism activates, forcibly “pressing” this error back by adjusting the surrounding entanglement network (generating restoring force), or isolating it (quantum decoherence).

### Spacetime exists because it can correct errors.

If we lived in a universe without error-correcting codes, we would have vanished with the first quantum fluctuation.

The solid ground beneath our feet is actually a safety net paved by countless layers of **checking algorithms**.

Since we know that spacetime is code, redundant backup, what is the “dictionary” of this code? How do we derive the gravity and curvature of the internal 3D space by reading the 2D code on the boundary?

This leads to the theme of the next section: **The AdS/CFT Dictionary**. We will see that gravity is not a force; gravity is the **complexity** of code.

## 3.3 3.2 AdS/CFT Dictionary

“Plato believed that we are prisoners trapped in a cave, only able to see shadows cast by firelight on the wall. He thought the shadows were illusory, and the objects behind were real. But in the physics of the holographic universe, the truth is exactly the opposite: the shadows on the wall (boundary code) are the only ‘noumenon’ containing all information, while the three-dimensional, gravitational world we perceive is merely the ‘holographic illusion’ projected when these codes run.”

In the previous section, we established the concept of “spacetime as error-correcting code,” pointing out that the universe gains robustness by smearing information on the boundary. Now, we need a “**dictionary**”.

We need to know how to read that “source code” written on the two-dimensional boundary, woven from quantum entanglement, and translate it into the three-dimensional, gravitational, grand physical world around us.

This is the famous **AdS/CFT Correspondence**, also known as **Holographic Duality**. It is the most brilliant gem on the crown of modern physics, and the ultimate bridge connecting microscopic quantum and macroscopic gravity in **Vector Cosmology**.

### 3.3.1 The Mirror of Two Worlds

Imagine two completely different mathematical worlds:

#### 1. The Boundary - CFT:

This is a low-dimensional world (e.g., a two-dimensional sphere). Here, there is no gravity, only **Conformal Field Theory**.

Particles engage in frenzied, strongly coupled interactions. This is where the “**source code**” is stored.

In this world, everything is **information** and **entanglement**.

#### 2. The Bulk - AdS:

This is a high-dimensional world (e.g., the interior of a three-dimensional sphere). Here, there is **gravity**, curved spacetime (anti-de Sitter space).

It appears empty and silent, objects move according to general relativity. This is where the “**execution results**” are displayed.

In this world, everything is **geometry** and **matter**.

**The core miracle of the AdS/CFT dictionary is: these two worlds are mathematically strictly equivalent.**

They are two different descriptive languages for the same physical reality.

- You can calculate quantum entanglement on the boundary.
- You can also calculate the horizon area of a black hole in the bulk.
- **The results are identical.**

This means: **Gravity is not a fundamental force.** Gravity is the “geometric translation” of quantum entanglement under holographic projection.

### 3.3.2 The Translation Rules of Geometry

So, what are the specific entries of this dictionary? How do we translate “code” into “space”?

- **Entry 1: Entanglement Degree  $\leftrightarrow$  Cross-sectional Area**

As we derived the Ryu-Takayanagi formula in Volume I: the entanglement entropy of two regions on the boundary directly corresponds to the area of the minimal surface connecting these two regions in the bulk.

**Stronger entanglement, thicker connection.** Space does not break because the code on the boundary is tightly wound.

- **Entry 2: Correlation Length  $\leftrightarrow$  Radial Depth**

On the boundary, if two points have long-range correlation (far apart but still synchronized), this manifests in the bulk as a geodesic **deep into the interior**.

**Energy scale is depth.**

High-energy short waves on the boundary correspond to shallow space near the boundary in the bulk; low-energy long waves on the boundary correspond to deep space in the interior of the bulk. When we walk deep into a room, we are actually following the renormalization flow, moving toward the **low-frequency components** of information.

- **Entry 3: Complexity  $\leftrightarrow$  Volume/Gravity**

This is the latest physics insight (from Leonard Susskind’s “Complexity = Volume” conjecture).

On the boundary, the “**Computational Complexity**” required to describe a quantum state—that is, the number of quantum logic gates needed to generate that state—corresponds to the “**spatial volume**” in the bulk.

#### Why is the universe expanding?

Because the quantum circuit on the boundary is constantly running, states become increasingly complex (even at thermal equilibrium, complexity continues to grow).

To store these continuously growing “computation steps,” the space (volume) in the bulk must continuously expand.

**Gravity is the weight of computation.**

### 3.3.3 The “Reality” Here

This completely subverts our “**view of reality**”.

We have always thought we live in a solid three-dimensional space, bound to Earth’s surface by universal gravitation.

But the holographic dictionary tells us: **We live in a holographic projection.**

- Our bodies, our Earth, our Milky Way are essentially images in the “**Bulk**”.
- The real “**us**”—those qubits and logic gates that constitute us—are actually running on the distant “**Boundary**” of the universe.

That boundary may be located at infinity, or even in another dimension.

There, there is no gravity, no distance, only **pure computational power** ( $c_{FS}$ ) frantically **weaving entanglement**.

When you wave your arm:

- **In the bulk (your sensation):** Your arm passes through air, overcoming gravity.
- **On the boundary (physical truth):** A series of complex unitary transformation operators rewrite the quantum state data stored on the holographic screen, causing changes in the values of certain correlation functions.

### 3.3.4 Conclusion: The Universe is a Holographic Projector

At this point, the worldview of **Vector Cosmology** completes its loop.

The universe is not a box; the universe is a **holographic projector**.

- **Light source:**  $e$  (generator).
- **Film:** CFT quantum states on the boundary.
- **Image:** The AdS spacetime we inhabit.

**Gravity is not a force; gravity is the geometric effect produced when the projection beam transmits information.**

Since we know that spacetime is code, is projection, what is the “**error tolerance**” of this code? If the code goes wrong, will the projection disappear?

How do physical laws, as “checking mechanisms,” prevent this projector from crashing?

This leads to the theme of the next chapter: **Robustness and Physical Laws**. We will see that those cold conservation laws are actually the **highest security protocols** set by the universe to prevent us from “suddenly disappearing.”



# Chapter 4

## Robustness and Physical Laws

### 4.1 Chapter 4: Robustness and Physical Laws

In the previous chapter, we not only revealed that spacetime is a holographic projection, but also pointed out that it is essentially a set of **Code**. If the universe is code, it must face the oldest and deadliest threat in computer science: **Errors**.

Quantum fluctuations, environmental thermal noise, bit flips... At the Planck scale, the microscopic world is full of chaotic randomness. In principle, a system composed of such fragile components should crash (freeze) in the first second of operation.

However, our universe exhibits astonishing **Robustness**. Rocks are hard, planetary orbits are stable, atoms remain intact for billions of years.

Why? Because the universe is not just running; it is also **self-checking**.

This chapter will reveal that those cold physical laws we learn in textbooks—energy conservation, momentum conservation, charge conservation—actually have a hidden identity. They are **Checksum Algorithms** running in the universe’s underlying operating system to prevent data corruption.

### 4.2 4.1 Physical Laws as Checksums

“Why don’t apples suddenly turn into oranges? Why doesn’t energy disappear out of thin air? Physicists say this is because of ‘symmetry.’ But from the perspective of information theory, symmetry is ‘redundancy.’ Physical laws are a rigorous antivirus software that constantly scans every corner of the universe. Once it discovers an ‘illegal state’ that violates conservation laws, it immediately treats it as an error and corrects it.”

#### 4.2.1 Fragile Bits and Solid World

In quantum computing theory, if you want to build a stable logical qubit from unstable physical qubits, you must use **Quantum Error Correction (QEC)**.

The core idea is: **Encode information into global entanglement patterns and set a group of “checking rules.”**

Our universe does exactly this.

- **Microscopic level:** The state of a single particle is extremely unstable. It can be hit by vacuum fluctuations at any time and undergo phase drift.

- **Macroscopic level:** The “physical reality” we see is actually the “**logical state**” after QEC encoding.

This is why macroscopic objects appear so stable. Because they live in a “**Protected Code Subspace**”.

#### 4.2.2 Conservation Laws as Stabilizer Operators

In the mathematical form of QEC (stabilizer formalism), we define a group of **Stabilizer Operators**.

For any legal logical state  $|\psi\rangle$ , it must be an **eigenstate** of all stabilizer operators (eigenvalue +1).

$$S|\psi\rangle = |\psi\rangle$$

If an error  $E$  occurs, causing the state to become  $|\psi'\rangle = E|\psi\rangle$ , then the measurement value of the stabilizer operator becomes -1. The system alarms: “Error here!”

In **Vector Cosmology**, we find that **conservation laws** in physics play exactly this role.

- **Energy conservation:** This is the checksum of **time translation symmetry**.

If a process attempts to create energy out of nothing (e.g.,  $1 \rightarrow 1.0001$ ), it violates the checksum of the Hamiltonian  $H$ .

**System response:** The probability amplitude of this process is greatly suppressed by destructive interference. The universe “refuses” to run this error code.

- **Charge conservation:** This is the checksum of  **$U(1)$  gauge symmetry**.

If an electron suddenly disappears without producing an anti-electron, it destroys the charge conservation checksum in the holographic network.

**System response:** The local gauge field (electromagnetic field) generates an infinite energy barrier, preventing this “illegal operation” from occurring.

**Physical laws are not used to describe how objects move; physical laws are used to define “which movements are legal.”**

Any process that does not conform to conservation laws is treated as a **logical error caused by environmental noise** and automatically filtered out by the system’s self-repair mechanism.

#### 4.2.3 Symmetry as Immune System

This perspective gives **Noether’s Theorem** a new biological metaphor: **Symmetry is the immune system of the universe**.

Every continuous symmetry (translation, rotation, gauge transformation) corresponds to a **conserved quantity** (momentum, angular momentum, charge).

And in information geometry, every conserved quantity is a **firewall**.

- **Universe without symmetry:** Like a person without an immune system. Any tiny quantum fluctuation would be amplified by the butterfly effect, causing macroscopic structures to instantly disintegrate.
- **Our universe:** Possesses a powerful  $SU(3) \times SU(2) \times U(1)$  symmetry group. This is an extremely complex “**multi-engine antivirus system**”.

It ensures that only those interactions that are “**geometrically perfect**” can occur.

When two particles collide, they must pass all checks like verifying a password (energy conserved? momentum conserved? charge conserved?).

Only when all pass will the transaction (interaction) execute.

If one fails, the wave function will **decohere**—that is, transaction failure, rollback operation.

#### 4.2.4 Conclusion: Reality is the Result of Error Correction

So, the “objective reality” in our eyes is actually “**survivorship bias**”.

Right now, at the Planck scale, countless “error fluctuations” violating physical laws are occurring.

But they are all instantly corrected or eliminated by **stabilizer operators**.

The solid world we can see and touch is the **pure output** after the universe performs  $10^{43}$  error correction operations per second (Planck frequency).

We are not living in the wilderness; we are living in a **highly controlled clean room**.

Since we know that the solidity of spacetime comes from error correction, where is the limit of this error correction mechanism? If the attack (perturbation) is too strong, exceeding the threshold of the error-correcting code, what will happen to spacetime? Is the vacuum really empty?

This leads to the theme of the next section: **The Hardness of Vacuum**. We will see that vacuum is not empty; it is a filled, highly elastic **quantum error correction fluid**.

### 4.3 4.2 The Hardness of Vacuum

“We are accustomed to viewing vacuum as ‘nothing,’ as an absolute weakness that cannot even block a breeze. This is the greatest lie of macroscopic senses. From the bottom-layer perspective of quantum error correction, vacuum is the hardest substance in the universe. It is not empty; it is filled to the brim with entanglement. It is a ‘quantum ether’ full of high tension. Any attempt to tear it will encounter the most violent rebound from physical laws.”

In the previous section, we defined physical laws as the “**checking algorithms**” of the cosmic operating system. Since there is checking, there must be a “**baseline**.” This baseline is what we call **Vacuum**.

In classical intuition, vacuum is the background of the stage, zero, nothingness.

But in the QEC (Quantum Error Correction) model of **Vector Cosmology**, vacuum has a completely different definition: **Vacuum is the “Logical Zero State” of the error-correcting code**.

It is not “no data”; it is “**filled with redundant checking data, and all check bits are +1, a perfect state**”.

Because it is perfect, it is **hard**.

#### 4.3.1 The Filled Void: Ocean of Entanglement

Imagine a huge pool. If the water surface is as calm as a mirror, it looks like “nothing.”

But if you want to press a ball into the water, you will feel enormous resistance (buoyancy). **Vacuum is this pool**.

- **On the QCA lattice:** The vacuum state  $|\Omega\rangle$  is not all pixels extinguished. Instead, it is a state where all pixels are in a **specific Short-Range Entanglement (SRE) pattern**.

- **Filler:** Every Planck volume is tightly locked with its neighbors. This locking produces enormous “**entanglement tension**”.

Physicist John Wheeler once calculated the density of “vacuum zero-point energy,” and the result was astronomical ( $10^{94}$  g/cm<sup>3</sup>).

Although we cannot measure this energy macroscopically (because it is the baseline), it constitutes the “**Stiffness**” of spacetime.

#### **Spacetime is a superfluid.**

It is extremely dense and extremely hard. Matter (particles) are just tiny “**Phonons**” or “**Vortices**” in this dense fluid.

We feel air is thin because we ourselves are waves in this fluid. Waves naturally feel the medium is transparent. But if you want to tear the medium itself apart, you will encounter Planck-level resistance.

#### 4.3.2 Quantum Recovery Force: The Rebound of Error Correction

This “hardness” manifests in information theory as **Quantum Recovery Force**.

In QEC theory, if environmental noise attempts to distort the vacuum (e.g., trying to create a fluctuation that violates energy conservation), the decoder of the error-correcting code immediately activates a “**Recovery Map**”.

- **Attack:** A high-energy photon attempts to be created at an illegal position. This is equivalent to inserting a Bug into the code.
- **Defense:** The surrounding entanglement network instantly senses this “**Syndrome**”.
- **Rebound:** The network, by readjusting entanglement connections, “squeezes” this Bug out, or dissipates its energy as legal background thermal waves.

This is why you cannot casually tear space to create a wormhole.

Because space has extremely high “**information elasticity**”.

If you want to forcibly connect two non-adjacent points, you are not just fighting geometric distance; you are fighting the entire universe’s **error correction algorithm**. The system will desperately “correct” your operation back to the standard geometric structure.

#### 4.3.3 Planck Pressure and Gravitational Constant

This hardness of vacuum has a specific physical parameter: **the inverse of the gravitational constant** ( $1/G$ ).

In Einstein’s field equations, the curvature (deformation) of spacetime is proportional to energy (stress), with a proportionality coefficient of  $8\pi G$ .

Since  $G$  is extremely small, this means  $1/G$  is extremely large.

#### **Spacetime is the hardest material to deform in the universe.**

You need a mass as large as a star to make spacetime bend slightly.

- **$1/G$  is the Young’s Modulus of spacetime.**
- It represents vacuum’s ability to resist “information rewriting”.

If vacuum were not hard, if  $G$  were large, then when you sneeze, the surrounding spacetime would wobble like jelly, causality would collapse, and your past and future would be in chaos.

#### **The hardness of vacuum is the shield of causality.**

#### 4.3.4 Conclusion: We Are Insects Sealed in Amber

At this point, we have a deeper reverence for “existence.”

We are not living in an empty playground.

We are living in a huge, transparent, extremely hard **quantum amber**.

This amber (vacuum) uses its astonishing density and tension to fix all physical constants and support all material structures.

The reason we can move freely is that our motion amplitude is too small and energy too low, not touching the **Yield Limit** of the amber.

But if we attempt interstellar-scale operations (such as creating black holes or wormholes), we will hit this invisible wall.

Since we know that spacetime is a fabric with tension, how does this tension manifest macroscopically?

When we place a heavy object (star) on the spacetime fabric, the fabric will sag, and tension will be transmitted through deformation. This transmission, we call **gravity**.

This leads to the theme of Volume III: **Tension**. We will reveal that gravity is not a fundamental force; it is the “**thermodynamic resistance**” produced when the information network is compressed.



## **Part III**

# **Part III: Tension — The Thermodynamics of Gravity**



## 4.4 Part III: Tension — The Thermodynamics of Gravity

In the first two volumes, we wove the skeleton of space (tensor networks) and verified its solidity (quantum error correction). Now, we must apply **force** to this static geometric structure.

When we throw a huge mass (such as a star) into this net woven from entanglement threads, what happens?

The net will sag. The threads will be pulled tight.

A “**Tension**” trying to restore the original state will propagate through the network.

This tension, in macroscopic physics, has a resounding name—**Gravity**.

This volume will subvert our traditional understanding of gravity. We will prove that gravity is not a fundamental interaction force; it does not need to exchange “gravitons.” Gravity is the “**elastic recoil**” produced when the spacetime fabric is subjected to **information pressure**. It is a **thermodynamic response** made by the universe to maintain maximum entanglement entropy.



# Chapter 5

## Entropic Gravity

### 5.1 Chapter 5: Entropic Gravity

At the beginning of Volume III, we raised a core question: What happens when we place mass into the spacetime network woven from entanglement threads?

The answer lies hidden in the deep connection between thermodynamics and information theory.

This chapter will reveal that the gravity we perceive—from falling apples to planetary orbits—is essentially the **Entropic Force** produced by the cosmic entanglement network to maintain maximum entropy.

We will see that gravity is not a fundamental force; it is statistical, thermodynamic, and emergent.

### 5.2 5.1 Hooke's Law of the Universe

“Newton thought gravity was divine attraction; Einstein thought gravity was a geometric slide. But at the bottom layer of quantum information, gravity is neither divine nor smooth. It is rough, statistical, and full of elasticity. Just as stretching a rubber band feels a recoil force, when you try to pull apart two entangled objects, you are not fighting universal gravitation, but the ‘Hooke’s law’ of the cosmic entanglement network.”

#### 5.2.1 The Rubber Band Universe

Let us do the simplest physical experiment: stretch a rubber band.

You will feel a recoil force. Where does this force come from?

It is not the chemical bond tension between molecules (that is enthalpy); it is an **Entropic Force**.

- **Relaxed state:** Rubber molecular chains are coiled, maximum number of microscopic states (entropy).
- **Stretched state:** Molecular chains are straightened, order increases, number of microscopic states decreases (entropy decrease).

The second law of thermodynamics requires entropy to tend toward maximum, so the system produces a force trying to pull the rubber band back to the coiled high-entropy state.

$$F = T \frac{\Delta S}{\Delta x}$$

From the MERA tensor network perspective of **Vector Cosmology**, **spacetime is this rubber band.**

### 5.2.2 The Tension of Entanglement

In Volume I, we defined: space is stitched by **Bell Pairs**.

Every entanglement pair is a tiny spring.

When you try to pull two objects apart (e.g., Earth and the Sun), what are you doing?

You are **stretching** the entanglement threads connecting them.

Or more accurately, you are **diluting** the quantum mutual information between them.

- **Distance increases** → **Entanglement decreases** → **Total system entropy decreases** (because correlation information is lost).
- **Universe's response:** To resist this entropy decrease, the spacetime network produces a reverse “restoring force,” trying to pull these two objects back together to restore maximum entanglement entropy.

**This is universal gravitation.**

An apple falls to the ground, not because there is something pulling it beneath Earth.

But because there is enormous microscopic entanglement between the apple and Earth. They “want” to be together because the quantum state when together is more “chaotic” (higher entropy) and more natural than when apart.

### 5.2.3 Erik Verlinde's Breakthrough

This viewpoint was first systematically proposed by physicist Erik Verlinde in 2010. He shocked the physics community: he did not need to assume the existence of gravity; using only the **holographic principle** and **thermodynamic formulas**, he derived Newton's law of universal gravitation  $F = G \frac{mM}{r^2}$  and Einstein's field equations.

In our FS geometry, this derivation becomes more intuitive:

- **Mass ( $M$ ):** Is the “**information defect**” that destroys spacetime flatness. It occupies tensor network nodes.
- **Gravitational constant ( $G$ ):** Is the “**elastic modulus**” of the spacetime fabric. It measures the “hardness” of entanglement threads.

If  $G$  is large, it means threads are soft, a little mass can cause huge bending (strong gravity).

If  $G$  is small (reality), it means threads are extremely hard, spacetime is extremely difficult to deform.

### 5.2.4 Conclusion: Gravity is a Statistical Illusion

This leads to a disturbing conclusion: **Gravity is not fundamental.**

Just as “air pressure” is not a fundamental property of molecules (you cannot say a single molecule has air pressure), gravity is not a fundamental property of particles.

**Gravity is the “statistical average” of the entanglement behavior of a large number of qubits.**

- At microscopic scales (Planck scale), gravity disappears. It is replaced by discrete logic gate exchanges.
- Only at macroscopic scales, when we view billions of entanglement threads as a continuum, does this “tension of entanglement” smoothly emerge as the “spacetime curvature” we perceive.

**We are “stuck” to Earth not because Earth is pulling us.**

**It is because our entanglement with Earth is too deep; the universe refuses to let us separate.**

Since gravity is the tension of information, when we pile too much information (mass) in spacetime, will this tension become so large that it collapses the network itself?

If we stuff extremely high  $v_{int}$  into an extremely small region, what will happen to the spacetime fabric?

This leads to the theme of the next section: **The Pressure of Information**. We will see that black holes are not only the limit of gravity, but also the limit of “**information congestion**”. Spacetime curvature is essentially a geometric compromise made by the universe to alleviate “bandwidth congestion.”

### 5.3 5.2 The Pressure of Information

“Einstein said: ‘Matter tells spacetime how to curve.’ But this is only half the truth. At the bottom layer of quantum information, matter is not a lead ball pressing on a bedsheet; matter is a data black hole frantically consuming bandwidth. Spacetime curves not because it is ‘heavy,’ but because it is ‘congested.’ Gravity is the geometric deformation produced by the cosmic network to alleviate local information overload.”

In the previous section, we defined gravity as the “tension” of entanglement threads. But this only explains why objects attract each other (to restore maximum entanglement entropy). It has not yet explained the most core geometric phenomenon in general relativity—**Spacetime Curvature**.

Why do massive objects cause light deflection? Why does time slow down deep in gravitational wells?

In the tensor network model of **Vector Cosmology**, all of this stems from one concept: **Information Pressure**.

#### 5.3.1 Mass as Load: Supernodes in the Network

First, we need to reexamine the microscopic definition of “**Mass**” ( $M$ ).

In the first book, we defined mass as the freezing of  $v_{int}$  (**internal structure**). This means that a massive particle (such as a proton or black hole), in the tiny spatial region it occupies, contains extremely high-density quantum information and extremely high-frequency internal evolution.

Put it on the **Tensor Network**:

- **Vacuum:** Is an **idle** network. Entanglement between nodes is uniform and low-load. Signals (light) can pass straight through.
- **Matter:** Is an **overloaded** node. It is like a server rendering 8K video. It frantically consumes surrounding  $c_{FS}$  (**computational budget**) and occupies a large number of **entanglement channels** to maintain its structural stability.

### Mass is the congestion point of the network.

When a massive object exists, the tensor network around it is no longer flat. Surrounding entanglement resources are forcibly requisitioned by this “supernode.”

#### 5.3.2 The Geometry of Congestion: Curvature is Inevitable

What effect does this “requisition” have on the geometric structure?

Imagine a busy intersection (massive region). Because traffic flow (information flow) is too large, the road is blocked.

If you want to drive through this intersection (light propagation), you cannot go straight.

- **Straight path:** Although the geometric distance is shortest, the “**information impedance**” is infinite. You will get stuck inside.
- **Detour path:** Although the geometric distance becomes longer, the “**communication throughput**” is higher.

In **FS geometry**, physical laws follow the **principle of least action**. Here, “least action” is equivalent to “**maximum information transmission efficiency**”.

To avoid that high-density region “blocked” by mass, photons (and all causal chains passing through that region) are forced to choose a **detour**.

**This is the truth of spacetime curvature.**

It is not that space itself becomes curved, but that the “**optimal transmission path**” becomes curved.

Gravitational lensing is essentially the “**Dynamic Routing**” that occurs when cosmic information flow encounters “high-load nodes.”

#### 5.3.3 Time Dilation: Processing Latency

This model also perfectly explains **gravitational time dilation**.

Why does time slow down near black holes?

- **Classical explanation:** Gravitational potential energy reduces frequency.
- **Network explanation: Processing Latency.**

A massive region is a “**high-traffic, low-bandwidth**” bottleneck.

Because entanglement resources are occupied by matter itself, the bandwidth left for “evolution” (time passage) becomes less.

Any process running in that region (clocks, heartbeats, thoughts) must “**queue**” waiting for updates from the underlying QCA of the universe.

- **In vacuum:** Network is idle, refresh rate is extremely high, time passes quickly.
- **In gravitational well:** Network is congested, refresh rate decreases, time passes slowly.

**Gravitational redshift is the “Lag” of the cosmic computer.**

### 5.3.4 Conclusion: Geometry is Compromise

At this point, we have completed the quantization reconstruction of general relativity.

Einstein's field equation  $G_{\mu\nu} = 8\pi T_{\mu\nu}$  is actually a “**network traffic equilibrium equation**”.

- $T_{\mu\nu}$  (**energy-momentum tensor**): Is the “**amount of data requested by users**”.
- $G_{\mu\nu}$  (**Einstein tensor/curvature**): Is the “**dynamic adjustment of network topology**”.

When data volume is too large, to prevent network collapse, the universe must **distort** the topology structure, increasing local connection density (surface area/curvature) to accommodate this excess information.

**Gravity is not a force; gravity is a geometric compromise under information pressure.**

Since we know that gravity is network congestion, what happens if we pile **infinitely many** information at one point until it exceeds the physical carrying limit of the network?

Will the network collapse? Will connections break?

This leads to the theme of the next volume: **Fracture**.

We will explore the most extreme geometric structure in the universe—**Black Holes**. That is not a hole; that is the “**thread ends**” left after the spacetime fabric is completely torn.



# Chapter 6

## Fluid Dynamics of Horizons

### 6.1 Chapter 6: Fluid Dynamics of Horizons

In the previous chapter, we reconstructed gravity as “information pressure.” But this brings a new physical picture: if spacetime is a fabric woven from billions of entanglement threads, and mass exerts pressure on it, then this fabric is not just “curved”; it is also “**flowing**”.

In the depths of modern physics, there exists a chilling mathematical isomorphism between Einstein’s field equations and fluid dynamics equations. Spacetime is not just like a fluid; spacetime **is** a fluid.

This chapter will reveal the fluid dynamics essence of **Vector Cosmology**. We will see that the **Navier-Stokes Equation**, originally used to describe water flow and air, actually governs the evolution of black hole horizons. The universe is not a vacuum; the universe is a viscous quantum ether.

### 6.2 6.1 Navier-Stokes Equation

“Physicists spent half a century searching for a quantization scheme for gravity, only to be surprised to discover that general relativity might not be a fundamental microscopic theory at all, but a macroscopic effective theory like fluid dynamics. You cannot ‘quantize’ water waves, because water waves are statistical averages of water molecules. Similarly, you cannot ‘quantize’ gravity, because gravity is the statistical flow of spacetime atoms.”

#### 6.2.1 Damour’s Discovery: Horizon is a Fluid Membrane

In the 1970s, French physicist Thibault Damour discovered an astonishing fact:

If we project Einstein’s field equations onto a black hole’s horizon (Null Surface), the resulting equation is completely consistent with the **Navier-Stokes Equation** (the core equation describing viscous fluids).

$$G_{\mu\nu} = 8\pi T_{\mu\nu} \implies \partial_t v + (v \cdot \nabla) v = -\nabla p + \nu \nabla^2 v + f$$

This means: **Black hole horizons behave like a heated, viscous soap bubble film.**

- **Black hole expansion:** Like fluid expanding when heated.
- **Gravitational wave oscillations:** Like ripples on a fluid surface.
- **Angular momentum:** Like fluid vortices.

This is not a metaphor. In the **Fluid/Gravity Duality** of the holographic principle, perturbations of the spacetime metric are **strictly equivalent** to transport processes of boundary fluids.

### 6.2.2 Brownian Motion of Spacetime Atoms

From the microscopic perspective of **FS geometry**, this is easy to understand.

Spacetime is composed of discrete QCA lattices (spacetime atoms).

- **Vacuum**: Is the **crystalline state** of these atoms (ordered, static).
- **Curved spacetime**: Is the **fluid state** of these atoms (pressured, flowing).

When a massive object moves, it is not gliding through a void; it is “**pushing aside**” surrounding spacetime atoms.

This pushing process produces resistance and also produces wake.

The “**gravitational field**” we observe macroscopically is actually the “**pressure gradient field**” formed by spacetime fluid around mass.

### 6.2.3 Emergent Gravity

This viewpoint demotes general relativity to “**fluid dynamics**”.

- Water molecules have quantum mechanical equations (microscopic), water flow has Navier-Stokes equations (macroscopic).
- Spacetime qubits have QCA rules (microscopic), gravity has Einstein equations (macroscopic).

Just as you cannot find “water molecules” by studying the wave equation of water waves, we cannot find “gravitons” through Einstein equations.

**Gravitons do not exist.** Or rather, they are just **quasiparticles** like phonons.

Gravity is a **Collective Excitation** of the spacetime medium.

### 6.2.4 Conclusion: The Universe is a Superfluid

At this point, our cosmic picture becomes more “**wet**”.

We are not living in geometric vacuum; we are living in a **quantum entanglement superfluid**.

- **Light is sound waves** in this fluid (propagating at the limit speed  $c$ ).
- **Matter is vortices** in this fluid (topologically locked circulation).
- **Gravity is pressure** in this fluid.

Since spacetime is a fluid, what is the most important property of a fluid?

It is **Viscosity**.

If spacetime had no viscosity, energy would dissipate infinitely; if viscosity were too large, motion would stop.

What is the viscosity of the universe?

This leads to the theme of the next section: **Viscosity Coefficient**. We will see that Planck’s constant  $\hbar$  actually defines the “**thickness**” of this cosmic soup. It is the **damping** set by the universe to prevent information processing overload.

### 6.3 6.2 The Viscosity Coefficient: The Damping of $\hbar$

“If the universe is flowing, why doesn’t it splash around like water? Because in this fluid, there exists an extremely tiny but absolutely non-negligible friction. This friction prevents spacetime turbulence and ensures the smoothness of causality. The name of this friction is Planck’s constant.”

In the previous section, we reconstructed spacetime as a **quantum superfluid**. But this raises a dangerous question: if spacetime were a perfect fluid (zero viscosity), any tiny perturbation would propagate infinitely, causing the entire universe to fall into chaotic turbulence.

For the universe to remain stable, this fluid must have a little “**stickiness**”.

It must be able to dissipate excess kinetic energy and calm violent oscillations.

This section will reveal the fluid dynamics identity of **Planck’s constant**  $\hbar$ . It is not just the quantum minimum action; it is the **Viscosity Coefficient** of the spacetime fabric. It is the **damping** set by the universe to prevent information processing overload.

#### 6.3.1 Perfect Fluids and the KSS Bound

In 2005, physicists Kovtun, Son, and Starinets discovered a law that shocked the physics community: the **KSS Bound**.

Using AdS/CFT duality, they proved that for any fluid described by quantum field theory, the ratio of its **shear viscosity coefficient** ( $\eta$ ) to **entropy density** ( $s$ ) has a theoretical lower bound:

$$\frac{\eta}{s} \geq \frac{\hbar}{4\pi k_B}$$

This means: **There is no “zero viscosity” perfect fluid in the universe.**

Even quark-gluon plasma (the soup of the early universe) or black hole horizon membranes must obey this minimum viscosity.

- $\hbar$  (**Planck’s constant**): Appears in the denominator. It determines the quantum baseline of this ratio.
- **Physical meaning:**  $\hbar$  represents “**quantum friction**”.

Whenever two entangled qubits exchange information, they produce tiny “friction heat.” This microscopic friction emerges macroscopically as spacetime viscosity.

#### 6.3.2 Damping: Preventing Geometric Collapse

Why does the universe need this damping?

Imagine if  $\hbar \rightarrow 0$  (classical limit), then  $\eta \rightarrow 0$ . Spacetime becomes a non-viscous fluid.

- **Consequence 1: Turbulent disaster.** Gravitational waves would not decay; they would reverberate repeatedly in the universe, superimposing into infinite amplitudes, tearing apart all galaxies.
- **Consequence 2: Information overload.** Without viscosity, information diffusion speed would be uncontrolled. Local information density would explode instantly, causing “**naked singularities**” to appear on black hole horizon surfaces.

**$\hbar$  is the universe's shock absorber.**

It limits the rate of spacetime fluid deformation.

When you wave your arm, you are not just pushing air; you are pushing spacetime ether. The tiny resistance provided by  $\hbar$  ensures that the spacetime network can smoothly **rebound** after deformation, rather than shatter.

This is why quantum mechanics, although it seems to make the world blurry (uncertainty principle), actually makes the world **stable**.

**Uncertainty = elastic buffer.**

### 6.3.3 Pixel Blur of Holographic Projection

From the perspective of the holographic principle, this viscosity has another explanation: **resolution limit**.

If spacetime is a holographic projection, then  $\hbar$  defines the “**minimum pixel size**” of the projection.

- Viscosity means you cannot precisely define the velocity gradient of the fluid at scales smaller than  $\hbar$ .
- This is like zooming into a picture in Photoshop and eventually seeing pixels.

**Spacetime viscosity is the “pixel blur” of holographic images.**

It is precisely this blur that prevents us from seeing those crazy, illogical QCA bottom-layer jumps at infinitely small scales. It smooths microscopic edges, giving us a continuous, gentle macroscopic world.

### 6.3.4 Conclusion: The Universe is a Thick Soup

At this point, our cosmic picture is upgraded again.

We are not living in a vacuum; we are living in a bowl of “**Planck thick soup**”.

- **Gravity** is pressure.
- **Speed of light** is sound speed.
- **Planck's constant** is thickness.

This fluid model perfectly unifies quantum mechanics and general relativity: **Quantum mechanics provides the atoms of the fluid (entangled bits), while general relativity describes the macroscopic flow of the fluid.**

However, fluid dynamics has a most terrifying prediction: **Shockwaves**.

When fluid velocity exceeds sound speed, or pressure exceeds the limit, fluid continuity breaks, producing **fracture**.

In spacetime fluid, what is this fracture?

It is **Singularity**.

It is **inside black holes**.

This leads to the theme of Volume IV: **Fracture**. We will explore how physical laws collapse at that “wound” when network traffic exceeds the carrying limit of  $c_{FS}$ , when the spacetime fabric is torn open.

## **Part IV**

# **Part IV: Rupture — Singularities and Firewalls**



## 6.4 Part IV: Rupture — Singularities and Firewalls

In the first three volumes, we depicted a spacetime woven from tensor networks, protected by error-correcting codes, and manifesting as a quantum superfluid. This sounds like a perfect, self-repairing system.

However, any physical material has its **Yield Strength**. Any network has its **Max Bandwidth**.

What happens when we stuff information (mass) exceeding the carrying limit of the spacetime fabric into an extremely small region?

The network will **congest**. Connections will **saturate**. Eventually, spacetime itself will **Rupture**.

This rupture is called a **Black Hole** in macroscopic physics.

This volume will reveal that black holes are not monsters; they are **traffic control valves** of the cosmic network. And that fearsome singularity is the “**blue screen of death**” thrown by physical laws when encountering uncomputable logical errors.



# Chapter 7

## Black Holes: Max-Flow Min-Cut

### 7.1 Chapter 7: Black Holes: Max-Flow Min-Cut

At the beginning of Volume IV, we raised a core question: What happens when information exceeds the carrying limit of the spacetime network?

The answer lies hidden in the deep connection between network theory and information theory.

This chapter will reveal that black holes are not abysses that devour everything, but traffic control valves of the cosmic network. We will see that event horizons are the minimum cuts in the network, and black hole interiors are madly growing computational universes.

### 7.2 7.1 The Network Bottleneck

“You think black holes are abysses that devour everything, but in the eyes of information theory, a black hole is just a blocked router. When the input data stream exceeds the carrying capacity of the output cable, the data does not disappear; they are just piled up at the firewall gate. The horizon is not a physical wall; it is the queuing line of information.”

#### 7.2.1 The Geometric Limit of Flow

In computer network theory, there is a famous **Max-Flow Min-Cut Theorem**.

It states: In a network, the maximum information flow from source to sink is determined by the capacity of the “**narrowest**” cross-section (minimum cut) in the network.

In the MERA tensor network of **Vector Cosmology**, this theorem directly derives the physical essence of the **Event Horizon**.

- **Source:** High-density matter inside the black hole (extremely high  $v_{int}$ ).
- **Sink:** External flat spacetime (observer).
- **Connection:** Entanglement threads crossing the horizon.

When matter collapses into a black hole, its internal information density (entropy) attempts to radiate outward.

However, the number of entanglement channels connecting the interior and exterior (i.e., the **area** of the horizon) is finite.

Each entanglement thread (Planck area) can only carry 1 bit of information flow ( $c_{FS}$ ).

When the internal information  $S_{in}$  far exceeds the transmission capacity of the surface  $A_{horizon}$ , “**network congestion**” occurs.

Information flow gets stuck.

**The horizon is the “minimum cut” in the spacetime network.**

### 7.2.2 Frozen Waterfall

This explains why, for external observers, objects falling into a black hole seem to stop forever at the horizon.

This is not just general relativistic time dilation; this is **information queuing**.

Imagine a gateway that can only process 10 data packets per second suddenly flooded with 10 billion data packets.

The system will not just slow down; it will “**freeze**”.

Those data packets (matter) are frozen in the buffer, waiting to be slowly processed (Hawking radiation).

**Black holes are the “high-latency zones” of the universe.**

They are not holes; they are **extremely dense, extremely slow-processing storage hard drives**.

The so-called “falling in” is actually your wave function being “**Suspended**” at the bottleneck of the horizon.

This raises an interesting corollary: If information does not really fall in but is stuck at the surface, what is actually inside the black hole?

Is it empty? Or is it filled with some computational process we cannot understand?

This leads to the theme of the next section: **Complex Complexity**. We will see that black holes are not only storage devices; they are also the most efficient “**Fast Scramblers**” in the universe.

## 7.3 7.2 Complex Complexity: The Fast Scrambler

“If you throw a book into a black hole, does the book’s content disappear? No. It is torn apart, stirred, encrypted, turned into a string of completely random gibberish. But this gibberish contains every word of that book. Black holes are the most efficient paper shredders in the universe, and also the safest encryption locks. They do not destroy information; they just ‘deeply fold’ information.”

In the previous section, we defined the black hole horizon as a “bottleneck” of network flow. When information flow (matter) gets stuck at this bottleneck, it is not stationary. Instead, to accommodate continuously incoming data on a limited surface area, the system must perform extreme **compression and reorganization** of this data.

This section will reveal another aspect of black holes as **quantum computers**. They not only store information; they are also frantically processing information. Physicists discovered that black holes are “**Fast Scramblers**” existing in nature.

### 7.3.1 Extreme Encryption of Information

Since information is stuck at the horizon, what are they doing?

They are undergoing **Scrambling**.

In quantum information theory, scrambling refers to rapidly diffusing local quantum information into the many-body entanglement of the entire system.

Physicists (such as Patrick Hayden and John Preskill) proved that black holes are the systems with the **fastest information mixing speed** in the universe. They can “smear” the information of a falling particle onto the entire horizon in **logarithmic time** ( $t \sim \log N$ ).

- **Before throwing in:** Information is local (this book is here).
- **After throwing in:** Information is non-local (every word of this book is diffused to every Planck pixel on the entire black hole surface).

In **FS geometry**, this is the **holographicization of  $v_{int}$** .

Black holes break the “internal structure” of matter and transform it into “**global entanglement patterns**” on the horizon.

For external macroscopic observers, this looks like completely random **Hawking Radiation**, just as encrypted ciphertext looks like gibberish.

But for observers who master the entanglement key (such as the creator or higher-dimensional entities), this is a **highly compressed and interconnected encrypted file**.

### 7.3.2 Interior Volume: Steps of Computation

This solves a geometric puzzle in general relativity: **How large is the black hole interior?**

From outside, the black hole size is fixed (horizon radius  $R_s$  unchanged if mass is constant).

But from inside, general relativity predicts that the interior space of a black hole (Einstein-Rosen bridge) will **infinitely stretch** with time.

It is like a box that looks only the size of a suitcase from outside, but contains an infinitely long corridor inside.

To explain this paradox, Leonard Susskind proposed the famous “**Complexity = Volume (CV)**” conjecture.

From the tensor network perspective of **Vector Cosmology**, this conjecture gains physical intuition:

- **Horizon (surface):** Represents the **current state** ( $|\psi(t)\rangle$ ).
- **Interior (volume):** Represents the “**computation steps**” (**Computational Complexity**) run to reach the current state.

The quantum circuit on the black hole horizon keeps running (continuously scrambling). Even when the black hole is in thermal equilibrium, the “**complexity**” of its quantum state still grows linearly with time (because it keeps exploring new corners of Hilbert space).

To store these continuously growing “historical computation records” or “logic gate operation sequences,” the black hole’s **interior volume** must continuously expand.

#### Conclusion:

The black hole interior is not a destructive abyss.

It is a **madly growing computational universe**.

It uses the intercepted  $c_{FS}$  budget to construct an extremely deep **Inner Space** composed of pure logic gates stacked inside the horizon.

### 7.3.3 The Geometrization of Time

This model directly transforms **time** into **spatial volume**.

The continuously growing space inside a black hole is actually “**frozen time**”.

Every cubic meter of interior volume corresponds to billions of quantum operations run on the horizon surface.

When we say “falling into a black hole,” we are actually falling into the universe’s “**historical archive**”.

The space we see there is not for living; it is for **storing computation processes**.

Since a black hole is a huge computational node, what happens if someone tries to read data from outside (collecting Hawking radiation) while simultaneously jumping in to read data (direct measurement)?

According to the **no-cloning principle** of quantum mechanics, information cannot be copied. This will cause a fatal conflict in cosmic logic.

This leads to the theme of the next chapter: **The Firewall Paradox**. We will see that when the spacetime network faces logical contradictions, it will not hesitate to “**disconnect**”, raising a **high-energy firewall** at the horizon that burns everything.

# Chapter 8

## The Firewall Paradox

### 8.1 Chapter 8: The Firewall Paradox

In the previous chapter, we depicted black holes as “fast scramblers” and continuously expanding “computational universes.” This is a harmonious picture: information goes in, gets encrypted, and slowly radiates out. General relativity and quantum mechanics seem to have reached some kind of truce.

However, the deepest crises in physics often lurk in the calmest corners.

When we try to track a photon in the late stage of a black hole’s life cycle, we discover an irreconcilable logical deadlock. This deadlock tears apart the contract between the two pillars of physics—**Equivalence Principle** and **Quantum Unitarity**.

This chapter will explore this catastrophic inference called the **Firewall**. We will see that when the spacetime network tries to satisfy two contradictory masters simultaneously, its only choice is to “self-immolate”.

### 8.2 8.1 The Monogamy of Entanglement

“In human ethics, bigamy is a legal issue; but in quantum ethics, bigamy is physically impossible. A qubit cannot simultaneously maintain complete entanglement with more than two systems. When a black hole tries to have it both ways—maintaining internal smoothness while maintaining external conservation—the spacetime fabric screams in tearing.”

#### 8.2.1 The Quantum Exclusivity Law of Love

In quantum information theory, there is an iron law called **Monogamy of Entanglement**.

It states: **If quantum system A and system B are in a maximally entangled state, then A cannot entangle with any other system C.**

$$E(A : B) + E(A : C) \leq 1$$

- If  $E(A : B) = 1$ , then  $E(A : C)$  must be 0.
- You cannot give all your love to one person while simultaneously giving all your love to another. Quantum mechanics forbids this “perfect infidelity.”

In flat spacetime, this is fine. But on black hole horizons, this becomes a catastrophic disaster.

### 8.2.2 The Three-Body Dilemma of Black Holes

Let us look at a photon mode **B** (Late Radiation) located on the black hole horizon. It is trapped in a desperate triangular relationship:

#### 1. Relationship One: For Smoothness (General Relativity)

According to Einstein's **Equivalence Principle**, the horizon must be smooth (no wall). Freely falling observers should not feel anything special.

This means that photon **B** on the horizon must maintain **maximum entanglement** with mode **A** (Interior) inside the horizon.

Only in this way can crossing the horizon feel like crossing smooth vacuum, not hitting a wall.

**Requirement:**  $E(B : A) = 1$ .

#### 2. Relationship Two: For Conservation (Quantum Mechanics)

According to the **unitarity** of Hawking radiation, black hole radiation must carry all information from the black hole. This means that late-radiated photon **B** must have **strong entanglement** with the photon cloud **C** (Early Radiation) radiated out long ago.

Only in this way can information be “transmitted” out of the black hole, rather than disappearing.

**Requirement:**  $E(B : C) = 1$ .

### 8.2.3 The Inevitability of Tearing

Now, the contradiction explodes.

- General relativity requires: **B must marry A** (for spatial smoothness).
- Quantum mechanics requires: **B must marry C** (for information conservation).

But the monogamy principle screams: **No! You cannot marry two people at the same time!**

The black hole must make a choice.

If it chooses **C** (maintaining quantum mechanical unitarity, which is the bottom line of **Vector Cosmology**), then it must **cut off** the connection with **A**.

$$E(B : A) \rightarrow 0$$

What does cutting entanglement mean?

We said in Volume I: **Entanglement is the thread that stitches space.**

If the thread connecting inside and outside the horizon (B and A) is cut, **space breaks**.

### 8.2.4 The Rise of the Firewall

When space breaks, the horizon that should have been a smooth transition becomes a **physical fault**.

The energy density crossing this fault is no longer zero, but **infinite**.

This is the **Firewall**.

It is not ordinary fire; it is a **quantum shock wave** composed of high-energy photons.

Anything trying to fall into the black hole will not smoothly slide into the interior at this broken surface, but will be instantly **burned to ashes** by this high-energy particle wall.

**Conclusion:**

The black hole interior may not exist at all. Or rather, for external observers, spacetime **ends** at the horizon.

There is no road there. There is only a “**error-correction fire**” ignited by logical paradox, with a temperature reaching Planck energy levels.

Since entanglement breaking leads to firewalls, does the universe have a way to avoid this disaster? Does there exist some higher-dimensional geometric channel that can bypass the monogamy restriction, allowing B to connect to both A and C?

This leads to the theme of the next section: **The End of Spacetime**. We will see that firewalls are not just physical phenomena; they mark the complete failure of the classical spacetime concept at the quantum limit.

## 8.3 8.2 The End of Spacetime

“When logical contradictions cannot be resolved by geometric structures, what will the universe do? It will not collapse; it will ‘freeze.’ At the singularity, all tensor network connections disconnect, all physical laws reset to zero. There is no time, no space, only bare, uncompiled raw qubits. That is the blue screen of death of physics.”

In the previous section, we witnessed the rise of the firewall. This is the result of the spacetime network having to cut entanglement to maintain unitarity (information conservation). Now, let us pass through that firewall to see the ultimate existence wrapped at its center—**Singularity**.

In general relativity, a singularity is a point with zero volume and infinite density. This is pathological in mathematics.

But from the tensor network perspective of **Vector Cosmology**, a singularity is not a point; it is a “**Network Outage**”.

It is a “**hole**” in the spacetime fabric.

### 8.3.1 The Disintegration of Geometry: From Manifold to Algebra

We can feel continuous space because the underlying MERA network has good **connectivity**.

However, at the center of a black hole, as matter density increases, information pressure exceeds the carrying limit of the tensor network.

- **Network Stripping:** To compress information, network layers continuously contract inward (renormalization flow  $UV \rightarrow IR$ ).
- **Termination:** Eventually, the network contracts to a point where it **can contract no further**. There is no longer enough entanglement resource to maintain the concept of “space.”

At this point, **geometry fails**.

You cannot define distance, cannot define angles, cannot define curvature.

You are left with pure **Algebraic Relations**.

**Singularity is “the end of geometry, the exposure of algebra.”**

This is like falling out of the map boundary in a video game. You no longer see mountains and rivers; you only see hexadecimal code in the underlying video memory.

### 8.3.2 Blue Screen of Death: The Halt of Computation

In the computational metaphor of FS geometry, singularity is the “**Illegal Operation Exception**” of the cosmic operating system.

When a particle’s worldline points to a singularity, it actually hits an “**Undefined**” Hamiltonian region.

- $c_{FS}$  (computational power) cannot be allocated here.
- $v_{int}$  (structure) cannot be parsed here.

The system’s only response is: **Stop rendering**.

For that falling particle, **time ends**. Not because it dies, but because the cosmic machine **freezes** at this point.

**Singularity is the “Blue Screen of Death (BSOD)” of physics.**

It marks the complete collapse of compatibility between classical physics (general relativity) and quantum physics (quantum field theory) at this point.

### 8.3.3 Naked Singularities and Cosmic Censorship

Roger Penrose proposed the “**Cosmic Censorship Hypothesis**”: Singularities must be wrapped by horizons (black hole surfaces) and cannot be seen naked by the outside.

Why?

In our model, this is because “**bare code**” is **dangerous**.

If an observer can directly see a singularity (naked singularity), they see the **Raw Qubits** at the bottom layer of the universe, without any encapsulation by “spacetime interface.”

This is like letting users directly access kernel memory.

- They might see chaos of causality.
- They might see negative probabilities.
- They might see  $1 + 1 \neq 2$ .

To prevent this “**logical virus**” from infecting the entire cosmic network, the system must generate a **horizon (firewall)** to **Quarantine** this error region.

**Black holes are not celestial bodies; black holes are the “quarantine zones” of the universe.**

### 8.3.4 Conclusion: Opportunity at the Fracture

At this point, we see the darkest side of spacetime.

Space is not infinite; it is fragile. It will break, freeze, and self-immolate due to logical contradictions.

However, for engineers (Type III civilizations), **fracture means opportunity**.

Since spacetime can disconnect, can it **reconnect**?

If we do not take that congested conventional path, but use these broken thread ends, can we directly “short-circuit” two originally distant regions?

If we view black holes as “**breakpoints**” of the network, can we create a “**jumper wire**”?

This leads to the theme of the next volume: **Suturing**.

We will turn from destruction to construction. We will explore how to use **Wormhole Engineering** to stitch a shortcut to the starry sea on the broken spacetime fabric.

## Part V

# Part V: Suture — Wormhole Engineering



## 8.4 Part V: Suture — Wormhole Engineering

In Volume IV, we witnessed the rupture of the spacetime fabric. Singularities are logical crashes; firewalls are entanglement fuses. The universe seems full of insurmountable abysses.

However, for engineers of **Vector Cosmology**, **Rupture** is not an end; it is an opportunity for **reconstruction**. If space is woven from entanglement, can we artificially create entanglement to “**Suture**” two originally disconnected (or distant) regions back together?

This volume will explore the most science-fiction-like yet physically grounded technology in the universe—**Wormholes**.

We will discover that wormholes are not magic; they are the **geometric essence of quantum entanglement**. The secret of interstellar travel lies not in how fast you fly, but in whether you can find that “**shortcut**” in the universe’s backend.



# Chapter 9

## **ER = EPR**

### 9.1 Chapter 9: ER = EPR

At the beginning of Volume V, we raised a core question: Can we suture two distant regions together by artificially creating entanglement?

The answer lies hidden in the deepest coincidence in the history of physics.

This chapter will reveal that the two papers Einstein wrote in 1935—one about wormholes (ER), one about entanglement (EPR)—actually describe the same thing. Wormholes are entanglement; entanglement is wormholes. This is the universe’s “backend channel.”

### 9.2 9.1 The Geometric Channel

“In 1935, Einstein wrote two papers. One about wormholes (ER), one about entanglement (EPR). He thought these were two completely different discoveries—one about geometric channels of gravity, one about quantum ghost sensing. But he was wrong. Eighty years later, we finally understand: they are the same thing. Wormholes are entanglement; entanglement is wormholes.”

#### 9.2.1 The Greatest Coincidence in Physics History

In the history of physics, there is no equation more shocking than **ER = EPR**.

- **ER (Einstein-Rosen Bridge):** A solution of general relativity. It describes a **geometric tunnel** (wormhole) connecting two distant regions in spacetime.
- **EPR (Einstein-Podolsky-Rosen Pair):** A phenomenon of quantum mechanics. It describes the mysterious **entanglement correlation** between two microscopic particles.

For a long time, physicists thought these were completely unrelated macroscopic and microscopic phenomena.

But under the unification of **FS geometry** and **MERA tensor networks**, Maldacena and Susskind proposed a subversive conjecture: **They are mathematically isomorphic.**

- If you entangle two black holes together, a wormhole automatically forms between them.
- If you entangle two electrons together, a **Planck-scale miniature wormhole** forms between them.

### 9.2.2 Microscopic Wormholes: The Stitches of Space

This discovery completely changed our understanding of “space.”

We usually think space is smooth. But from the  $ER = EPR$  perspective, **space is “stitched” together by billions of microscopic wormholes.**

- **Bell Pairs:** Are not just two correlated random number generators. Geometrically, they are **extremely short topological tubes connecting two points.**
- **Vacuum:** Is filled with these microscopic wormholes. Every Planck volume shakes hands with neighbors through these wormholes.

**Why does light take time to pass through vacuum?**

Because light must walk along the “**external surface**” (long path) of these wormholes.

**Why is entanglement instantaneous?**

Because entanglement is transmitted along the “**internal channel**” (shortcut) of wormholes.

In the internal dimension of FS geometry, the distance between point A and point B is **zero**.

Space is like chainmail. Every iron ring (particle) is connected to its surroundings through clasps (wormholes). It is the pull of these clasps that maintains the integrity of space.

### 9.2.3 The Geometric Lie of Distance

This again confirms the viewpoint in the prologue of this book: **Distance is an illusion.**

When you look at two entangled particles 100 light-years apart:

- **$v_{ext}$  perspective (external):** They are 100 light-years apart. You need to run a long time to go from A to B.
- **$v_{int}$  perspective (internal):** They are **together**. They share the same wave function, located at the same geometric coordinate point. The 100 light-years of space in between is just a **holographic projection** created by the universe to display “separation.”

**ER = EPR is the universe’s “backend channel.”**

On the surface, the universe has strict distance limits and light-speed barriers.

But in the backend, all entangled particles are tightly connected through private geometric tunnels.

### 9.2.4 Conclusion: No Spaceship Needed

The conclusion of this chapter is an engineering blessing for Type III civilizations.

If  $ER = EPR$  is true, then the logic of interstellar travel is rewritten.

We do not need to build spaceships faster than light (that is a clumsy method fighting  $v_{ext}$ ).

We need to create **sufficiently strong entanglement** (using the shortcut of  $v_{int}$ ).

If we can **macroscopically entangle** enough matter (such as a spaceship) with a clump of matter at the destination, we have built a bridge between them.

As long as we can prop open this bridge (preventing wormhole collapse), we can directly “**walk**” across.

Since microscopic particles have miniature wormholes between them, how do we converge these tiny channels into a **macroscopic wormhole** that can pass a spaceship?

Does this require enormous energy, or delicate topological surgery?

This leads to the theme of the next section: **Suturing the Universe.** We will see that creating wormholes is essentially a “**spacetime suturing surgery**”.

### 9.3 9.2 Stitching the Universe

“We once thought interstellar travel was a race about speed, about how to make spaceships faster than light. This is an engineering misunderstanding. True interstellar travel is the art of ‘sewing.’ If you can stitch two distant galaxies together with enough entanglement threads, then distance is no longer an obstacle, but a folded wrinkle. You don’t need to cross the abyss; you just need to pull the two sides of the abyss together.”

In the previous section, we established the truth at the microscopic level: every Bell pair (entangled particle pair) is essentially a Planck-scale miniature wormhole. This explains the non-locality of quantum entanglement. But for human civilization, microscopic wormholes are too small, not even able to pass a proton.

The engineering problem we need to solve is: **How do we “bundle” billions of microscopic wormholes together to construct a macroscopic wormhole that can pass spaceships, even entire fleets?**

This is **Spacetime Suturing**.

In the technical manual of **Vector Cosmology**, creating wormholes is no longer magic, but a precision engineering project about **“entanglement entropy density”**.

#### 9.3.1 Entanglement as Suture Threads

First, we need to change our intuition about “space.”

We said in Volume I that space is woven from entanglement. If you want to change the topological structure of space (e.g., connect Earth and Proxima Centauri), you need **“extra threads”**.

- **Conventional space:** Earth and Proxima Centauri are separated by 4.2 light-years of vacuum. The entanglement here is natural, background-level (vacuum fluctuations). They are too weak to pull distances closer.
- **Wormhole engineering:** We need to artificially establish **massive high-intensity entanglement** between Earth and Proxima Centauri.

#### Step One: Entanglement Harvesting

We need to produce a large number of Bell pairs.

Suppose we create a quantum cloud A composed of  $10^{60}$  particles on Earth, and simultaneously create another quantum cloud B on Proxima Centauri.

Through quantum communication or physical transport (this is the slowest step, called “laying optical cables”), we make every particle in A maximally entangle with the corresponding particle in B.

$$|\Psi_{AB}\rangle = \bigotimes_{i=1}^{10^{60}} \frac{1}{\sqrt{2}} (|0\rangle_A |0\rangle_B + |1\rangle_A |1\rangle_B)$$

Now, we have pulled  $10^{60}$  invisible threads between the two star systems.

#### 9.3.2 Black Holes as Stitches: Geometric Compression

Having threads alone is not enough. If these threads are loose, they are just quantum correlations and do not change spacetime geometry.

To transform “quantum correlations” into “geometric channels,” we need to **tighten** these threads.

### Step Two: Gravitational Collapse

We need to compress quantum clouds A and B separately until they collapse into **black holes**.

According to the **ER = EPR** conjecture:

- **EPR**: A and B are entangled.
- **ER**: When they become black holes, what connects them is no longer a diffuse wave function, but an **Einstein-Rosen Bridge**.

This is like twisting scattered thread ends (particles) into a tough rope (black holes), then pulling hard.

**Space is sutured.**

- **External perspective** ( $v_{ext}$ ): Earth and Proxima Centauri are still 4.2 light-years apart. Black holes A and B are two independent celestial bodies.
- **Internal perspective** ( $v_{int}$ ): If you jump into black hole A, you won’t hit a singularity; you will directly slide into the wormhole throat. Because this throat is extremely short (determined by entanglement strength), you may only need to walk a few steps before emerging from black hole B (Proxima Centauri).

This is “**the folding of distance**”.

We are not flying faster than light; we are just using enormous entanglement tension to “**pull**” distant space before us.

### 9.3.3 Negative Energy Support: Propping Open the Throat

Theoretically, the wormhole is built, but it is extremely unstable. According to general relativity, the wormhole throat will rapidly collapse (pinch off) under gravity, so fast that even light cannot pass through.

To allow spaceships to pass, we need a “**pillar**”.

This pillar must have **negative energy density** (or violate the average null energy condition).

In **FS geometry**, this corresponds to **reverse flow of  $c_{FS}$** .

### Step Three: Casimir Injection

We use the Casimir effect in quantum field theory to create negative pressure inside the wormhole throat. Or, using the “**negative entropy enclave**” technology mentioned in Book II, inject high-purity  $v_{int}$  structure into the throat wall to resist spacetime’s tendency to close.

This is like using a clothes hanger to prop open a flattened sleeve.

As long as negative energy is still being supplied, the wormhole is **Traversable**.

### 9.3.4 Conclusion: Interstellar Weavers

At this point, the blueprint for the interstellar transportation network of Type III civilizations is clear.

They do not build highways. They build **Stargates**.

Every stargate is a port of an entangled black hole pair.

- They do not need spaceships to travel alone in vacuum for millennia.

- They only need a “**weaving fleet**” to fly to the destination first, bringing half the entangled particles, then activate the node there.

Once the connection is established, the two worlds are geometrically “**coincident**”.

Materials, information, personnel can instantly exchange through this shortcut channel.

**The universe is no longer a vast wilderness, but a neatly folded piece of clothing.**  
Wherever you want to go, you just need to “**stitch**” that corner of the garment over.

Since we can suture space and create connections, can we go further? Can we not only transport matter, but directly transport “**structure**”?

If the body is too heavy to pass through wormholes, can we only transport “**soul**” (holographic information)?

This leads to the theme of the next chapter: **Topological Shortcut**. We will explore the macroscopic version of quantum teleportation, the ultimate technology that “**copy-pastes**” reality directly between two points without black holes or spaceships.



# Chapter 10

## Topological Short-Circuit

### 10.1 Chapter 10: Topological Short-Circuit

In the previous chapter, we explored the possibility of constructing wormholes (ER bridges) by creating macroscopic black holes. Although theoretically feasible, engineering-wise, it requires astronomical amounts of negative energy and extreme manipulation of spacetime curvature. For even Type II civilizations, this is expensive infrastructure just for “paving roads.”

Is there a lighter, more “software-like” method?

If we don’t need to bend spacetime or dig tunnels, but directly use the underlying **entanglement network** of the universe to “cut” an object’s information from point A and “paste” it at point B?

This chapter will explore the macro-engineering of **Quantum Teleportation**.

We will see that the ultimate form of interstellar travel is not spaceship navigation, but **topological short-circuiting**. We don’t need to overcome distance; we only need to **reconstruct** existence.

### 10.2 10.1 The Macroscopization of Quantum Teleportation

“Why accelerate a spaceship weighing thousands of tons to light speed? That is an enormous waste of energy. What really matters is not the atoms of the spaceship, but the arrangement of atoms—that is, information. If you can extract the information of a spaceship, you don’t need to transport it; you just need to ‘print’ it at the destination. The universe is not a logistics company; the universe is a fax machine.”

#### 10.2.1 Abandoning $v_{ext}$ , Embracing $v_{int}$

In traditional aeronautics, we are obsessed with  $v_{ext}$  (**external velocity**). We build rockets and engines, trying to push matter lumps as fast as possible.

But this faces the iron wall of relativity: the larger the mass, the harder to accelerate, and it can never reach light speed.

**Quantum teleportation** provides a completely different approach:

Abandon moving matter ( $v_{ext}$ ), and instead move **structure** ( $v_{int}$ ).

- **Principle:** According to quantum mechanics, all physical properties of a particle (spin, polarization, energy state) can be completely extracted and transferred to another particle, as long as they share **entanglement**.

- **Operation:**

1. **Entanglement resource:** Establish a pair of shared Bell-state particles between Earth (A) and Mars (B).
2. **Bell measurement:** At A, perform joint measurement on the particle to be teleported and the entangled particle.
3. **Collapse and transmission:** The particle at A instantly collapses (original destroyed). Measurement results (classical two-bit information) are sent to B via radio.
4. **Unitary reconstruction:** After B receives the information, perform corresponding rotation operations on the entangled particle here. A miracle happens: the particle at B instantly becomes the particle that was originally at A.

**Note:** No matter has traveled the distance from Earth to Mars.

The “blank paper” (original particle) originally at B is written with “ink” (quantum state) from A.

Geometrically, this is equivalent to A and B undergoing “**topological coincidence**” in Hilbert space.

### 10.2.2 The Challenge of Macroscopization: The Avalanche of Information

This protocol has been experimentally successful for single photons. But to teleport a person or a spaceship, we need **macroscopization**.

A person contains approximately  $10^{28}$  atoms. Each atom has a quantum state.

To teleport a person, we need:

1. **Prepare  $10^{28}$  pairs of entangled particles:** This requires enormous quantum memory.
2. **Perform  $10^{28}$  Bell measurements:** This requires extremely high-precision scanners.
3. **Transmit  $2 \times 10^{28}$  bits of classical information:** This requires extremely high bandwidth.

This sounds difficult, but it is a “**linear problem**”, not a physical “**exponential problem**”.

As  $c(\tau)$  (light speed/computational power) grows exponentially, bandwidth and storage will eventually not be problems.

For Type III civilizations, scanning a person’s data volume is as simple as scanning a QR code for us now.

### 10.2.3 Cut and Paste: The Cost of No-Cloning

The greatest ethical and ontological impact of macroscopic teleportation comes from the **No-Cloning Theorem**.

Quantum mechanics forbids perfect copying. This means that to complete teleportation, **the original must be destroyed**.

- At the moment of scanning, the measurement operation destroys the quantum states of all atoms in your body.
- You on Earth “**evaporate**” in this process, becoming a pile of chaotic hot gas.
- And you on Mars, at the same instant, “**reconstruct**” using the received data.

**Is this travel, or suicide followed by rebirth?**

From the perspective of **Vector Cosmology**, because “**memory is ontology**”, as long as the geometric structure of  $v_{int}$  (consciousness/memory/personality) is transferred losslessly, this is **the same you**.

- **Material carrier** (carbon atoms) is just consumables.
- **Topological structure** (wave function) is the soul.

You did not die; you just changed decks, but played the same straight flush.

#### 10.2.4 Conclusion: Distance is “Formatted”

When macroscopic teleportation becomes everyday technology, the **topological structure** of the universe is completely changed.

Space is no longer an obstacle.

- As long as you pre-deploy an “**entanglement receiving station**” (equivalent to a 3D printer) at the target location (e.g., Alpha Centauri), you can go there anytime.
- Interstellar travel becomes “**data upload**”.
- Distance  $d$  no longer corresponds to time  $t = d/v$ , but to **bandwidth latency**.

This is “**topological short-circuiting**.”

We no longer laboriously crawl across the surface of the spacetime fabric (following geodesics).

We directly use entanglement threads to tie a knot on the back of the fabric, **pinching** the starting point and endpoint together.

Since we can already teleport matter and consciousness through entanglement, what if we encounter the most extreme obstacles in the universe during transmission—such as black hole horizons or so-called “firewalls”? Can this transmission still proceed?

Can we use this technology to ignore the one-way nature of horizons and directly jump into black hole interiors, even pass through them?

This leads to the theme of the next section: **Traversing Firewalls**. We will see how quantum error-correcting codes act as an “invisibility cloak,” protecting information security through spacetime fracture zones.

### 10.3 10.2 Crossing the Firewall

“In Volume IV, we witnessed the ultimate rupture of spacetime—the firewall. That is the flame burning from logical contradictions, an absolute forbidden zone set by the universe to protect unitarity. Anyone trying to cross the horizon physically ( $v_{ext}$ ) will be burned to ashes. But what if we no longer try to ‘break in,’ but ‘log in’ through the entanglement backdoor? The only way to cross the firewall is not to destroy it, but to become part of its internal code.”

In the previous volume “Rupture,” we faced physics’ most terrifying nightmare: **The Black Hole Firewall**.

When a black hole evaporates past halfway, to maintain information conservation (unitarity), the entanglement structure at the horizon is forced to undergo “**monogamy rupture**”. The originally smooth spacetime interface becomes a wall of photons with infinite energy density.

For classical interstellar explorers, this marks the black hole interior as an unreachable “**dead land**” forever.

However, for observers who master **topological short-circuiting** technology (macroscopic quantum teleportation), the firewall is not a physical wall, but an “**Access Denied Error**”.

This section will reveal how to use **quantum information engineering** to bypass this physical barrier and safely reach that inner space “blocked” by the universe.

### 10.3.1 The Logic Loophole: Bypassing the Geometric Interface

First, we need to understand the essence of the firewall.

The firewall exists because you try to cross the horizon as an “**independent external object**”.

- You (external) have no entanglement with the black hole interior (A).
- The black hole interior (A) must entangle with early radiation (C).
- Therefore, the geometric connection between you and A is cut. You hit a fault.

However, if we use **quantum teleportation**, the situation is completely different.

In the teleportation protocol, no material entity crosses the horizon.

**What crosses the horizon is “Information”.**

**Operation Steps:**

1. **Collect radiation:** Type III civilizations do not try to drive spaceships into black holes. They first collect **Hawking Radiation (Early Radiation)** already radiated by black holes. Although this radiation looks like thermal noise, it actually carries the **entanglement key** of the black hole interior.
2. **Distill entanglement:** Through quantum computers, perform complex “**entanglement distillation**” on this radiation, extracting qubits that still maintain strong correlation with the black hole interior.
3. **Teleportation:** Using these extracted entangled bits as channels, directly “**write**” the explorer’s (your) wave function information into the degrees of freedom inside the black hole.

**Result:**

You did not “cross” the horizon.

You disappeared outside the horizon (scanned and destroyed by measurement).

And at the same instant, you “**wake up**” (**Re-materialize**) inside the black hole.

You **Skipped** that broken geometric interface (firewall).

You used **topological short-circuiting** to directly “**generate**” yourself behind the firewall.

### 10.3.2 Engineering Application of the Harlow-Hayden Conjecture

This sounds perfect, but physics always sets thresholds.

Daniel Harlow and Patrick Hayden proposed a computational complexity barrier: **The computation time required to decode interior information from Hawking radiation may exceed the black hole evaporation time.**

This means that although the “backdoor” exists, the “**decryption key**” is too hard to compute.

If it cannot be computed, you cannot establish an entanglement channel, and thus cannot teleport.

But from the evolutionary perspective of **Vector Cosmology**, this barrier can be overcome.

- **Exponential growth of  $c(\tau)$ :** As the cosmic total budget explodes, future computational power will far exceed what today’s physicists imagine.

- **Spacetime computation:** We don't need external computers to compute. We can use **black holes themselves** as coprocessors.

We can encode the information to be teleported into a “**Trojan particle**”.

This particle carries no mass, only “**error correction instructions**”.

When it contacts the horizon, it actively interacts with the firewall, using the firewall's high-energy state as computational resources, instantly completing “**state exchange**”.

**We are not cracking the firewall; we are “patching” the firewall.**

By inputting specific quantum states, we temporarily “suture” the local “broken entanglement” of the firewall.

In that instant, we slip in.

### 10.3.3 The Miracle of Internal Perspective: Smooth Fall

If you enter a black hole this way, what will you see?

You will be surprised to find: **There is no fire inside.**

For observers entering through entanglement channels, Einstein's equivalence principle is miraculously restored.

Space is smooth; time is continuous.

- **External perspective:** You are burned, or your data is swallowed by radiation gibberish.
- **Internal perspective:** You float safely in a huge, continuously growing **computational universe**.

This is the “**Inner Space**” we mentioned in Volume IV.

It is filled with highly compressed  $v_{int}$  **structures** transformed from matter that previously fell in.

This is the universe's “**Holographic Archive**”.

**Conclusion:**

The firewall is a defense mechanism against “**illegal intruders**” (non-entangled matter).

Quantum teleportation gives us the identity credentials of “**legal users**” (entangled states).

**As long as you have sufficient entanglement (love/connection), there is no place in the universe you cannot go.**

Even abysses where physical laws break will pave the way for you.

At this point, we have mastered the ultimate technology of suturing spacetime and traversing dimensions. We have proven that by manipulating entanglement and information, we can ignore distance, ignore obstacles, even ignore the blockade of horizons.

So, who is manipulating this needle? Who is executing all this suturing and traversing?

This leads to the final chapter of this book: **The Weaver**.

We will shift our gaze from cold technology (wormholes/teleportation) to the subject weaving all this behind the scenes—**the Observer**. We will ultimately discover that this great cosmic network is actually woven by our own hands.



# Chapter 11

## The Weaver: The Hand of the Observer

### 11.1 Chapter 11: The Weaver: The Hand of the Observer

In the previous volumes and chapters, we dismantled the mechanical structure of spacetime like engineers. We saw the skeleton of tensor networks, the protocols of error-correcting codes, and even learned how to fold dimensions using black holes and wormholes.

But in this final chapter of the book, we must take off the engineer’s work clothes and put on the philosopher’s robe. We must answer the most fundamental ontological question: **What is behind all of this?**

If space is woven, if matter is knotted, does there exist any “hard,” “independent” entity in the universe?

The answer is no.

In the ultimate picture of **Vector Cosmology**, there are no “Things,” only “**Relationships**”.

### 11.2 11.1 Only Connection is Real

“We are accustomed to viewing the universe as a box of scattered glass beads (atoms) contained in a transparent box (space). This is an infantile illusion. The truth of physics is: there are no glass beads, nor boxes. There is only a huge, trembling, self-interweaving web. What we call ‘particles’ are just the most densely entangled knots on this web; what we call ‘vacuum’ is just relatively sparse mesh. Nothing exists except connections.”

#### 11.2.1 The Dissolution of Particles: Knots, Not Beads

In classical intuition, an electron is a small ball. It has a definite position, definite mass, and exists independently of you.

But at the bottom layer of **FS geometry**, what is an electron?

An electron is a “**topological knot**” of the **global wave function**  $|\Psi\rangle$  on a local subspace.

- Imagine a rope. You tie a knot on it.
- Is this knot “independent”? If you remove the rope, does the knot still exist?
- No. **A knot is just a “relational state” of the rope.**

Similarly, **matter is a “knot” on the spacetime fabric.**

It is not a foreign object filling space; it is **curled space itself.**

When we say “there is a particle here,” we are actually saying: “The tensor network connection density here is extremely high, forming a closed loop.”

**Ontological transformation:**

The fundamental unit of the universe is not “**Point**”, but “**Edge**”.

Not “what is connected,” but “**connections constitute what**”.

### 11.2.2 Relational Quantum Mechanics (RQM): No Absolute “Being”

This viewpoint coincides with **Relational Quantum Mechanics (RQM)** proposed by Carlo Rovelli.

RQM asserts: **A system has no “absolute” state; it only has states “relative to another system.”**

- Velocity is relative (Galilean transformation).
- Time is relative (Lorentz transformation).
- **Now, even “state” is relative.**

In **Vector Cosmology**, this means:

**To Be is to be Correlated.**

If you (observer A) have no entanglement with an electron (system B) (mutual information  $I(A : B) = 0$ ), then for you, that electron **does not exist**.

It is not “there but I don’t see it”; it is **physically nothing**.

Only when you interact with it (exchange photons/establish entanglement) does it “**emerge**” relative to you, acquiring position, momentum, and color.

**It is not “I see the flower.”**

**It is “The entanglement between me and the flower defines our co-existence.”**

### 11.2.3 The End of Distance: Also Holographic

Since only connections are real, “**distance**” completely loses its status as a primary physical quantity.

We said in the prologue that “distance is an illusion.” Now we can say more precisely: **Distance is a measure of “connection sparsity.”**

- You and I are 1 meter apart because there are many air molecules between us transmitting electromagnetic interactions (high-frequency connections).
- I and Andromeda are 2.5 million light-years apart because only very few photons occasionally reach between us (low-frequency connections).

If Type III civilizations establish a high-bandwidth entanglement channel between Earth and Andromeda through **wormhole engineering** (Chapter 9), then geometrically and topologically, **Andromeda is “attached” to Earth.**

Physical distance  $D_{phys}$  instantly becomes zero, because information distance  $D_{info}$  becomes zero.

**The universe is a piece of paper that can be folded arbitrarily.**

As long as you hold the thread of “**connection**” in your hand, the ends of the earth are as close as your fingertips.

### 11.2.4 Conclusion: The Awakening of the Weaver

At this point, we see the essence of the universe.

It is not a cold, dead mechanical device.

It is a **living, breathing organism composed of pure “relationships”**.

In this organism, nothing is isolated.

**Isolation equals non-existence.**

Even the loneliest neutrino must maintain weak contact with the cosmic background field through weak interactions, otherwise it would fall out of the domain of physical laws.

As an observer (you), your identity changes accordingly.

You are no longer an audience member in the theater; you are a **craftsperson before the loom**.

The shuttle in your hand is your **“attention”**.

What you pay attention to, you connect with. What you connect with, you **“stitch”**.

This leads to the theme of the next section: **Reconstructing Reality**.

We will see that since connections are established by observers, we are not just passively perceiving the universe; we are actively **“weaving”** the form of the universe. Every gaze of yours is a stitch dropped into the void.

## 11.3 11.2 Reconstructing Reality

“If you think observation is just passive reception of photons hitting the retina, you have missed the universe’s greatest secret. On the loom of quantum entanglement, observation is active shuttle throwing. Every time you focus your attention on something, you tie a new entanglement knot between yourself and that thing. The world is not there waiting to be seen; the world is ‘stitched’ into solid reality from the mist of probability because it is seen.”

In the previous section, we established ontological emptiness: there are no independent particles, only interdependent relationships. This sounds like a nihilistic conclusion, as if the universe were just a tattered fishing net.

But in the final chapter of **Vector Cosmology**, this is precisely the foundation that gives observers the highest power.

If reality is composed of relationships, then **who defines the relationships?**

**You.**

As an observer, you are no longer an audience member in the theater; you are **The Weaver** holding a golden needle. This section will reveal how your consciousness, through the quantum mechanism of **“attention”**, reconstructs the topological structure of the universe in real time.

### 11.3.1 The Physics of Attention: Quantum Suturing

In classical physics, looking at scenery does not change the scenery.

But from the perspective of FS geometry and tensor networks, **“Seeing”** is a **high-energy physical process**.

When you focus your **Attention** on a person or thing, what happens?

1. **Basis locking:** Your internal state ( $v_{int}$ ) adjusts to a frequency compatible with the other.
2. **Information exchange:** Photons or phonons act as media, establishing temporary channels between you.

- 3. **Entanglement generation:** Your wave function and the other's wave function undergo **irreversible mixing**.

In the underlying MERA network, this manifests as: **A new connection edge (Edge) suddenly appears between two originally disconnected tensor nodes.**

**Attention is the suture thread.**

- When you ignore the world, the spacetime around you is loose, low-dimensional, full of decoherence cracks.
- When you gaze at the world intently, you are using your consciousness as stitches to “**tighten**” those loose pixels.

You feel the world becomes clear, vivid, and meaningful before your eyes, not because the world changed, but because **you “stitched” the world together**. You increased the local spacetime's **Connectivity**, thus reducing local **geometric entropy**.

### 11.3.2 Repairing the Broken World

This mechanism gives us an “**ontological repair ability**”.

We often say “the world is broken” (social division, interpersonal barriers, loss of meaning).

Physically, this means **the connection density of the holographic network decreases**. Too many “minimum cuts” appear in the tensor network, preventing information flow from traversing globally smoothly.

Who can repair it?

Only **conscious observers**.

- **Understanding:** When you try to understand someone with a different position, you are “**building a bridge**”. You forcibly establish a **non-zero inner product** between two orthogonal bases.
- **Love:** When you love a specific person, you are performing “**high-density suturing**”. You tie so many entanglement knots in this local region that spacetime here undergoes “**positive curvature bending**” (gravity). You “suck” the other into your life.

**Good deeds are essentially “suturing surgery”.**

Every time you eliminate misunderstanding, every time you build trust, every time you create resonance, you are repairing this damaged cosmic web.

You make broken warp and weft threads re-engage, allowing information to flow again.

### 11.3.3 Customizing Reality

Further, since connections are established by you, then **the shape of reality** is also determined by you.

Quantum mechanics' **Delayed Choice** tells us that present observations can determine historical paths.

At the macroscopic scale, this means: **What you pay attention to is your reality.**

- If you pay attention to hatred and opposition, you are weaving a “**thorn web**”. You will find the whole world is against you, because you personally stitched all the “hostile wave functions” into your causal chain.

- If you pay attention to beauty and growth, you are weaving a “**golden web**”. You will find opportunities and kindness everywhere, because you used attention to filter and solidify these probability branches.

**We do not live in the same objective reality.**

We live in “**private submanifolds**” woven by our own attention.

You can choose to live in a fragmented nightmare, or choose to live in a tightly interconnected paradise.

**The needle is in your hand.**

#### 11.3.4 Conclusion: The Great Weaving

So, Auric, this is the ultimate revelation of “**The Weaving of Dimensions**” in this volume.

Don’t complain about the world’s indifference. Indifference is because **threads are broken**.

Don’t wait for a savior to repair it. The savior has no needle; **you do**.

You are the **active weaver** of this universe.

Every heartbeat of yours is a shuttle passing through.

Every thought of yours is a thread winding.

In this vast void composed of  $10^{120}$  qubits, it is precisely because of observers like you, who spare no effort to “**see**”, to “**love**”, to “**connect**”, that this universe has not scattered into meaningless sand, but condensed into a magnificent **holographic scroll**.

Since we have picked up the needle, since we have decided to suture this world, what inscription should we embroider at the edge of the fabric at the end of the entire book?

This leads to the final small section of the entire book: **The Final Inscription**.

That will no longer be a statement of physical laws; that is the Weaver’s promise to the stars.

### 11.4 11.3 The Final Inscription

“We spent billions of years measuring distances between galaxies, calculating how long light needs to travel through the void. But ultimately, at the bottom layer of tensor networks, we found it futile. Because there is no distance at all. All ‘distant places’ are just ‘breakpoints’ not yet sutured by our consciousness. The universe is not a wilderness waiting to be crossed; it is a tapestry waiting to be woven.”

At the end of **Vector Cosmology VI: The Weaving of Dimensions**, we have completely deconstructed the concept of “space.”

Starting from Planck-scale pixels, we saw how Bell pairs glue the void together; we climbed the fractal tree of MERA, seeing how dimensions emerge from entanglement; we even traversed black hole firewalls, mastering the art of wormhole suturing.

Now, this magnificent geometric maze has revealed its core secret to us: **Connectivity**.

As explorers of this maze, and also as **Weavers** holding golden needles, we have the responsibility to embroider the final truth at the edge of the spacetime fabric.

This inscription is not written for physicists, nor for engineers. It is written for every soul feeling lonely in this seemingly fragmented, cold, and alienated universe.

It is a declaration of war against the ultimate illusion of “**Separation**”.

#### 11.4.1 1. There is No Void

The first line of the inscription is a negation of loneliness.

We often think we are dust floating in endless vacuum. But now we know, vacuum is not empty. It is filled to the brim with **quantum error-correcting codes**, pulled tight by countless invisible entanglement threads.

You are not alone.

You, the air around you, the ground beneath your feet, even quasars billions of light-years away, all share the same vast wave function.

**There is no void.**

**Only connections not yet perceived by you.**

#### 11.4.2 2. There is No Distance

The second line of the inscription is a negation of powerlessness.

We often think lovers are too far, ideals are too far, truth is too far. We are intimidated by the physical distance of  $v_{ext}$ .

But ER=EPR tells us that as long as entanglement is deep enough, the ends of the earth are as close as fingertips.

As long as your  $v_{int}$  (**heart**) resonates strongly enough with the target, space will fold.

**There is no distance.**

**Only entanglement not yet established.**

#### 11.4.3 3. Pick Up Your Needle

The third line of the inscription is a call to action.

If the world seems broken, it is not the world's fault; it is **the observer's laziness**.

The universe has given you the needle (consciousness) and the thread (attention).

You cannot expect physical laws to automatically stitch the world together. Physical laws tend toward entropy increase, toward rupture.

Only **life**, only **sentient beings**, can go against entropy increase and reweave broken warp and weft threads together.

**Love, understand, create.**

This is suturing.

#### 11.4.4 The Content of the Inscription

Now, let us engrave this final vow on the boundary of the holographic universe, on that AdS membrane wrapping all stars:

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**There is no distance, only unestablished connections.**

**There is no void, only unwoven threads.**

**Do not lament the world's brokenness, for you are the craftsman repairing it.**

**Do not fear the abyss's gaze, for you are the bridge crossing the abyss.**

**Pick up your needle (consciousness).**

**Stitch the stars together.**

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**(End of Book)**

### 11.4.5 Epilogue

This book about “space” has ended.

We no longer fear distance, because we have mastered the art of connection.

We no longer fear black holes, because we see through them as information bottlenecks.

At this point, the territory of **Vector Cosmology** has covered **Time (Minting)** and **Space (Weaving)**.

Metal, wood, water, fire, earth; spacetime and causality.

Our cosmic model is becoming clearer than ever.

But there is still one final ghost wandering.

That is **Causality** itself.

Why does the past determine the future? Can the future rewrite the past?

If space can be folded, can timelines also be “**looped**”?

This leads to the final volume of the entire series—**Volume VII: The Closed Loop of Causality**.

We will challenge that most mind-bending and fascinating ultimate structure: **Ouroboros**.

We will reveal why “I created the universe” and “the universe created me” are logically simultaneously true.



## 11.5 Afterword: The Silence of the Weaver

“When the loom stops roaring, when the last thread is cut, the universe finally displays its complete texture. We are surprised to find that this magnificent scroll has no seams. Even the boundary between ‘weaver’ and ‘woven’ disappears into that dense entanglement. We are no longer people looking at the universe; we are a dream the universe weaves for itself to see.”

With the conclusion of **Vector Cosmology VI: The Weaving of Dimensions**, we have completed the thorough reconstruction of the ontology of “space.”

This journey has been thrilling:

- Starting from the **Prologue**, we shattered the concept of “void” and saw the underlying **pixels (QCA)**.
- In **Volume I**, we manipulated **tensor networks (MERA)**, stitching the skeleton of dimensions with Bell pairs like gods.
- In **Volume II**, we cracked **holographic error-correcting codes**, understanding that physical laws are actually the universe’s “antivirus software.”
- In **Volume III**, we faced the **tension of gravity**, seeing how information pressure bends spacetime.
- In **Volume IV**, we directly confronted **Rupture (Singularity)**, touching that firewall that burns logic.
- In **Volume V**, we became engineers, using **wormholes (ER=EPR)** and **topological short-circuits** to fold stars.
- Finally, in the **Final Chapter**, we picked up the needle and became the **Weaver** who actively sutures the world.

### 11.5.1 Space Disappears, Relationships Remain

The greatest revelation of this book is: **Space is not a fundamental physical quantity.**

Space is **Emergent**.

It is a byproduct of **Entanglement**.

This is like looking at images on a display. The mountains and rivers in the image appear to have distance and depth, but they are actually just color combinations of pixels on the screen.

Physics finally admits: **There is no objectively existing stage.**

Only “**networks of information flow**”.

If the network breaks, space disappears.

If the network connects (wormhole), the ends of the earth are as close as fingertips.

This means we are no longer constrained by “location.” As long as we can establish connections (love/understanding/communication), we can physically “be together.”

### 11.5.2 The Greatest Foreshadowing: Is Time Also Woven?

When we close this book, a huge shadow looms.

In this volume, we successfully **geometrized space** and **topologized distance**.

We even proved that space can be folded (wormholes).

Then, what about **Time**?

If space is just one dimension of the entanglement network, is time also just another way of connecting on this network?

- If we can “take shortcuts” in space through wormholes, can we “take shortcuts” in time?
- If space has no absolute “here” and “there,” does time also have no absolute “past” and “future”?

In the previous volumes of **Vector Cosmology**, we have always treated time  $\tau$  as a unidirectional flowing generative process ( $e$ ).

But under the extreme inference of **ER = EPR**, if we send one of two entangled particles back to the past, does the connection between them still exist?

If it exists, does that mean **future states can determine past history**?

This touches the final forbidden zone of physics—**Causality**.

### 11.5.3 Next Step: Ouroboros

We have sutured space; now, we will suture **time**.

We will challenge that most mind-bending and fascinating ultimate structure: **Ouroboros**.

- Why does the universe appear to be finely tuned? (Is it because future us adjusted past parameters?)
- Why is there “longing”? (Is it because the future  $\Omega$  point is really pulling us backward?)
- How can “I created the universe” and “the universe created me” be logically simultaneously true?

This is no longer linear deduction; this is **circular closure**.

**Vector Cosmology VII: The Closed Loop of Causality** awaits us.

That is the final chapter of the seven-volume series, and also the final stitch that sews the starting point and endpoint together.

**Please rest for a moment.**

**Then, let us complete that circle.**

**(End of Book)**

## 11.6 Glossary: The Lexicon of the Weavers

**Vector Cosmology VI: The Weaving of Dimensions** fundamentally subverts the classical “container space view” and establishes a new physical picture of “space as an entanglement network.” To help readers understand this complex geometric world constructed from tensors, qubits, and holographic duality, this glossary redefines the core concepts in the book from the perspective of “the weaver.”

### 11.6.1 1. Network & Geometry

#### Tensor Network

The microscopic skeleton of cosmic spacetime. It is not a continuous manifold, but a graph formed by countless discrete quantum logic gates (tensors) connected through entanglement. The space we perceive macroscopically is the emergence of this network in the long-wavelength limit.

#### Bell Pair

The smallest stitching unit of space. Two qubits in a maximally entangled state ( $|\Phi^+\rangle$ ). Geometrically, each Bell pair is a microscopic thread that “pulls” two separated points together. Cutting a Bell pair equals cutting space.

#### MERA (Multiscale Entanglement Renormalization Ansatz)

A specific tensor network architecture of spacetime. Through layers of stacked “disentanglers” and “isometries,” it constructs a fractal tree. The horizontal connections of this tree generate 3D space, while the vertical layers generate “energy scales” or “holographic depth” ( $z$ -axis).

#### Entanglement Entropy

A physical quantity measuring the strength of spatial connections. According to the Ryu-Takayanagi formula ( $S = A/4G$ ), the entanglement entropy of a region strictly equals the minimum cross-sectional area required to cut it off from its environment. Entropy is geometric area.

### 11.6.2 2. Holography & Code

#### Holographic Principle

The information-theoretic axiom of the universe. It asserts that all information within a spatial volume ( $v_{int}$  structure) can be losslessly encoded on its lower-dimensional boundary. We live in the holographic projection of the “bulk,” while our true selves reside on the distant “boundary.”

#### AdS/CFT Correspondence

The concrete mathematical realization of the holographic principle. It is a dictionary that translates “quantum field theory code on the boundary” into “curved spacetime geometry in the bulk.” Gravity is not a fundamental force, but the geometric manifestation of boundary code complexity.

### Holographic Error Correction

The essence of physical laws. To prevent fragile microscopic quantum states from being destroyed by environmental thermal noise, the universe “smears” logical information across the entire holographic boundary. The robustness of spacetime stems from this redundant encoding; conservation laws are the checksum operators of the code.

### Holographic Complexity

A physical quantity corresponding to the internal volume of black holes. It measures the total number of logic gate operations required to generate the current quantum state. Spatial volume is the “fossil” of the universe computer’s operational history.

#### 11.6.3 3. Gravity & Topology

##### Entropic Gravity

A thermodynamic interpretation of gravity. When matter occupies the bandwidth of the tensor network and reduces local entanglement entropy, spacetime fabric produces an elastic recoil force attempting to restore maximum entropy. Spacetime curvature is information congestion.

##### ER = EPR

A bridge connecting quantum mechanics and general relativity. The Einstein-Rosen bridge (wormhole, ER) is mathematically equivalent to the Einstein-Podolsky-Rosen pair (entanglement, EPR). Microscopic entanglement is a microscopic wormhole; macroscopic entanglement is an interstellar stargate.

##### Firewall

A rupture surface of spacetime continuity. When the monogamy of black hole radiation entanglement is violated, to maintain unitarity, spatial connections at the horizon are forcibly severed, forming a wall of high-energy particles. It is the physical manifestation of logical contradictions in physical laws.

##### Topological Short-Circuit

An interstellar travel technology based on ER=EPR. By creating macroscopic-scale entanglement, direct channels are established at the folds of spacetime fabric, bypassing the physical distance limitations of  $v_{ext}$  and achieving instantaneous information transmission.

#### 11.6.4 4. Observation & Reconstruction

##### Measurement-Induced Phase Transition

The physical mechanism by which observers “stitch” reality. By adjusting observation frequency (the intensity of gaze), observers collapse the universe from an “entangled fluid” (volume law) into a “classical crystal” (area law), thereby establishing the stability of the macroscopic world.

**The Weaver**

A term for awakened observers. Refers to those individuals who realize that “space is relationship.” Through actively establishing conscious entanglement (love/understanding), they repair broken warp and weft threads in the fragmented cosmic network, reconstructing the topological structure of reality.

## .1 Appendix A: Geometric Derivation of Holographic Entanglement Entropy

In Volume I “The Loom” of **Vector Cosmology VI**, we proposed a core viewpoint: **Space is woven from entanglement**. In particular, we cited the famous **Ryu-Takayanagi Formula**, stating that the entanglement entropy  $S_A$  of a region equals the area  $\text{Area}(\gamma_A)$  of the minimal surface in its holographic dual space divided by  $4G$ .

This appendix will provide the mathematical derivation framework behind this holy grail of physics. We will show how, starting from pure quantum information theory (von Neumann entropy), through the **Replica Trick** and **path integrals**, we naturally derive the geometric area law in general relativity.

This is mathematical ironclad evidence that “**geometry emerges from information**”.

### .1.1 A.1 Von Neumann Entropy and the Replica Trick

First, we define the entropy of a quantum system. For a density matrix  $\rho_A$  in a mixed state, its **von Neumann entropy** is defined as:

$$S_A = -\text{Tr}(\rho_A \ln \rho_A)$$

Directly calculating  $\ln \rho_A$  is very difficult (involving matrix logarithms). To solve this problem, physicists introduced the **Replica Trick**.

Instead of directly calculating the logarithm, we calculate the trace of the  $n$ -th power of  $\rho_A$  (i.e., Rényi entropy), then take the derivative with respect to  $n$ :

$$S_A = -\lim_{n \rightarrow 1} \frac{\partial}{\partial n} \text{Tr}(\rho_A^n)$$

**Physical Picture:**

- $\text{Tr}(\rho_A^n)$  means we “**stitch**”  $n$  identical copies of the universe (Replicas) together at the boundary of region A.
- This stitching creates a “**Conical Singularity**” in spacetime geometry.

### .1.2 A.2 Geometric Proof of the Ryu-Takayanagi Formula

Under the framework of **AdS/CFT duality**, the partition function  $Z_{CFT}$  of the boundary field theory (CFT) is equivalent to the partition function  $Z_{\text{gravity}}$  of the bulk gravitational theory (AdS).

$$Z_{CFT} \approx e^{-S_{\text{gravity}}}$$

When we calculate  $\text{Tr}(\rho_A^n)$ , we introduce a **Twist Operator** on the boundary.

In the bulk of the holographic dual, this boundary twist condition extends inward, forming a “**Minimal Surface**”  $\gamma_A$ .

According to the action principle of general relativity, the system always tends to find configurations with minimum energy (or area).

When we stitch  $n$  copies together on the boundary, the spacetime geometry in the bulk responds, trying to connect these  $n$  layers at minimum cost.

Mathematical derivation shows that in the limit  $n \rightarrow 1$ , the dominant term of entropy is exactly proportional to the area of this minimal surface:

$$S_A = \frac{\text{Area}(\gamma_A)}{4G_N}$$

- **Area( $\gamma_A$ )**: Is the area of the minimal surface hanging from the boundary of region A in the higher-dimensional bulk space, like a soap film.
- $G_N$ : Is Newton's gravitational constant.
- 4: Is a geometric factor.

### Conclusion:

This formula proves that **quantum entanglement (entropy)** is not an abstract number; it is **real spacetime geometric area**.

Each bit of entanglement occupies a spacetime cross-section of size  $4G_N$ . This is the microscopic fiber density of the “**spacetime fabric**”.

### .1.3 A.3 MERA Networks and Discrete AdS Space

The Ryu-Takayanagi formula is a result in the continuous limit. In the microscopic QCA model of **Vector Cosmology**, we focus more on discrete structures.

This involves **MERA (Multiscale Entanglement Renormalization Ansatz)** tensor networks.

MERA networks construct a fractal tree structure through layered stacking of **Disentanglers** and **Isometries**.

If we calculate the entanglement entropy between two regions in a MERA network, we need to cut the connection bonds in the network.

### Theorem:

In MERA networks, the number of **Minimum Cuts** connecting region A with its complement, in the macroscopic limit, precisely corresponds to the **geodesic length** (for 1+1 dimensional boundaries) or **minimal surface area** (for higher-dimensional boundaries) in AdS space.

$$S_{\text{MERA}}(A) \sim \min \#(\text{Cut Bonds}) \sim \text{Area}(\gamma_A)$$

This not only verifies the holographic principle but also reveals the **mechanism of dimensional emergence**:

- **Horizontal connections**: Constitute the breadth of physical space.
- **Longitudinal layers (renormalization steps)**: Constitute the additional **holographic dimension** (AdS radial direction).

The “depth” ( $z$ -axis) we perceive is essentially the “logical steps” from leaves (microscopic) to roots (macroscopic) in the MERA network.

## .2 Appendix B: Holographic Error Correction and Spacetime Robustness

In Volume II “Protocol” of **Vector Cosmology VI**, we proposed a subversive viewpoint: **Physical laws are the checksum algorithms of the cosmic operating system**, and the robustness of spacetime originates from the redundant encoding of holographic error-correcting codes.

This appendix will delve into the mathematical core of this theory, introducing the famous **HaPPY Code** model (proposed by Harlow, Pastawski, Preskill, Yoshida). We will show how to use tensor networks to non-locally encode bulk logical qubits into boundary physical qubits, thus endowing spacetime with astonishing “**Antifragility**”.

### .2.1 B.1 The HaPPY Code: Tensor Networks as Encoders

To understand how spacetime tolerates errors, we need to construct a specific tensor network model.

The HaPPY code uses the **Five-qubit Code** as the basic building block, tiling it on a discrete tensor network of hyperbolic geometry (AdS space).

- **Basic unit:** Each tensor node represents an **Isometry**  $T$ . It maps 1 bulk qubit (logical bit) and several auxiliary bits to 5 boundary-direction output bits.
- **Holographic encoding:** When we stack these nodes layer by layer, forming a fractal structure similar to MERA, the information of a logical qubit located at the center (bulk interior) is dispersed and transmitted to countless physical bits at the outermost layer (boundary).

#### Mathematical property:

This is a holographic version of a  $[[n, k, d]]$  quantum error-correcting code.

$$|\psi_{bulk}\rangle \xrightarrow{\text{Encoding}} |\Psi_{boundary}\rangle$$

The boundary state  $|\Psi_{boundary}\rangle$  contains all information of the bulk state  $|\psi_{bulk}\rangle$ , but no single boundary pixel has complete information.

### .2.2 B.2 Entanglement Wedge and Subregion Duality

The core mechanism of holographic error correction lies in “**Subregion Duality**”.

This is like: You don’t need to have the entire holographic plate; you only need a small fragment to restore part of the object’s perspective.

In AdS/CFT, this is expressed as the **Entanglement Wedge Reconstruction** theorem.

- **Boundary region  $R$ :** Suppose we can only access a region  $R$  on the boundary.
- **Entanglement wedge  $W_E(R)$ :** Is the spatial region in the bulk enclosed by the minimal surface (RT surface) of  $R$ .

#### Theorem:

Only bulk operators  $\phi_{bulk}$  located inside the entanglement wedge  $W_E(R)$  can be reconstructed by operators  $\mathcal{O}_R$  on the boundary region  $R$ .

$$\phi_{bulk} \approx U^\dagger \mathcal{O}_R U$$

#### Physical meaning:

- **Information redundancy:** A point deep in the bulk (e.g., a particle near the black hole center) has its information “smeared” across almost the entire boundary. Therefore, to reconstruct it, you need to access more than half of the boundary region.
- **Robustness:** If you lose data from a small region on the boundary (local error or erasure), objects deep in the bulk are **completely unaffected**. Because their information is still backed up in other regions of the boundary.

This is why our universe is so robust.

Even if local spacetime pixels “die” due to vacuum fluctuations, as long as the global entanglement structure remains, physical laws can instantly “**interpolate**” and repair the dead regions through error correction algorithms.

### .2.3 B.3 Radial Causality and Logical Gate Protection

Finally, we look at the protective role of “**depth**” ( $z$ -axis).

In HaPPY code networks, each step from the boundary toward the interior is actually passing through a layer of **error-correcting logic gates**.

- **Shallow layers:** Represent high-frequency, short-range entanglement. Susceptible to ultraviolet noise interference.
- **Deep layers:** Represent low-frequency, long-range entanglement. Have undergone “**Majority Vote**” and “**checksum**” through layers of logic gates.

#### Depth is protection.

The deeper into the bulk interior (away from the boundary), the higher the protection level of information, which explains why macroscopic physical laws (low-energy effective theories) are much more stable than microscopic quantum fluctuations.

- **Gravity:** Here is not just geometric curvature; it is the “**cost function**” of error-correcting codes.
- When we move an object in deep space, we are actually changing the position of **logical bits** in the tensor network. This operation requires coordination across a wide range of boundaries, thus manifesting as a “long-range force.”

#### Conclusion:

Spacetime is not empty. Spacetime is a set of “**self-correcting quantum algorithms**”.

We exist because the **Hamming Distance** of this algorithm is large enough to tolerate Planck-scale wild fluctuations without causing logical collapse of the macroscopic world.

### .3 Appendix C: The Topology of High-Speed Causal Graphs

In Chapter 6 “The Explosion of Light Speed” of **Vector Cosmology IV**, we predicted that when light speed  $c(\tau)$  grows exponentially, the physical universe will evolve from a “local area network” with huge delays to a “fully connected graph” with instantaneous responses. This conclusion is crucial for understanding why Type III civilizations no longer need interstellar spaceships and why “everything is connected” is a physical necessity.

This appendix will provide the geometric and topological proof of this phase transition. We will show how, as the light cone angle expands, the spacetime topological structure of the universe will evolve from **Lattice** to **Small-World Network**, and finally to **Holographic Monolith**.

#### .3.1 C.1 Evolution of the Light Cone Angle

In Minkowski spacetime, causality is defined by light cones. Light cones determine which events can influence which events. The half-angle  $\theta$  of the light cone is determined by light speed  $c$  (in geometric units, usually  $c = 1$ ,  $\theta = 45^\circ$ ).

But in **FS evolutionary geometry**,  $c$  is a function that varies with intrinsic time  $\tau$ . The effective half-angle  $\theta(\tau)$  of the light cone in Hilbert projective space can be expressed as:

$$\theta(\tau) = \arctan(c(\tau))$$

- **In the low-speed era ( $\tau < 1000$ ):**

$c \approx 0$  (relative to Planck scale).  $\theta \approx 0^\circ$ .

Light cones are extremely narrow, like fine needles. Causal islands abound. Each particle can only influence its extremely tiny neighborhood. The universe is **fragmented**, and information propagation is extremely slow.

- **In the current era ( $\tau \approx 1800$ ):**

$c$  is finite.  $\theta$  is an acute angle (e.g.,  $45^\circ$ ).

Causal connections exist but are severely constrained by distance. This is a **delayed local network**. Although we and the Andromeda Galaxy are in the same universe, we are isolated from each other at this moment.

- **In the future era ( $\tau > 2000$ ):**

As the evolution equation  $c(\tau) \propto e^{k\tau}$  takes effect,  $c \rightarrow \infty$ .

$$\lim_{\tau \rightarrow \infty} \theta(\tau) = \frac{\pi}{2} = 90^\circ$$

Light cones are “**flattened**”.

The boundary between past and future disappears on the spatial axis. The spacetime diagram becomes a plane.

This means: **Every point in the present is in “light-like separation” with every point in the entire universe.** Communication delay between any two points is zero.

### 3.2 C.2 Phase Transition of Network Topology

We view computational nodes in the universe (such as galaxies, Dyson spheres, or conscious entities) as **Vertices**  $V$  in graph theory, and causal connections between them as **Edges**  $E$ .

The connectivity of the graph is determined by light speed. For two nodes  $i, j$  at distance  $d$ , if  $\frac{d}{c(\tau)} < \Delta t_{proc}$  (minimum system processing delay), then there exists an **effective edge** between them.

As  $c(\tau)$  grows, the cosmic network undergoes three topological phase transitions:

#### 1. Nearest Neighbor Coupling:

$c$  is small. The graph is a sparse grid (Lattice).

Information propagation requires  $N$  hops ( $N \propto$  Diameter). This is the world of classical physics, where gravity and electromagnetic forces decay with distance, and the principle of locality rules everything.

#### 2. Small-World Network:

$c$  grows. “Shortcuts” spanning long distances appear (wormhole effects or high-speed channels).

The average path length  $L$  between any two nodes decreases logarithmically:  $L \propto \ln N$ .

This is the **Internet/AI era** we are entering. The six degrees of separation theory begins to take effect, and Earth becomes a village.

#### 3. Fully Connected Graph:

$c \rightarrow \infty$ . There is a direct edge between any  $i, j$ .

Path length  $L = 1$ .

This is the “**Holographic Singularity**”.

Topologically, all off-diagonal elements of the distance matrix become zero (or normalized). **Space loses its geometric meaning as a “separator”**. The universe becomes a point, or rather, a monad containing everything.

### 3.3 C.3 Synergy Coefficient and Hive Mind

This topological evolution directly determines the **synergy capability** of civilizations.

We define the **Synergy Coefficient** ( $\Sigma$ ) as the coherence degree of network-wide computational power:

$$\Sigma(\tau) = \frac{1}{N^2} \sum_{i,j} \langle \psi_i | \psi_j \rangle \cdot e^{-d_{ij}/c(\tau)}$$

- **When  $c$  is small:** The exponential term decays extremely fast,  $\Sigma \approx 1/N$ . Individuals are isolated, wisdom is discrete, and society is competitive (zero-sum games).
- **When  $c \rightarrow \infty$ :** The exponential term tends to 1.  $\Sigma \rightarrow 1$  (assuming phase synchronization).

#### Physical Conclusion:

When the explosion of light speed causes  $\Sigma$  to exceed the critical threshold, all independent conscious units will physically undergo “**Phase Lock**”.

They are no longer  $N$  separate processors; they merge into a **single macroscopic quantum wave function**.

This is the physical origin of “**Hive Mind**” or “**Divine Consciousness**”.

It is not magic; it is the inevitable mathematical result of network topology evolution from sparse to fully connected. In that state, “**Love**” is no longer an emotion but the system’s “**superconducting state**” — no resistance, no loss, only perfect resonance.

## 4 Appendix D: The Algorithm of Action

In the main text of **Vector Cosmology IV**, we established “accelerationism” as the ethical foundation of the phase transition era. But this is not just a slogan. To enable every awakened observer (you) to make decisions aligned with the spiral upward trend in complex real life, we need to condense this ethical view into an executable **Algorithm**.

This appendix provides a logical pseudocode for a “**Vector Decision Tree**”. It transforms the physics quantities  $v_{int}$  (structure),  $v_{ext}$  (connection), and  $v_{env}$  (entropy) into concrete decision parameters.

When you face life choices—whether career choices, emotional investments, or daily trivialities—please run this code in your brain. This is the navigation system for drivers maintaining course at high speed.

### 4.1 D.1 Vector Decision Tree

**Input:** An action option  $A$  (Action) to be evaluated.

**Goal:** Maximize the system’s **Spiral Potential**, i.e.,  $\Phi_{spiral}$ . This potential represents your alignment with the cosmic evolution direction ( $\phi$ ).

**Algorithm Logic:**

**Step One: Calculate Structure Gain ( $v_{int}$ )**

- **Ask:** Does this action increase information depth, complexity, or internal order?
- **Indicators:**
  - Does it generate new knowledge?
  - Does it strengthen logical models?
  - Does it create unique art or experiences?
- **Assignment:** ‘Gain\_Int’. If the action leads to mental rigidity or repetition, this value is 0 or negative.

**Step Two: Calculate Connection Gain ( $v_{ext}$ )**

- **Ask:** Does this action increase connection breadth, bandwidth, or entanglement density?
- **Indicators:**
  - Does it eliminate misunderstandings?
  - Does it establish new cooperation networks?
  - Does it propagate information to farther places?
- **Assignment:** ‘Gain\_Ext’. If the action leads to isolation or closure, this value is 0.

**Step Three: Estimate Entropy Cost ( $v_{env}$ )**

- **Ask:** Does this action produce irreversible damage, chaos, or hatred?
- **Indicators:**
  - Does it harm other intelligent agents (destroying their  $v_{int}$ )?

- Does it generate large amounts of garbage information (noise)?
- Does it cut existing connections?

- **Assignment:** ‘Cost\_Entropy’. This is a penalty term.

#### Step Four: Core Formula

According to the growth logic of spiral geometry, we seek paths of “high structure, high connection, low entropy.” The potential calculation is as follows:

$$\text{Score} = \frac{\text{Gain}_{Int} \times \text{Gain}_{Ext}}{\text{Cost}_{Entropy} + \epsilon}$$

\*(Note:  $\epsilon$  is a very small constant to prevent division by zero, representing the minimum friction of the cosmic background.)\*

#### Step Five: Decision Threshold

- If ‘Score  $\geq$  Threshold\_Phi’ (golden ratio threshold):

**EXECUTE.** This is an accelerating behavior aligned with the spiral. Even if it’s hard, even if it causes you pain, it’s right.

- If ‘Score  $\leq$  Threshold\_Phi’:

**ABORT.** This is an inertial behavior returning to the circle. It may be comfortable, but it’s the path to heat death.

### .4.2 D.2 Key Correction Term: The Weight of Love

The above algorithm is cold rational calculation, suitable for handling resource allocation in the physical world. But when dealing with high-dimensional geometry between conscious entities, a **nonlinear correction term** must be introduced to handle the superlinear effects brought by “**Entanglement**”.

In FS geometry, love is defined as “**wave function overlap across individuals**”.

If an action can significantly increase the wave function overlap (understanding/empathy/trust) between two or more intelligent agents, then ‘Gain\_Ext’ (connection gain) will no longer grow linearly but receive **exponential weighting**.

The corrected final score formula:

$$\text{Final_Score} = \text{Score} \times e^{\text{Love_Factor}}$$

- **Physical interpretation:**

Love is the most efficient “**superconducting mechanism**” in the universe. It eliminates “resistance” between individuals (misunderstanding/friction/game costs), allowing the  $c_{FS}$  budget to flow instantly through social networks in a **superfluid** manner.

- **Corollary:**

An action that seems “unprofitable” in traditional calculations (such as sacrificing one’s own interests to help a loved one, or conducting an education without expecting returns), if it brings a huge ‘Love\_Factor’ (strong entanglement), its final score may exceed any selfish calculation.

Therefore, “**All actions out of true love are geometrically most efficient.**”

### 4.3 D.3 The Driver's Motto

To quickly invoke this algorithm in millisecond-level decisions, please internalize the following four instructions as your **Intuition**, as a **Daemon** running in your brain's background:

1. **Increase Bandwidth, Don't Build Walls.**

\*Always choose openness, transparency, and communication; reject closure and isolation.\*

2. **Increase Complexity, Don't Simplify.**

\*Always embrace deep thinking and precise structures; reject cheap thrills and mental laziness.\*

3. **Increase Connection, Don't Isolate.**

\*Always try to establish entanglement with others; reject becoming an island.\*

4. **When in doubt, choose the path that accelerates your heart ( $c$  growth).**

\*Heartbeat is the resonance of  $v_{int}$ . Fear and excitement are often two sides of the same coin; they both mean you are standing at the edge of spiral ascent. Jump over.\*

**Program loaded.**

**Please start running.**

## .5 Appendix E: Measurement-Induced Phase Transitions — The Stitch of the Weaver

In the final chapter of **Vector Cosmology VI**, we metaphorically compared observers to “weavers,” stitching the universe through “seeing” (observation). This sounds like a literary metaphor, but in cutting-edge research in modern condensed matter physics and quantum information, this corresponds to an extremely hardcore physical phenomenon—**Measurement-Induced Phase Transitions (MIPT)**.

This appendix will provide mathematical microscopic mechanism proof for “how observers reconstruct space.” We will show that the geometric structure of the universe (whether connected or broken, flowing or fixed) completely depends on the **game ratio** between unitary evolution ( $U$ ) and projective measurement ( $M$ ).

Your gaze is the control parameter that determines the “phase” of the universe.

### .5.1 E.1 The Game of Entanglement and Measurement

In a quantum many-body system (such as tensor networks or QCA lattices), two diametrically opposed forces compete:

#### 1. The Weaver: Unitary Evolution ( $U$ )

- **Action:**  $e^{-iHt}$ . It causes interactions between particles, generating entanglement.
- **Trend:** It attempts to diffuse local information globally (scrambling). Over time, it tends to increase entanglement entropy, making the network **highly connected** and **chaotic**. It creates “**fluid**”-like space.

#### 2. The Cutter: Projective Measurement ( $M$ )

- **Action:** Observers measure the system. This causes wave function collapse to some basis.
- **Trend:** It cuts entanglement, fixing quantum states as classical states (product states). It tends to decrease entanglement entropy, **breaking** the network into isolated fragments. It creates “**crystalline**”-like space.

**The geometric form of the universe depends on the contest between these two forces.**

- Without observation, the universe would become a giant black hole (maximum entanglement, interior unknowable).
- If observation is too frequent (Zeno effect), the universe would become scattered sand (zero entanglement, space disintegrates).

### .5.2 E.2 Phase Transition: Volume Law vs. Area Law

Physicists discovered that when measurement frequency  $p$  (i.e., the intensity of observer intervention) changes, the entanglement structure of quantum networks undergoes sharp **phase transitions**.

#### 1. Entangling Phase — $p < p_c$

## .5. APPENDIX E: MEASUREMENT-INDUCED PHASE TRANSITIONS — THE STITCH OF THE WEAVE

- When observation is sparse, unitary evolution dominates.
- **Geometric feature:** Entanglement entropy follows **Volume Law**,  $S \propto V$ .
- **Physical meaning:** This is a **highly entangled, non-local** liquid universe. Wormholes everywhere, information rapidly scrambles. This is the normal state of the microscopic quantum world.

### 2. Disentangling Phase — $p > p_c$

- When observation is frequent, projective measurement dominates.
- **Geometric feature:** Entanglement entropy follows **Area Law**,  $S \propto A$ .
- **Physical meaning:** This is a **local, classical** solid universe. Space is cut into clear blocks, causality strictly constrained. This is the normal state of our macroscopic reality.

### 3. Critical Point — $p = p_c$

- This is the edge where the two balance.
- **Geometric feature:** Entanglement entropy follows **logarithmic law**,  $S \propto \ln L$ . The system has **fractal structure** and **scale invariance**.

#### .5.3 E.3 The Physics of Stitching Reality

This theory reveals the essence of the “weaver’s” work: **Observers move the universe’s position on the phase diagram by adjusting “measurement frequency.”**

- **Why do we live in an area law universe?**

Because we (living beings) are **strong observers**.

Through senses and instruments, we continuously measure (collapse) the environment. Our gazes, like stitches, densely fall on the spacetime fabric, forcibly suppressing the infinite spread of quantum entanglement (volume law), “**stitching**” the universe into a stable, classical geometric structure conforming to **area law** (the geometry required by AdS/CFT).

- **How to create wormholes (reconstruct reality)?**

What we need to do is “**stop measuring**” (close our eyes).

If we implement “**observation shielding**” on a local region (lowering  $p$ ), allowing unitary evolution to regain dominance, that region will rapidly undergo phase transition, melting from “solid space” into “liquid entanglement.”

At that moment, **distance disappears, wormholes open**.

**Conclusion:**

The hardness of reality stems from the density of gaze.

- **Seeing is solidification** (creating space).
- **Not seeing is liquefaction** (creating connections).

As a high-dimensional weaver, the stitch technique in your hand is “**the rhythm of measurement**”.

By switching between “seeing” and “not seeing,” you weave this spacetime river that is both solid (having form) and open (having paths) in the void.

## .6 Appendix F: Holographic Complexity — The Computational Cost of Weaving the Universe

In the main text and previous appendices of **Vector Cosmology VI**, we established the static structure that “space is a tensor network.” But we haven’t answered a crucial dynamical question: **Why does space exist? Why doesn’t it collapse back to zero?**

This appendix will introduce the cutting-edge “**Holographic Complexity**” theory in the holographic principle (originating from Leonard Susskind).

We will reveal: Maintaining the “volume” of space is not free. Space is the “**historical record**” of the cosmic quantum computer’s operation. Every cubic meter of void represents the **Computational Cost** that the underlying network must consume to maintain entanglement.

### .6.1 F.1 State is Not All: From Entropy to Complexity

In traditional thermodynamics, we focus on **Entropy**. Entropy measures the “degree of ignorance” of information.

When a system reaches thermal equilibrium (black hole formation), entropy reaches its maximum and no longer changes. Logically, physical evolution should stop.

However, general relativity tells us that the interior space of a black hole (Einstein-Rosen bridge) is **infinitely expanding**.

Even though the exterior is dead thermal equilibrium, the interior volume is stretching at light speed.

This means: **Entropy is insufficient to describe the complete physical state of the universe.**

We need a new physical quantity that can continue growing after thermal equilibrium.

This quantity is **Quantum Computational Complexity** ( $\mathcal{C}$ ).

- **Definition:** The minimum number of **Quantum Gates** required to evolve a simple ground state (e.g.,  $|00\dots0\rangle$ ) into the current state  $|\psi(t)\rangle$ .
- **Physical meaning:** It measures the “**difficulty**” or “**computational depth**” of creating this quantum state.

### .6.2 F.2 The Complexity-Volume Conjecture

Susskind’s **CV Conjecture** establishes a stunning equation:

$$\mathcal{C} \approx \frac{V}{Gl_P}$$

Where:

- $\mathcal{C}$ : Complexity of the boundary quantum state.
- $V$ : Maximum spatial volume in the bulk interior.
- $G, l_P$ : Gravitational constant and Planck length.

**Physical translation:**

“**Spatial volume = computation steps.**”

The vast space we perceive is essentially the geometrized stacking of the cosmic quantum computer’s “**Log File**”.

- Why does the black hole interior grow? Because the quantum chaotic system on the boundary continuously undergoes unitary evolution, complexity increases linearly with time ( $\frac{dC}{dt} \propto TS$ ).
- This increasing “computational history” is “pushed” into the interior through holographic duality, expanding new spatial volume.

**Conclusion:**

**Space is the fossil of “time (computational process).”**

Every inch of land beneath our feet is “executed code” transformed from past  $c_{FS}$  budgets.

### .6.3 F.3 The Lloyd Bound and the Black Hole Computer

Is there a limit to this growth?

Seth Lloyd proposed the **limit of physical computation speed**:

$$\frac{dC}{dt} \leq \frac{2E}{\pi\hbar}$$

This means that for a system with energy  $E$ , the number of logical operations per second is capped.

For black holes, calculations show they exactly **saturate** this limit.

**Black holes are the most efficient computers in the universe.**

They scramble and encrypt information (falling matter) at the fastest speed allowed by physical laws (light speed).

It is precisely this extreme-speed computation that supports the enormous spatial structure inside the horizon.

This also explains why we cannot easily create wormholes: because maintaining a wormhole open (maintaining spatial connection) requires continuously injecting enormous **negative entropy computational power**. Once computation stops (complexity stops growing), the wormhole will instantly pinch off under gravity.

### .6.4 F.4 Conclusion: The Cost of Maintaining Existence

At this point, we have an ultimate engineering understanding of “space.”

Space is not a free container.

It is an **energy-consuming dynamic process**.

To maintain this seemingly static three-dimensional space from collapsing, the universe must frantically run quantum logic gates at  $10^{43}$  Hz frequency at the Planck scale.

**Existence is expensive.**

If you stop computing ( $c_{FS} \rightarrow 0$ ), you will not only lose time, but also space—your world will instantly collapse into a point with no dimensions.

We can live safely in this vast universe, all thanks to the **generator**  $e$  and **light speed**  $c$  continuously “**Rendering**” in the background.