<u>**Specifying a Quantum of Consciousness**</u>

<u>The Conscious, Observership-Dependent Universe Described by a Novel Interpretation of QFT as a Hierarchy of Fields as Rotational Projections of the Scalar Field onto 3 Spatial Dimensions</u>

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<u>**Abstract**</u>

Using a model of the universe where CPT symmetry is preserved through the bang, we postulate a novel interpretation of QFT where there exists a hierarchy of the quantum fields. We propose a universe where the scalar field rotates in the bulk. Viewing this field in an observership-dependent geometry results in all other quantum fields as projections in 3 spatial dimensions. The path integral of rotational paths is the structure of a phase singularity from which scroll waves propagate in 3 dimensions, playing a causal role in particle generation. All fermions have a twisted filament which requires a counter twisted filament to be coupled to it. Via this mechanism all fermions can be viewed as simple neural networks with some fundamental sum of entropy. This intrinsic entropy translates to all fermions having some fundamental phi value. In the absence of contributing to the phi of a higher order system, all fermions should be considered a Maximally Irreducible Concept System. We suggest that this system specifies a quantum of possible consciousness in the universe.

Introduction

We know that we are conscious. We imagine that there must be some sort of explanation of this phenomenon. In seeking insight into this explanation we begin by determining what aspects of the particular consciousness with which we are familiar, that is our own consciousness, must be universal to any consciousness in order for that phenomenon to be called consciousness. We asked ourselves, by considering our own consciousness, what parts of our consciousness could not be divorced from our experience without fundamentally changing our experience to something that could no longer be considered consciousness? What parts of our consciousness are so deeply intrinsic to our experience, that anything else that could rightly be considered consciousness, not necessarily consciousness like our own, but any kind of consciousness at all, must also possess those parts of consciousness?

The conclusions that we reached are that at the core of our own consciousness are 2 fundamental aspects of our experience:

1. Consciousness endows the agent with some ability for reflection on or awareness of oneself. This idea is embodied in what is possibly the most well-known sentence in all of philosophy: “I think, therefore, I am.” In order for there to be an experience of consciousness, there must be some kind of awareness of the experience.
2. Consciousness endows the agent with a perspective that is uniquely prescribed to that agent. Consciousness is a view from within, simultaneously looking inward, at a sort of mental reflection of oneself, and outwards, from the vantage point of being oneself. There is no way to share with another agent the first-person perspective that is unique to oneself, and there is no way for oneself to experience the unique perspective of another agent’s experience.

It seems apparent that any novel ideas that might further our understanding of phenomenal consciousness will likely provide a mechanism for these aspects of conscious experience. This is exactly what we are proposing in this work; a mechanism at the quantum scale of our material universe whose structure appears to mimic the experience of being conscious.

What we are proposing, at least on the surface, seems to be an astounding, outlandish description of a universe that creates itself, with consciousness embedded in the observable universe as deeply as mass or charge. As the reader makes progress through this explanation of our theories, we hope that what begins as an outlandish claim will start to seem an imaginable prospect, then plausible, reasonable, likely, and eventually we hope to show that given the premises we will describe, what begins as an outlandish claim will eventually take shape as a set of unavoidable conclusions.

We have taken measures throughout this work to describe ideas that are most often discussed in the language of abstract mathematics and to conceptualize these ideas, often times using visual models to convey complex math visually, translating them to mediums of geometry and topology, where math can be more easily visualized. We have taken a great effort to do this to the end of writing a theory of consciousness that is generally accessible to an audience of philosophers more likely to be intimately familiar with the hard problem of consciousness.

We will start by describing a model of the universe that has been recently proposed by cosmologists as an answer to the problem of dark matter. We adopt this model in our answer to the hard problem of consciousness. In the inflationary model, which is the model of the universe that most people would be likely to be familiar with, there is a violation of time symmetry at the bang. The CPT symmetric model avoids this symmetry violation by extending through the bang and simultaneously generating a universe/anti-universe pair with transformations for charge conjugation, parity and time reversal symmetries. It is the inherent duality of this model that will be the foundations that allow for the dual-natured existence of a conscious agent who holds a dual perspective of looking out from oneself and in at oneself from a single vantage point of being oneself.

In the next sections we will give a primer for understanding some key ideas from the realms of physics and math which will be necessary to build upon in our work. The first of these will be a primer for the standard model of particle physics, and what distinctions will become important between scalar, vector and spinor particles, and likewise between the fields that generate these particles, when considering a hierarchical take on quantum field theory that posits that the scalar field is the most fundamental of the particle fields, and that all other fields are projections of the scalar field in an observership-dependent geometry. The next will be a primer for a mathematical tool commonly used in quantum mechanics; the path integral formulation. We will describe the key ideas used in finding the path integral, and then we will apply these ideas in a novel way by conceptualizing what it might mean to the formulate the path integral of a rotational path through the bulk.

Moving on we will provide a primer for entropy, and specifically Shannon entropy, to ensure that all readers are familiar with what it means to quantify the amount of potential information in a system as Shannon entropy, which is the basis of Information Theory. After we've ensured that all readers have an understanding of entropy as information we will be able to move forward onto describing what is likely the most profound discovery in the natural sciences since quantum mechanics; the holographic principle. By describing entropy as information, and quantifying that information in a region of space that can be described equally by density or by volume, this region being a black hole, physicists in the 1990's discovered that if you describe the sum of entropy that should seemingly be in a black hole using 3 spatial dimensions, that value is much greater than if you solved the same problem instead using the mass of the black hole. In trying to reconcile this conundrum, physicists were led to the amazing discovery of the holographic nature of our universe, as a projection into 3 spatial dimensions from information encoded on just 2 dimensions. This mind-bending idea will provide a basis for our posit that the observable universe is a projection into 3 spatial dimensions that relies on observership within the universe. We propose that the duality within a fermion's phase singularity endows that fermion with a special role as an observer, and that observership is then given causal power in generating the 3 spatial dimensions of the universe in a geometry that is coherent with all observers in all frames, in effect creating objective reality.

From there we will delve into the dynamics of a kind of oscillation called a scroll wave. These fascinating oscillations provide local solutions for field equations. In other words, these oscillations are the kind of waves that the universe is made of. We will show that the particular brand of scroll wave that produces a particle in that is described mathematically as a spinor particle, and classified in the standard model as a kind of particle called the fermion, requires a phase singularity at its core which amazingly seems once again to form a structure which mimics what it feels like to be conscious. What's truly astounding about this is that these happen to be the type of oscillations specific to all particles of matter that exist in the universe. Anything with any substance to it in the cosmos, any of the fundamental components of anybody that is having a conscious experience of reading this, as you are right now, can be described mathematically by a particular kind of wave in a field that has at its core a phase singularity, and this phase singularity's ability to mirror its own behavior around any arbitrary coordinate seems to divide one, unified phase singularity at the core of a scroll wave into 2 parts; one half saying “I think” and the other saying “I am.”

In the final chapters of this work we take the proposals that we have built, and we will look at them through the lens of Integrated Information Theory. While our work doesn’t rely at all on an acceptance of IIT, we will show that applying our ideas to IIT or a theory of consciousness like that aims to quantify a system’s ability to become conscious, will lead to the conclusion that any fermion should be granted a fundamental value of consciousness. Applying the notions of IIT and similar theories seems to indicate that there is a quantum unit of consciousness prescribed to every particle of matter in the universe. In the closing pages of this paper, we will advocate for our particular interpretation of this work as a panpsychist take on consciousness. This work could certainly lends itself well to the materialist, as it specifies a physical mechanism for generating consciousness that can be quantified and described mathematically. The dualist could likewise say that the dual nature of the fermion’s phase singularity and the observership-dependent projection of the universe into 3 spatial dimensions closes the causal loop between the material and immaterial worlds. We, however, are sympathetic to the notion that what we are proposing in this work seems to indicate that consciousness is deeply embedded in the universe, and that without a conscious observer, there is no material universe. The conclusions that we were led to lead us to the further conclusions that the material *is* the immaterial. The universe *is* consciousness.

Chapter 1

The CPT Symmetric Model of the Universe

In recent years scientists at the Perimeter Institute have proposed a model of the universe that preserves CPT symmetry through the Bang. This model of the universe will be the material framework that we will be assuming in this paper. In this section, we will describe this model in broad terms. Later on in this paper, we will propose our own perspective on the CPT model. Our aim will not be to modify the details of the this model. Our aim will be to, after we have described other prerequisite ideas, give an interpretation of Boyle and Turok's work which will be consistent with the philosophical implications of consciousness' role in the universe that we postulate in our own work.

Here we intend only to give a general picture of the CPT symmetric universe which we will expand on throughout the paper. We start by giving a description of the most generally accepted model of the universe; the inflationary model, so that we might contrast the CPT symmetric model against the more familiar inflationary model.

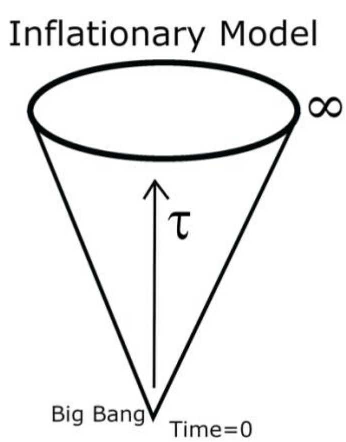

Figure 1.1

In the inflationary model time symmetry is spontaneously violated at the bang. Since time did not exist prior to the big bang, this model describes a universe in which the bang is the origin of time; the coordinate 0 on the temporal axis. Figure 1.1 shows this model of the universe. In this model time begins at the bang and increases with the expanding universe, starting with a value of 0 at the bang and increasing, unidirectionally, towards infinity.

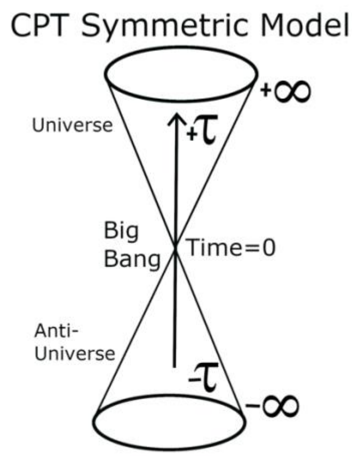

Figure 1.2

Figure 1.2 shows the CPT symmetric model. This model avoids the violation of time symmetry via the inclusion of an anti-universe. The anti-universe is a mirror image of the universe, with reflections for all values of charge, parity and time. Rather than tau beginning at the bang and extending towards infinity tau extends from -∞ *through* the bang and towards ∞.

<u>CPT Transformations</u>

We can build an understanding of this universe by first providing an explanation of what exactly CPT symmetry is. CPT symmetry is the combination of reflections of charge conjugation, parity transformation and time reversal. (It is more useful to think of time reversal less like rewinding a video and more like reversing the trajectory of all particles.) Before we gain an understanding of why the combination of these 3 symmetry transformations makes possible an anti-universe, we will explore each of these symmetries on their own.

Charge Conjugation Symmetry

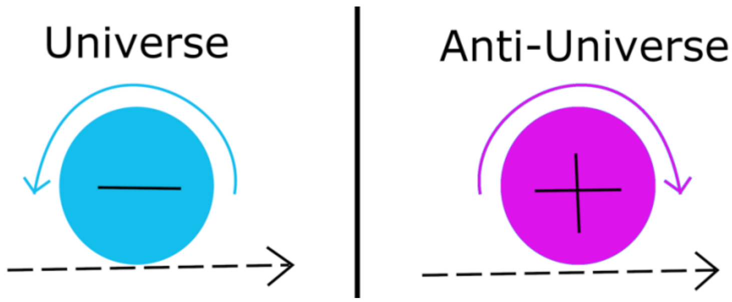

Figure 1.3

Charge conjugation symmetry is the idea that if the charges were flipped on all charged particles in the universe, things would seem just as they do now. Before we understand this type of symmetry, we should first get a bit of a primer on what charge is. The fundamental origins of charge is a bit of an open question, although we can give a "good enough" description of what causes charge by saying that if a particle is spinning against the direction of its motion along field lines, as shown in the frame of the left side of Figure 1.3, the particle will have a negative charge. If the particle is spinning with the direction it moves in, then the particle will have a positive charge.

If you were to try to swap the electron cloud of an atom with cloud of positively charged positrons, the antimatter counterpart to the electron, the positively charged nucleus would repel the positrons and the atom wouldn't hold together. If, however, you were to swap the color charges on the quarks that make up the protons and neutrons (color charge is the specific brand of charge unique to particles that take part in strong force interactions, like quarks) the nucleus of that antimatter atom would hold a negative charge and could balance that charge with a positron cloud just the same as atoms in the universe balance their positive charge by attracting electrons.

With this in mind, we can understand that Figure 1.3 shows a symmetry of charge conjugation. If every particle in the universe simultaneously had a reflection of the sort shown between frames in Figure 1.3, all the particle interactions of the universe would behave exactly the same as they do now, only with opposite signs for all charges.

Parity Symmetry

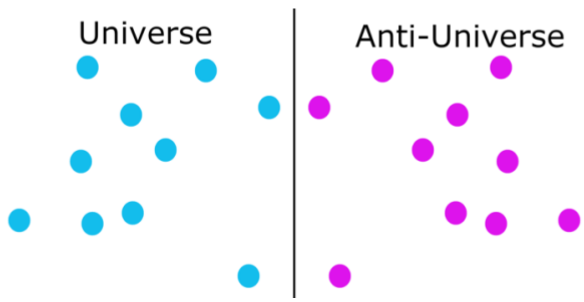

Figure 1.4

Figure 1.4 shows a symmetry of parity transformation. Parity is the idea that if everything in the universe were arranged as a mirror image reflection, everything would still behave the same. It’s important to note that in the graphic above there is a reflection across just 1 axis. This is simply to help visualize parity transformation. Symmetry of parity transformation requires a reflection across any arbitrary point, reflected across 3 axes, in the 3 spatial dimensions.

Time Reversal Symmetry

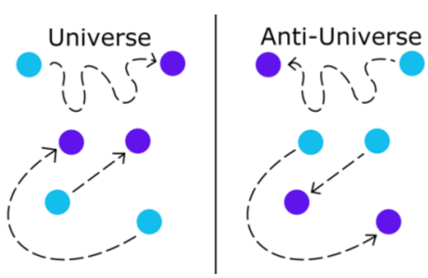

Figure 1.5

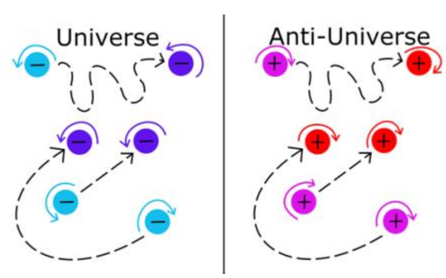

Figure 1.6

Time Reversal symmetry isn’t exactly what might come to mind when you think of time reversal. Time reversal symmetry is reversing the motion of all particles. That is, retracing the spatial movement of a particle, shown in Figure 1.5, and reversing the spin of a particle, shown in Figure 1.6. Keep in mind that reversing the spin of a particle will flip its charge because by reversing is spin, we are reversing the spin relative to the direction that its moving relative to its direction of travel along field lines. We can avoid flipping the particle's charge by also its direction of travel. It is the combination of reversing these 2 types of motion that constitutes a time reversal symmetry. A more technical description of time reversal symmetry is a symmetry transformation which constitutes a reversal of the momentum and spin of all particles.

Time reversal is the same as a combination of charge conjugation symmetry and parity transformation. CP symmetry is equivalent to Time Reversal symmetry.

Combining C, P and T Transformations

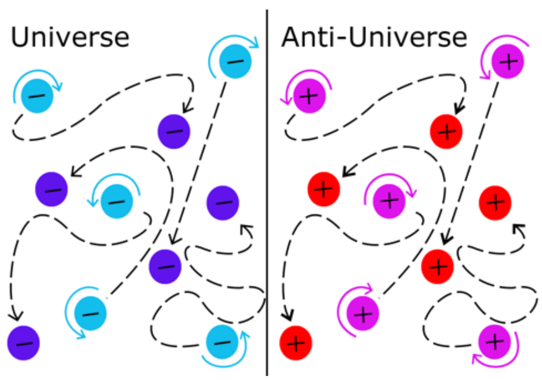

Figure 1.7

The combination of these symmetries is in some ways like looking at the reflection of a reflection. The result of combining these symmetries is that any system is indistinguishable from its CPT reflection.

We can start building to a CPT symmetry by conducting a charge conjugation symmetry, as depicted in Figure 1.7. Here all the particle spins are reversed, resulting in all charges being flipped.

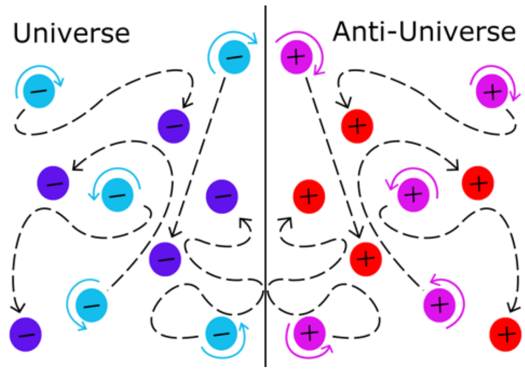

Figure 1.8

Next, we conduct a parity transformation. This results in everything being transformed into the mirror image of itself. Again, this image is reflected across just 1 axis. The important thing to keep in mind is that in a parity transformation any object's momentum is carried in the exact opposite direction.

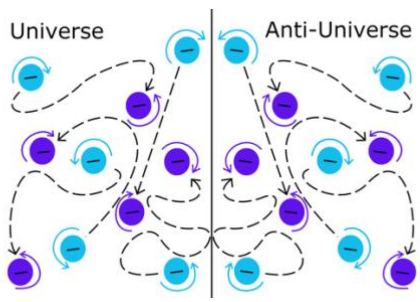

Figure 1.9

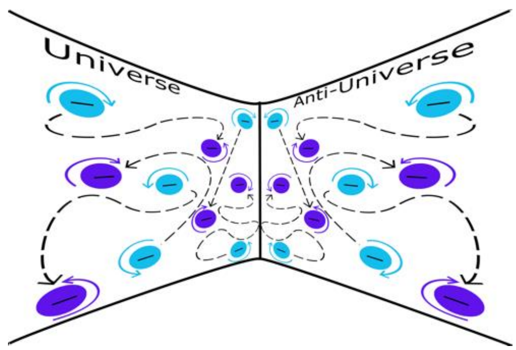

Figure 1.10

In Figure 1.9 we add a symmetry of time reversal. Once again, we reverse the spin and momentum of all particles. This leaves us with a system that looks and behaves exactly like the original. In Figure 1.10 we imagine folding this image across the center line, so that the image is 2 sheets laid directly on top of one another. In doing this we see how every particle is perfectly paired with another particle on the other sheet of the 2-sheeted universe. After performing reflection transformations of charge, parity and time, every particle in the universe is matched up perfectly with its counterpart in the anti-universe, with universe/anti-universe counterparts having momentum carrying each particle in the same direction, as well as spinning in the same direction relative to the direction of their momentum, resulting in the universe/anti-universe particles generating equivalent charges.

<u>The 2-Sheeted Universe</u>

What we've discussed so far has covered the nature of the universe/anti-universe system locally. To better understand this system generally we will consider this model of the universe on the cosmological scale.

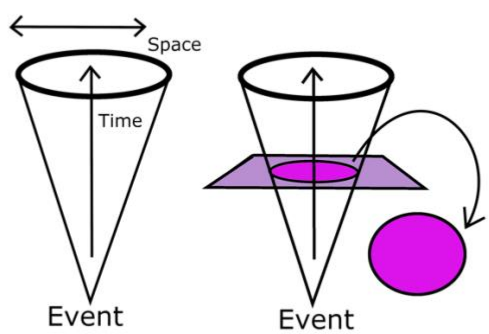

Figure 1.11

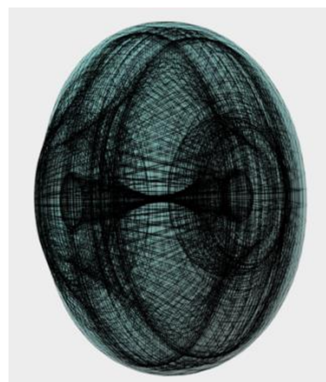

Figure 1.12

When thinking about the structure of the universe/anti-universe pair, a helpful mental picture to paint is the idea of a time cone. A time cone, sometimes called a light cone, is the idea that when any event takes place at some spatiotemporally unique coordinate, it has causal potential moving unidirectionally forward in time, represented by the length of the cone, and expanding outwards spatially from the 3-dimensional location of the event, represented by the radius of the circle found by the intersection of a plane perpendicular to the time axis, with the location of the intersection corresponding to a particular time after the event. See Figure 1.11.

The description of a time cone that we have provided is a very technical one, and it comes across as pretty dense. The technical description is important to have on record because we'll need to have that understanding in order to build up other ideas. Hidden in the dense jargon is what is really a very intuitive concept. The universe is causal. Physics is all cause and effect, and it must be in that order. Causes have to precede effects on a timeline that moves in only 1 direction. It wouldn't make much sense to have an effect come prior to the action that caused that effect. A time cone is just a way of visualizing this principle. If some event, Event A, acts as a cause, then every event in a chain of cause and effect moving outwards as the radius of a sphere expanding in 3 spatial dimensions from the spatial coordinates where Event A occurred, with the radius of that sphere being the speed of light multiplied by the amount of time that has passed since Event A, and forward in time, has the possibility that Event A might have had some causal role in it.

The reason that the light cone moves outwards as the radius of a sphere, where the radius of the sphere is $c \times (Time\ since\ Event\ A)$ is that for anything to have a causal role in any effect there must be some sort of interaction that occurs, and the fastest that anything can possibly be communicated or have influence on anything else is limited by the speed of light.

Figure 1.11 is a 2-dimensional representation of a 4-dimensional idea. To make this work, we need to put time on one axis, and the 3 spatial dimensions on another, single axis. To get a better idea of what the structure of a time cone for the universe would be like, we need to try to think about a 4-dimensional hypercone. Start by thinking about a 2-dimensional plane. Let's say a tabletop. On a table we can move things in 2 dimensions, we'll assign these the x-axis and the y-axis. The x and y axes are perpendicular to one another. Presumably there is a floor underneath our table. The floor is also a 2-dimensional plane. The difference between the 2 is their respective locations on another axis, an axis which is perpendicular to both the x-axis and the y-axis. This is the height dimension. We'll assign this the z-axis. From the plane of the table there is a parallel plane below us, the floor, and a parallel plane above us, the ceiling. We can have parallel planes on different coordinates on the z-axis because there are 2 directions that we are able to move in with the addition of a dimension, both of which are perpendicular to all other dimensions.

We can't see a 4-dimensional object the same way we can see a 3-dimensional object. We have to do our best to imagine a dimension that has 2 directions, each of which are perpendicular to the 3 spatial dimensions.

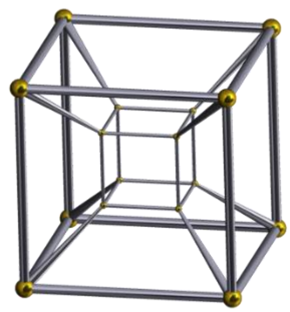

Figure 1.13

The usual way this is done is by placing edges extending outwards from the center and in towards the center, at 45°, at the vertices of a cube. An example of this shape, a tesseract, is shown in Figure 1.13. It becomes more difficult still to visualize a 4^{th} dimension when we are dealing with shapes that have curves instead of straight edges and flat faces. Looking at a hypercone straight along the length axis of the cone, you'd be looking into a cone that is set into a sphere. Looking at a hypercone from the sides, top or bottom, it would be identical to a hypersphere. As where our time cone in Figure 1.11 expands upwards on the time axis, our representation of a hypercone in Figure 1.12 curls back on itself as it expands outwards. It curls back so that what would be the largest part of the cone in 3 dimensions, the upper edge of the cone, comes back to a single point in 4 dimensions. The hypercone curls back so that the upper edge of the cone all comes together at the back side of the origin of the cone. The 3-dimensional representation of this is essentially 2, 3-dimensional conic shapes inside of a sphere.

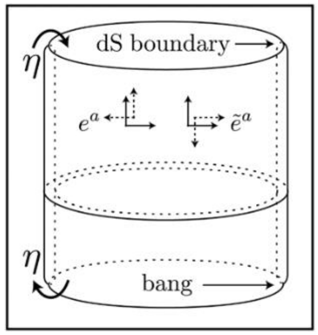

Figure 1.14

The point in the hypercone where, in our 3-dimensional representation, the farthest boundary of the cone curls back and comes together at a single point, on the back of the origin of the cone, is a place where there is a maximum amount of curvature, where the curvature of the shape has a boundary. It's similar to the idea of walking north around the globe. At some point, walking on a curved globe, you'll reach a point, at the north pole, where you cannot continue to walk north anymore. Any continuation of your path will be in the opposite direction.

A map of spacetime with constant positive curvature, taking a spherical shape, is called de Sitter space. Figure 1.14 is taken from Boyle and Turok's article "Two-Sheeted Universe, Analyticity and the Arrow of Time." This is a depiction of their model of the two-sheeted universe. Notice that the big bang and the de Sitter boundary are placed on opposite sides of the 2-sheeted picture of the universe. Thinking of these boundaries in the 4-dimensional hypercone, the bang can be thought of as the origin of the time cone, and the de Sitter boundary would be the point where the farthest edge of the cone reaches a curvature boundary. Continuing on any path that reaches that boundary would necessarily bring you back in the opposite direction. Boyle and Turok propose a model of the universe where this happens via that path continuing beyond the de Sitter boundary, but on another sheet of the universe, where crossing this boundary brings you back in the other direction, towards the bang, towards the origin of time, backwards in the time cone of the universe. In order to do this, crossing the de Sitter boundary results in reflections of charge conjugation, parity transformation, and time reversal.

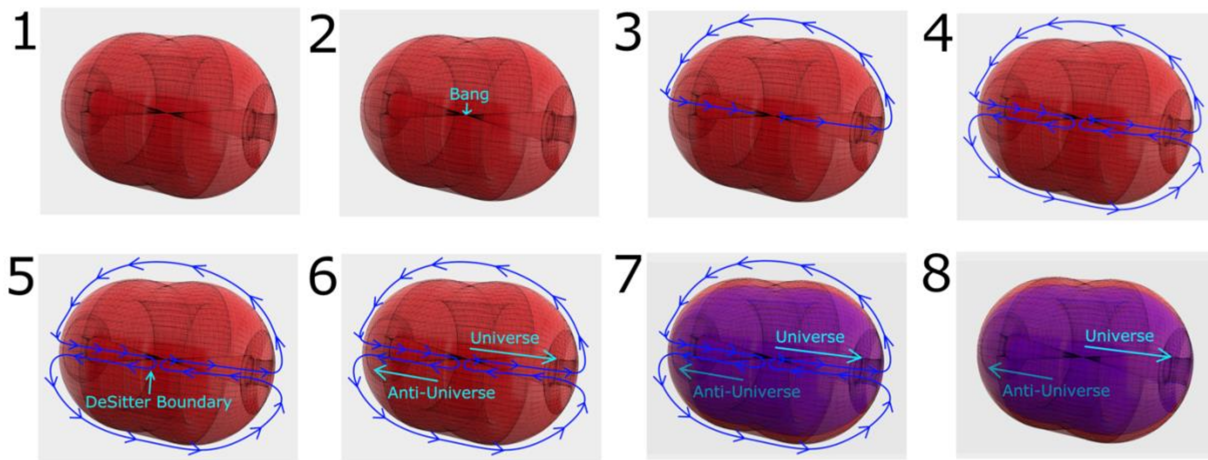

Figure 1.15

In Figure 1.15 we can get an idea of what this model of the universe might look like. Frame 1 shows the structure of a hypercone. In frame 2 we see that the origin of the hypercone is the big bang. Frame 3 shows how the 4-dimensional hypercone would expand outwards, and curl back towards its origin, coming at it from the other direction. Frame 4 shows how a 2-sheeted universe would allow a path to continue beyond the curvature boundary, by the path continuing on another sheet of the hypercone. Frame 5 shows this boundary, the de Sitter boundary, being located at the origin of the hypercone. Frame 6 shows how the continuation of a path beyond the de Sitter boundary would create a universe/anti-universe pair. Frames 7 and 8 show how the universe/anti-universe pair exists as 2-sheets of the same universe system, with every spatiotemporally unique coordinate in any half of the system, in the universe or anti-universe, matching up with its partner coordinate in the other half of the universe/anti-universe pair.

This model of the universe is the framework in which we will be building our case for a panpsychist take on consciousness. In the next sections we will show how this model of the universe leads to the conclusion that any fermion, any particle of matter that exists in the universe, has some quantifiable value of potential for consciousness that it can contribute to a system. We will show that the logical extension of this is that in the absence of contributing to the consciousness of a higher order system, any matter particle can rightly be attributed with some amount of consciousness. In the coming sections we will use the model of the universe which we have described here, along with Integrated Information Theory, to show that the potential for consciousness assigned to any fermion will specify the quantum of consciousness that exists in the universe.

Chapter 2

Scalars, Vectors and Spinors

In this section we will provide an explanation of scalars, vectors and spinors, bridging the ideas of these objects as mathematical concepts to their physical manifestations. We will specify the types of standard model particles which are associated with each.

Scalars

When discussing the objects in this section, it will be useful to think of a space, a box, a room, whatever structure you can think of to contain some spatial volume. Each object described can be thought of as occupying some particular coordinate in that space.

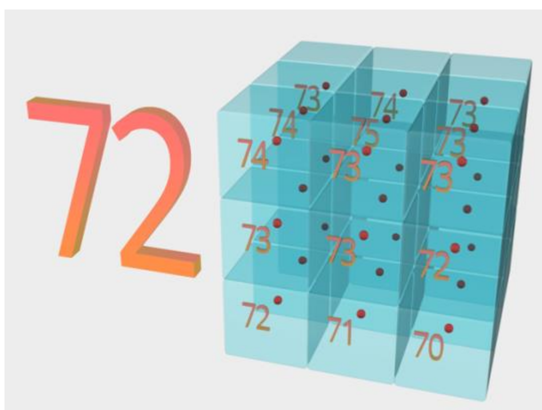

Figure 2.1

The coordinate that we associate with any scalar is given a numerical value. Coordinates in a scalar field can be thought of as that point in space having some value associated with it. For example, imagine the temperature of the room you are in is 72°F. That figure is a measure of the average kinetic energy of air molecules in the room. If the average temperature of the room is 72°F, then there might be places near the floor where the air is colder at that particular point. There might be some coordinate near the floor where the temperature is 70°F. The warmer air in the room will rise and near the ceiling the temperature might be 74°F. Even though the average temperature of the room is 72°F, if you think of the room as an *x,y,z* coordinate system, not all coordinates will record a temperature of 72°F. Every coordinate in the room will be associated with some particular temperature, and that temperature will be a scalar value, a value of the scalar field measuring temperature in the room, at that coordinate.

In Figure 2.1 every red dot at the center of each section of the room can be thought of as a coordinate having some scalar value for temperature associated with it. As molecules of air in the room exchange their kinetic energy with one another and move towards equilibrium, the scalar values, or the temperature, at each of the red dots will likely vary from one moment to the next. The red dots, however, will remain fixed locations in the room. The scalar value at each of these coordinates is a measure of how the air molecules bumping into one another and exchanging kinetic energy with one another affects the thermal energy of the space occupying that coordinate. There is nothing tactile to it. It is just a value assigned to a coordinate in space.

Scalars are non-orientable, which means that a scalar value doesn't have any preferred direction that it faces or any movement or influence in any one spatial direction over another. Scalars are also unaffected by reflections or by spatial transformations. Take the example of the room with an average temperature of 72°F from before. Let's say that you are observing some coordinate in that room. This coordinate has a temperature of 73°F, 1°F above the average temperature. There are certainly things that might change the scalar value, or the temperature, at this coordinate. If, for instance, the exchange of kinetic energy between air molecules moves the room towards equilibrium, then it's likely the scalar value of that coordinate would approach the average temperature of 72°F. However, whatever the scalar value at that coordinate is, in this case 73°F, it is that value no matter how you measure it. If you measure it from the left or right side of that coordinate, from above or below that coordinate, it's still going to be 73°F. If the room uniformly doubles in size, or shrinks to half its size, assuming that everything scales with the room, that coordinate will still have a scalar value of 73°F.

We have taken some time to thoroughly explain scalars as a value, but that's not because scalar values need a lot of explaining. They are easy enough to understand. What is more difficult to conceptualize is the idea that a scalar value could be a particle. The Higgs boson is a scalar particle. It is the only particle with a spin number of 0. This means that this particle has no orientation, it is the same if viewed from every direction, it has no direction or momentum. It's difficult to think of a particle as something that could not possibly have any momentum or direction. The simple, not so simple, explanation is that particles do not exist in the sense that they are commonly thought of. Particles do not exist in the sense of being an individual, tactile entity.

There is something more fundamental underlying the existence of fundamental particles. This sounds paradoxical, and much of this paper will be devoted to explaining this concept. The Cliff's notes version is that particles only exist as excitations in fields. Fields are more fundamental than particles. Fields exist everywhere in the universe. A field can be thought of as being like the water that a fish swims in. The fish might be unaware of the water, because it's everywhere and it just seems to be the medium of existence. Fields, like the water, are everywhere, they are the medium of existence, and they are fluid and oscillate and hold energy, just like the water. Each of these fields has some baseline amount of energy, called the vacuum energy of the field, and a particle is just the energy of the field increasing at a particular point in the field, and by a specified value. As you read this paper, this idea will become more fully formed. We address it briefly here because without some sort of primer it begs the question of how a scalar value could be associated with a particle. The short answer is that a scalar particle is an excitation of the scalar field.

<u>Vector Bosons</u>

Spin 1 particles are represented mathematically as vectors. As where scalars are only assigned a magnitude, vectors specify a magnitude and direction. Graphically, vectors are drawn as an arrow, pointing in some direction, the length of the arrow corresponding to the magnitude of the vector.

These ideas are all kind of abstract, mathematical constructs that represent a particle, but it only really makes sense when you understand the role of spin 1 particles in physical systems. All particles having spin 1 are part of a classification of particles called bosons. Bosons are force carrier particles. Their role is to mediate interactions between other, more substantive types of particles.

To understand how these force carriers work, we need to first get a little bit of cosmology under our belts. There are 4 fundamental forces in the universe: the electromagnetic force, the strong nuclear force, the weak nuclear force and gravity. Each of these forces has force carriers specific to it that mediate its particle interactions. The electromagnetic force has the photon, the strong force has the gluon, the weak force has the W and Z bosons, and gravity is theorized to have the graviton.

We'll use the electromagnetic force for our examples. Electrons are part of a classification of particles called fermions, which we'll discuss in more detail in the coming pages. For now, we just need to know that fermions are matter particles, and that they all have some sort of charge. We know that like charges repel one another, and opposite charges attract one another.

In contrast, photons are massless bosons. They don't really have any substance to them the same way that matter particles do. They are just pure energy in the form of electromagnetic radiation.

Chemistry is essentially the study of electron interactions. When elemental atoms combine to form molecules, they do so by sharing electrons with one another. When chemical interactions happen and energy is converted from potential, chemical energy to kinetic, thermal or radiation energy, this all starts with electrons emitting photons. For you to be reading this right now and processing it, it requires biochemical reactions on the surface of your brain and neuron firings, which require electron exchange and photon absorption and emission. In order for anything interesting to happen with matter in the universe, electrons have business to do with one another. The thing is that electrons are all identical to one another. They all have a negative charge, and as such they will repel one another as they get closer. In order to conduct their business, they need to mediator. They need a particle to carry the force or the momentum of one of these electrons to another. The particle that does this is the photon.

Thinking of a particle as vector isn't easy to intuit if you just know that a spin 1 particle is a vector boson, and a vector is an arrow that specifies direction and magnitude. But, if you consider a particle, like a photon, as a particle that has no material substance to it, that is just energy radiating through space at the speed of light, it makes sense that it is represented by an arrow that specifies the direction of that radiation and the amount of energy that is being radiated.

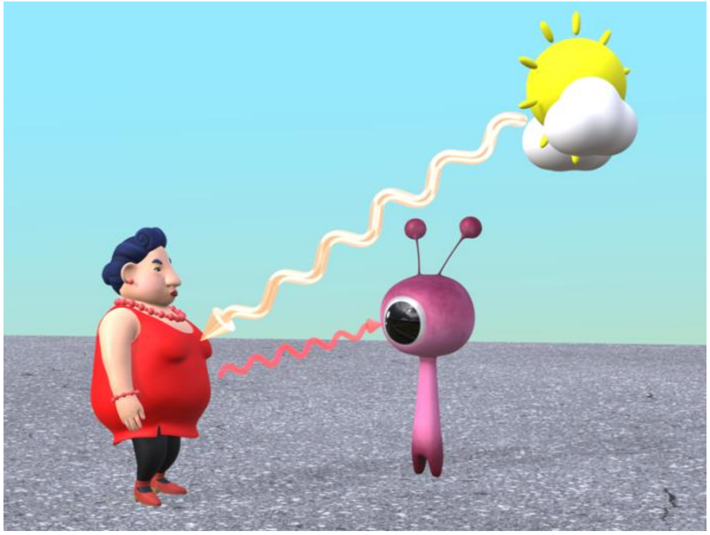

Figure 2.2

Consider Figure 2.2. When the sun shines on your friend's red shirt, the photons are emitted at wavelengths that cover the entire visible spectrum (and then some). Those photons all have some energy to them and are emitted from the sun in the direction of your friend's shirt. Your friend's shirt is made of fermions, and those fermions absorb most of the photons that are directed towards it from the sun. However, the photons having a wavelength that corresponds with red visible light are reflected towards your eye. The hydrogen that is burning in the sun isn't interacting with your friend's shirt. Your friend's shirt isn't interacting with your eye. There are particles that can be represented by vectors that are allowing the sun and your friend's shirt and your eye to do business with each other.

Spinors

The type of particle that is the most difficult to intuitively make a connection between its mathematical representation and its material structure is the spinor particle. That is because the spinor has some tactile substance to it. Spinor particles are particles with ½ integer spin numbers. Vector particles, having a spin number of 1, complete 1 full rotation after rotating for 360°. Spinor particles, having a spin number of ½, complete ½ of a full rotation after rotating for 360°.

This means that if a spinor particle is oriented so that you're looking at the front of it, after 360° of rotation it will be oriented so that you're looking at the back of it. After rotating for 720° it will have completed 1 full rotation and it will again be oriented so that you're looking at its front. Spinor particles are locally coupled to spacetime in their immediate vicinity.

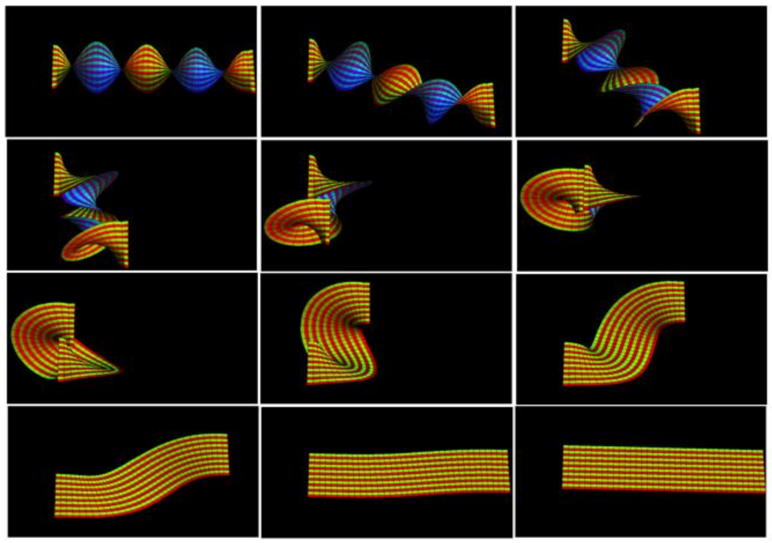

Figure 2.3

This is a difficult idea to conceptualize. One popular method for understanding this idea is called the "Dirac's belt trick." Shown above, this involves a belt that has been twisted twice, in other words rotated for 720°, and how the twists can be straightened out without flipping over either side of the belt. Notice that in the first frame the two ends of the belt are parallel. Throughout the entire movement the ends of the belt remain parallel. The 2 twists of the belt are removed without ever turning over. This doesn't work if the belt has only 1 twist in it, it needs to have 720° of rotation bound up in it.

This trick doesn't exactly provide an idea of what spinors are. What it does do is give a visual example of how the distortion of the space around an object can be projected as a distortion of the object itself. When an object is coupled to the space around it, distorting space and distorting an object also become coupled. This coupling of space and an object doesn't appear to happen until there have been a sum of 2 rotations. We postulate that this is the unique characteristic of particles with spin numbers of spin ½ that give fermions the unique property of having a mathematical representation, that when manifested as a material structure, gives that structure some sort of tactile substance to it that is lacking in scalar and vector particles. In essence, while they are still reducible to excitations of quantum fields, fermions are closer to what is generally understood by the common definition of particles, as individual, independent entities of substance, than particles of spin 0 or spin 1.

Understanding that all particles are excitations of the field associated with that particle, it's helpful to consider what sort of excitations these might be. It would be correct to say that these excitations are an increase in energy. It would also be correct to say that all particles are oscillations, or waves, in a field. The field is also constantly oscillating. The field oscillates with some amount of energy as a baseline. The energy of the waves in the field is the vacuum energy of that field. An increase in energy needs to come in specific amounts of energy. The energy needs to come in specific amounts because there needs to be a specific amount of energy in order to excite the field enough to generate particle creation. It's not possible, for example, to excite the electron field with half the energy required to generate an electron and create half an electron, or a smaller electron. Electrons are fundamental particles, which means that they cannot be broken down into any component particles. If the field isn't excited enough to create an electron at the point in the field, then there will be nothing discernable at that coordinate in the field. *

It is the particular type of oscillations that produce fermions that will be of interest to us. Again, we'll reserve an in-depth discussion of the type of oscillation, a scroll wave, for another section of this paper that will be devoted entirely to developing a thorough understanding of these oscillations. What we need to understand about them at the present is that they are a self-propagating oscillation that can exist in excitable media of 3 or more dimensions. In this case, the media that houses these oscillations is the quantum fields of the fermions. These scroll waves have an inherent duality to them. The core of these scroll waves, the part that they propagate out from, cannot exist on its own. Scroll waves that take on the structure of a spinor particle need for this core to have an equivalent counterpart from which another part of the scroll wave will also propagate. After a few cycles these oscillators which are coupled to one another find equilibrium, merging into a single entity that requires each of its 2 parts to exist. It is this duality within the single entity that gives fermions the unique property of being a particle that has some sort of substantial structure to it. The oscillations of this structure seem to interact with themselves. Spinor particles seem to be coupled to the surrounding spacetime, pushing out and sort of gripping onto it, but the energy of the oscillations seems to be pulling back in towards the structure itself, ensuring that the core structure of these spinors continue to behave as mirror image reflections of themselves, ensuring their continued existence through time. As where scalar particles just need to exist as a sort of changing value at a point in the field, and vector particles just need to exist as an oscillation that transfers energy or momentum across the field, there is something different about the duality of the spinor particles that seems to require that they exist as a tactile structure which sort of freezes a moment in time within that structure. The mirror image cores of these oscillations pushes the oscillation both backwards and forwards through time at once. Half of the spinor's structure is grounded in the universe, the other half in the anti-universe.

It is this dual structure, this mirror image of itself, that acts as a structure that mimics what it feels like to have something that it is like to be me. It is this structure of duality that is repeated over and over in conscious systems, in the mirror image hemispheres of the brain, the identical neurons, atoms, particles… It is this structure that provides a material basis for the understandable sentiment of the dualist that there must be a duality to one's own existence, because it *feels* like there is a me that I can observe when I look in the mirror, and it also *feels* like there is a me that I can observe from the inside perspective that only I can observe from. The dualist could certainly argue that this duality to the material that conscious systems are constructed of provides evidentiary support for the claim of the material and immaterial realms. This could perhaps rightly be argued to be the missing link in the chain of causation between the immaterial and material. We feel that there is a more compelling case to be made that while there is a duality to our consciousness, both the immaterial and the material are housed in the same structure of the excitations of the fermion fields, and therefore the fundamental components of consciousness are already present in the vacuums of quantum fields.

* There is something referred to as "virtual particles" that is generally accepted in particle physics. These virtual particles come in and out of "existence", although the point of talking about virtual particles is that they never really come into existence. It is largely a term of convenience for physicists to talk about the superpositions of fields between times of observable particle interactions. We will not discuss virtual particles in depth in this paper. We will, however, give a detailed account of our theory which will describe the scalar field as the most fundamental of the quantum fields, and that the vector and spinor fields are projections of the scalar field's rotation. This will inherently give an explanation that satisfactorily accounts for the energy that might be present in a field that doesn't meet the threshold for particle creation, which is commonly dealt with through the inclusion of virtual particles.

Chapter 3

Rotational Path Integral

Here we propose the notion that the fields which produce the spinor particles are the products of a rotating scalar field. More accurately, we introduce the idea that the scalar field rotates in a higher dimensional bulk, and this rotation in n-dimensions is projected to a lower number of dimensions which is the observable universe. Keeping in mind that this lower dimensional universe is a universe/anti-universe pair, with symmetries across charge, parity and time reversal, we see show that the sum of rotations can be described is effectively described by a path integral formulation of paths of rotation, the sum of which describe paths on the surfaces of n-dimensional spheres. Using the Borsuk-Ulam theorem we show that starting with manifolds embedded in an arbitrary dimensional space, we create a series of continuous maps, each bringing us from an n-dimensional brane to an (n-1)-dimensional brane, which will eventually describe the surface of a 2-dimensional sphere embedded in 3 dimensions.

The surface of these spheres will be the plane constructed of paths which are the path integral of rotation of the scalar field. We are able to circumnavigate the specific mathematics without sacrificing an accurate and rigorous explanation of this mechanism by describing the usefulness of the formulas and theorems involved in this process, what they prove and the role each is meant to perform in this process, and then providing the logical process, given the premises of these theorems and formulations, and what has been described thus far in this paper, how the conclusion follows from these premises.

Path Integral Formulation

The gist of the idea of a path integral is this: A particle is moving from Point A to Point B. The particle doesn't move by the laws governing classical mechanics. The particle moves as if it were a wave. Between the time the particle is found at Point A and the time when it arrives at Point B the particle is in a superposition of all possible locations that a particle could be at between Point A and Point B.

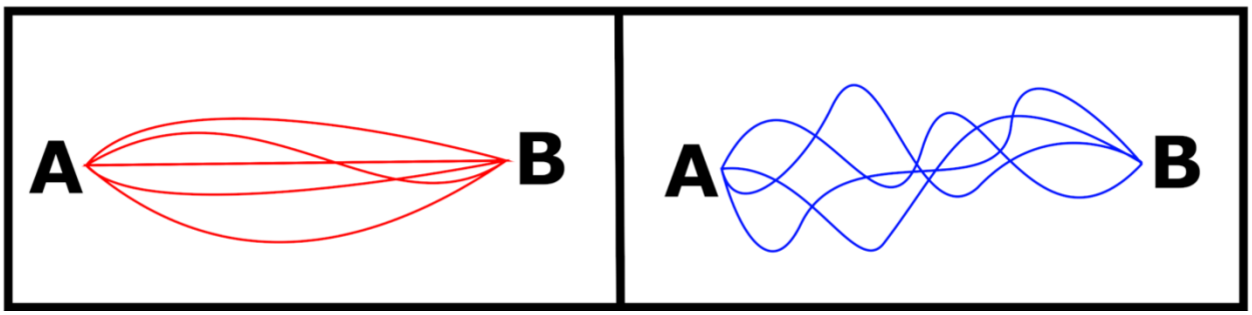

Figure 3.1

This means that in addition to the more obvious paths that you could draw between A and B, there would be some other, less obvious paths from A to B. Because the particle is in a superposition from the time its location is known at Point A and the time that its location is known again, when it arrives at Point B, any possible path that begins at A and ends at B must be considered. The path integral formulation assigns a probability amplitude to every path. The more likely the path, the higher the probability amplitude of the associated path. In figure 3.1, the paths on the left are more direct, and it is more likely that a particle in a superposition between A and B would be found somewhere along those paths than the paths on the right. The paths on the left are accordingly assigned greater probability amplitudes than those on the right.

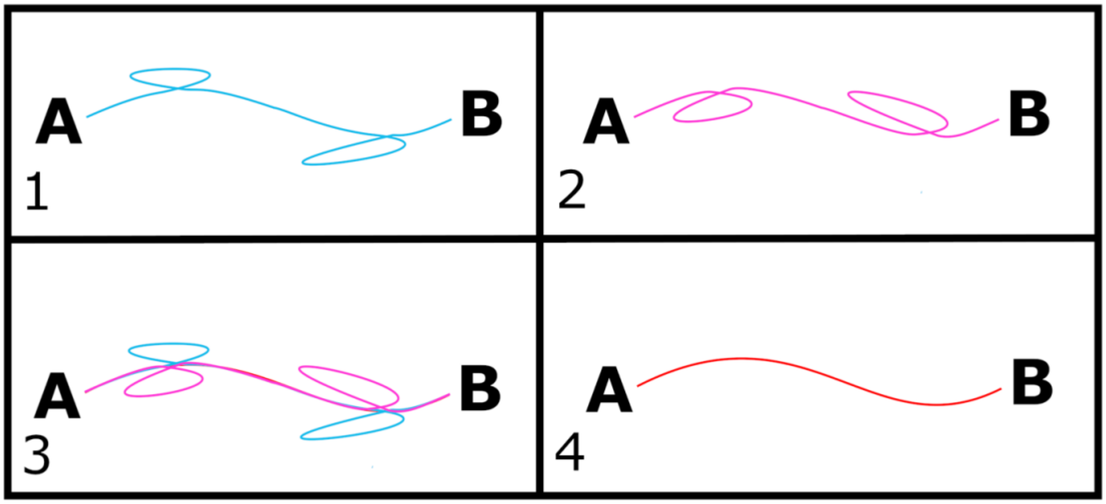

Figure 3.2

Since the only known points on the path from A to B are its starting and end points, any and all paths that have those points in common are possible. When integrating the probability amplitudes of all paths, what we find is that the paths which diverge the most and take the most detours from a direct path between A and B cancel one another out. In Figure 3.2 we see a path in frame 1 that diverges twice to loop around on its way from A to B. These divergences don't do anything overall to advance the particle from A to B. Since the particle is in a superposition of all possible states between A and B, this path should seemingly still warrant some probability. However, there is nothing that could warrant any preference between the path with the divergences in frame 1 or the path with the divergences in frame 2. Since the particle exists in a superposition between A and B, it's not exactly as if there is some probability that the particle takes the path in frame 1 and there is some probability that the particle took the path in frame 2. The particle in effect takes all possible paths simultaneously.

A particle in a superposition is able to interfere with itself. Therefore, the parts of the path where the path strays away from the path shown in frame 4 destructively interferes with one another. The loops on the path in frame l and the loops on the path in frame 2 interfere with one another in such a way that they cancel one another out, and neither of those paths are available for the particle to take.

As depicted in frame 3, there is essentially one path (which is that path that we see in frame 4) with opposite but equal divergences from that path. The path in frame 4 is all of the common points in the paths in frames 1 and 2. The path in frame 4 is a path that leads from A to B in its own right, and therefore must have some probability. What we find when we integrate all possible paths is that paths 1 and 2 have parts of those paths that are common to both paths (the path in frame 4), and parts of the paths that are unique to each of them. The parts that are unique to each path being equal in amplitude, or energy, and opposite in direction, or momentum, destructively interfere with one another. When we integrate these paths, the destructive interference cancels out paths 1 and 2, or at least the parts of them that are opposite of one another, giving those specific paths a probability amplitude of 0, while the parts of the path that are common to both paths constructively interfere. What we find is that because the specific parts of paths 1 and 2 that are canceled out results in that specific path having a probability amplitude of 0, while still allowing for the possibility that the parts of the path that is common to both paths could see the particle taking those parts of the path, this possibility ends up contributing to the probability amplitude of the path in frame 4. The result is that the probability amplitude of the paths in frames 1 and 2 becomes 0, while the probability amplitude of the path in frame 4 is increased.

One key difference between the path integral as it is commonly used and the path integral for our purposes is that the path integral is most often used to describe the path of a particle starting at some known location, say a device that emits electrons for observation, and some detector which can record the location that the electron arrives at on the detector's surface. (The double slit experiment is a good example of how the path integral is typically applied.) The path integral formulation for our purposes instead describes a path from some point on the scalar field as it rotates in any number of dimensions around a central point and arrives back at the original starting point. (At least this will be a useful way to think of this kind of application of the path integral formulation for the time being.)

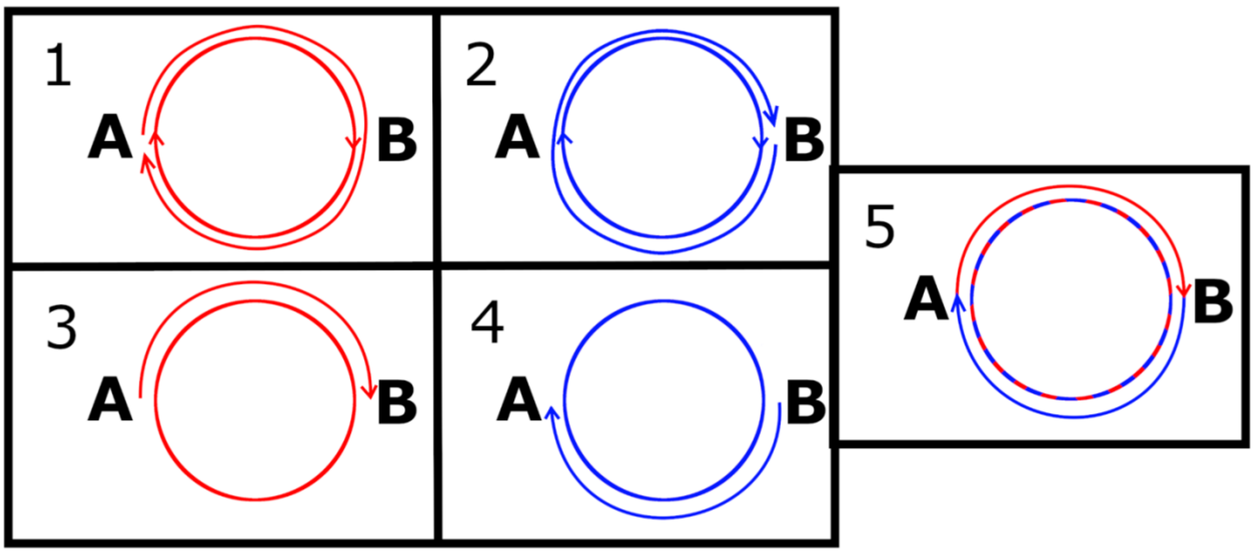

Figure 3.3

Instead of a path integral which describes the probability amplitude of all possible paths from A to B, the way that we should think of the path integral is as a method of integrating the probabilities of paths from A, by way of B, back to A. As we see in Figure 3.3, there are several equivalent ways to think about the path integral in this context. (The important part of this discussion of the path integral will involve the path itself, not the path as a means of traversing from one point to another. For example, think about the roads that you take to get from your home to work. Assuming that they are all 2-way streets, those same roads can get you from your home to work to start your shift, and when your shift is over, they will get you from work to your home. We are not so much concerned with the dynamic action of your movement along those streets. What interests us is the static streets themselves.)

In frame 1 we see a circle with points that are exactly opposite one another, or antipodes, specified on it. The path begins at point A, passes through B, and returns to A, while maintaining a constant distance from a point at the center of the path. Frame 2 shows the mirror image of this path, which starts and ends at B, and goes through point A. This is the same path. Each of these paths essentially rotate point A and/or point B for 360° until it returns to its original orientation. Frames 3 and 4 show 2 paths where A and B swap locations, each rotating for 180°. The sum of these paths creates a path equivalent to the paths in frames 1 and/or 2. (Keep in mind that we aren't concerned with the beginning or ending of our path, but instead with the path itself. Therefore, it won't make a difference to us if A and B are oriented as they originally were, only that the path this is the sum of frames 3 and 4 is an equivalent path to that in frames 1 and 2.) Frame 5 shows a depiction of this path that will likely be the most helpful way to think about this rotational path integral moving forward; as a path that is 2 halves of a rotation around a fixed point, and those 2 halves of rotation describe the path most efficiently, while that path can equivalently be described by either of the antipodes rotating around that same point for 360°.

Higher Dimensional Space, The Bulk, and Branes

The Bulk

The bulk is what might exist beyond our universe. Typically, the bulk is thought to be some higher dimensional space. (The universe has 3 spatial dimensions and 1 temporal dimension, so higher dimensional would have more than those dimensions.) More dimensions allow for more directions that can be navigated. Every additional dimension extends out in 2 directions, opposite one another, and both perpendicular to all other dimensions. The idea of extending in a direction that is perpendicular to all 3 spatial dimensions is difficult to imagine. It is easier to conceptualize what it would be like to exist in only 2 dimensions, and what something that is 3-dimensional would mean to bodies confined to a 2-dimensional space, and to then try to generalize that notion to what it might be like for bodies confined to 3 spatial dimensions, as is the case with the universe's 3 spatial dimensions, to exist within a higher dimensional space.

n-Dimensional Space

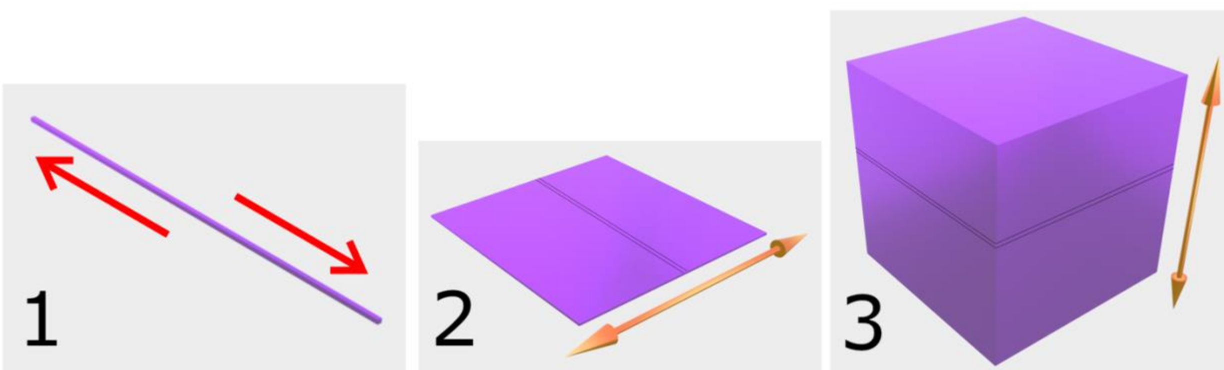

Figure 3.4

In Figure 3.4 we begin with a 1-dimensional line. A single dimension dictates that it can be navigated in 2 directions. On the line in frame 1 those directions are indicated by the red arrows. Note that the arrows are parallel to the line, so that any path that a body confined to a single dimension could take would be synonymous with the entirety of that dimension along that path.

In frame 2 every point on the line segment is extended into a direction perpendicular to the directions that can be navigated on that 1-dimensional line. This creates a 2-dimensional plane. In mathematical terms, the addition of another dimension is said to add 1 degree of freedom. If any point on a line, say a number line, can be described by a single coordinate, then 2 coordinates would be needed to describe a point on a 2-dimensional plane. This is familiar in the Cartesian coordinate plane, which describes points using an (x,y) coordinate system.

In frame 3 we see that just like every point on the 1-dimensional line was extended in a direction perpendicular to all directions that can be navigated on the line, every point on the 2-dimensional plane is extended into a direction perpendicular to all directions on the plane. Again, the addition of a dimension is synonymous with the addition of a degree of freedom, and any point in this 3-dimensional volume would require 3 coordinates to be accurately described.

Embedded Dimensions

Embedded dimensions are the idea that some sort of structure that is confined to a certain number of dimensions can exist in a higher dimensional space, extending into the other dimensions, but without being able to navigate the higher dimensions outside the confines of the dimensions of the lower dimensional structure. This idea is somewhat analogous to people walking around on the surface of the Earth. Imagining that the topography of Earth's land masses was completely flat, with no changes in elevation, the Earth would appear to us as a flat, 2-dimensional plane. We could see birds flying through the air, navigating 3 spatial dimensions. We would see fish swimming in water, navigating 3 spatial dimensions, but it would seem to us that we would lack a degree of freedom since we would be confined to the planar surface of Earth's land masses. However, an observer from outer space would look down and see us walking on the 2-dimensional spherical surface of a 3-dimensional ball. That observer would see people, birds and fish all moving through 3 spatial dimensions.

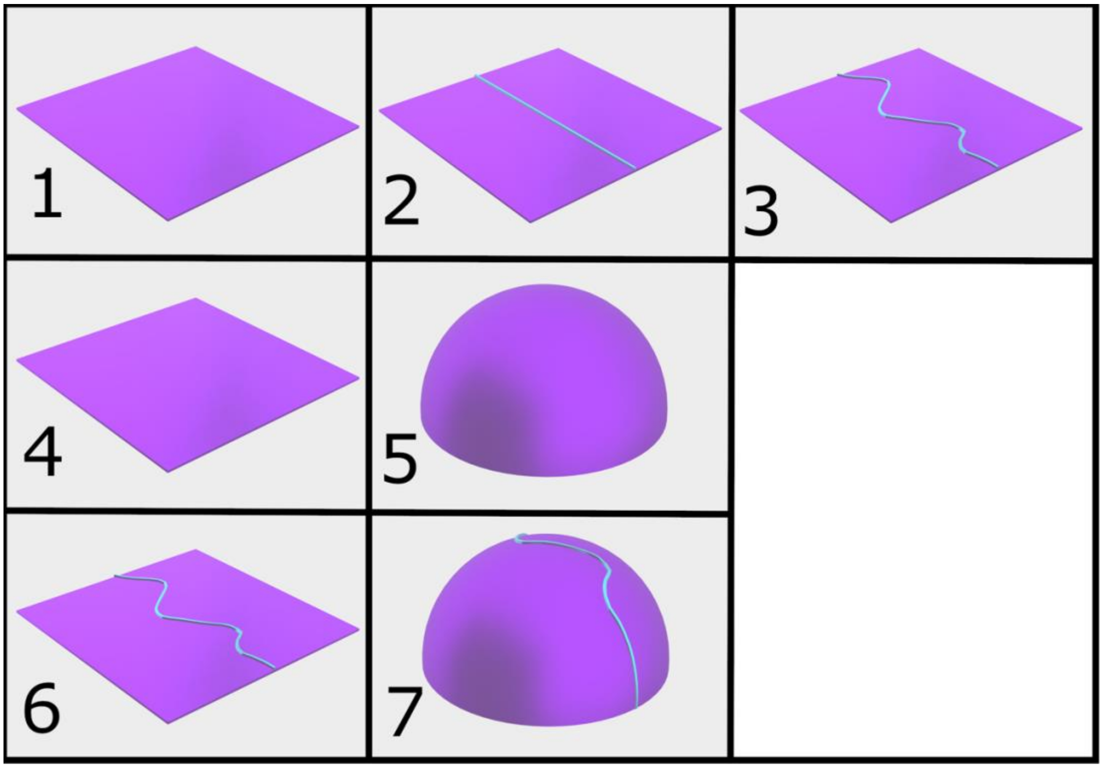

Figure 3.5

In Figure 3.5 we see a flat, 2-dimensional plane in frame 1. In frame 2 there is a 1-dimensional path that is placed on that 2-dimensional plane. For an observer on that path, there are only 2 possible directions which can be navigated, and they would conclude that they are navigating in a single dimension. From our perspective they also appear to exist in only 1 dimension. In frame 3 there is a difference in the number of dimensions that are being navigated in that path based on the perspective of the observer. An observer on that path would still only be able to move forwards or backwards and would believe themselves to be in a 1-dimensional space. From our perspective, we see that 1-dimensional path going across the plane, but also curving, extending up and down the plane. We see that path a 1-dimensional path embedded in 2 dimensions.

In frames 4 and 5 we apply this same idea to a 2-dimensional plane that extends into a 3^{rd} dimension. In frames 6 and 7 we see this same thing happening, but this time as the 2-dimensional plane is embedded in the 3^{rd} dimensions, it takes with it in tow the 1-dimensional path that had already been embedded in 2 dimensions. The result is that the 1-dimensional path becomes embedded in 3 dimensions. If you imagine that the path is a train track, it's easy to see that no matter if the train track is straight, like it is in frame 2, winding on the 2-dimensional plane as it is in frames 3 and 6, or winding on a curved surface as it is in frame 7, the train would still only be able to move along the single path laid out by the train track.

Branes

Branes are a mathematical construct used to describe lower dimensional spaces that are embedded within higher dimensional space. Since we don't know if there is anything beyond our universe (or anything beyond our universe/anti-universe pair), we can only speculate about the dimensionality of what the bulk might be like. We inform our speculations about the bulk based on what we observe in the universe.

What we can see is that our universe appears to have 3 spatial dimensions and 1 temporal dimension, which appears to be unidirectional. As we will discuss later in this paper, investigating the universe in some of its most extreme environments, namely black holes, has led to the discovery that there appears to be a basis to the observable, 3-dimensional physicality of the universe that has a 2-dimensional geometry. This is what we know about the dimensionality of our universe. From that, we can construct theoretical models of our universe as a confined region within the bulk. This confinement can have boundaries that are spatial, dimensional or temporal, at a minimum.

Spatial boundaries are common in the world. You may have a backyard, which may have a fence along its perimeter to define its spatial boundaries. Temporal boundaries are less intuitive to us, but we have discussed one in this paper already. In the CPT model of the universe there is a time reversal transformation between the universe and the anti-universe. This means that the arrow of time is reversed in the anti-universe. (If you recall, the additional symmetries of charge conjugation and parity effectively reverse that arrow again, so that the arrows of time are parallel in the universe and anti-universe.) This temporal boundary is the foundation of the 2 sheeted nature of the universe/anti-universe pair.

Dimensional boundaries are a horse of a different color. We can make analogies to what dimensional boundaries might be like, as in the examples of a train moving along a track or people confined to Earth's surface. While these analogies serve the purpose of making the gist of dimensional boundaries intuitive, there is still something lacking from the idea of a dimensional boundary like this. The problem is that our own intuition of spatial dimensions is the product of our own experiences and the evolution of the psychology of our species, all of which has taken place in a framework that is 3+1-dimensonal. In all of these examples we take the perspective of an agent that is able to see *why* the lower dimensions available to agents on the Earth's surface, or on the train track, are the only dimensions available for them to navigate *from their perspective*. In each of these examples those agents are still navigating 3-dimensionally from our perspective.

There are examples of dimensional boundaries that seem to be present all around us that are less intuitive. For example, the Higgs field is everywhere in the universe, occupying all of the 3 spatial dimensions, but it is a field described by just 2 degrees of freedom. The holographic principle posits that there is a reality that exists that gives rise to the 3-dimensional geometry of everything around us, including ourselves, which has a 2-dimensional geometry. These kinds of embedded dimensions are more difficult to grasp. The tool that has been developed so that these kinds of dimensional boundaries can be incorporated into model building of the universe and the bulk is the concept of branes.

When thinking of branes, it's helpful to know that the word comes from "membranes." Branes are a mathematical tool that can be thought of as a dimensional membrane which confines things that are part of that brane, or confined to that brane, to the dimensional confines of that brane. Usually, the brane being discussed has a numerical precursor attached to it. For example, we could say that the train is confined to the 1-brane of the train track, which is embedded in the 2-brane of the planar land masses, which is embedded in the 3-brane of the universe's spatial dimensions. We can imagine that the bulk may be some unknown, possibly higher number of dimensions, so we can say that it is n-dimensional. If we want to discuss dimensional restrictions where fewer dimensions are available than are in the bulk then we can refer to them as (n-1)-branes, (n-2)-branes, etc.

Borsuk-Ulam Theorem

The Borsuk-Ulam theorem is a theorem in the mathematical field of topology that proves that any continuous function that maps a sphere in any number of dimensions onto a map in one fewer dimension, there will be a pair of antipodal coordinates on that sphere that map to the same coordinate in that dimension. This sounds like a lot, but we'll pick it apart in the following pages.

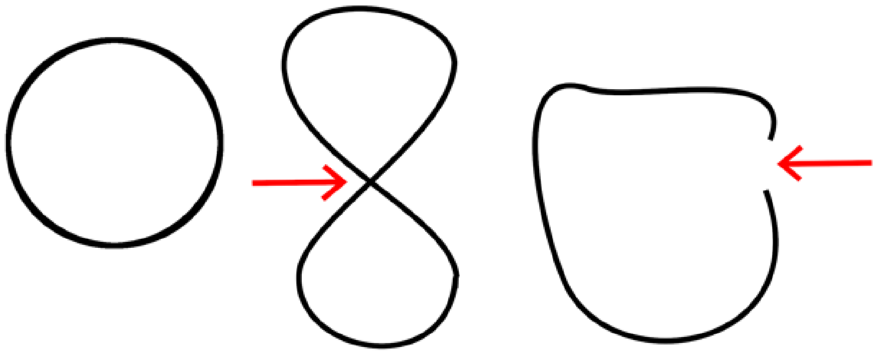

Figure 3.6

Topology

Topology is a field of study in math that is similar to geometry. The main difference is that while geometry typically classifies shapes based on the number of sides or faces, and the angles of adjacent sides or faces, topology isn't concerned with the number of sides, or the angles of adjacent sides. Topology only distinguishes *manifolds* (the term that topology uses instead of "shapes") from one another by the number of openings in its boundaries and the number of times that its boundaries cross over one another. Figure 3.6 shows the characteristics of manifolds that would distinguish them from one another.

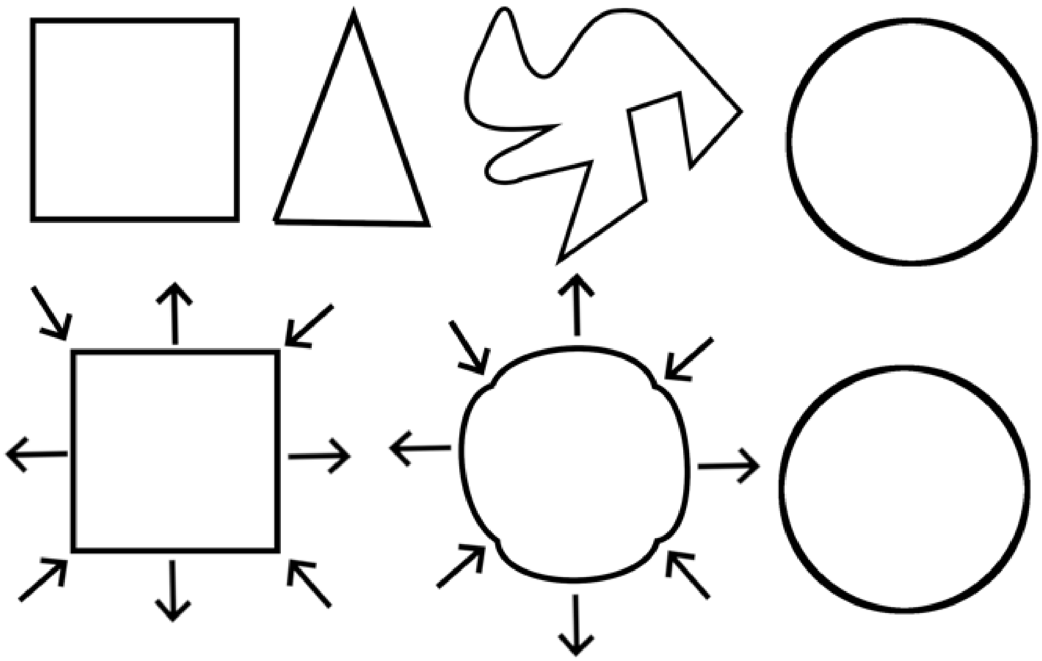

Figure 3.7

The reason that topology doesn't distinguish between shapes the same way that geometry does is because topology treats all manifolds that can be distorted to take the shape of another manifold as being equivalent to each other. In Figure 3.7 we see that by pushing the corners of a square in and pulling the middle of its sides out, it can be distorted into a circle. Likewise, any of the manifolds in Figure 3.7 could be distorted to take the shape of any of the others. The characteristics that would not allow for this sort of distortion would be if the boundary of the manifold had any points where it crossed over itself, or any openings in its boundary, as they do in Figure 3.6. This makes topology a particularly useful field in the natural sciences, where often times boundaries of naturally occurring structures are not idealized polygons. It is often easier to describe something as an M2 manifold, for example. (Manifolds in topology are referred to as "M-some integer number" with the integer number being the number of dimensions of the manifold. So, an M2 manifold would be something like a hollow sphere, or a hollow cube, an M3 manifold would be a solid ball, or a solid cube, etc.)

Continuous Mapping

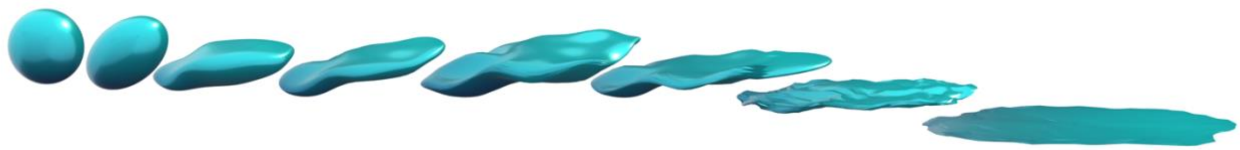

Figure 3.8

A continuous mapping function is one that maps all points on a manifold from one topological space to another, without cutting the boundary of that manifold, and without crossing the boundary over itself. Figure 3.8 shows an example of the continuous mapping of a sphere in 3-dimensional space onto a flat, 2-dimensional plane. The Borsuk-Ulam theorem tells us that when this happens, no matter how the sphere was flattened out, just so long as it wasn't cut or folded over on itself, there will be 2 coordinates that were antipodal points on the sphere that fall on top of one another on the flat, planar surface. An easy example to think about is to imagine taking a globe, pressing down on the top of it so that it flattens out, and the North Pole and the South Pole would fall on top of one another.

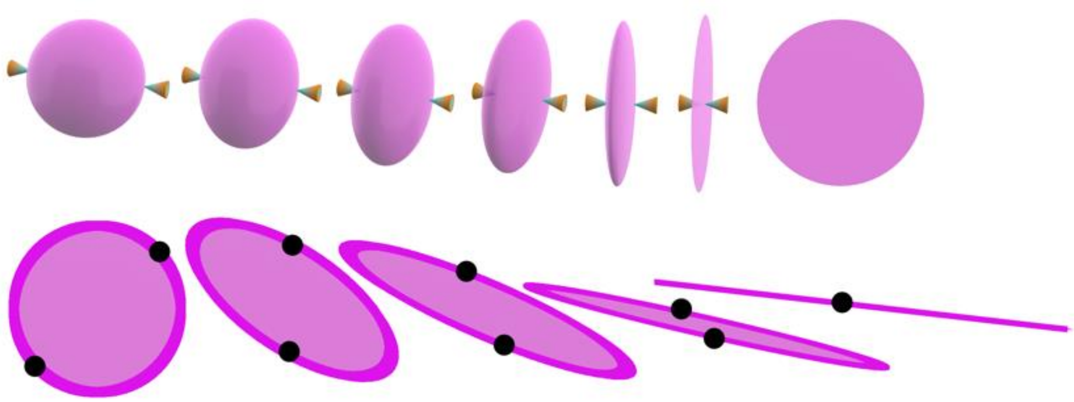

Figure 3.9

Keeping in mind that the Borsuk-Ulam theorem applies to spheres of any number of dimensions, we see in Figure 3.9 how this process could continue. Starting with a 3-dimensional sphere, we continuously map to a 2-dimensional circle, and then again to a 1-dimensional line.

Rotational Path of the Scalar Field

In order to avoid confusion later on in this paper, we're going to need to give away the ending a little bit here. We are going to be describing a way of formulating a path integral that sounds as though we are taking points in space and rotating around another point to serve as the center of rotation to define some volume of space within a sphere, and specify a path on the surface of that sphere. To be fair, it will sound like that's what we're going to be doing, because that's exactly how we're going to be describing it. Really, the end goal is to describe an observership-dependent universe with a geometry that is constructed from the perspective of any observer. We will be proposing that the fermion fields are projections of the scalar field where the field has been sort of bound up on itself from the perspective of an observer so that there is a path, which we will be describing using the path integral formulation applied to a rotation around a point to describe the perspective of an observer, that when described only from the information available to an observer, becomes twisted and contorted in such a way that the path described by the observer has specific properties that will be consistent with that path being associated with a particular kind of field oscillation that requires a geometry at its core that is exactly like the path described from the perspective of an observer, which would be an observer placed at what we will be describing in this section as the center of rotation of the path.

As we continue on it this paper, all of this will be spelled out explicitly. For now please just allow us some liberties, knowing that our aim is to lay some foundational ideas here that aren't exactly literal descriptions of what we're proposing, but we have included because we feel that these ideas will be useful later on when we are attempting to translate ideas that are typically described using abstract math to a language that is more intuitive and easier to conceptualize.

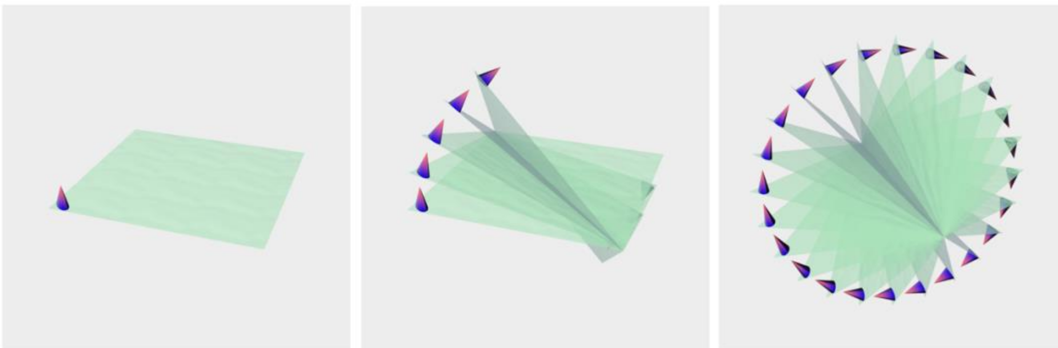

Figure 3.10

We suggest the possibility that the scalar field, being invariant to scale in any number of dimensions, can be taken as a slice, or a 2-brane, embedded in a higher-dimensional bulk. As the universe rotates in the bulk, we as agents that are a part of the universe, confined to this spatial 3-brane that is the universe, do not see the scalar field's movement via rotation in higher dimensional space. An agent from outside of the universe would have a perspective that would show any coordinate on the scalar field creating some path through its rotational movement in higher dimensional space. In Figure 3.10 we see how the rotation of a 2-dimensional surface around any axis on that surface creates a path perpendicular to the dimensions of that surface.

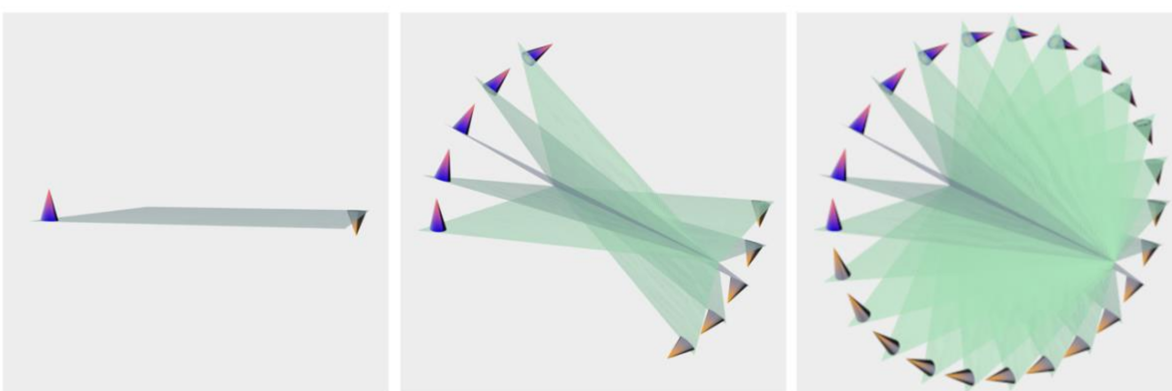

Figure 3.11

As we have established already, the rotation of a field around some point that becomes the center of rotation creates a path that is synonymous with a path created by any point that is equidistant from the point that is the center of rotation, or the sum of any antipodal points rotating for half of a complete rotation. In Figure 3.11 we see 2 points on the plane that are on opposite sides, but equal distance, from the axis that the plane is rotating around. After the plane completes half of a rotation a complete path is described by the sum of the rotation of these 2 points.

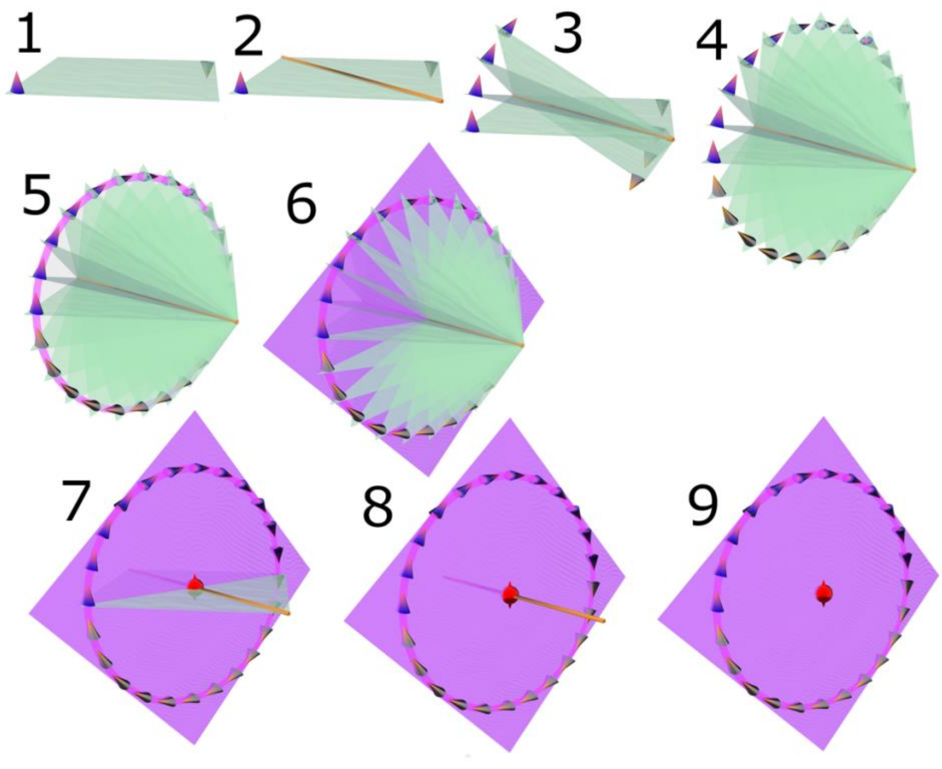

Figure 3.12

The rotation of the scalar field in the bulk creates some ambiguity, or perhaps illusions, about the dimensionality of spaces for observers confined to lower dimensional branes, such as is the case with us as observers who are a part of the universe. In Figure 3.12 we see how the 2 points on the plane rotate around some axis. This axis is shown in frame 2. We see the rotation create a path, which is highlighted in frame 5. If we connect all the points on this path it will specify a plane perpendicular to the rotating plane. This plane is introduced in frame 6, as the plane shown in purple.

In frame 7 we introduce an observer located at the center of rotation. This observer could be embedded on the original, green plane, in which case the observer would not be able to perceive the rotational path. Since the observer is on the plane that is rotating, the observer cannot be aware of the plane's movement in a dimension which the embedded observer is not able to perceive. This is similar to the idea that we are usually unaware that we are on a planet that is rotating, because everything around us is rotating with us. We are embedded on the same plane as the surface of the Earth.

Looking back at frame 7, only an observer from outside the green 2-brane would be able to see the path created by the rotation of the 2-brane. An observer on the purple plane would be aware of the path specified by the rotation of the green plane. An observer on the purple plane, if free to move about the plane, could walk the path specified by the 2 points on the green plane that are both equidistant from the center, but in opposite directions on the plane, as they rotate around the center of rotation.

The observer in Figure 3.12 might be confined to the 1-dimensional axis around which the 2-brane rotates, or the observer might be confined to a single point at the center of rotation. Just so long as the observer is oriented on the green plane, or in other words embedded on the green 2-brane, then in any of these scenarios the rotational path would not be obvious to that observer.

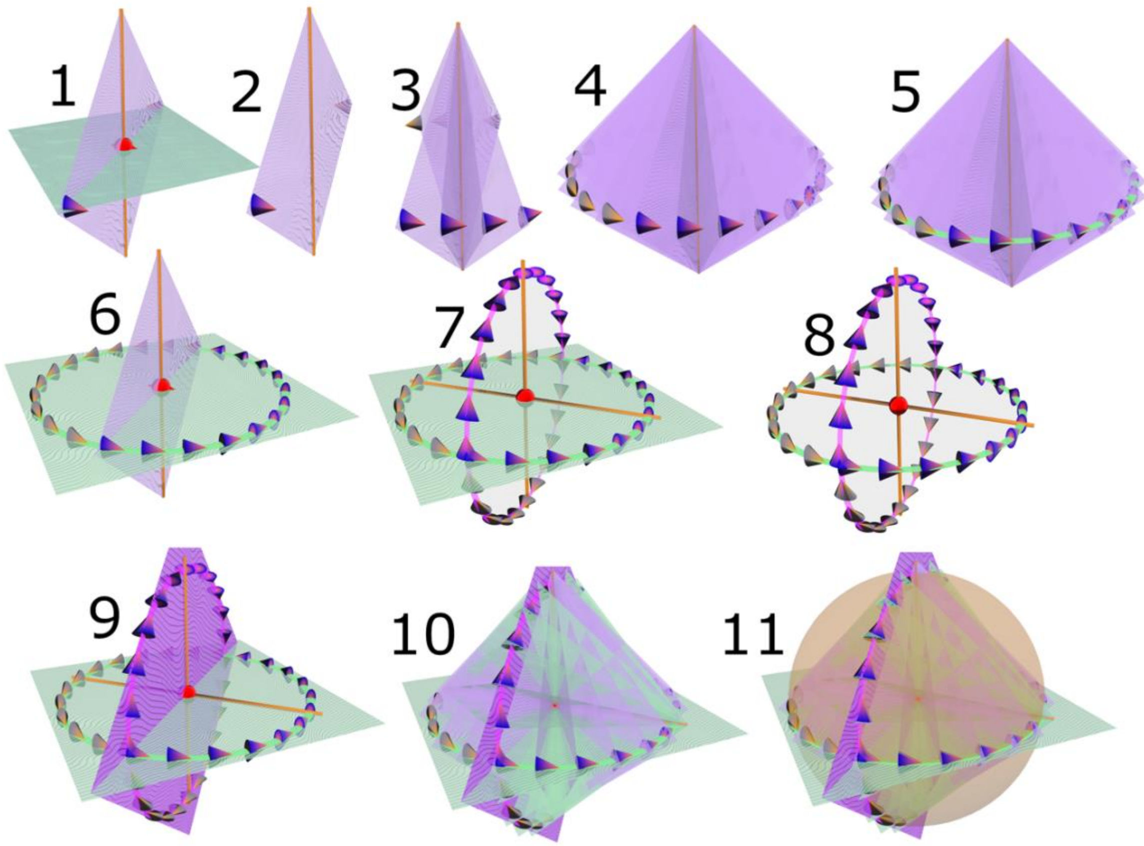

Figure 3.13

However, to an observer not embedded in any of these branes, there could be an observer at the same location at the center of rotation that has exactly the opposite dimensional information available to them. In other words, an observer on the purple plane is able to perceive the path specified by the rotation of the green plane. An observer on the green plane, in turn, would be aware of a path specified by the rotation of the purple plane, a path which an observer embedded on the purple plane would not be able to perceive.

To illustrate this idea, we simply rotate the axis of rotation 90°, so that the paths are perpendicular to one another. Keeping in mind that in Figure 3.12 we showed how the purple plane was a product of the path specified by the rotation of the green plane, we can now specify

2 points on that purple plane equidistant from the center of rotation. Now, when we rotate the purple plane for half of a complete rotation, we specify a path. This path is highlighted in green, in frame 5.

In frame 6 we conduct the same process that we used to specify the purple plane in the previous image. We connect all the points of the green path to one another, and in doing so we find that we have recreated the green plane.

The point that we're trying to illustrate is this: By embedding an observer onto a plane, arbitrarily choosing 2 points on the plane equidistant from the observer in opposite directions, and then rotating a plane around the observer, making the location of the observer the center of rotation, you specify a path that is not apparent to an observer on that plane. If, however, the observer is not necessarily confined to any particular orientation, then the observer would be free to reorient themselves so that the path would be apparent to them. (If you recall from Chapter 2, scalar quantities are non-orientable. A "scalar observer" would be free to orient themselves however they please.) They could describe the path as being a circle on a new plane that they would specify from their perspective at being at the center of that circle. In effect, specifying a path by the rotation of the green plane creates the purple plane. Specifying a path by rotating the purple plane recreates the green plane. This is the process that we see playing out in frame 7, 8 and 9.

In frames 10 and 11 we see the illustration of the idea that when we embed an observer in a 2-brane, and then rotate the brane in a space that should not be perceivable to an observer embedded on that brane, but then consider that the observer at the center of rotation is a scalar value, and is non-orientable, that specifying any sort of rotational path in effect specifies the sum of all rotational paths that are equidistant from the center of rotation. By creating the green plane with a scalar observer at its center, you create the purple path. This process could play out any number of times so that you could specify any number of paths and any number of planes all around that center of rotation. Effectively, by specifying any path you are specifying an infinite number of paths. The sum of these paths would create the surface of a sphere that is equidistant from the observer at the center of rotation. This is the orange sphere shown in frame 11.

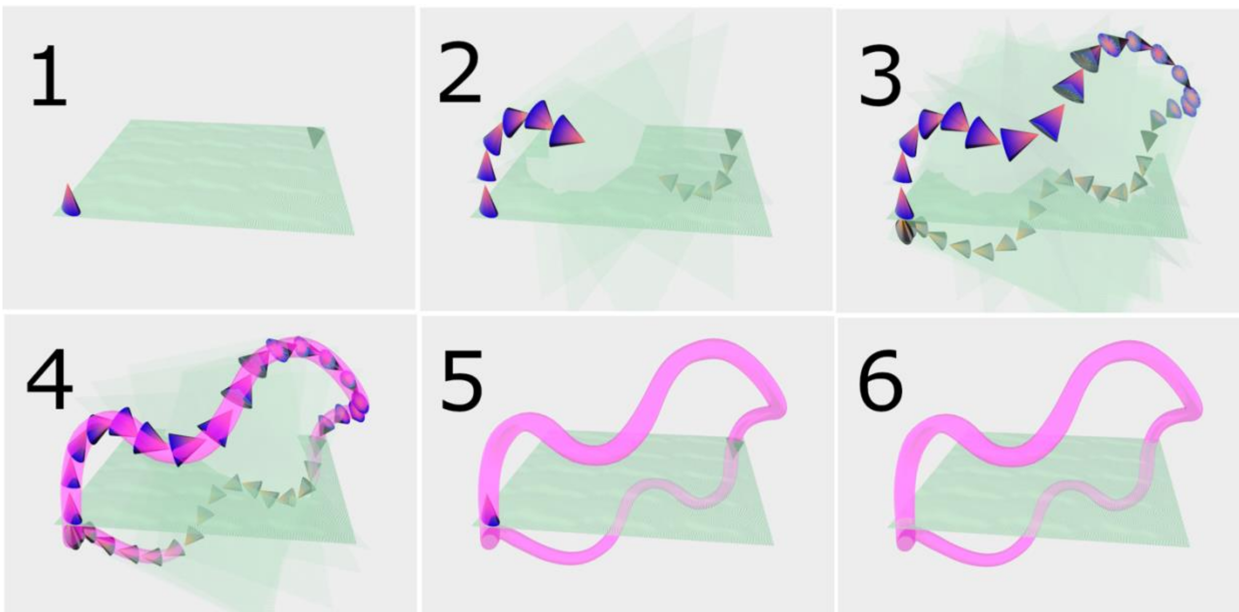

Figure 3.14

In Figure 3.14 we see that a plane with a 2-dimensional geometry rotates, and as the antipodes arrive at the starting location of each other, a single path of rotation is defined. As where before we had only been looking at paths that were formed by a plane rotating across a fixed axis, so that the rotational path forms a flat, 2-dimensional plane, here we are considering a path that is formed by a plane rotating not just around 1 fixed axis, but a path that rotates on 3 axes around a fixed point, that point being the center of rotation. The antipodes rotate as mirror images of one another. They are fixed to a flat plane, so that as one turns one way, the other antipode will compensate by turning the other way along the path. Each half of the path will appear as equal and opposite if viewed from a single vantage point. However, each half of the path will look identical to the other half if viewed from a vantage point that is the same relative to the part of the path being considered. This is familiar to us as a parity symmetry.

This is just meant to illustrate the idea that the path doesn't need to be a straight path. In fact, it won't be a straight path. For now, we can think of the straight paths as being an application of the path integral formulation to the idea of a rotational path. Later we'll show that the specific paths that are of interest to us require that the path twists around itself. Here we are just interested in showing that any path will specify a spherical surface which contains all possible paths.

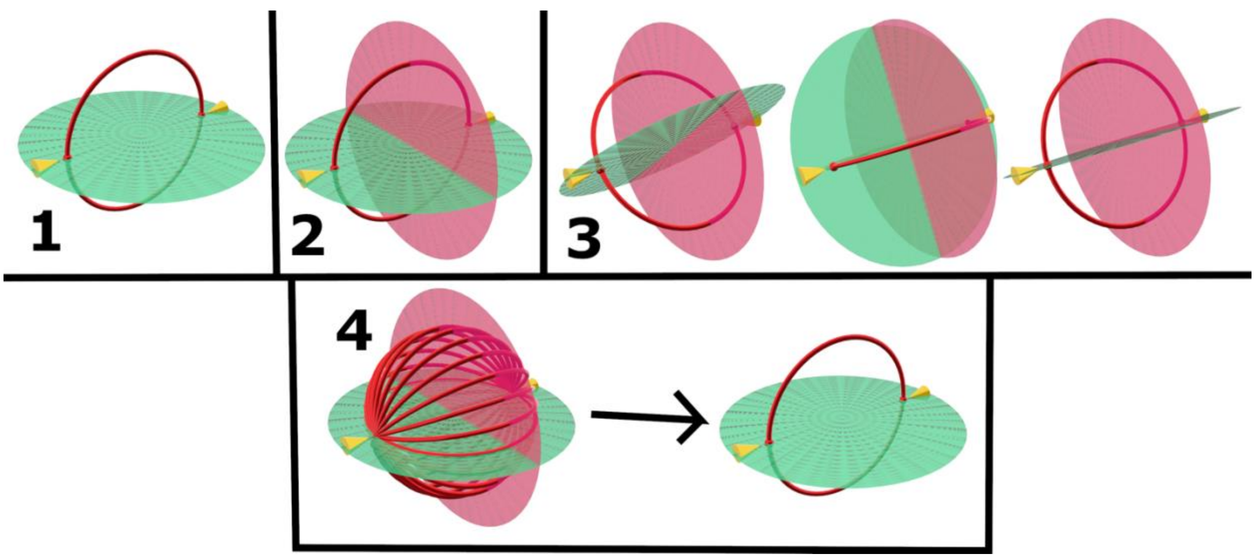

Figure 3.15

We have established how the rotation of the scalar field for half of a complete rotation will establish a path of rotation of that field around a point that is the center of rotation. We see an example of this in frame 1. We have also established that this field could be oriented in any manner, it can rotate in any fashion and in doing so will necessarily distinguish some center of rotation, and the principle of least action dictates that any possible path can be equivalently described by a maximally efficient path in a manner similar to the path integral formulation. This is the idea that the most efficient way to describe a path, the way that a path would be described using the path integral formulation, would be a straight path.

If we are considering the path shown in frame 1, the only thing that needs to be consistent about that path created by antipodes rotating for 180° around a center of rotation, so that the antipodes essentially swap positions, is that the path is perpendicular to a plane that bisects the path and includes the center of rotation. We see this perpendicular plane as the red plane in frame 2. No matter how we orient the green plane, it will always be perpendicular to the red plane, as shown in frame 3. Because of this, we can arbitrarily choose any maximally efficient path that is equidistant from the center of rotation and is perpendicular to the path of rotation to serve as the path integral. In other words, any regular circle where the halfway points are the antipodes can be the path.

In frame 4 we can think of all of the paths as being any arbitrarily chosen path created by the path integral formulation, where the antipodes on the green plane essentially just swap places. All of the paths shown on the left part of frame 4 are all of the possible path integrals that have those same antipodes. We could also think of this as taking a single path and rotating it, so that it sort of hinges on the antipodes and sort of spins around those as fixed points. Thinking about it this way we hope will help illustrate why we are able to arbitrarily choose any maximally efficient path with those antipodes to stand in for all possible path integrals with those antipodes.

- Any maximally efficient path, so any path that rotates the antipodes around just 1 axis, describes a path integral.

- Since we can arbitrarily choose the axis to rotate the antipodes around, the sum of all possible path integrals forms a sphere.
- Choosing any of those maximally efficient paths is sort of like taking the integral of the path integral. The difference is that the path integral says that any path from A to B has some probability of occurring. We can assign a probability amplitude to each possible path and in doing so rule out the paths that don't contribute anything new to the more probable paths from A to B.
- Here we have already gone through that process, and since we are describing a rotational path where A to B also requires a path from B to A, there is an infinite amount of equivalent path integrals.
- Essentially, we are saying that any path integral is as good as any other, so we can arbitrarily choose any path integral to stand in for all path integrals that share those antipodes.

We have explained how establishing a plane, and then rotating that plane will establish a path. Reorienting the observer at the center of rotation will establish another plane that contains the path specified by the rotation of the first plane. Rotating the 2nd plane will do the same thing, this time reestablishing the original plane. This logical process can continue until the combination of all paths will form a spherical surface with the observer at the center of rotation, which is also at the center of the sphere.

Now, in these last few paragraphs, we have described how we can efficiently describe the sphere by any arbitrarily chosen path. Our end goal in this seemingly redundant process will be to show that we are able to establish a sphere that contains all possible paths of rotation, but that any path on this sphere has any arbitrary number of degrees of freedom. More specifically, we will show that the paths are projections that are reconstructed from information encoded on a 2-dimensional surface containing all the information about the path that is available to the observer at the center of the sphere. First, we must establish that the paths could contain any number of degrees of freedom. So, every time that we go through this process of describing a path, then showing that the path could potentially be any path of a collection of paths that collectively form a sphere, and then showing that there is a method of efficiently describing the entire sphere by just 1 path, we can think of this process as adding 1 potential degree of freedom to the rotational path.

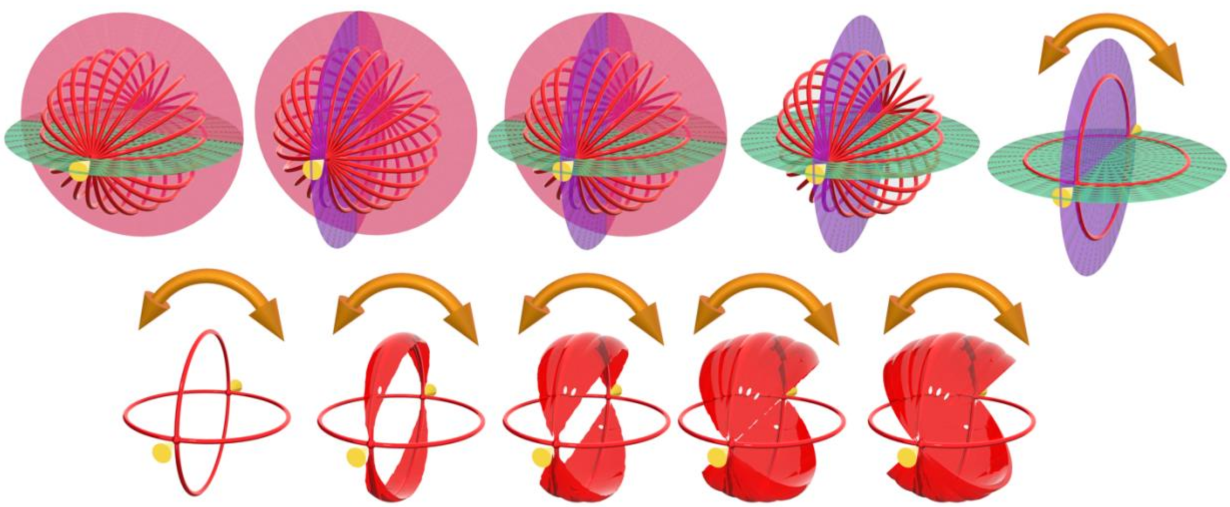

Figure 3.16

We have also established how this rotational path will create a plane that is perpendicular to the rotating field, but is *parallel* to the path that has been arbitrarily chosen to serve as the path integral. This is the purple plane in Figure 3.13, shown again here in Figure 3.16. We are speaking of a path integral that is a 1-dimensional path, that becomes embedded on a 2-dimensional plane. However, this path is the simplified representation of a path that is the result of 2 points on a 2-brane of the scalar field rotating in a higher dimensional space. Because of this we need to consider the possibility that this 1-dimensional path has some potential “depth” to it when viewed from an observer not embedded in the dimensions of the universe. This is similar to the idea that a train track can twist and turn across the flat plains, embedding the 1-dimensional track in 2 dimensions, but that same meandering across 2 dimensions becomes embedded in 3 dimensions when those turns are happening on hills and valleys instead of the flat plains. If you're looking at the path of the train from the side of the mountain, so that you are only able to see the train moving in the direction it's traveling, and in elevation, then the meandering and turning on the landscape will be lost to you. With this in mind, we can clarify how we should consider the rotational path integral.

In Figure 3.15 we looked at the path integral being an arbitrarily chosen path, being a more efficient way to represent all the possible trajectories of a field rotating perpendicular to a plane that bisects the paths through the center of rotation. Not instead of, but in addition to thinking of the path integral like this, it will be helpful to think of any single path as kind of condensed version of paths that might be kind of "spread out", or as having some sort of intrinsic potential to wobble in and out from the planar surface of the sphere formed by the sum of all possible paths. This spreading out should be thought of as being perpendicular to any path integral.

In the first row of images in Figure 3.16 we see what we have already covered: we have described how any path establishes a plane, and by reorienting the observer at the center of rotation we establish 3 planes that are all perpendicular to one another, giving us 3 degrees of freedom to move around antipodal points on the surface of the sphere to establish a rotational path. We have also described how any path can be chosen to stand in for all path integrals that share antipodal points. We can think of any chosen path integral as being able to sort of spin around, in the direction of the gold arrows in Figure 3.16, using the antipodes as fixed points that the path sort of hinges on.

In the bottom row of images in Figure 3.16, we reestablish the spherical surface, but this time taking into consideration that the path may be influenced by its movement away from the plane that forms the surface of the sphere. We give the path some depth, and instead of thinking of the path as a static, rigid path, we think of the path as being a sort of fluid, dynamic path on the surface of the sphere. While any path that the observer describes could be on the surface of the sphere, it might be influenced by the path's behavior that isn't contained on the surface of the sphere.

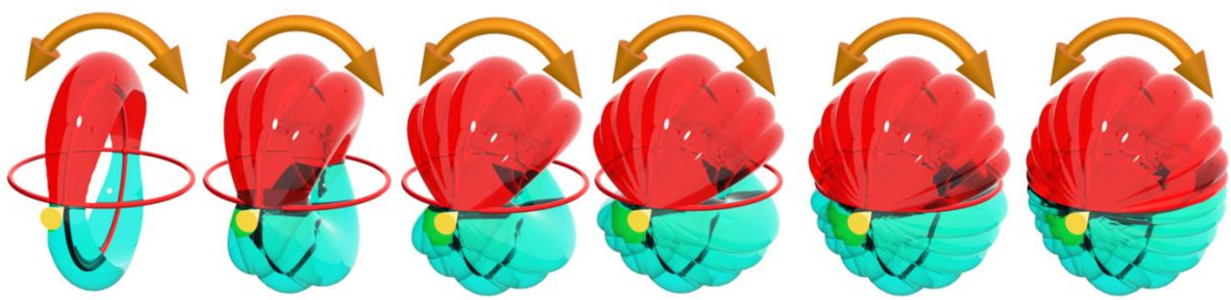

Figure 3.17

Additionally, we should think about what it would take to spread out the paths across the entirety of the sphere's planar surface. We have previously established that in order to completely describe a path, we only need to rotate the field for half of a complete rotation. Similarly, in order to describe the entire possible spherical surface of a single path being spread out across that surface, we only need to consider each part of the path as being spread out halfway around the sphere in order to accurately describe all possibilities. Likewise, we can think of the spreading out in a similar fashion. What we are discussing with this notion of the single path integral having some potential to be spread across the surface of the sphere formed by all possible path integrals essentially has to do with what the rotation of the 2 antipodes on the scalar field may have looked like from an observer not embedded in the 3-dimensional universe. This foundations of this “wobble” come from what the path might be doing in the higher dimensional bulk. The differences between this sort of “compression” of all possibilities of the path into a single path, and the path integral representing all possible paths should be thought of in the following ways:

- The path integral can be thought of as the projection of higher dimensional paths onto a 2-dimensional plane. This plane may show a meandering path on the 2-dimensional plane, which can be represented more accurately with the path integral formulation.
- The wobble is the possibility that the path could be changing all the time during its rotation, and in any number of dimensions, and that the information about the rotational path integral that would be available to an observer at the center of rotation might not be strictly representative of the dynamics of the rotational path.
- To an observer embedded on any plane that is fixed between 2 antipodes, any changing, dynamic behavior of the path would not be apparent.
- However, if you imagine that the antipodes are free to move around the sphere formed by all possible paths just so long as they remain at antipolar coordinates relative to one another, then we can imagine a plane connecting those antipodes freely spinning around inside of the sphere. This sort of dynamic, changing behavior of the path would be apparent to an observer not on the plane that connects the antipodes.

- The single, rigid path is a tool of convenience. It is a straight, 1-dimensional path that accounts for all possible paths which the rotation might be jumping back and forth on. The actual paths of rotation could be changing all the time. The single path integral accounts for all of them at all times, so that path integral can be thought of as sort of shifting to the position of whatever path of rotation is actually being taken at any given moment.
- Thinking of the path integral as a single, rigid path, like the one shown in Figure 3.15 will be the most convenient way to think of the mechanism of a rotating field generating a path.
- Understanding that this way of thinking about the path integral is really just a stand in for the sort of fluid, impressionable, dynamic spherical plane shown in Figure 3.17 will be a convenient way of relating the idea of a rotational path described by the path integral formulation to Quantum Field Theory, where fields are thought of as fluid, dynamic pools of oscillating energy.

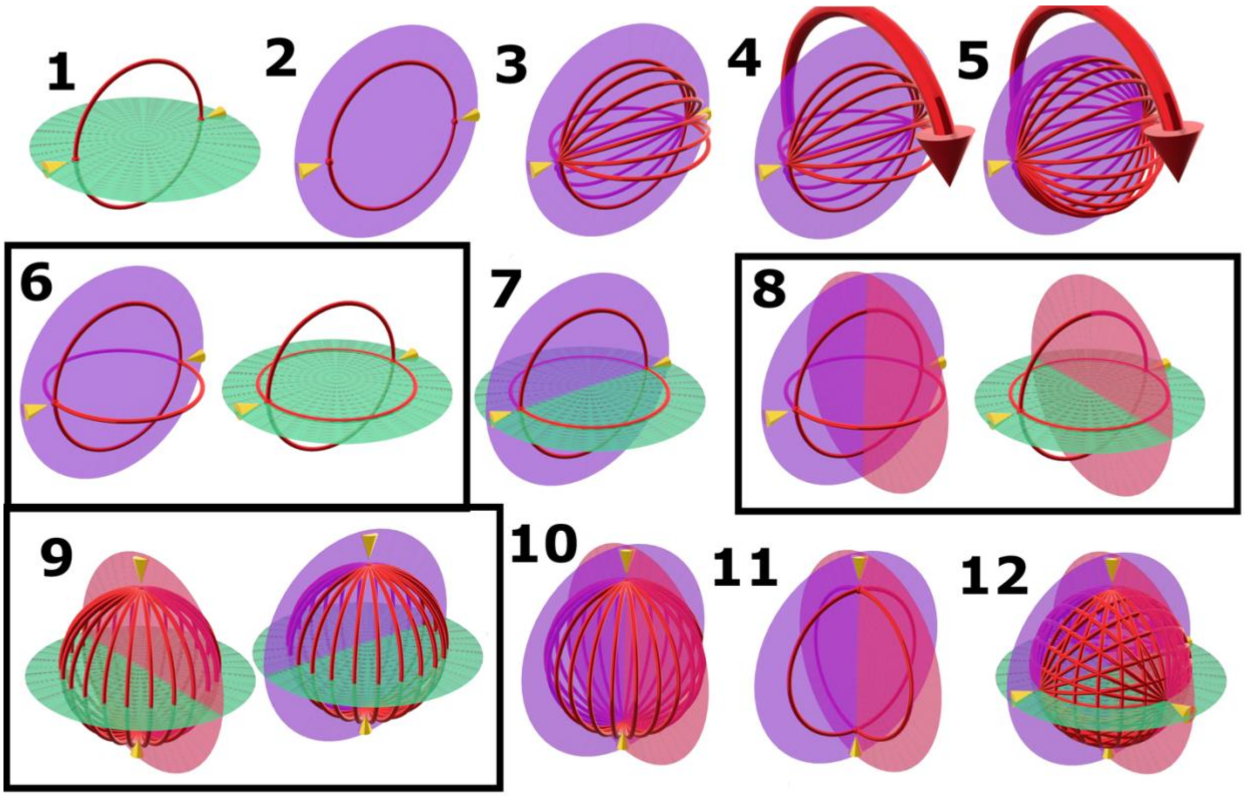

Figure 3.18

So far, the red plane has only been a logical construct used to describe the paths of the green and purple planes. (It is the plane that bisects the paths of the green plane, is perpendicular to both the purple and green plane, etc.) The green and the purple planes are the only planes that ever have any antipodal points on them.

The paths being spread out along the paths shared by 2 parallel planes gives the red plane some substance to it. Since the planes need to rotate with a flat, 2-dimensional geometry, that becomes embedded in a 3rd dimension, the antipodes need to stay on opposite sides of the sphere from one another during the rotation, and an observer embedded on either of the planes at the center of rotation should be unaware of either planes' rotation. With the understanding that each path is a path integral of all rotational paths of antipodes confined to a plane, and of the spreading out of those paths on the spherical surface formed by the sum of all path integrals, one can imagine that any set of antipodal points, shared by both the green and purple planes, could attempt to rotate simultaneously on paths that are shared by both the green and purple planes, but are perpendicular to one another. If the fields are required to maintain their geometry as they rotate, then attempting to rotate on paths that are perpendicular to one another, then there would come a threshold during the rotation where an observer embedded either the green or purple plane would become aware of the plane's rotation. When the antipodes crossed the red plane, an observer at the center of rotation would see an internal parity transformation. Everything would swap places to that observer; left would become right, up would become down. This is avoided by the fields rotating on all 3 spatial axes at the same time. In a sense, this gives the red plane some "substance" to it. Looking at frame 12, we see that this establishes antipodes, and paths stemming from those antipodes, at all planar intersections, rather than just at the intersection of any 2 planes.

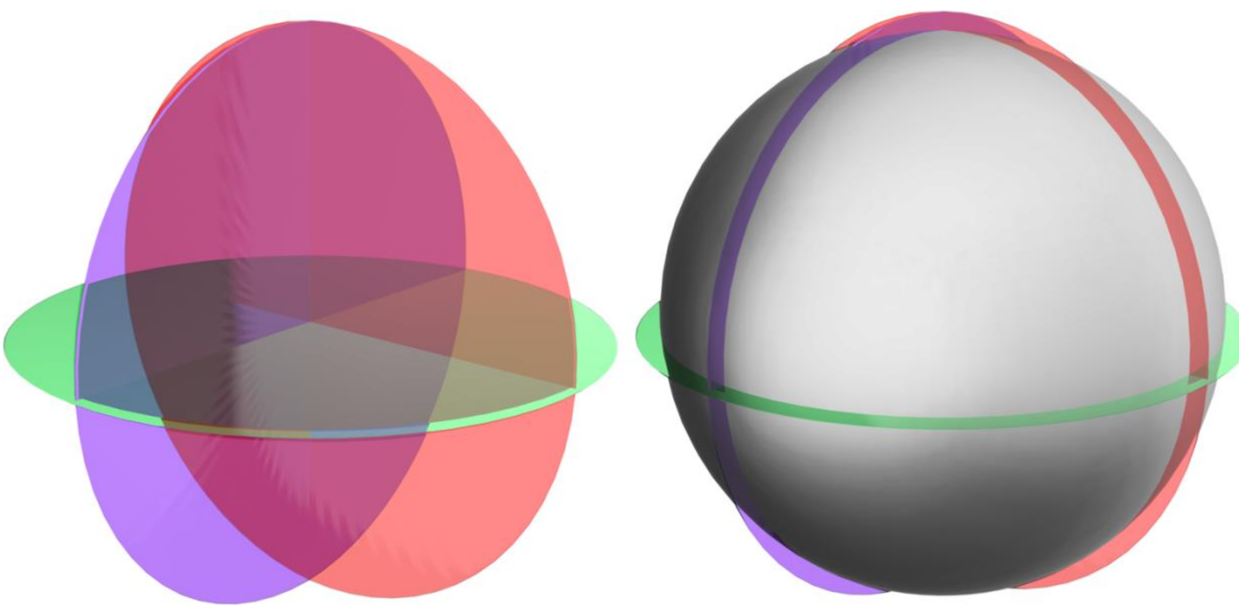

Figure 3.19

Another way of thinking about this is that the sum of the 3 planes divide the sphere into 8 identical pieces, shown in Figure 3.19. We'll explore this idea in greater depth later in this paper, but the gist of it is that if you were to pick any point on the sphere and rotate the sphere on all 3 axes, that point on the sphere would establish some rotational path. Any point that you pick will be reflected in each of the 8 pieces of the sphere. You can only find truly unique paths by choosing different points within that same slice of the sphere. Choosing any point outside of that slice of the sphere just amounts to choosing a point within that same slice of the sphere, and then reflecting it across 1 or more planes.

Quantum Field Theory

We have talked about planes rotating in different dimensional spaces, or being embedded in a certain number of dimensions, but in reality there is no rigid plane with fixed antipodal points that needs to remain rigid as it rotates as a whole. This is just a logical construct that we have been using thus far as a placeholder for the idea that a field's rotation that would necessarily describe some spatial boundaries, and that oscillations within this region would necessarily have 2 points opposite one another on the perimeter of whatever region, in whatever number of dimensions, was defined by the field's rotation, which would be the collective maximum amplitudes of the sum of all oscillating energy within that region.

This sounds like a lot, but it's a pretty familiar idea once we understand it in familiar terms. Imagine doing a cannon ball into a long, rectuangular swimming pool. As you enter the water your body will displace water, pushing it out of the way, causing oscillations in the pool. The water you displace will push outwards towards the sides of the pool in all directions. You will also have displaced water so that it moves in an upward, vertical direction, causing waves in the pool. There will be a sort of vaccum in the the water where you jumped in and displaced the water as you entered the pool. This vaccum will fill in with water, which will create another vaccum in the area immediately surrounding it, etc. In short, there will be a big wave followed by a series of increasingly smaller waves moving outwards in all directions from the place where you jumped into the pool. These waves will eventually hit the sides of the pool and the energy from the waves moving towards the sides of the pool will sort of bounce off the walls of the pool and create waves reflected at an opposite angle than the angle they hit the side of the pool. Assuming you jumped into the middle of the rectangular pool, the waves will hit the long sides of the pool first, those waves will be bouncing off the sides of the pool and affecting the other waves as they move lengthwise through the pool, towards the short edges of the pool.

Once the waves reach the short edges of the pool, they will reflect off those walls and start moving towards the middle of the pool, and towards one another. When they run into one another in the middle of the pool, the energy will be create a sort of smaller wave pool where the waves will locally bounce off one another and then eventually transfer energy, and waves with less total energy will again begin moving outwards from the center of the pool towards the edges. This will continue to happen, the longer the system evolves the more complicated it will be to describe the forces acting on one another as the system will moves towards a state of maximum entropy.

This is all a very wordy and overly complicated way of saying that when you do a cannonball into a pool, the water will slosh around in that pool. We have discussed some of the forces acting within the system, and really only a very small number compared the sort of description Leplace’s Demon would give of the same system. We can take a macroscopic view of the entire pool, and give a more efficent description of the forces acting on the water in the pool.

If Leplace's Demon could prescribe a force vector (an arrow pointing in a direction to indicate the direction of force being applied, and magnitude, represented by the length of the arrow, to indicate the amount of force being applied) to every molecule of water in the pool, we could imagine dividing the pool into 1 mL units, and we could take all of the vectors for each of the molecules each mL of water in the pool, and combine those vectors so that we could describe each mL of water in the pool with a single vector that accounts for all the forces and counterforces of all the molecules in that mL. We could continue this process so that every centiliter of water could be described by a single vector, then we could describe every deciliter by a single vector, then every liter… Eventually we could describe all of the forces in the pool by just 2 vectors. (Describing the pool by a single vector would only be useful if we were considering the pool as a part of a larger system. Here we are concerned with the behavior of the water in the pool, with the pool being the top of the hierarchy of systems we are considering.) These vectors would be the sum of all the forces and counterforces to one another causing all of the water to slosh around in the pool. These vectors could be seen as the sort of "antipodes" of the system of the pool. Because the system is dynamic, because the water is sloshing around, forces pushing and pulling on the water in the pool, this method will necessarily distinguish 2 antipodes at any given moment, and the location of the antipodes will likely be changing in time with the behavior of the dynamic system. In simple terms, the direction that the water is pushing or pulling in the pool will change as the water sloshes around.

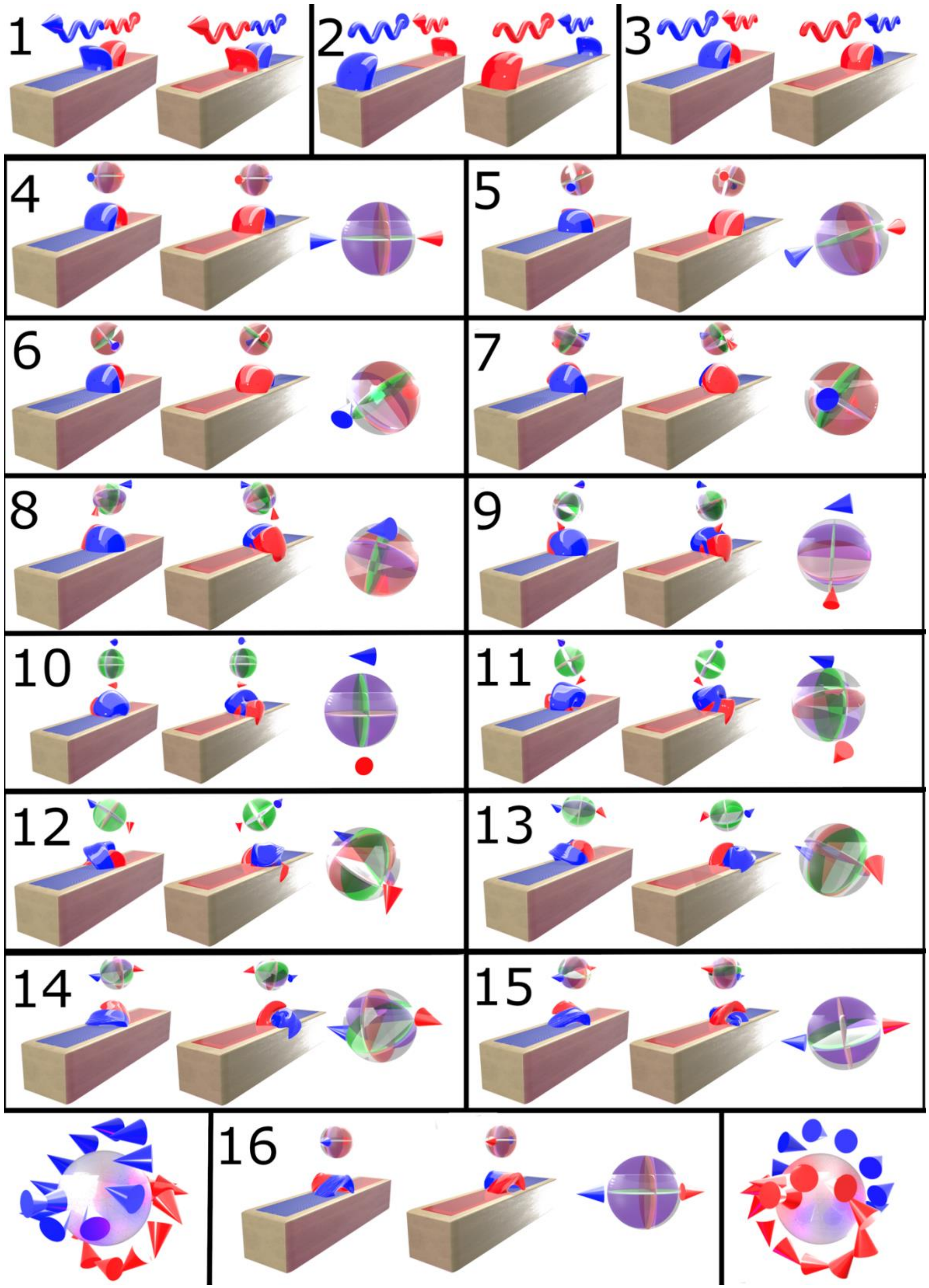

Figure 3.20

Now that we're able to distill the behavior of the water in the pool so that it is described by just 2 vectors, we'll take a closer look at what happens when these vectors "crash into" one another. In Figure 3.20 we have a pool that is divided into 2 halves. The water on one half is red, and the water on the other half is blue. Using the method described above we are able to describe the cumulative forces in the pool by just 2 vectors. In Frame 1 we see these vectors pointing away from one another, manifesting as oscillations, or waves, that are moving from the center of the pool, lengthwise towards the short edges of the rectangular pool. In frame 2 we see the waves reflect off the short sides of the pool, and the oscillations are described as vectors that are pointing towards one another, which equates to the reflected waves both moving through the water towards one another and the middle of the pool. In frame 3 we see these waves meet one another in the pool's center. This will be the focus of our discussion in these paragraphs.

In frame 4-16 each frame shows the wave pool from 2 different angles, shown from vantage points of opposite corners of the pool from one another. Above the pool in each image is a sphere and 2 cones. Inside the translucent sphere it is bisected by the 3 planes perpendicular to one another, green, purple and red, that we are familiar with from the images that we've been looking at in this chapter. The cones on opposite sides of the sphere are located at antipodal points on the sphere, and are representative of the forces in the wave pool being described efficiently as 2 vectors. (The cones in Figure 3.20 are not entirely mathematically rigorous in representing the vectors as the system evolves. As we'll discuss, each of these vectors moves freely around single axis. This is done to help illustrate the idea that a single path of rotation effectively creates projections of that path in 3 spatial dimensions.) Next to the images of the wave pool in each frame there is a close up look at the sphere and cones, from a vantage point from the side of the sphere. The system of the sphere, planes inside the sphere, and the cones, rotates with constant and equal rotation around the center of the sphere, on the 3 axes of the 3 spatial dimensions. Each of the cones rotates independently of the rotation of the larger system around the center of the cone, each on just 1 axis, with each of these axes being perpendicular to one another, with 1 axis shared by the planes of both rotations. In other words, the entire sphere rotates in place, bringing the planes and the cones along in tow. Independently of the sphere's rotation, one of the cones rotates in place on the green plane, and the other rotates in place on the purple plane.

As we see the system evolve through the frames in Figure 3.20, we see the waves that have crashed into one another at the center of the pool twisting and writhing around one another. This is a simplification done to efficiently create a visual representation meant to convey an idea of what is happening when the waves crash into one another. In a fluid, like water in a pool, the water in each half of the pool will bleed into the other half. The waves in the pool are energy, oscillations, that is moving the water around. When the waves crash into one another they will transfer their momentum to each other. We see the waves become twisted together, and as they sort of twist around one another, interlocking with each other, they sort of emerge on the other side, transferring the momentum back in the direction that they came, oscillating outwards from the center of the pool again. This result is contingent on 2 things happening with the waves:

1. The waves crashing into one another must carry a roughly equal amount of momentum into the collision. If one wave has a much larger value of momentum than that wave will absorb the opposite momentum of the other wave and carry on in its original trajectory.

2. The waves must be twisting in opposite directions from one another. When the waves crash into one another, they must be twisting as mirror images of each other. They must have opposite chirality. They need to sort of fill the void the other creates as it twists.

This is represented by the red and blue cones spinning independently of one another, each on its own plane.

One last thing to take note of in Figure 3.20 is the 2 images on the bottom row, on either side of Frame 16. Figure 3.20 shows the evolution of the system of the waves in the pool. This is represented by the rotating sphere and the cones. Each of the frames shows the sphere rotated by 15° on each of the 3 spatial axes. This is a constant rotation, equal in magnitude in every dimension. If the sphere were rotated 180° across any single axis, the result would be a mirror image reflection of the sphere across whatever axis the sphere is rotated. The combined rotation across the *x*, *y*, and *z* axes results in the sphere, and the cones, at their starting coordinates and in their original orientation.

Notice that a rotation of 180° across all 3 axes creates a path on the surface of the sphere where the cones reach a maximum distance that is one quarter the way around the sphere from the starting position. As the sphere rotates, bringing the cones along with it, the sphere starts with 0° of rotation and as the rotation across all axes increases, the cones move farther away from their starting location until the cones reach a maximum distance from the origin when it is rotated 90° across 3 axes. Once the sphere rotates 90°, the combined rotation across 3 axes results in a mirror image of the path from 0° to 90°, bringing the path back towards its origin until, after 180° of combined rotation across all 3 spatial axes, the cone is back at the origin, in its original orientation. In Figure 3.20 the cone is reversed after 180° of rotation. This is because in addition to the rotation of the sphere, each of the cones rotates independently of the sphere's rotation on a single axis, rotating around a point at the center of the cone.

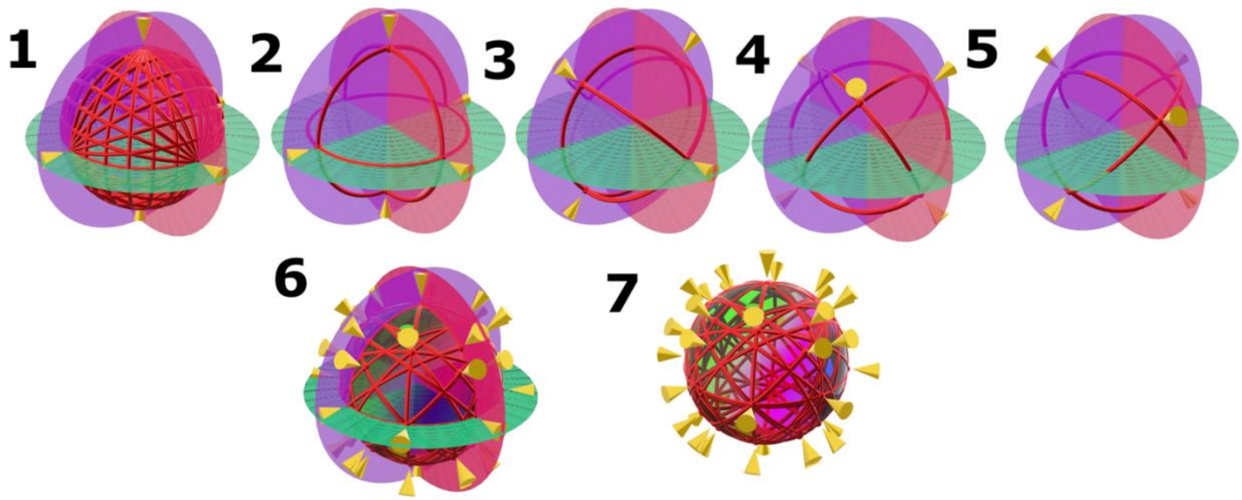

Figure 3.21

Now that we have established that the rotation of a 2-dimensional field creates a path which specifies a plane perpendicular to the rotating plane, which in turn establishes a path that reestablishes the original rotational plane, we can see how the rotation of a field around any arbitrary axis will naturally establish paths equidistance from a point that becomes the center of rotation. Another way to say this is that the rotation of the scalar field will establish rotational paths equidistant from some point at the center of all paths, the sum of which will form a 2-dimensional, spherical plane that is embedded in 3 dimensions.

Keeping in mind that every rotational path necessarily establishes 2 antipodal points on the sphere created by the paths, we can see in Figure 3.21 that the sphere is the sum of paths created by the rotation of antipodes. For any pair of antipodes on the sphere there is a continuous mapping function that maps the antipodes to a manifold in 1 fewer dimensions, as described in the Borsuk-Ulam theorem, that could map any antipodes to the same point, which would be the center of the sphere.

In Figure 3.21 we see the red, green and purple planes that we have previously discussed, each of these planes creates a set of rotational paths, shown if frame 1, which can be described most efficiently by a single rotational path integral, shown in frame 2. As you can see in frame 2, each of these paths establishes 2 antipodal points which are 90° around the surface of the sphere from any of the antipodes of the perpendicular planes. In frames 3, 4 and 5 the antipodes are rotated by 45° around a single axis in each frame. In frame 5 we see a set of paths which are perpendicular to each other, but askew from all of the rotational axes as those in frame 2.

So far we have established that the sum of all paths of rotation creates a 2-dimensional, spherical plane that is embedded in 3 dimensions, each of these paths establishes a plane, which establishes 2 perpendicular planes, and each plane establishes 2 antipodal points on that sphere. The point that we are illustrating here is that the sum of all these antipodes also creates a spherical, 2-dimensional surface, only instead of this surface being thought of as a sum of paths, it is a collection of individual points that sum to create a spherical surface.

We now have 2 methods of specifying a path on the surface of this sphere. This might seem somewhat redundant, since the sphere created by the paths and the sphere created by the antipodal points describes the same spherical surface. As we've briefly alluded to, and as we'll discuss in greater detail in the coming chapters, we won't be dealing with paths that look like the paths we've discussed in this chapter. We will be concerned with paths that return to their origins, and weave in and out of themselves, and may not ever circumnavigate the sphere like the paths in this chapter all do.

The paths in this chapter have been useful in establishing the idea of a path integral of a rotational path, which is an important step to building our model of consciousness, but it's not the end goal. We need to understand that by establishing any point, we establish that point's antipode on a spherical surface. By establishing any set of antipodes, we establish 3 perpendicular planes that bisect the sphere through its center. By establishing those planes, we establish antipodal points on the surface of the sphere at all of the intersections of the planes. By establishing those antipodes at the intersection of the planes, we reestablish the surface of the sphere, only this time instead of the sphere being established by the infinite paths that connect antipodes, the sphere is established by the infinite antipodes that are all equidistant from the center of the sphere. This is the sphere shown in frame 7.

We are constructing a method of describing a specific region of the quantum fields, the region synonymous with the surface of an imaginary sphere, with the end goal of being able to bridge the gap between the mathematical description of these localized regions of the quantum fields and a conceptual description of the same. Our purpose for this is as a means to the end of using the CPT symmetric model of the universe, along with a concept that we'll be covering in this paper known as the Holographic Principle, which describes a method for calculating the upper limit on the amount of entropy in a system, and through that lens using the tools that we have been developing in this section to build a novel interpretation of Quantum Field Theory in which we will look at particles that have been previously accepted as fundamental quanta, instead viewing them as very simple systems, or very small neural networks, in which the structure of these particles have 2 distinct parts that are codependent on one another's existence.

Using this new take on QFT, we will look at these very simple systems as very small feedback loops that have some positive value of Shannon entropy, or information, which can be quantified as bits of information. (Perhaps more technically these could be called as q-bits, or quantum bits. Although, the q-bit is a standardized value in quantum mechanics, thought to be the most fundamental value of information that is possible. This interpretation of QFT may require rethinking what value of information *actually is* the most fundamental value of information that could be quantized.) Once we have established the methods that endows these particles with some value of information entropy, we will apply the methods proposed in Integrated Information Theory to show that any of these particles could be what is called in IIT a Maximally Irreducible Concept System (MICS). In other words, we will show that when we use the method of calculating a system's potential for consciousness proposed in IIT, we see that there is a fundamental value of consciousness attributed to every particle of matter in the universe.

Chapter 4

Entropy

Entropy is important. Entropy is a bit elusive in definition. There are a few metrics which are commonly used to quantify entropy, and each metric has its own definition of entropy that lends itself well to the metric which is being used to quantify entropy as a value of the definition that lends itself well to that particular metric. There's possibly a bit of circular reasoning involved in that explanation. It's more probably more accurately thought of as a way in which entropy is measured for different ends.

Thermal Entropy

One common definition of entropy is as the amount of disorder in a system. This disorder can translate to the random scattering of particles in a system, which translates to particles bumping into one another and exchanging energy. More disorder equates to more particles bumping into one another. The more frequently this bumping into between particles happens, the more energy is exchanged. A greater frequency of particles bumping into one another means either particles moving faster, with more kinetic energy per particle, or particles packed more closely together, with a greater number of particles with a greater sum of kinetic energy. If we want to increase the kinetic energy within a system, we have 2 options:

1. We can give the particles within that system more kinetic energy per particle.
2. We can keep the kinetic energy per particle the same, but increase the number of particles in the system.

Both methods result in the system having a greater sum of kinetic energy.

Particles vibrating around and bumping into one another causes the kinetic energy of the particles to transform into thermal energy, which we can measure as the temperature of a system. To think of entropy as the amount of disorder in a system lends itself well to measuring the thermal entropy, or entropy quantified as temperature, of a system.

Information Entropy

Another common definition of entropy is to say that entropy is the amount of unknown information about a system. We can think of any system as a collection of fundamental particles and/or energy. There is a finite number of possible states that energy can be in, and a finite number of possible states that fundamental particles can be in. Within a physical system there are a finite number of possible configurations that any sum of mass and energy in a system can be in.

For example, we can measure the mass of a star. If all we know is the mass of a star, we can't be certain of how much matter is in the star. We know that there is a formula that describes the relationship between the massive property of matter and energy, the formula $E = Mc^2$. We can be certain of the sum of mass-energy equivalence of the system of the star. We could measure the density of the star, we could observe the electromagnetic waves emitted by the star to determine the composition of the star, we could measure the temperature of the star, the luminosity of the star, etc. All of this might give us insight into the ratio of energy in the form of fermions or energy in the form of bosons in the star (or the amounts of matter and radiation in the system). Knowing something about the composition of the star could help determine how much of the energy of the star must be in the form of quarks, needed to form protons and neutrons, and how much might be in the form of electrons.

We started only knowing the mass of the system. Knowing only the mass of the system, the energy in the system could be in any possible state. By observing the system we can use what we learn about the system to eliminate possible states of the energy in the system. For example, web can use the temperature, density, size, luminance, and spectroscopy of the star to determine if it is burning hydrogen, or how much of heavier elements might be present in the star's core. If there is iron in the core of the star, for example, then we know that there must be a greater amount of the apparent mass of the star that is in the form fermions and electrons than there might be in the form of massless energy, like photons, as would be the case if the star were less dense or had a greater proportion of hydrogen.

Every possible state of the system that we are able to eliminate by observing or measuring the system reduces the amount of unknown information about the system. What's left, what we can't know about the system, is the total sum of unknown information about the system, which we can quantify as the sum of Shannon entropy in the system. This definition of entropy lends itself well to quantifying entropy to be useful in Information Theory. Shannon Entropy is measure in bits of information.

(Claude Shannon was the founder of Information Theory. Therefore, quantifying entropy as the amount of unknown information in a system is done using the metric of Shannon entropy.)

This is the definition of entropy that will be most useful to us in the discussion of this theory of consciousness. Information entropy just *seems* as though it would be the best fit when trying to make a connection between entropy and consciousness. That isn't why it will be useful to us. Considering entropy as Shannon entropy will be useful to us because of the insights that have been made in cosmology and neuroscience, in the study of black holes and in formulating ideas about the possible relationship between consciousness and computational cognition, respectively, that have already been established by considering the entropy of a system as unknown information about the system. To remain consistent with these respective areas of study, we will derive our own use of Shannon entropy from 2 areas of research.

The first way will be in our discussion of the holographic principle. We'll save an in-depth discussion of this topic for the chapter devoted to it. For now, it will suffice us to know that the holographic principle is the idea that there is a more fundamental version of reality that exists on a 2-dimensional geometry.

This was discovered in the 1990's by physicists who were studying black holes, and specifically trying to quantify the maximum possible amount of entropy that the system of a black hole could have. When discussing the holographic principle entropy is typically thought of as Shannon entropy. This is because quantifying the maximum possible entropy of a black hole was being done as a means to seek an answer to the question of what happens to something when it enters a black hole. The problem that was being addressed was the paradox created by the rule that information can never be destroyed, but anything, and any information contained in that anything, that goes beyond the event horizon of a black hole is lost forever to an observer outside of that black hole. To an observer outside of the event horizon, that information seemed to be lost forever, aka destroyed.

The other reason to think of entropy as Shannon entropy is that when we will eventually pull everything that we've been discussing so far together to make an argument that we should be able to attribute every fundamental matter particle with some fundamental value of consciousness, we will describe every fermion as a very simple neural network, or a very simple information system. In this light, any fermion could be seen as a sort of information feedback loop. We will then apply this idea to an established theory in neuroscience that aims to quantify consciousness, or at least the potential for consciousness, known as Integrated Information Theory, more commonly referred to as “IIT.”

As its name implies, this is a take on Claude Shannon’s more general Information Theory, which looks at the universe as groupings of information. IIT specifically addresses information that meets certain criteria so that it should be thought of as integrated information. The gist of it is that when a system contains a maximal amount of integrated information within a hierarchy of systems, that system has the potential for consciousness. We’ll get into it more in the section devoted to IIT. The take away here is that we will argue that in the absence of playing a role in the consciousness of any higher order system, any fermion could, in theory if not in practice, be a very simple system that could be attributed with some fundamental value of consciousness. In order to make this translation from our works’ application to IIT as organic as possible, it will best serve us to think of entropy as unknown information about a system.

Chapter 5

The Holographic Principle

The holographic principle was discovered through the study of black holes. That doesn't mean that it only applies to black holes. As we'll discuss, it makes sense that a deeper understanding of our universe could have only come by considering a situation where a region of space has reached the maximum possible density for a region of space of some particular volume.

For a black hole to form there must be a sufficient amount of mass and energy within some region of spacetime, the boundary of which is called the Schwarzschild radius. This is the spherical radius that if you were to take some amount of mass and energy (depending on the amount of mass/energy that is being considered) and cram it into a volume of that size, the mass of that object would distort spacetime to such a degree that the density of that region of spacetime would approach infinity. Time would stop at the boundary of that region, nothing, not even light, that entered that region could ever leave the region of the black hole, and the effects of gravity within that region of spacetime would become so intense that gravity would warp spacetime to such a degree as to create a singularity within the black hole.

You can take any amount of mass or energy and figure out the Schwarzschild radius, the radius of a spherical volume of space that amount of mass would need to be crammed inside of in order to form a black hole, for that amount of mass. For example, the Earth has a mass of 5.927×10^{24} kg and a spherical radius of about 6,378 km at the equator. If you were to cram the entire Earth into a region of space having a radius of a little less than 9 mm, the Earth would become a black hole.

Once Earth was compressed to a black hole anything that has a trajectory that would bring it close to Earth would become part of the black hole. For example, we are constantly being bombarded with photons from the Sun. Even though these photons are massless, they still have some amount of energy. Every photon that bumped into that 9 mm region of spacetime would be absorbed by the black hole. However, that 9 mm radius sphere already has an infinite density. So, if a photon runs into the black hole, it can't just be absorbed into that same volume of space. In order to accommodate the extra photon, the black hole Earth would have to increase the space the black hole occupies by some amount. Specifically, it would increase the radius of the black hole by 1 Planck length.

Photons move at the speed of light, the upper speed limit of the universe. If you add energy to a photon, that added energy can't possibly be added to increase the speed the photon travels through space. The photon is already traveling through space as fast as anything in the universe could possibly ever move.

Instead, the energy makes the photon cycle faster. It increases the frequency of the wave. Since the photon still travels linearly, or travels over distance, at the same, maximum possible velocity, then a faster cycling of the wave part of the photon's movement, or in an increased frequency of the wave cycle of the photon, results in a shorter wavelength.

If a photon is travelling at the speed of light, roughly 300,000 km per second, and the wave part of the photon has a frequency of completing 1 wave cycle every second, then we know because the wave moves 300,000 km in 1 second, and it takes the photon 1 second to complete 1 wave cycle, that the wavelength must be 300,000 km. If we give that photon a boost of energy, and since that energy can't possibly push the photon to travel any faster, the energy causes that wave part of the photon to cycle faster, or more frequently, that now the photon must cycle 2 times every second. The photon is still covers 300,000 km every second, but now it cycles twice instead of just once over that 300,000 km. The wavelength of the photon must be reduced to 150,000 km by increasing the energy of the photon. We can conclude that increasing the energy increases the frequency which, in turn, decreases the wavelength of the photon.

Einstein's most famous equation, $E = Mc^2$, shows an equivalence between mass and energy. Therefore, if we can take any amount of mass and cram it into a small enough region of space and get a black hole, we should be able to do the same thing with any amount of energy.

The Planck length is the length at which, if a photon were to have so much energy that it would become a black hole, its wavelength would be 1 Planck length. Therefore, the Planck length is the smallest scale that it makes any sense to measure anything in the universe.

Now that we've seen that there is a finite amount of stuff that can be packed into any given volume of space, and there is a limit on how densely packed anything can be, we'll consider what this means for the entropy of a system.

We know that entropy is the amount of disorder in a system, with the high end of the scale being total disorder, or total equilibrium. If the system were to evolve to a state where you could measure it at the smallest sampling size that could possibly give a description of the system without inherently distorting the picture that you're taking of the system, and all samplings of the system would be identical, there is no way for the system to become more disordered. The system would be in a state of total equilibrium.

For example, let's say that you were to take a glass of water and add some food coloring to it. Let's say that you mixed the food coloring into the water so that there was a 99:1 ratio of water to food coloring. That means for every 99 water molecules there is 1 food coloring molecule. (It probably doesn't actually mean that, because they're likely different sized molecules, but this makes the analogy simpler.) If the glass of water contained a total of 100 million molecules that would mean there would be 99 million water molecules and 1 million food coloring molecules. No matter how ordered or unorder the system was, if you counted the entirety of the glass of water you would get a 99:1 ratio in the sample.

If you made the sample size half of the glass of water, then you could get many, many different results. It could be that you had just put the drops of food coloring in and they hadn't yet dispersed. If you counted the bottom half of the glass and the top half of the glass separately, you'd find one sample to have 50 million water molecules and 0 food coloring molecules, and the other half to have 49 million water molecules and 1 million food coloring molecules. If you were to divide that same glass of water, with all of the food coloring in dense drops at the top of the glass, in half differently, perhaps cutting it in half vertically, right through the center of the drops, you might get samples that showed 49.5 million water molecules and 500,000 food coloring molecules in each sample. Therefore, we can say that 50 million molecules is too large of a sample size to accurately determine if the system has achieved a state of maximum entropy.

On the other hand, if we decide on a sample size of 50 molecules, then we would get some samples that would have 50 water molecules and 0 food coloring molecules, even if the system was in a state of maximum entropy. The smallest sample size for this system that could tell us if the food coloring is evenly distributed in the glass of water is 100 molecules. If we are able to take 1 million samples that are each dimensionally identical and each has a composition of 1 food coloring molecule and 99 water molecules, then the system will have achieved a state of maximum possible entropy.

If we apply this same logic to a system that has a maximum amount of stuff packed into the spatial region that system occupies, i.e. a black hole, we are able to conclude that there must be a maximum amount of entropy that any system can have. That total amount of entropy can be calculated using the sum of mass and energy that a system has and the volume of space that the system occupies. When we are considering the maximum possible entropy, we need not distinguish between mass and energy, because in a state of the most possible disorder of a system, we won't know the phase of matter in that system. We will only consider this as a single value referred to as the mass-energy of the system.

However, when the system being considered is a black hole, the volume of the system is determined by its mass. Since a black hole has a maximum possible density, you couldn't possibly fit any more stuff, or mass, into the spatial region occupied by a black hole. Since we are dealing with a known density, and that density is the maximum possible density that any region of spacetime could possibly have, we can equally describe a black hole by its mass, or by its volume. The volume of a region of infinite density dictates the mass of that region, and the mass of a region of infinite density dictates the volume of that region.

It follows that we ought to be able to take any value of a 3-dimensional volume of space, and since we know the mass-energy of that volume of space, determine the maximum amount of entropy that could be contained in that volume of space. We find ourselves with 2 methods for determining the maximum possible entropy of a black hole; one formula using the mass-energy, and another formula using the spatial volume, to calculate the maximum possible entropy of a black hole.

The upper limit on the maximum amount of possible entropy of a system is called the system's Bekennstein bound. When using the mass of a black hole to determine its entropy, the

Bekennstein bound is found using the formula $S \leq \frac{4\pi k G M^2}{\hbar c}$. In this formula *S* the value of entropy; *k* is Boltzmann's constant, which is the relationship between the kinetic energy in a system and the temperature of that system, here it is used relate the thermodynamic temperature of a system to the amount of disorder in the system; *G* is the gravitational constant; *M* is the mass of the black hole; $\hbar$ is the reduced Planck's constant, which is a value that correlates the frequency of a particle with the amount of energy in that particle, keeping in mind the mass-energy equivalence, it is used in this formula to correlate the frequency of a particle with mass; and *c* is the speed of light.

It's not necessary to have a mathematical understanding of this formula, or to have a deep understanding of the constants and what they are doing. We have included this information to aid the reader in developing an understanding of how this formula processes some variable values, like mass, with some fundamental constant relationships of the universe, like Planck's constant or Boltzmann's constant, to determine the relationship between mass and entropy, if the reader cares to do so. It's not vital to understanding the ideas presented in this paper that the reader understands the intricacies of this formulation. The important take away is that there exists a tried-and-true method for determining the maximum value of entropy in a system.

This formula gives the upper limit on the entropy of a black hole based on its mass-energy. Keeping in mind that a black hole is an object that actually exists in the universe, an object which occupies some 3-dimensional volume of space in the universe, and that this volume is completely filled with mass-energy so that the space that is occupied by the black hole is completely saturated with mass-energy to the degree that the density of mass-energy in that volume of space approaches infinity, it would seem that we should be able to equivalently calculate the Bekennstein bound of a black hole by reworking the formula and instead of the mass-energy of the black hole, using the *volume* of space, in 3 dimensions, that a black hole occupies, knowing that the volume of a black hole is entirely dependent on its mass.

As it turns out, when the maximum entropy of a black hole is calculated using this method, the result is that the system seems to allow for a greater sum of entropy than should be allowed by the mass of the system. However, when one of the dimensions is removed from the equation, and the input variable used to find the Bekennstein bound is the 2-dimensional surface area that is the spatial boundary of the black hole rather than the 3-dimensional volume that includes the spatial boundary as well as everything inside of that boundary, the value of the Bekennstein bound using just 2 spatial dimensions turns out to be the exact same value as the Bekennstein bound when the upper limit on the entropy of the system is calculated using its mass. This version of the formula for the Bekennstein bound of a black hole is $S \leq \frac{kA}{4l_p^2}$ where S is entropy; k is Boltzmann's constant; A is area; and l_p is the Planck length. (The number 4 in this equation comes from the surface area of a sphere; the formula for which is $4\pi r^2$.)

Notice that in this formula the Planck length is in units squared, not units cubed. The square units imply only 2 dimensions. This is the holographic principle. This is the idea that the reality of our universe, with its 3 spatial dimensions, has a deeper, more fundamental basis to it, where, much like a hologram, a 3-dimensional projection is constructed entirely from information encoded on a 2-dimensional plane.

This is the most profound discovery in physics since quantum mechanics. All of the information about our 3-dimensional universe can be, *and in fact is,* encoded on just 2 spatial dimensions. Nothing about our 3-dimensional universe is lost when we subtract one of the dimensions. There is currently no consensus as to why or how this is the case, but the holographic principle says that it must be the case.

In the coming pages we will propose a mechanism that gives a plausible explanation for this phenomenon. We will propose that all of the information available to an observer looking out into an n-dimensional bulk is described by a 2-dimensional geometry from that observer's perspective. This is where the information is lost. Then, when the universe is reconstructed in 3 spatial dimensions only the information that has been encoded in 2 dimensions is used in the reconstruction. Therefore, when we are in a 3-dimensional universe and learn that there is a version of reality that underpins our 3-dimensional universe, and that this version of reality has only 2 dimensions, it seems curious that we wouldn't to lose any information when losing a dimension. The proposition is that the information was lost before the construction of the 3-dimensional universe, so there was never any information to lose when a degree of freedom is removed.

Chapter 6

Scroll Wave Dynamics

In this section we will be discussing scroll waves. Scroll waves are kind of oscillator. Our interest in them is that they are the specific type of oscillation that is the local solution to field equations. Here will describe how the field excitations which manifest in the universe as the fundamental particles known as fermions, which all matter is comprised of, are specific types of oscillations that necessitate a duality within themselves in order to exist. These oscillations of the quantum fermion fields propagate outwards from a phase singularity which is contorted in such a manner as to require that it be threaded by another phase singularity with opposite chirality so that the system maintains a coupling number of 0. (For readers familiar with QFT, it should be noted that this coupling number is not the same coupling number which describes a field's interaction with the Higgs mechanism.)

Vacuum Energy and Quantized Excitations

Quantum Field Theory (QFT) is the most accurate description of the universe that we have developed. The gist of it is that there are fields that exist everywhere in the universe, and these fields generate particles or transmit energy between particles. When these fields become locally excited, the field generates a particle. These excitations are oscillations, or waves, in the field. These aren't exactly like waves as you'd think of waves in the ocean. The type of waves that excite the fields are a type of oscillator that requires that the medium the oscillation is propagating through is able to be excited.

As where waves in the ocean push and pull the ocean itself, with the energy of the wave being transmitted to the water, so that the energy of the wave carries the water along with it, these waves need whatever is carrying the wave to use the energy of the wave itself, as opposed to the energy being applied to whatever is carrying the wave. If you think of the energy of a wave in the ocean being applied to the water in the ocean, causing the ocean to rise and fall in a cyclical pattern, moving the water up and down while also moving it in the direction that the wave is traveling, then a more apt analogy would be a spot in the ocean where the water is boiling, and that spot would move around in an otherwise generally calm ocean.

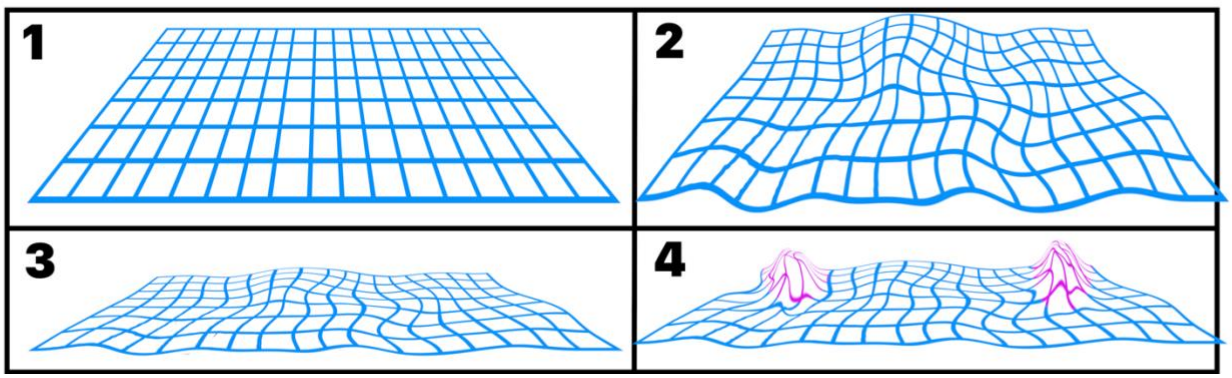

Figure 6.1

The fields are not entirely calm in the absence of a particle excitation, however. Each field has some baseline value of energy everywhere in the field. This is called the vacuum energy of a given field. Looking to Figure 6.1, in frame 1 we see grid that is meant to represent a quantum field. This field permeates space, and it exists everywhere simultaneously. This field isn't still, as it is shown to be in frame 1. Rather, this field has some baseline vacuum energy oscillating everywhere and at all times. This is shown in frame 2. In frame 3 we see the same thing, but from a little different angle. This is a field in its ground state. It is a 0 particle field, in a ground state where all of the fluctuations in the field are attributed to its vacuum energy. In frame 4 we see 2 spikes in the field. This is where there are excitations localized to a small region of the field. There is more energy in that small area than just the quantum fluctuations from the vacuum energy. These excitations are how the field generates particles. These excitations *are* the particles of that field. If the field that we are looking at is the electron field, then the excitations in frame 4 *are* electrons.

These excitations can only come in discreet values. (Discreet here doesn't mean secretive, it means a specified amount.) The *quantum* field generates *fundamental* particles because the excitations which we call particles are the smallest, or most *fundamental*, specific value of localized energy, or *quantized* amount of energy, that will generate a particle in that field. In the electron field, it's not possible to take half of the amount of energy that it takes to generate an electron and localize it in the field and generate half of an electron. The electron is a *fundamental* particle. The localized energy that generates an electron is a *quantum* value.

In the move Father of the Bride there is a memorable scene where the character played by Steve Martin is having confrontation with employees at a grocery store because he is upset that hot dogs are sold in packs of 8 and hot dog buns are sold in packs of 12. He starts ripping opens packs of hot dog buns, taking out 4 buns, and putting them back on the shelf, saying that he's not going to pay for 4 hot dog buns that he doesn't need. Unfortunately for this character, both hot dogs and hot dog buns are sold in quantized amounts. The quantum of hot dogs in a package is 8, and the quantum of hot dog buns in a package is 12. Just like there is no getting 2/3rds of a package of hot dog buns, there is no generating 2/3rds, or ½, or any other non-integer number of electrons. You've got to buy the whole package.

<u>Phase Singularity</u>

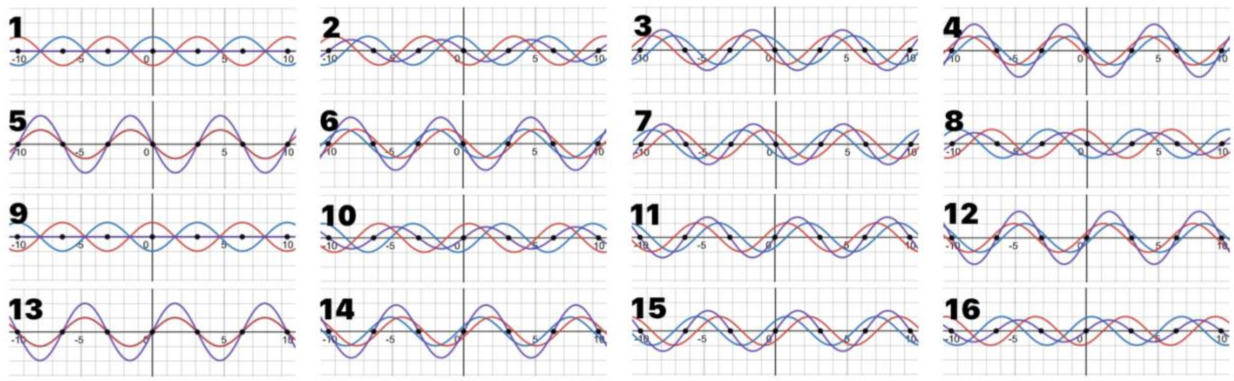

Figure 6.2

In Figure 6.2 we see 2 identical sine waves, in red and blue, moving in opposite directions. The resulting wave, seen in purple, is the standing wave. In frame 1 the red and blue waves are perfectly out of phase with one another. The destructive interference perfectly cancels the wave out, and the standing wave is entirely on the midline, with an amplitude of 0. As the waves move past one another the difference in the phase between the waves is changing, and the resulting standing wave goes from a maximum destructive interference, in frame 1, to a maximum constructive interference, in frame 5. In frame 5 the constructive interference doubles the amplitude of the wave.

The black dots on the midline represent the nodes. Notice that no matter where in the periodic phase shift of the waves, the nodes remain fixed, with the standing wave always intersecting the midline at the nodes. The combined sum of constructive and destructive interference at the nodes never changes. The standing wave oscillates up and down between the fixed nodes.

The nodes of 2-dimensional sine wave pictured above are coordinates on the 1-dimensional midline of that sine wave. These nodes are points where wave interference between 2-dimensional waves is always perfectly destructive, so that the red and blue waves always cancel one another out. The result is that the net amplitude of the standing wave at the nodes is always 0. At these nodal points on the midline there is a definitive amplitude of each wave, which is exactly the same as the other, and a definitive phase of each wave, which is exactly the opposite the other, so that the interference between the waves is certain to be destructive interference.

This is not the same as a phase singularity. A singularity is a point where one of the inputs, or parameters, becomes undefined. The idea of a singularity isn't the most intuitive. A phase singularity in particular seems especially paradoxical. The somewhat standardized analogy that I've heard a few times is the idea of the time at the north or south poles. The time zones are divided along longitude lines, which converge at the poles. So, if you're standing on the north pole and somebody asks you what time it is, you can't rightly give a definitive answer.

Time zones are discreet, which means that they come in fixed quantities, and you can't have an increment of a time zone. Chicago and Fargo are both on Central Time. Chicago is closer to Eastern Time, which is an hour later than Central Time. It's not as if Chicago is a half hour later than Fargo as though it's getting closer to Eastern Time, because time zones add to or subtract from Zulu Time, by some discreet quantity, or whole number, of hours.

Ignoring that time zones are discreet quantities, if you were standing on the North Pole the time for you would be every value on a continuous range from midnight on some day to 23:59:59 on that same day. If somebody were to ask you for the time, you could only answer that it is simultaneously every moment of the day. Precisely because, for you as an observer on the North Pole, it is every moment, and it is all times, then also for you, it is also not any time. Time implies some specific value, an exact temporal coordinate, or it's not the time with which we are familiar. Therefore, if you're standing at the North Pole and somebody asks you what time it is, the correct answer is that it is no time at all. Time is undefined. For anybody standing on the North Pole, the time of day is a singularity.

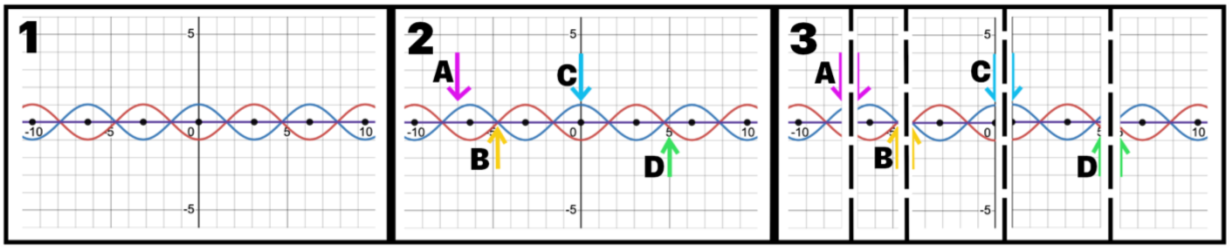

Figure 6.3

The next analogy that we'll use to describe the idea of a phase singularity might lend itself better to building an understanding of a phase singularity as the core of a spiral wave or the filament of a coil wave, but it might not be as clear as the analogy about the time zones at the poles.

Looking at Figure 6.3, the singularity of a spiral wave is almost like taking the midline of the sine wave of in frame 1, and turning it 90°, so that you're looking at it straight on, and the entire midline looks like a single point. If you're reading this on paper, that would mean that you turn the paper so that you're looking straight on at the edge of the page.

In Figure 6.2 we saw how the evolution of the standing wave creates a standing wave which oscillates up and down between fixed nodes. To understand the idea of a phase singularity we'll take a single frame from that image and pick it apart in Figure 6.3. Keep in mind that the red and blue waves are the individual sine waves moving in opposite directions. The wave that we are concerned with is the wave that is the product of the red and the blue waves, or the standing wave. Although you can't really see the purple standing wave against the black midline in Figure 6.3, the standing wave is still there. Because the red and blue sine waves are perfectly out of phase with one another, the standing wave has an amplitude of 0 at every point, and it is contained entirely on the midline.

Just as before, think of printing this graph out on a sheet of paper, turning that paper, and looking at the edge of it. If we are looking at it like this, then we are seeing the midline head on. We would see this midline as just a dot, a single point. We could look at the front of this sheet of paper and see all values of the phases of the red and blue waves as they contribute to the standing wave.

In Figure 6.3 there is just 1 phase of the wave system. We need to think of that phase as being the product of 2 individual phases. Every location along the width of the paper would be associated with some particular phase of the red and blue waves. In frame 2 we use the 4 arrows to specify 4 specific values for the phase of the waves. Even though the arrows each indicates a different phase of the red and blue waves, the amplitude of the standing wave at each point is 0. The interference of the red and blue waves at this particular phase is perfectly canceled out so that the resulting standing wave has an amplitude of 0 at every coordinate on the x-axis.

Looking back at Figure 6.2 we see that we could deduce the phase of the red and blue waves just by looking at the purple standing wave in any of the frames, with 2 exceptions; frames 1 and 9. In frames 1 and 9 the entire standing wave is contained on the midline. We could of course say with certainty that the red and blue waves are perfectly out of phase with one another in either of those frames, but we could not say where the crests and troughs of the red and blue waves are. Notice that in frame 1 the blue wave's coordinate at center of the graph, or at $x = 0$ is (0,1). The red wave in that frame has a coordinate (0,-1). In frame 9 the blue wave has a coordinate (0,-1) and the red wave has (0,1). The standing wave is exactly the same in both of those frames, but the red and blue waves are mirror images across the x-axis of themselves in either frame. It's not possible from looking at the sine wave to say whether we are looking at frame 1 or frame 9.

Coming back to Figure 6.3, if we were to cut the paper at the dashed lines in frame 3 and turn the paper so that we are looking at the midline head on, there would be no way for us to tell which piece of the paper we were looking at just by looking at the standing wave. Each cut represents a different phase of the red and blue waves, the waves which create the standing wave, but an ambiguous value for the phase of the standing wave. Looking head on at the edge of the cut paper we see the standing wave as a phase singularity for the red and blue waves. The single dot representing the standing wave represents all possible phases of the red wave and the blue wave. The phase of the red and blue waves is undefined.

2-Dimensional Spiral Waves in Excitable Media

Spiral waves are the 2-dimensional version of scroll waves. We are discussing them only to build towards an intuitive understanding of scroll waves.

Excitable Media

We've touched on the difference between oscillations that are more familiar; waves in water, pressure waves in air, etc., and oscillations that require excitable media for the oscillation to self-propagate in. Here we will expand on what we've established so far so that we can understand exactly what excitable media is before we begin discussing oscillations in the excitable media.

Excitable media is the medium which these types of oscillations are able to propagate through by changing some characteristics, the state, the mass-energy phase, a chemical reaction, some change in the substance which is facilitating the oscillator's self-propagation. By contrast, a sound wave for instance might be the result of a piano. A key is pressed on the piano, this causes a hammer to strike one of the strings inside the piano, which causes that string to vibrate. As these vibrations, or waves, move through the string, the string pushes and pulls against the air that is immediately surrounding it. The molecules of air that are directly affected by the string's oscillating push and pull against the air molecules that are immediately surrounding them. This causes small fluctuations in the localized air pressure. These pressure waves disperse in all directions, moving away from their source at the piano. When these pressure waves cause fluctuations in the air next to our ear drums, we interpret these changes in air pressure as the sound of a piano.

Through this whole process the air becomes more or less dense, the molecules become packed together a little more tightly, or the pressure drops and the molecules have a little bit more room to move around before they bump into other molecules of air, but the composition of the air remains unchanged. There is nothing that is different about the molecules of air in either the presence or absence of a pressure wave from a piano.

Waves in the ocean behave in a different manner, but relative to oscillations in excitable media they're in the same wheelhouse as pressure waves in the air. Ocean waves are oscillations of energy that acts on the water by pushing and pulling the water in a circular motion, with those circular patterns traveling linearly over distance. Just like the sound waves in the air, waves in the ocean act as a force pushing and pulling on the water, which pushes and pulls on the water next to that water, etc. Again, this kind of oscillation doesn't change the water, it just moves the water around.

Oscillations in excitable media don't act *on* the media so much as they act *in* the media. They change something about the thing that they are oscillating in. It's as if they flip something on or off in the medium that they are oscillating in. After the oscillation flips the media to on at a given location the wave moves to the next part of the media that is off, and flips it to on. In order for the media to be flipped on it must be in an off state. If the oscillation flips all of the available media to an on state before it has time to reset itself to off, then the wave burns itself out and the oscillation ceases to self-propagate.

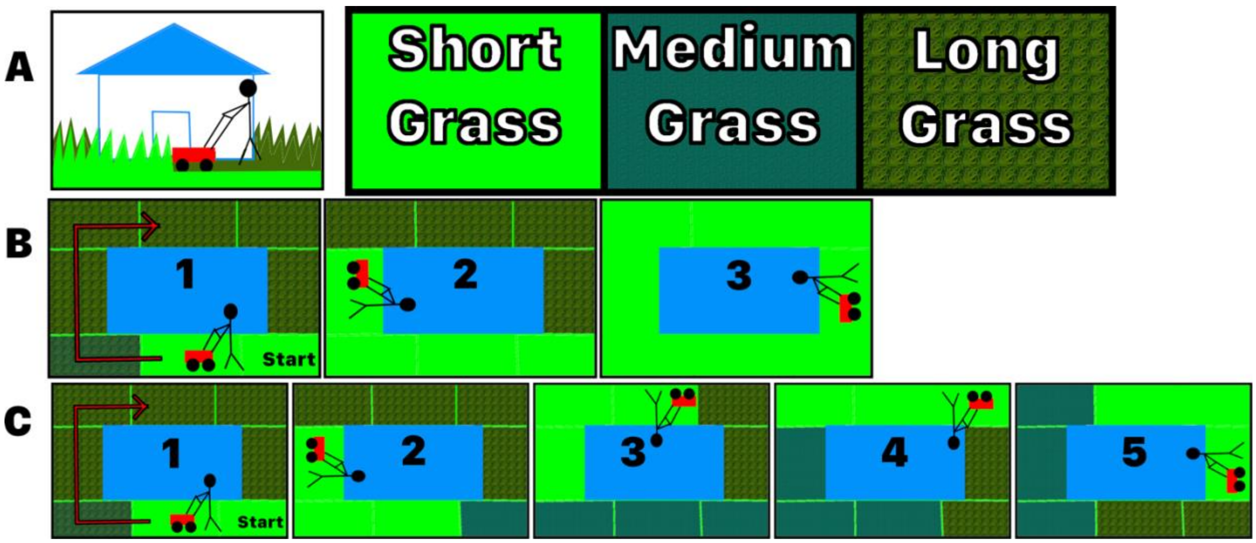

Figure 6.4

In Figure 6.4 we make an analogy of a person mowing the grass around their house to understand oscillations in excitable media. In Row A we see a side view of this person mowing the lawn in front of their house with a blue roof. Next to that is a key to help understand what is being depicted in the rest of the image. In Row B we see this person start mowing their lawn at the bottom, right corner of the frame. As they make their way around their house the lawn behind them is cut short, and as a result when they have completed one full revolution around their house they will have cut all of the grass short and there will be none left to mow. This is shown in Frame 3 of Row B.

If their lawn were to grow sufficiently fast or if they were to mow the lawn sufficiently slowly, then it would be possible that when they returned to the location at which they started, that the lawn would have regrown and they could just keep mowing in circles around their house. This is shown in Row C. As this person is mowing, the grass behind them begins to grow back. Before they complete one full revolution the grass at their starting location has already regrown.

<u>Spiral Waves</u>

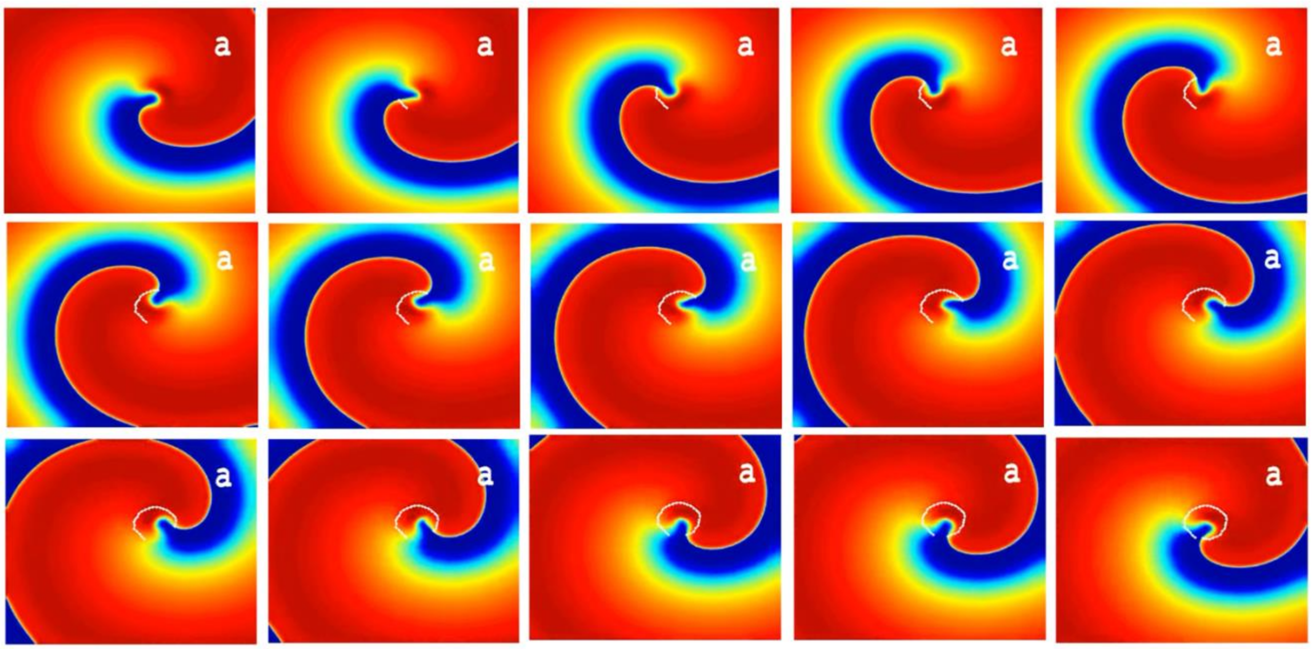

Figure 6.5

Figure 6.5 shows a 2-dimensional spiral wave as it evolves over a period of time. At the center of this spiral wave is a phase singularity. This singularity that the wave propagates outward from is called the core. The path that the core takes dictates the behavior of the spiral wave. The path of the core in the example above is shown as a white line. The core of this particular spiral wave follows a very even trajectory. The path forms a circle, and the resulting spiral wave is very uniform and predictable.

A wave is some sort of oscillating dynamic disturbance that propagates through something. We have discussed how sound waves make a disturbance of the air pressure, ocean waves make a disturbance in the displacement of water, here the substance that the spiral wave is disturbing isn't affected spatially like the air or water are by their respective waves. Here there is a chemical reaction that is taking place. The core is the single point from which the waves propagates outwards, but it is the whole yellow band in Figure 4.5 that is the front edge of the spiral wave.

As the wave propagates through the medium the chemical chain reaction at the front of the wave affects the media directly in front of it, causing it to undergo the same chemical change. This reaction takes some amount of time before the medium in any particular location is completely changed. This change can be seen by looking at the bands of color in the spiral wave. The medium in its ground state is red. As the chain reaction propagates through the medium and reaches some part where the medium is in its ground state it turns the medium yellow. This is the front edge of the spiral wave. As that medium more completely undergoes the chemical change it goes from yellow, to green, to light blue, until it has completely undergone a change and that part of the medium can no longer propagate the chemical chain reaction, as all of the medium in that region has already undergone the chemical change that is occurring in the chain reaction. This is the part of the spiral wave that is dark blue.

However, this chemically altered state of the medium is not stable, so the medium will naturally return to its ground state. This is what's happening in the band at the back edge of the spiral wave. After the medium has returned to its ground state, it remains in its ground state until the spiral wave propagates back around to that region, once again exciting the medium and repeating the cycle.

1-Dimensional Filaments and 3-Dimensional Scroll Waves

Filaments

The phase singularity at the center of a 2-dimensional spiral wave is a 0-dimensional point called the spiral wave's core. When we expand a spiral wave from 2 dimensions to 3 dimensions, we get a scroll wave. If we are extending the self-propagating wave into another dimension, we also need to expand the phase singularity that the wave propagates from into another dimension. The center of a 3-dimensional scroll wave is a 1-dimensional phase singularity called the scroll wave's filament.

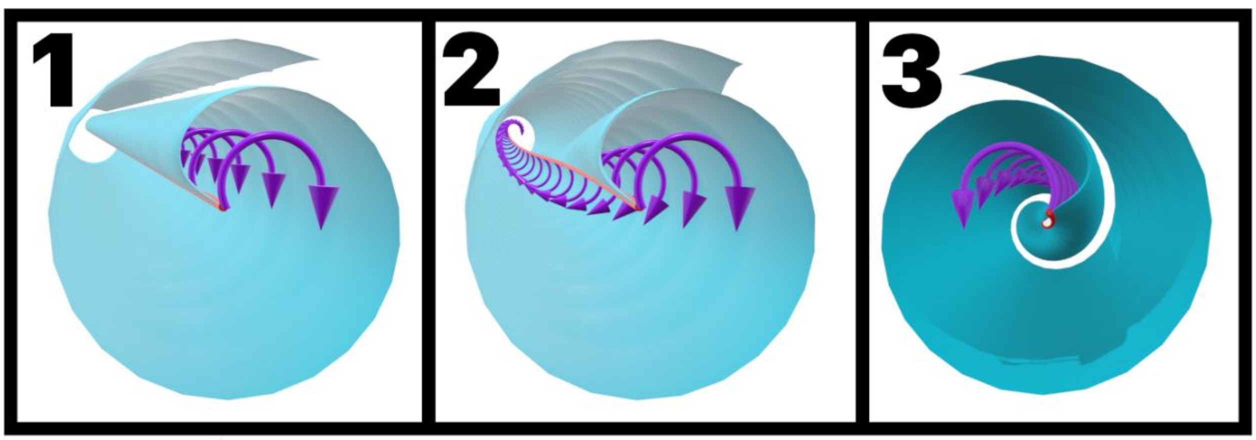

Figure 6.6

In Figure 6.6 we see a straight scroll wave. The long, thin, red cylinder running through the center of the wave is the wave's filament. The purple arrows indicate the direction of propagation from the filament at any point on the filament. Frame 1 shows probably the easiest way to start thinking about a scroll wave. A scroll wave like this would be like taking any frame in Figure 44 and making a bunch of copies of it, and stacking them on top of each other so that the 2-dimensional spiral wave extends into the 3rd dimension. A more realistic way to picture scroll waves is the way that they appear in frames 2 and 3. These would be more like taking all of the sequential images in Figure 44 and stacking them on top of one another so that the 2-dimensional images extend into the 3rd dimension. Frame 1 shows a scroll wave where every part of the phase singularity is in an identical phase. In frames 2 and 3 every part of the phase singularity is in a sequential phase to the parts of the filament in its immediate vicinity.

A scroll wave's filament is responsible for the oscillation's structure and dynamic behavior. In any dynamic system where a scroll wave is propagating through some excitable media in 3 dimensions, the filament will move, twist, and writhe until the scroll wave either burns itself out by exciting all of the available media before the media is able to return to its ground state, interferes with itself so that the 2 parts of the wave front run into one another and cannot propagate into any media that is not in its ground state, or until the filament finds a stable geometry that will allow it to continue to propagate through the medium.

One typical way that this happens is that the filament curls back on itself until its ends connect to form a loop. When this happens it is called a scroll wave ring.

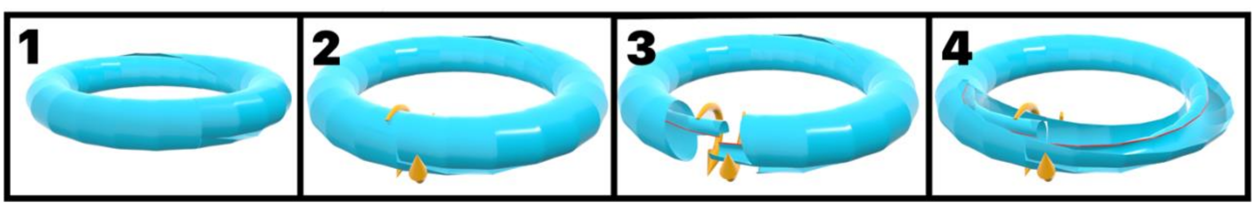

Figure 6.7

In Figure 6.7 we see a scroll wave where the filament has curled around and connected its ends to form a scroll wave ring. Notice that throughout the entire scroll wave, it maintains its chirality, or the direction, clockwise or counterclockwise, that it is twisting. It is always propagating in the same clockwise motion anywhere along the filament. When we sort of cut the scroll wave open in frames 3 and 4 we can clearly see that even at the point where the ends of the filament connect, and one part of the filament is propagating down and to the left and the other part is propagating up and to the right, they are both propagating in a clockwise rotation.

This sort of mismatch in the propagation is only a spatial mismatch, a mismatch in the phase of the propagation, and it can be overcome by the scroll wave simply by the parts of the scroll wave coupling to the parts nearest to it until the ends of the filament phase shift to be in phase with one another. This scroll wave is said to have a coupling number of 0, because the ends of the scroll wave are able to couple with one another with a simple phase shift. Any scroll wave ring, or system of scroll wave rings, needs to maintain a coupling number of 0 in order to maintain self-propagation.

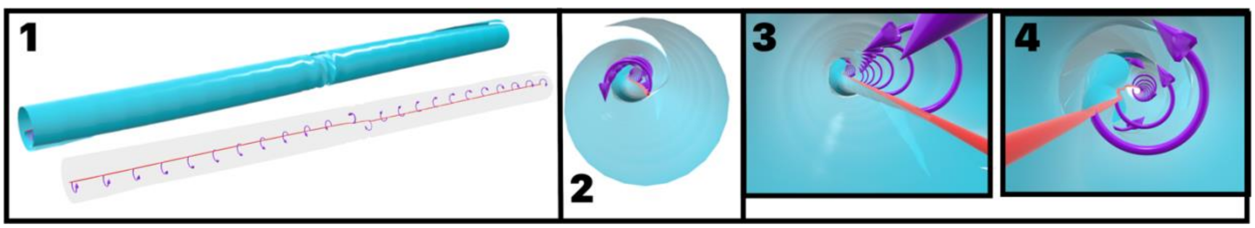

Figure 6.8

When a scroll wave gets a highly localized twist in its filament that is perpendicular to the gradient of the medium, the chirality of the scroll wave is reversed. Figure 6.8 shows an example of a straight scroll wave with this type of twist in it. (In practice the filament of a straight scroll wave with this kind of twist would break. We are using it to illustrate an idea about the filaments of scroll wave rings.) Notice that the chirality of the propagation from the filament is reversed at the location of the twist in the scroll wave.

Later in this paper we'll have a larger discussion about what kind of twist in a filament is able to reverse the chirality of its propagation, and what a filament having this kind of twist means in the larger context of the model that we are building. For right now it will suffice us to think about the filament being a 1-dimensional line, responsible for the propagation of a 3-dimensional oscillation. If we reverse the direction of rotational propagation at any point on the 1-dimensional filament we get a propagation with the same chirality, but in the exact opposite phase of oscillation. This type of mismatch can be overcome by a phase shift. When the direction is reversed across 2 axes simultaneously, both axes perpendicular to the 1-dimensional filament, and each being perpendicular to the other, then the chirality is reversed. Thinking back to our previous discussion of CPT symmetry, this type of reversal is analogous to being either a simultaneous charge and parity symmetry transformation or a time reversal symmetry transformation.

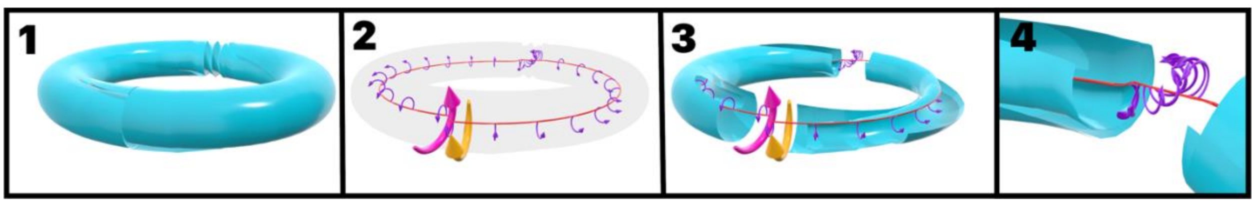

Figure 6.9

When the filament with this type of highly localized twist curls around to form a scroll wave ring, the ends of the filaments have a chiral mismatch and are not able to couple to one another by a phase shift. The system no longer has a coupling number of 0.

In order for the system to maintain a coupling number of 0 the filament must be coupled to another filament with a mirror image chiral mismatch. This can manifest in several ways, but the one that is of interest to us is when the filament becomes knotted, and specifically knotted in such a way that it allows for continuous growth and propagation of the scroll wave.

Knot Theory in Scroll Wave Dynamics

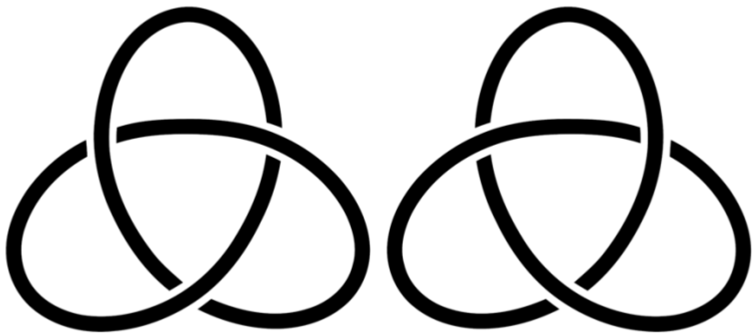

Figure 6.10

The knots that we are talking about here are not knots like you'd tie in a rope. These are mathematical knots. A mathematical knot is a line whose ends connect to one another so that it cannot be unwound without either cutting the line or passing it over itself. Figure 6.10 shows the simplest knot, the trefoil knot. There are 2 types of trefoil knots that differ by chirality. On the left is the left-handed trefoil knot, and on the right is the right-handed trefoil knot.

Scroll waves are a relatively recent discovery in pure mathematics (circa 1970's-1980's). The dynamics of these oscillations are very complex, and there is much that is yet undiscovered about their structure and behavior, particularly in spaces of more than 3 dimensions. One discovery that has been made within the last few years (see the article by Weingard, Steinbock and Bertram) is that if the filament of a 3-dimensional scroll wave, the filament having a twist so that its ends form a chiral mismatch if formed into a simple loop, if that filament is mapped onto an inert trefoil knot, the scroll wave will continue to self-propagate and the filament will continue to grow, maintaining its structure even after it is no longer attached to the inert knot.

The takeaway from this discovery is that there are certain geometries that a filament can find itself in that will result in a continuous propagation and growth of the scroll wave. In the absence of any other factors, it seems that this propagation and growth could and would continue ad infinium.

Rotational Path Integral as the Foundation of a Scroll Wave's Filament

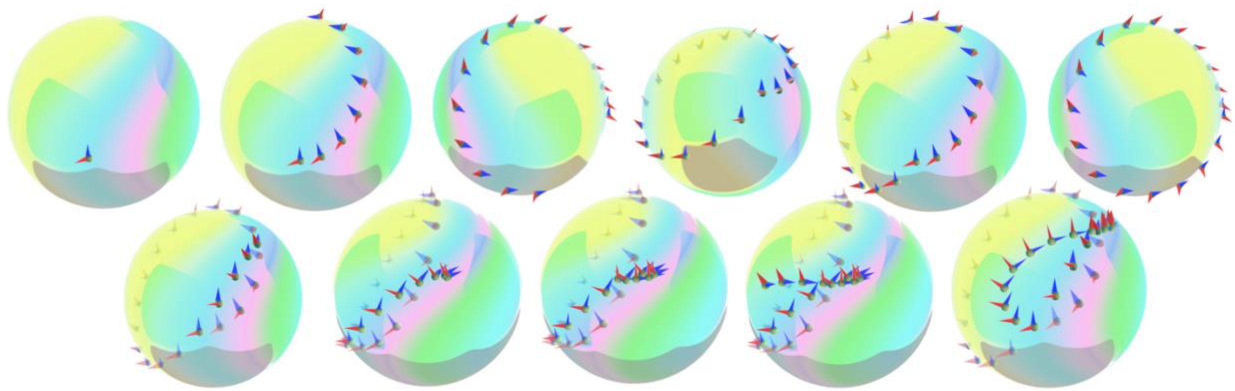

Figure 6.11

In Figure 6.11 we see the path that is formed by taking any arbitrary point on a spherical plane embedded in 3-dimensional space and rotating that point around the center of the sphere with a constant change in the degree of rotation. To be as clear as possible about the rotation that we're describing, to make the images in Figure 6.11 we placed the ball with the red and blue pointers (we'll call this the "pointer" for brevity) at some arbitrary location on the surface of the larger, multi-colored sphere. To move the pointer and make a path, we made a copy of the pointer at its starting location, specified the center of the sphere as the center of rotation, and rotated the pointer 10° around the x-axis, 10° around the y-axis, and 10° around the z-axis. This is the 2^{nd} location of the pointer. We did the same thing for 20°, then 30°, etc.

The top row of images in Figure 6.11 shows the pointer starting at 0° of rotation and reaching a maximum of 180° of rotation across all 3 axes. Notice that after 180° of rotation the pointer is oriented the same way and is in the same location as it was in its starting position.

In the bottom row of images on Figure 6.11 we continue that pattern up to 360° of rotation. Again, we return to that starting position with the pointer in its beginning orientation.

Notice that the path does not make a smooth, closed loop after 180° of rotation. The path makes 2 loops that together are a smooth, continuous transition of coordinates around the spherical plane. Even though the pointer is in its original location and orientation after 180° of rotation across the 3 spatial axes, it has a lot more rotation "bound up" in its path than it does at its original orientation.

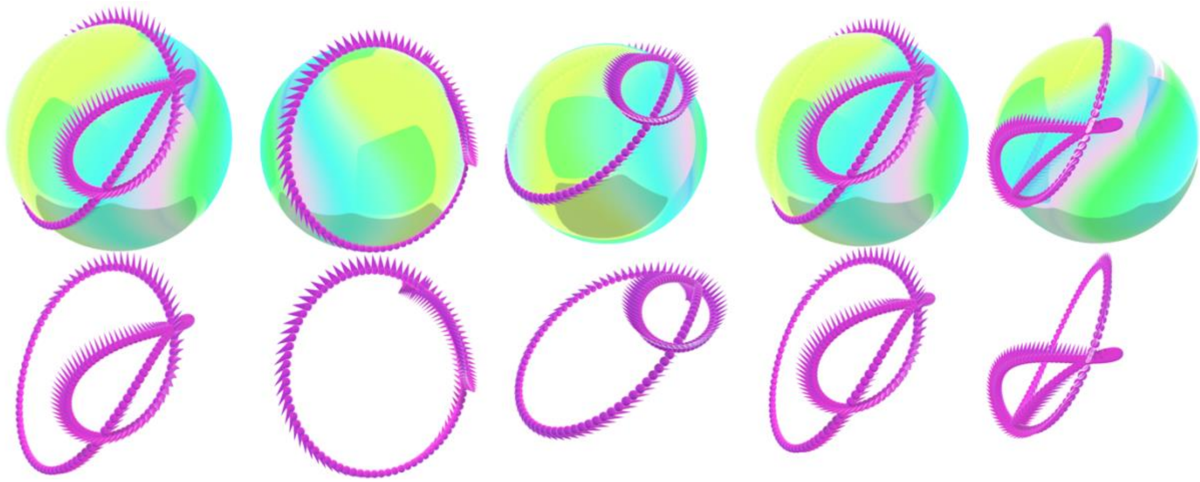

Figure 6.12

180° of rotation is the maximum amount of "bound up" rotation that the pointer can have on its trajectory along this path. This is because the rotation is occurring on a plane with constant positive curvature. Knowing that after 180° of rotation across all 3 axes the pointer is in its original position and orientation, it's helpful to think of the path as being a path that is based around a single point, a point which reoccurs 3 times along the path; at the start, at the halfway point, and at the end. Given those boundary conditions, think of the path as being generated by the pointer being displaced as much as it possibly can from its central hub before adding any further displacement will turn its path to start coming back towards its starting position.

In Figure 6.12 we have added enough pointers to create a continuous path from 0° of rotation all the way to 360° of rotation. Notice that as the pointer begins to move away from its starting position, it is travelling in a low, sweeping, curved trajectory. When it returns to this central hub at the halfway point in its path, it has 180° bound up, or embedded, in its trajectory. As such it comes to the central hub of the path with a very straight, linear trajectory.

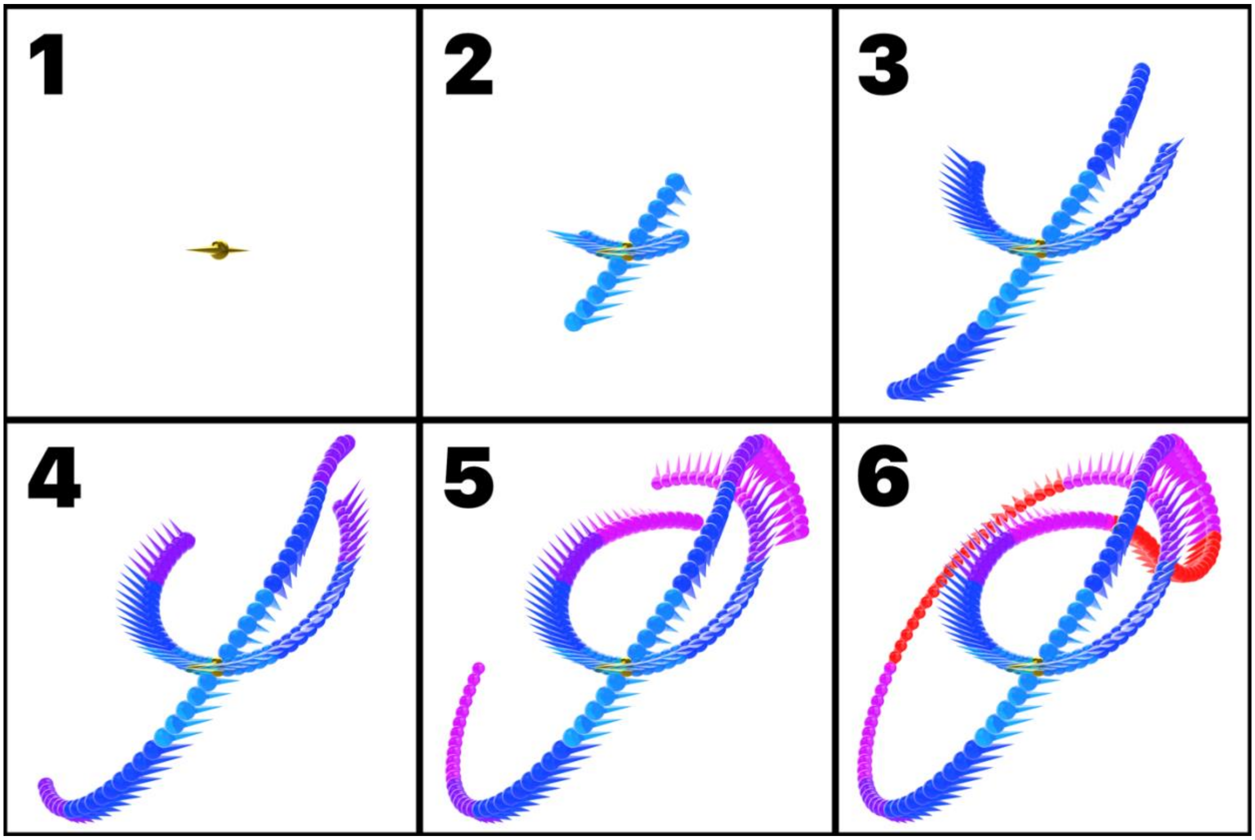

Figure 6.13

In Figure 6.13 we see a visualization of how we should be thinking of this rotational path integral. Rather than thinking of the pointer beginning at 0° of rotation, increasing its rotation across the 3 axes, reaching 180° of rotation across each axis, returning to the starting position and continuing to increase its rotation around the axes until it comes full circle at 360°, we should think of it as displacement away from the central position of the path. Keeping in mind that rotating 350° around each axis is the same thing as rotating -10° around each axis, we can view this displacement from the central hub of the path as displacement via a symmetry of the angle of rotation.

What we are proposing here is that a fermion can be viewed as a system, and that at any given moment in time the system will be in some particular state. A fermion is an oscillation in a quantum field associated with that particular type of fermion particle. The type of oscillation that a particle is, is a 3-dimenional scroll wave. The dynamics of the scroll wave are dictated by the structure of the filament. Therefore, the state that the system is in at any given moment in time is dictated by the structure of the scroll wave filament.

The filament of a fermion has some boundary conditions on the state that it can be in for the particle to have the properties of a fermion and for that particle to exist in the observable universe. We are suggesting that if you consider a system of all the possible states that a particle could be in from one moment to the next, then the state that the fermion exists in at any given moment could be viewed as the system being in a state of a localized minimum value of entropy in the temporal dimension. We are suggesting that we look at each moment in time as a local point of minimum entropy in the temporal dimension.

The 2^{nd} law of thermodynamics states that in any closed system entropy will always increase. While entropy increases both forwards and backwards in time, we propose that each moment in time is a state of minimum entropy in a system where the universal wave function describes a state of maximum excitement for a scroll wave propagating through an excitable medium.

To rigorously describe the mechanism of this sort of “temporal entropy” requires the use of complex number systems which create an algebra that is noncommutative and non-associative. (This is an abstract algebra where $a \times b \neq b \times a$ and $a \times (b \times c) \neq (a \times b) \times c$.) We are able to gain an intuitive and more useful understanding of the idea of dimensional entropy through analogy with a phenomenon called Gimbal lock.

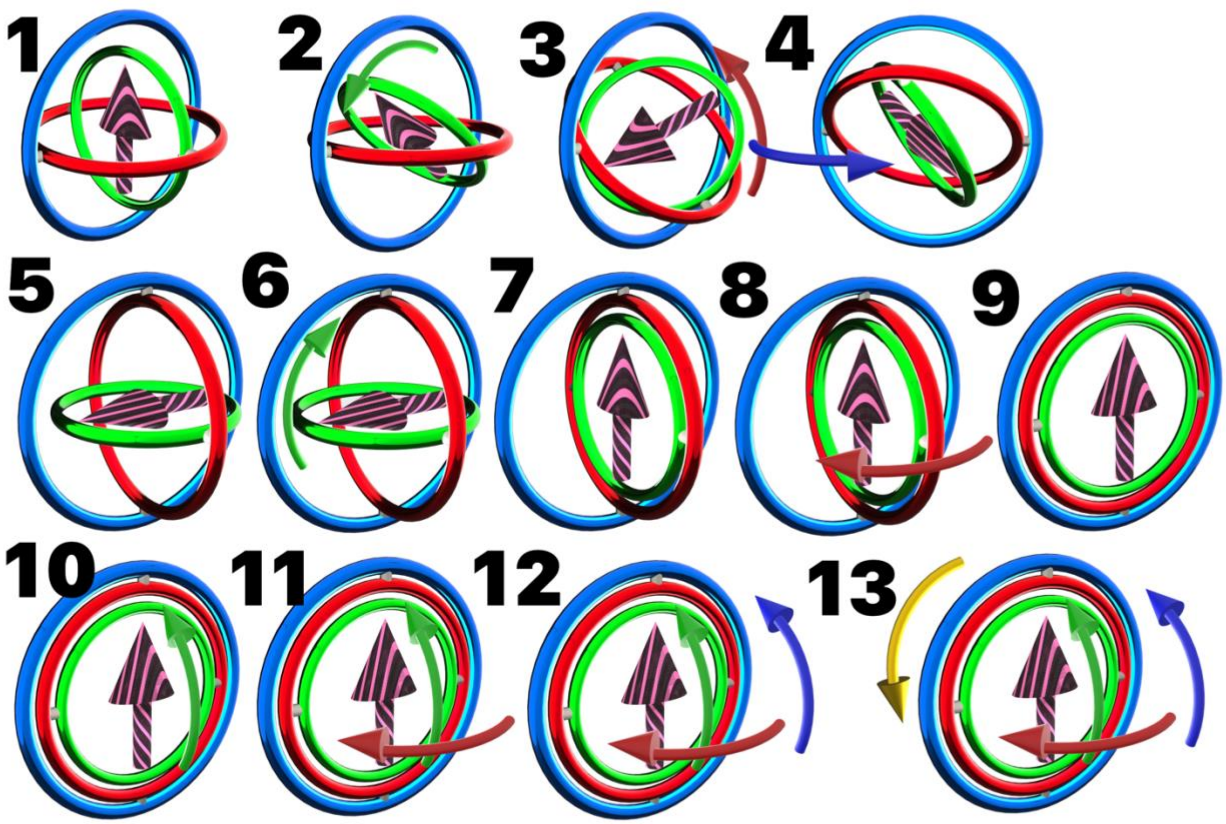

Figure 6.14

Gimbal lock is a common problem in 3-dimensional computer programming, animation, engineering, or anywhere that rotations in 3 dimensions need to be processed by a computer. The computer needs to calculate the rotation around each of the x, y and z axes in some order. In Figure 6.14 we see an arrow that we will rotate in 3 dimensions. Each of the rings surrounding the arrow represents a different axis that it can be rotated on. The rings are ordered in the hierarchical arrangement that the computer will process them in. The green ring is coupled to the arrow, so that anytime that it rotates the arrow rotates with it. The red ring is coupled to the green ring, so that if it rotates it will bring the green ring in tow. Since a rotation of the red ring will always result in a rotation of the green ring, a rotation of the red ring will also result in a rotation of the arrow. The blue ring is coupled to the red ring, so that any rotation of the blue ring will rotate the entire system.

In frames 2-4 we can see that through the sum of these rings, the arrow is free to rotate in any direction. In frame 5 the system is rotated 90° on its side. In frame 6 we see the green ring rotate 90° so that it is parallel with the red ring in frame 7. Notice that here, even though 2 of the planes are parallel to one another, the arrow still has 3 degrees of freedom in its rotation. It can rotate side to side, via the blue ring, front to back, via the green ring, or spin around, via the red ring. In frame 8 we rotate the red ring 90° so that all 3 planes are parallel to one another, and in frame 9 the system is in Gimbal lock. Frames 10-12 show the axis that each ring is able to rotate on. Because the green and blue rings will rotate on the same axis, we lose a degree of freedom. We are not able to rotate the arrow around the axis shown by the gold arrow in frame 13.

In order to build a useful analogy, we need to expand the concept of gimbal lock to higher-dimensional spaces. This means adding more rings. It may or may not be possible, through deductive reasoning and rigorous math, to make well informed speculations about the number of dimensions that might exist in the bulk. For the ends of what we are proposing in this work doing so would not contribute much to the argument. In this analogy we will include 12 rings to represent a 12-dimensional bulk. To be clear, we are describing the bulk as a 12-dimensional space solely because 12 is a convenient number that ends up serving the purpose of being useful in this analogy as efficiently as possible. We neither intend to suggest that the bulk might be 12-dimensional nor that we have any reason to think that the bulk is something other than 12-dimensional.

Before we get into the specifics of this analogy, we should first expand a bit on the idea of a geometry based on an algebra that is neither commutative nor associative. A noncommutative number system which is often used specifically to avoid Gimbal lock is the quaternion number system. So far we have been talking about rotations of the scalar field in a manner similar to how a particle is thought of as being in a superposition of all possible states. We have been describing a rotational path integral where we consider the beginning and ending orientation of a specified point/local region of spacetime, and then consider all of the possible rotational paths that could have contributed to that ending orientation. A noncommutative algebra does exactly the opposite by specifying one particular rotational path.

A commutative algebra says that $a \times b = b \times a$. A multiplication that lacks this property seems like a very foreign concept when dealing with numbers as a logical abstraction. But, if you think about math as translations on a number line or coordinate grid, then this begins to make a big more sense.

Typically, multiplication is a 1-dimensional transformation on a number line. For example, in the problem 5×6 we have the first factor specifies a quantity of 5 positive units, so 5 units to the right of 0 on the number line, the 2nd factor specifies taking that quantity a set number of times and adding it to itself, and since the 2nd factor is positive, we add this quantity to itself that number of times to the right of 0. The result is….drumroll please, a quantity of 30 units to the right of 0. In a commutative algebra it works out the same if you take 5 units of 6 to the right of 0 or 6 units of 5 to the right of 0. In other words: you can take 5×6 or 6×5 and either way the result will be 30.

Using a noncommutative algebra, we should think of this translation not happening on a 1-dimensional line, but on a 2-dimensional plane. Starting at the origin, or at 0 on this plane, we should think of the first factor as describing a vector that displaces a specified quantity from the origin on this plane. (In a noncommutative algebra the axis that it is displaced on is specified by the factor.) The 2nd factor then specifies rotating a specified quantity either clockwise or counterclockwise around the origin on that plane, so that it's moving towards intersecting axis, either the positive or negative part of that axis depending on if the 2nd factor is positive or negative. If we take the problem 2×5 with this sort of process in mind, then it's easy to imagine that if you move 2 units to the right on the horizontal number line, and then rotate 5 'clicks' upwards towards the vertical number line, or if you move 5 units to the right on the horizontal number line and then rotate 2 clicks upwards towards the vertical axis, that these 2 unique transformations would yield 2 different results.

(To be clear, this isn't a totally accurate depiction of what is happening in a noncommutative algebra. Here we are essentially saying something along the lines of "$a \times b = c$ but $b \times a = d$." The quaternions, which is the most commonly used number system with a noncommutative algebra, would be more along the lines of "$a \times b = c$ but $b \times a = -c$." Just like how the imaginary numbers extends the real numbers into the complex plane to make them 2 dimensional, the quaternions extend the real numbers into 4 dimensions. They are useful in manipulating ideas by abstracting those ideas as quantities and using math to manipulate those quantities. Here we are trying to renormalize these abstracted quantities back to ideas that are easier to conceptualize. With that end in mind, it's much easier to conceptualize a noncommutative algebra without having to imagine 4 intersecting planes. We feel this concept is thus a more useful tool in understanding how this pertains to the larger picture as it plays a role in tackling the hard problem of consciousness.)

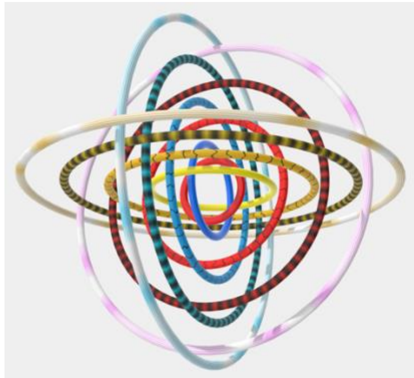
Figure 6.15

Figure 6.15 shows the extension of the 3-dimensional system of rings, each rotating on 1 of the spatial axes, extending this idea to include 12 dimensions. Obviously, we cannot make a 12-dimensional graphic, so the different patterns on the rings denote that those rings represent the next 3 dimensions of the 12-dimensional space, as rings shown in the 3-dimensions that we are able to visually represent. (The solid-colored red, blue and yellow rings are represent 1 dimension each, the next pattern represents the 4th, 5th and 6th dimensions, etc.)

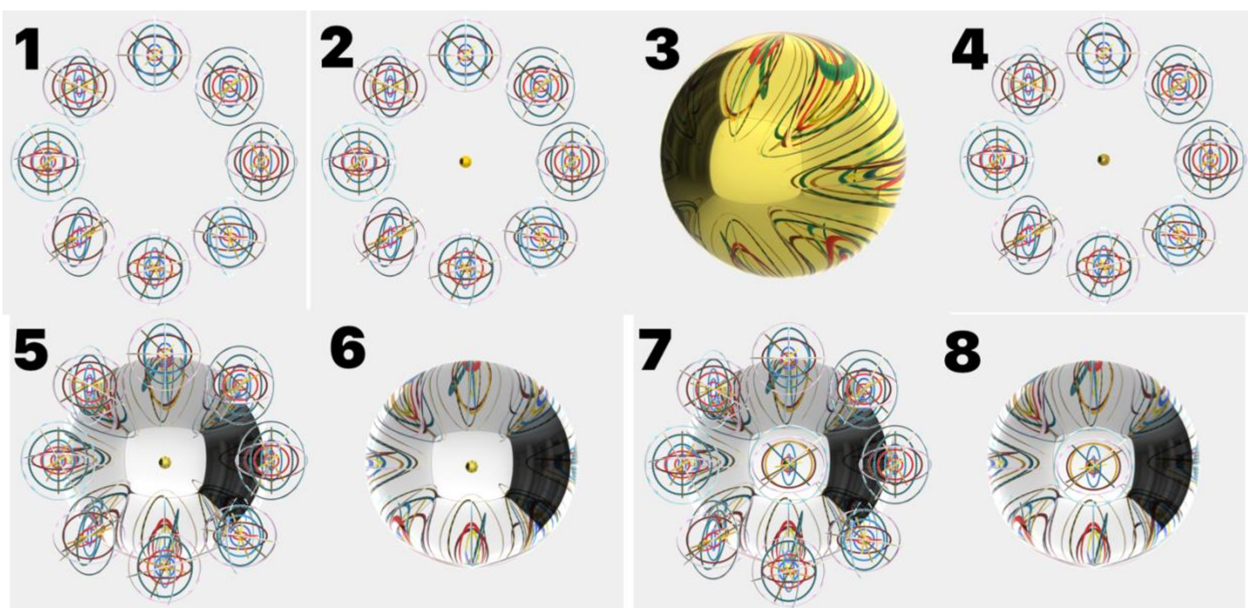

Figure 6.16

In Figure 6.16 we see a visualization of the basic process involved in this analogy. In a geometry based on a noncommutative and non-associative algebra, we should think of these rings as being in a superposition of all possible configurations, as we see in frame 1. One important thing to keep in mind is that these are not static systems. The whole idea behind this analogy is that of the rotational path integral. We are considering how the scalar field might be rotating in relation to a higher dimensional bulk. We are only concerned with how it might be rotating, based on what we are able to observe of its behavior from our perspective.

In frame 2 we see a sphere at the center of the possible states of the rings. The different configurations of the rings are seen on the reflective surface of the sphere. Some of the information about the configuration of the rings might be lost when looking at the reflection as opposed to looking at the actual rings. For example, if there are 2 rings in Gimbal lock and they are turned so that from the perspective of the sphere, you'd be looking at them edgewise, you would not be able to see the smaller ring. The larger ring would block your view of the smaller ring on the same plane and any information about the smaller ring would be lost by only looking at the reflection in the sphere.

In frame 5 we see another sphere, this one cut in half so that we can see inside of it, also reflecting the different configurations of the rings. In frame 6 the rings are removed and there are just the images of the reflections. Once one of the spheres has the images of the rings on its surface, the other surface could reflect that image. However, it would only be able to reflect the information about the configurations of the rings that was encoded on the surface of the other reflective sphere.

If the reflections, whether it be the same image reflected back on itself, or 2 perspectives reflecting towards one another, combine to form a composite, holographic projection of the configurations of the rings, then that holographic projection could only ever have as much information about the different, higher dimensional configurations of the rings encoded in it as the sum of the information encoded on the reflective surfaces of the spheres. This is shown in frame 8.

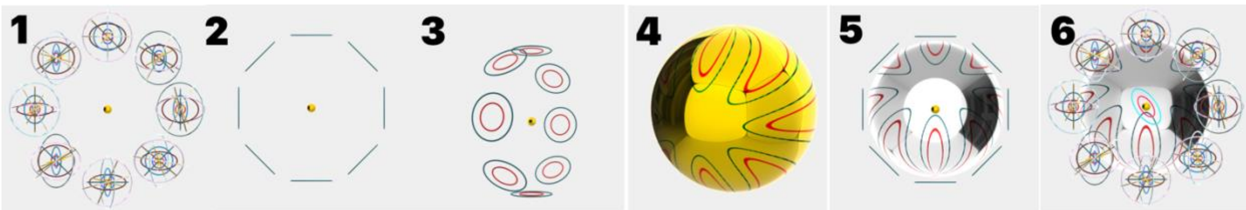

Figure 6.17

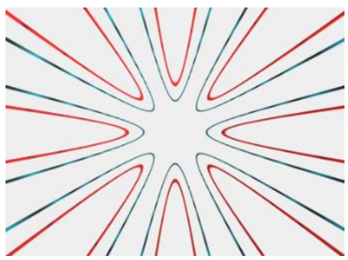

Figure 6.18

In Figures 6.17 and 6.18 we explore in a bit more detail what is happening with the Gimbal lock-esque kind of “flattening” of the higher dimensional rotations into the reconstructed projection of the rings. In frame 1 we see all of the possible states of the rotating rings in all different configurations. However, in each of these unique configurations there is a commonality. That is that there are 2 of the rings, the same 2 rings in each set of rings, that are on the same plane as one another, and those Gimbal locked rings are all in the same orientation *relative to the perspective of the gold sphere*. In frames 2 and 3 we can see that the rings are all oriented so that they are facing the sphere flat on, so that an observer from the sphere’s perspective would see them each as 2 flat circles. Figure 6.18 shows a view of these rings, looking straight forward, from the perspective of the gold sphere. In frames 4 and 5 we see the reflection of just the rings that are in Gimbal lock relative to the sphere, so that the information about those locked rings is encoded on the surfaces of both reflective spheres. In frame 6 we see the locked rings, having the information about them encoded on the surfaces of the reflective spheres, reconstructed and projected back out like a holograph.

A holograph requires specific information about the image that it represents to be encoded onto a 2-dimensional dimensional surface so that when a laser is reflected through that surface it will reconstruct the image in 3 dimensions. In 2012 concert goers at Coachella were surprised to see 2Pac on stage rapping to the crowd, performing, in 3 dimensions, 16 years after he'd been murdered. What the crowd was seeing was a holograph of 2Pac. At each moment in time a laser had to be projected through a 2-dimensional surface that contained all of the information about a specific image of 2Pac so that the image that the crowd was seeing could be reconstructed in 3 dimensions on the stage.

Even if the holograph contained all the necessary information about any specific image of 2Pac that was to be shown at any specific instant, but it also contained information about any of the other images of 2Pac that were meant to be shown, or all images of 2Pac that exist, even though it contained all of the right information, the crowd would not have seen 2Pac. They wouldn't have been able to decipher the information about the image of 2Pac that they were meant to be presented with from all of the other information that would have been projected onto the stage. What they would have seen on the stage would have just been a formless blob of light.

In order for the crowd to see 2Pac on the stage that night, they needed the system of the holograph's information embedded on a 2-dimensional surface and the lasers shining through it to be in a state at each moment in time that is closely analogous to what we are calling a state of minimal temporal entropy.

In frame 6 only the 2 rings that are in Gimbal lock with one another in each of the configurations of rings and in equivalent geometry relative to the gold sphere are reconstructed and projected back out like a holograph because they are the only ones that are in a state of minimal temporal entropy. All of the other rings have an excess of information reflecting off of the spheres and any information about the specific state of the rings in any of the systems of rings is lost in the blob of their combined reflections.

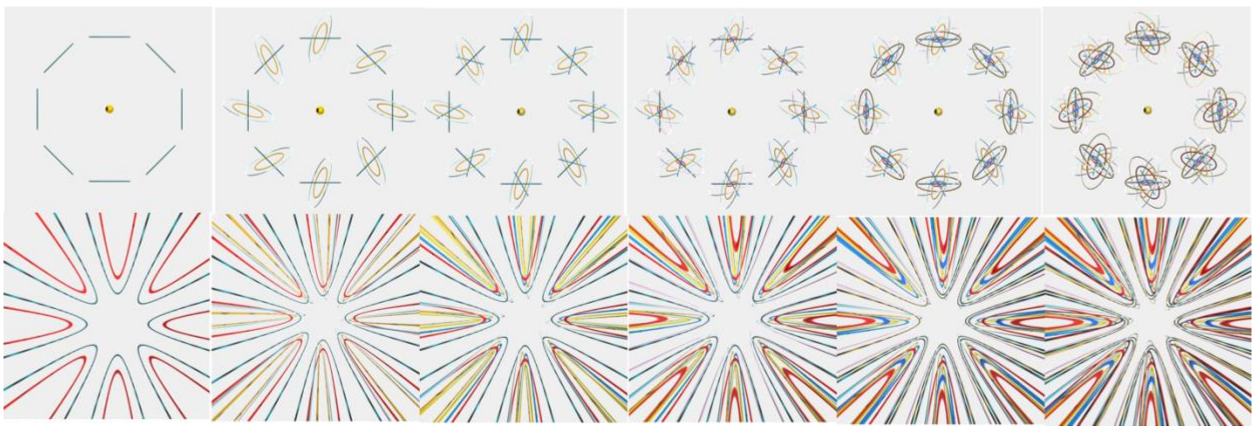

Figure 6.19

In Figure 6.19 we get a look at the rings getting into Gimbal locked pairs in each of the systems, those locked pairs of rings becoming oriented so that they are all in equivalent geometric configurations relative to the gold sphere, and what that would look like from the outside looking in, and from the inside looking out. It is the bottom row of images, seen from the perspective of the gold sphere, that enables us to understand how these different configurations are able to be efficiently described by a single configuration of the rings that is reconstructed from the information about the rings that is available to an observer on the gold sphere, and projected back out to create a holograph of the system of rings.

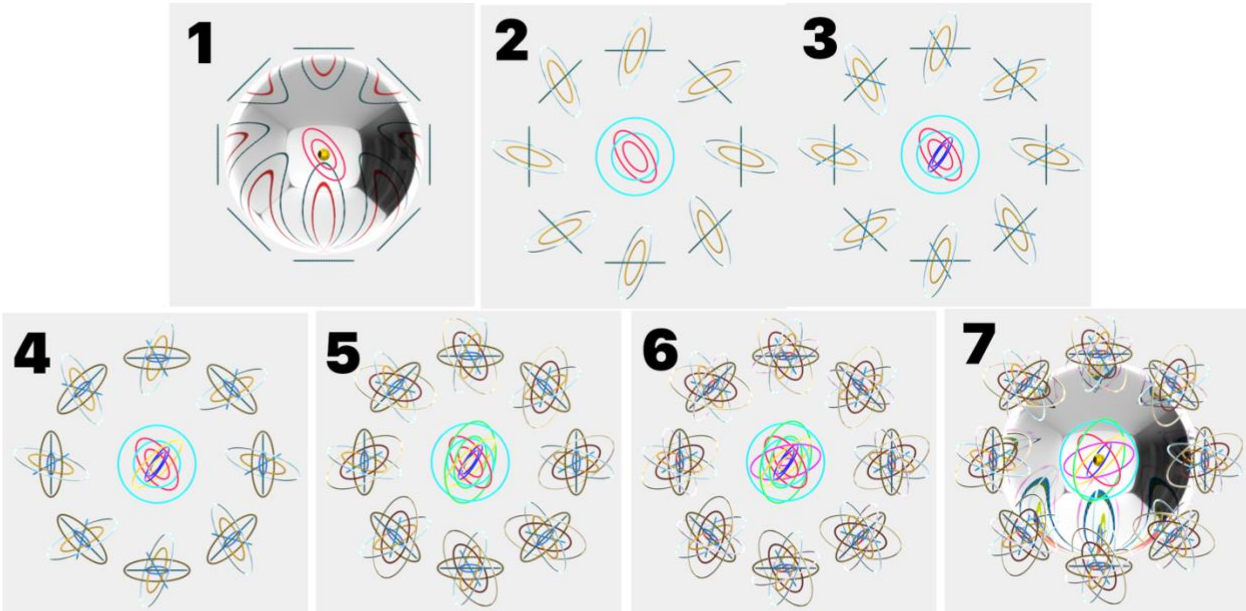

Figure 6.20

In Figure 6.20 we see a similar process that we saw depicted in the previous image, with one key difference. In this image the rings that are locked together on a plane are projected back out as a holograph using the same color. We do this to highlight that the rings that are we have been using to represent 1 degree of freedom per ring, or 1 spatial axis in a 12-dimensional bulk, are now locked together so that every pair of locked rings reduces the degrees of freedom that we can rotate in by a single degree of freedom. Once all of the rings are locked with at least 1 other ring, we can more efficiently describe the projected holographic rings by reducing the number of rings that are reconstructed as holographs to only 1 ring per color, or 1 ring per degree of freedom. In frame 6 we see all 12 rings reconstructed, as 6 pairs of locked rings. In frame 7 we see just 6 rings reconstructed and projected out as holographs, each representing a single degree of freedom.

We have half of the number of rings in frame 7, so it would stand to reason that we only have half of the information about the system available to us. Here it behooves us to remind ourselves what we are representing with this analogy of the rings. This analogy is meant to help convey some ideas about what unseen factors might be affecting the behaviors of scroll waves propagating in an excitable medium, that medium being the quantum fermion fields. These scroll waves propagate outwards from a 1-dimensional phase singularity, the scroll wave's filament. We have proposed that this filament is the product of a rotational path integral formulation as the scalar field rotates in a higher dimensional bulk. Another way to say this is that the scalar field is rotating with a higher number of degrees of freedom.

Scroll waves are used to represent coupled oscillators. Coupled oscillators are things that have some sort of cyclical behavior, which accounts for the "oscillator" part of their title, that affect and are affected by other, local, oscillators of the same type. This is the "coupled" part of the coupled oscillator. A common example of scroll waves representing coupled oscillators is found in the pacemaker cells in the heart. In order for our hearts to function properly there needs to be millions of pacemaker cells firing electrical impulses, signaling other cells to constrict, all done in synchronicity.

Most readers will be familiar with the experiment where several swinging pendulums are set in motion, in local vicinity to one another, all at different times and different rhythms. Before long the pendulums are all swinging in time with one another without any sort of outside influence. The oscillators adjust themselves to be in time with their neighbors by their virtue of their common natural resonances and the harmonics of those resonances. This is very similar to what is happening with the pacemaker cells in the sense that these are all oscillations that are finding a common rhythm with their brethren, but the difference is that one is an oscillation *of the potential states of the medium*, as is the case with the pacemaker cells as self-propagating oscillations in an excitable medium, and the other is oscillations *of the spatial displacement of the medium itself*, regardless of the state the medium is in.

Fermions *are* oscillations of a field. They are a point where the field becomes locally excited enough to generate a particle. However, the fields are not in a static state outside of the generation of particles. What we are suggesting is that while particle generation is the local solution to field excitations, from the perspective outside of an observer that is made of these local excitations, a perspective where the dimensionality of the bulk is apparent, the unidirectional passing of time would be a series of solutions to field excitation, the collection of a fundamental quantum fields, which are all projections of the scalar field's rotational path in a higher-dimensional bulk. Degrees of freedom are stripped away by the nature of a field oscillating as it rotates, so that the harmonics of these oscillations run into one another as it rotates in a higher number of dimensions. Just like how the pendulums all found their way to synchronicity with one another, the oscillations of the scalar field find their way to the common harmonic frequencies shared by all of the field as it spins around on itself. As degrees of freedom are removed, via finding common harmonics in the rotating oscillations, there will come a point where the ways the degrees of rotational freedom have become locked together from the singular perspective of any observer will necessarily reconstruct the n-dimensional bulk into 3 spatial dimensions. Observership, in effect, creates reality.

The mathematical proof of this idea has to do with Fermat's final theorem and the mass-energy equivalence. The mass-energy equivalence requires a specific value for *c*, and it requires that value to be a constant for any observer in any frame of reference *in this universe, in 3 spatial dimensions and 1 temporal dimension.* It's plausible to think that there could be a mass-energy equivalence in a higher (or lower) dimensional space, with a different value for *c.* All that we can know for certain is that as observers in this 3-dimensional universe, c must, and in fact does, hold a value of 299,792,458 meters per second, for all observers in any frame of reference. This effectively sets the clock for each observer. It dictates that time passes at the rate that it does for each observer at any particular spatial coordinate. This is all anchored in Einstein's famous equation, $E = Mc^2$. It's possible to imagine different physical laws or fine tuning that would dictate a different form of this equation, say $E = Mc^3$ or $E = Mc^4$ be true, but that's not what we observe. What we observe is that in a universe with 3 dimensions of space, there is an equivalence between mass and energy, when the mass of an object is divided by the speed of light times itself.

Another important piece of this puzzle that we observe in the universe are the inverse square laws. Energy dissipates relative to the inverse of the square of the distance from its source. Gravity decreases by the inverse square of the distance between objects. The same is true of the electromagnetic force. The fact that these are all laws of the inverse square of distance is only true because we are experiencing a universe with 3 spatial dimensions. When something is distributed evenly in all directions in 3-dimensional space, the boundary of that region is described by a sphere. The surface area of this sphere is found by taking 4 time the square of the radius. If we were experiencing a universe with 4 spatial dimensions, we would find that these laws would all be inverse cube laws, as formula for the surface area of a 4-dimensional hypersphere requires that the value of the radius be cubed. These types of inverse square laws are particular to a universe with 3 dimensions of space.

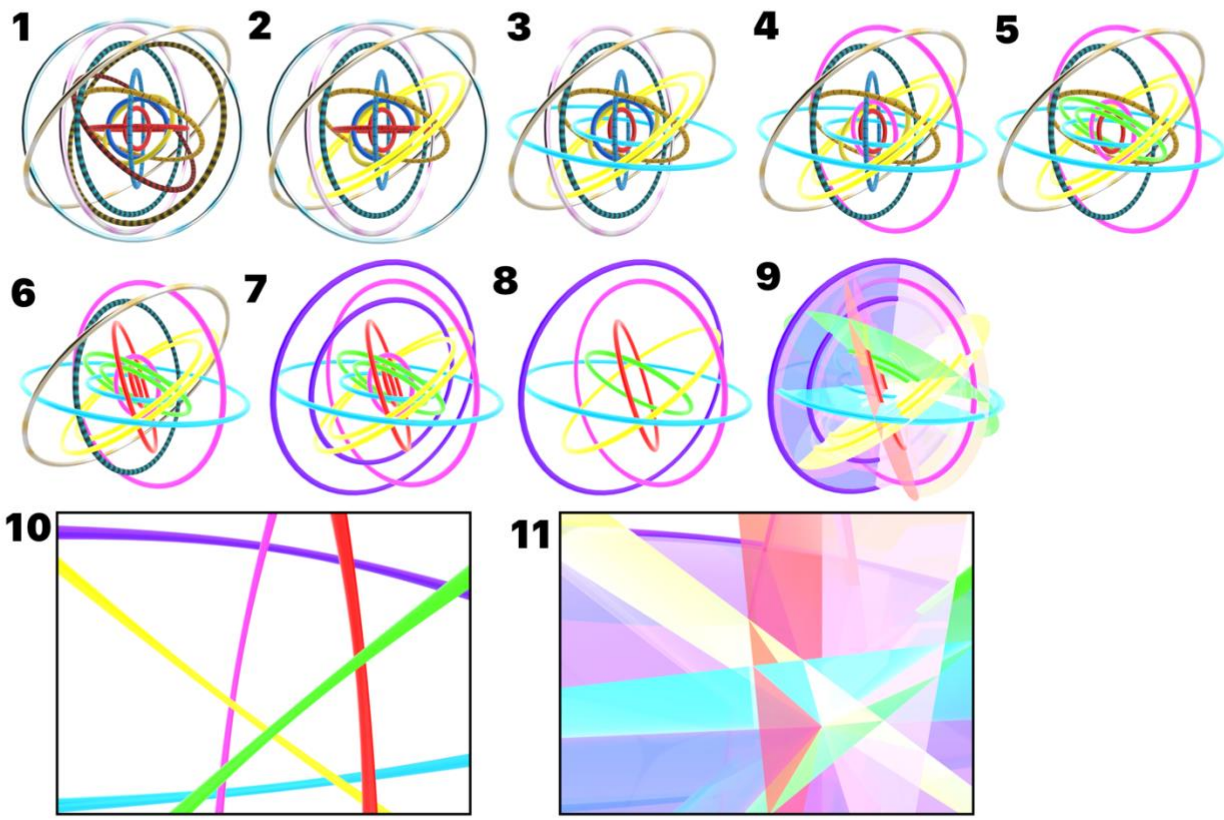

Figure 6.21

In Figure 6.21 we see the dimensional rings becoming locked together as we did before. This process plays out in frames 1-6. In frame 7 all of the rings are locked together so that, from the perspective of an observer at the center of the rings, 12 dimensions can be described by 6 rings. Frame 8 shows the system described by just 6 rings.

Moving forward we will be concerned with the spatial geometry in any, n-dimensional space. The number of degrees of freedom available becomes ambiguous when observership is given a causal role in the universe. With this in mind, frame 9 shows a way of categorizing the locked dimensions that will be more useful to us. Rather than looking at each of the dimensions as a ring which might become oriented so that it is locked with 1 or more dimensions from an observer's perspective, we should think of these rings, or each grouping of locked rings, as a plane that intersects all of the other planes at the vantage point of the observer. Frame 10 shows what the observer's perspective would look like if we were to describe the system using 6 rings, as we do in frame 8, while frame 11 shows the system from the observer's perspective if we see the system as a set of intersecting planes, as we do in frame 9.

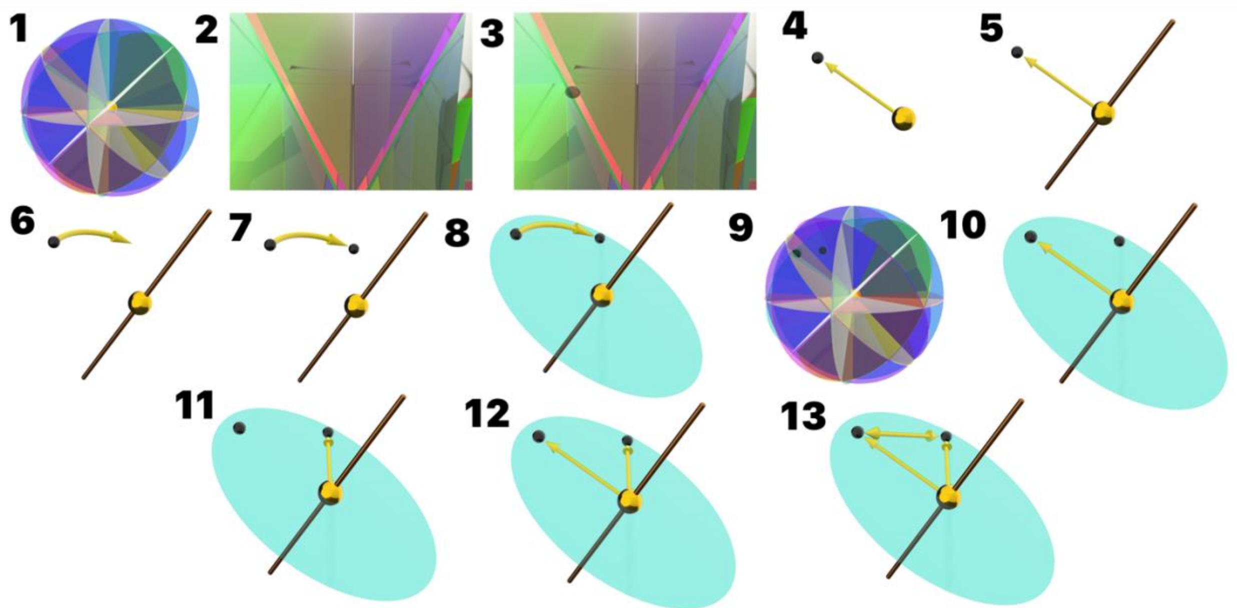

Figure 6.22

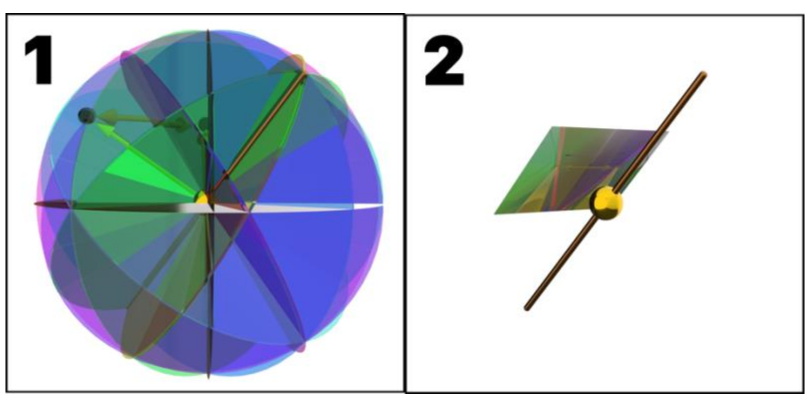

Figure 6.23

In Figure 6.22, frame 1 shows some higher-dimensional space, represented by a set of intersecting planes. At the center of this system is a gold sphere. This represents the perspective of an observer. Frame 2 shows the observer's perspective. In frame 3 we choose any arbitrary point in any n-dimensional space, away from the observer. It does not matter how many degrees of freedom are needed to accurately describe that point, because from the perspective of the observer, any number of dimensions can be sort of “flattened out.”

This flattening out of any n-dimensional space is shown in Figure 6.23. From the perspective of the observer at the gold sphere, their view of the system would be identical in either of the 2 images in 6.23, because only certain information is available to a single observer with a singular perspective. In either case, all of the same information about the system is communicated to the observer. The difference is that in frame 1 the information is communicated to the observer via a direct observation of the system by the observer. In frame 2 the observer is looking at a picture that appears to be identical to the observer’s subjective observation of the system, and contains all of the same information available to the observer that is available to them via direct observation. All of this information has been encoded onto a 2-dimensional plane, and the observer makes a direct observation of that plane.

This is analogous to the idea of wearing virtual reality glasses. If you put on VR glasses and it presents you with information that is about a video game that you are playing, and that video game is set in Alaska, all of the information about Alaska that you could gain via direct observation, from the perspective that you would have if you were in Alaska, is communicated to you via the 2-dimensional screen in the VR glasses. All of the spatial information about Alaska that you would have communicated to you via direct observation is encoded onto a 2-dimensional surface.

Frame 4 shows that there is some distance between the observer and the chosen point. When quantifying distance we are able to use a metric of spatial units, like feet or kilometers, or if there is some sort of standardized pace car, we can measure distance by the amount of time that it takes that pace car to travel from A to B. A useful metric for this type of distance measuring is the speed of light. For instance, a lightyear is the amount of distance that light is able to travel in 1 years' time. So, we'll call the point that the observer has chosen Point A, and if we imagine that the observer fires a laser a Point A, and 2 seconds later the observer sees the reflection of the laser return to the observer's location, then we know that it must have taken the laser 1 second to go to Point A, 1 second to return, and therefore Point A must be a distance of 1 lightsecond from the observer.

In frame 5 we chose any arbitrary axis that passes through the observer's vantage point. We rotate the point 90° around that axis, shown in frame 6. We then specify another point which we'll call Point B, shown in frame 7.

We know that the universe is isotropic, so there is nothing special about either of these points. What we are interested in is the geometry that specifying any arbitrary points will describe. Not all conceivable spacetime geometries must be available, but the principle of least action requires that the geometry that allows for the most efficient movement and transfer of energy be available. The most efficient path, all things being equal, between any 2 points is a straight path. The most efficient minimal surface, again, in an idealized environment, is a flat plane. Therefore, in addition to any other geometries that might be found in spacetime, the universe must allow for at least the potential for a typical, Euclidean geometry to accurately describe spatial relationships of the universe.

Therefore, now that we have specified 3 points, A, B and C, we can imagine a flat, 2-dimensional plane that is specified by connecting these 3 points, shown in frame 8. Frame 9 reminds us that that plane is a mathematical construction used to describe a reality that could be in any number of dimensions. Frame 10 shows the most efficient path between the observer, at Point C, and Point A.

We know that the speed of light is a constant and a maximum, and that by measuring the time that it takes light to travel from the observer, reflect off of point A, and return to the observer, that Point A is 1 lightsecond away. Frame 11 shows the most efficient path between the observer and Point B. Again, by observing light traveling at the speed of light, no matter what that speed might be, we can say that Point B is whatever distance away that light is able to travel in 1 second. Since the speed of light is a constant, it will also specify the distance between points B and C, shown in frame 13.

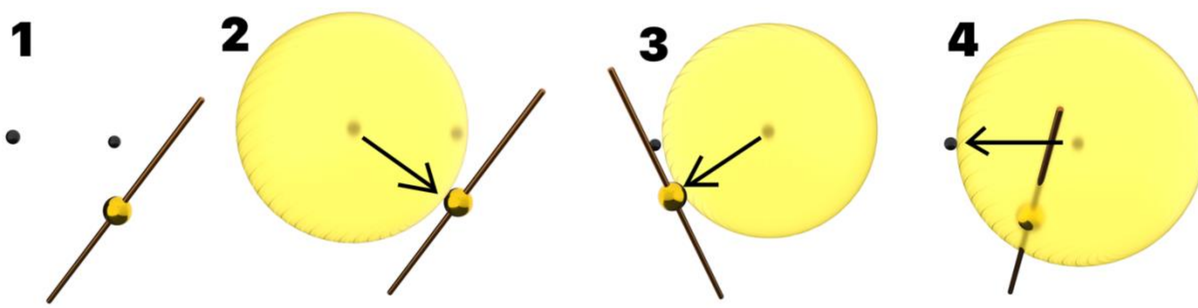

Figure 6.24

Another thing that must be true is that radiation energy must dissipate as an inverse proportion of the distance between objects, raised to some power based on the number of dimensions of space. In our 3-dimensional universe this is the inverse of the distance squared, because as we move farther away from the source of an object's radiation the energy that is emitted from a single point at the source gets spread out over the surface of sphere in 3 dimensions. This idea is shown in Figure 6.24. For example, the formula to determine the force of gravity between 2 objects is $F_g = G\frac{m_1+m_2}{d^2}$ where F_g is the force of gravity, G is the gravitational constant, m_1 and m_2 are the masses of 2 different objects, and d is the distance between those objects. As we've touched on already, this is because the radiation energy dissipates as sphere emanating from the source of the energy as is grows equally in all directions available, which is dependent upon the surface area of the sphere drawn at any particular distance from the source of radiation energy.

It's possible to imagine that the universe might have found itself with different laws of nature and/or different spatial dimensions. We know from the holographic principle that the universe has some version of reality, or some underpinnings to the universe that we observe, and that these underpinnings have a 2-dimensional geometry. It's reasonable to imagine that a 2-dimensional geometry of the universe might be distorted so that the laws of nature would be fine-tuned to that geometry. For example, in a 2-dimensional universe it's reasonable to think that radiation energy would dissipate inversely proportional to the distance from the source of the radiation.

This is a logically coherent conclusion. Assuming that radiation will dissipate equally in all possible directions, then given a 3-dimensional geometry the distance from the source of radiation to an object measuring the strength of radiation energy would be input as the radius of a spherical surface embedded in 3-dimensional space, which dictates that the value for the radius be squared. In a 2-dimensional geometry that same distance would be input as the radius of a flat circle, dictating that the radius has an exponent of 1. (An exponent of 1 doesn't change the value of a number, $x^1 = x$.) Therefore, in a 2-dimensional geometry radiation energy would dissipate as a direct inverse proportion to the distance.

The speed of light is the upper limit on velocity in the universe. This doesn't have so much to do with any special ability that light has to move super-duper fast. It has to do with the fact that light is a self-propagating, electromagnetic wave, and empty space has some inherent resistance to becoming an electric field or a magnetic field. This resistance is measured by 2 different metrics. They are, at least for the case of waves propagating through empty space, 2 sides of the same coin. These metrics are the permittivity and permeability of free space.

Permeability is the ability of space to allow magnetic field lines to be poked through it. Think of it like a sewing needle constantly pulling thread in a helical shape through a stack of fabric. If that fabric is a very light linen, then the needle and thread won't experience much resistance. If that material is a thick, heavy, wax-coated canvas then the needle and thread will be very difficult to pull through the fabric. The linen is much more permeable than the canvas.

Permittivity is the measure of the resistance of a medium, in our case the resistance of free space, to the electric field caused by the introduction of an electric field. In order for the electric field to transmit energy through some medium, it needs to polarize that medium. If something is not polarized, it takes some effort to polarize it. The amount of effort that it takes to polarize a medium when an electric field is introduced to that medium is measured as the resistance to an electric field, or the permittivity of the medium.

Electromagnetic waves move through empty space at the maximum rate that they are able to permeate space with magnetic field lines to house the magnetic part of the electromagnetic force, and polarize free space to permit the movement of the electric part of the electromagnetic force. The speed of light isn't about the light, or about the electromagnetic force, so much as it is about the vacuum allowing the propagation of the electromagnetic force. In our 3-dimensional universe the speed of light is inversely proportional to the square root of the product of the permeability and permittivity of space. To see it spelled out in the mathematics, it looks like this: $c = \frac{1}{\sqrt{permeability \times permittivity}}$.

More importantly than setting the speed limit on how fast light can go from A to B, it sets a limit on how fast any massless packet of energy can go from A to B. Since anything with mass takes more energy to accelerate than anything with no mass, the speed limit of massless objects in necessarily greater than massive objects.

This is important because the physical universe is governed by the rules of causality. For anything to affect something else in the physical universe, it needs to exchange energy in some form or another. The quickest way to get this done is by radiation energy, electromagnetic waves, gravitational waves, etc. These can be transmitted no faster than the speed of light. The speed of light is the speed of causality. While relativity says that the rate at which time passes is relative to the observer's frame of reference, all observers must agree on the order in which events take place, or the order of causation.

Here's the conjecture: The universe reconstructs the spatial dimensions from information about the ontological nature of our universe that is available in the higher-dimensional bulk, which has been encoded onto 2-dimensional surfaces, which informs a holographic projection of the observable universe. In this mechanism of reconstructing space as a holographic projection certain things must remain true:

1. The speed of light must be a constant. It doesn't necessarily need to be the constant that we observe it to be in 3-dimensional space, but it needs to have a constant value for all observers in all frames of reference.
2. The speed of light needs to be synonymous with the maximum speed at which any physical phenomenon might have a causal role in the behavior of anything else in the universe, and this upper limit on the speed of causality needs to be set by the permeability and permittivity of space to electromagnetism.

3. Radiation energy must dissipate inversely relative to the distance from the source of radiation, with all points equidistant from the source forming an (n-1)-dimensional sphere embedded in n-dimensional space.
4. There must be an equivalence between mass and energy that is dependent on the speed of light, and this equivalence will be particular to n-dimensional space in that the formula will require that the speed of light be raised to the (n-1) power.
5. There will be a correlation between spatial relationships of objects and the temporal dimension in that the distance between objects can be equivalently described by a metric that specifies a unit of length or by quantifying the amount of time that it takes for light to travel from one point to another.
6. The principle of least action dictates that any holographic projection that reconstructs the universe as n-dimensional spacetime needs to allow for the possibility of straight paths and flat planes.

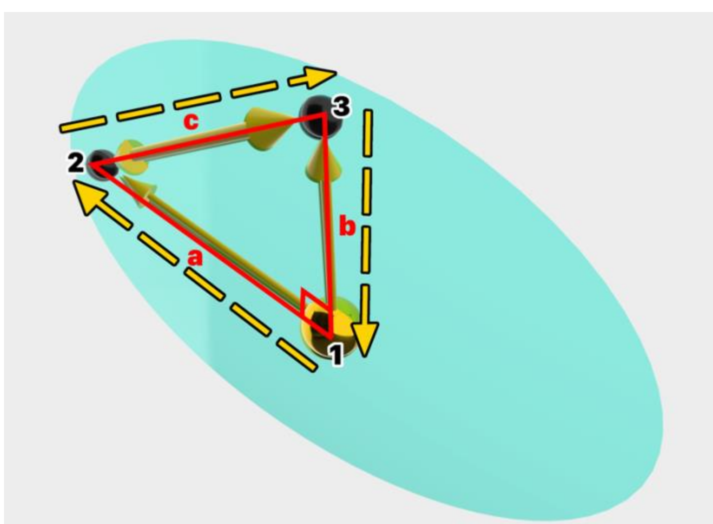

Figure 6.25

With these requirements laid out, we can take on the thought experiment of projecting into higher numbers of dimensions. Figure 6.25 shows a geometry which, according to the requirements that we've just set forth, needs to at least be possible in the universe. Imagine from the perspective of an observer at the location indicated by the gold sphere labeled with a 1, shining a light so that it follows the path of the gold arrows. Starting at 1, you shine the light towards 2, it reflects off 2 and moves towards 3, then reflects off 3 and comes back to 1. Since we know that 2 and 3 are rotated 90° around the observer from one another, the path going from 1 to 2 to 3 to 1 forms a right triangle. In a universe where the laws of nature include the principle of least action, the universe needs have a geometry that allows for the possibility that light could travel in straight lines from 1 to 2 to 3 and back to 1. The universe needs to have a geometry that would allow for solutions to the equation $a^2 + b^2 = c^2$ in Figure 6.25 to be possible.

You could find the values for *a*, *b* and *c* by measuring the time that it takes for light to travel from 1 to 2, from 2 to 3, and from 3 to 1. You could also determine these distances by measuring the intensity of the light when it started at 1, measuring it again at 2, again at 3, and again when it returns to 1 and using the inverse square law to determine how much the light had dissipated between these points. Because the 3-dimensional universe dictates that the laws of nature be inverse square laws, we can be certain that the geometry of our universe allows for there to be true values that provide solutions for $a^2 + b^2 = c^2$ so that the triangle *abc* is possible in our universe. Specifically, we can be absolutely certain, because we are dealing with inverse squares, that we will be able to measure values that we measure, say the decrease in the intensity of light over a distance from one point to another on the triangle described above, and that because these measurements are the results of being inversely proportional to the square of the distance, that if we square the measurement to solve for the distances *a*, *b*, and *c*, that it will give values for *a*, *b* and *c* that make $a^2 + b^2 = c^2$ a true statement.

Since we know that in a 3-dimensional universe where the laws of nature are described by inverse squares of distances, and that the universe allows for a geometry that is consistent with the principle of least action, we can reason that we should be able to take measurements of these values described in the inverse square formulas and manipulate them so that we can solve for the speed of light.

For instance, we can take the formula which describes the inverse square law for the illuminance of light, which is $E = \frac{I}{d^2}$, where E is the illuminance at any given distance from the source of the light, *d*, and *I* is the intensity of the light at its source, and begin to manipulate it. Since we know that we can find *d* by taking the speed of light, *c*, and multiplying that by the time, *T*, that it takes light to travel from one point to another, we can rewrite the formula as $E = \frac{I}{(cT)^2}$. Since we are able to measure any part of this formula, all of the variables can be used to find the one constant, the speed of light. We can rewrite this formula as $c = \frac{\sqrt{EI}}{T}$, and because we are dealing in 3-dimensional space, we can be certain that accurate measurements will return a result for *c* that is the actual speed of light. What's more, since we know that the speed of light is dependent on permeability and permittivity, $c = \frac{1}{\sqrt{permeability \times permittivity}}$, we could use the inverse square law that describes the decrease in illuminance of light over distance and rearrange it so that we can find the measured values of permeability and permittivity of free space.

When we try to do this again, so that the holographic nature of the universe might be projected out into 4 spatial dimensions, we need to rework the laws of nature so that instead of inverse square laws we have inverse cube laws. In 3 dimensions it will always have to work out that a path in Figure 6.25 from 1 to 2 to 3 and back to 1, which needs to be at least possible in a universe where the principle of least action is a law of nature, that these measured distances will always work out so that the distance, the speed of light, the illuminance, the permeability and permittivity of free space, are all in step with one another because the geometry needs to allow for values of a, b and c so that $a^2 + b^2 = c^2$ can have true solutions which can be obtained by measurement. We should be able to measure the distance by measuring the passage of time as light travels from one point to the next, or any by measuring any value, such as illuminance, that can be found using inverse square laws, and using those measured values and reworking the formula to solve for the distance between the objects. The distance between objects that are arranged like points 1, 2 and 3 in Figure 6.25 will necessarily have to have values that could be squared so that this formula has true solutions from measured values. These measurements can be taken so that we are solving for the illuminance, the intensity of the light source, the distance, the time, the speed of light, the permittivity of free space, or the permeability of free space, and any way that you cut it, it's going to work out.

When we add a dimension and replace the inverse square laws with inverse cube laws, it could still work out. There could be some measured value that would provide true solutions so that the principle of least action isn't violated, or that could still allow for a geometry where there is the possibility that the principle of least action isn't violated, so that you could take the illuminance of light measured from 1 to 2, 2 to 3, or 3 to 1, and use that measured value to solve for the speed of light, as we described for 3 spatial dimensions. What you'd find is that the speed of light would have a different value. Again, this isn't a deal breaker. It's difficult to imagine what a 4-dimensional space would be like, let alone what the constants of nature would be. This would, of course, mean that the permeability and/or permittivity of free space hold different values. Again, this might be possible.

A solution to this problem that seems to be more compelling would be that in a 4-dimensional space, instead of requiring solutions that could exist on a flat plane and allow for straight lines from 1 to 2 to 3 and back to 1 so that there are measured values that plug into different formulas of inverse cubes that would provide equivalent solutions to measured values of distance so that $a^2 + b^2 = c^2$ be true, that we would instead look for the measured values to provide true solutions so that $a^3 + b^3 = c^3$ be true. The problem is that there are no solutions that make $a^3 + b^3 = c^3$ a true statement. In fact, there are no values of *x* that are greater than 2 that provide any true solutions to the statement $a^x + b^x = c^x$. It seems that the most plausible scenario is that the universe which we experience is a holographic projection into 3 spatial dimensions because that is the greatest number of spatial dimensions that allow for a geometry to exist which doesn't violate the laws of nature.

Combining Observership of Higher Dimensional Spaces and Rotational Path Integral to Describe the Boundary Conditions of a Scroll Wave Filament

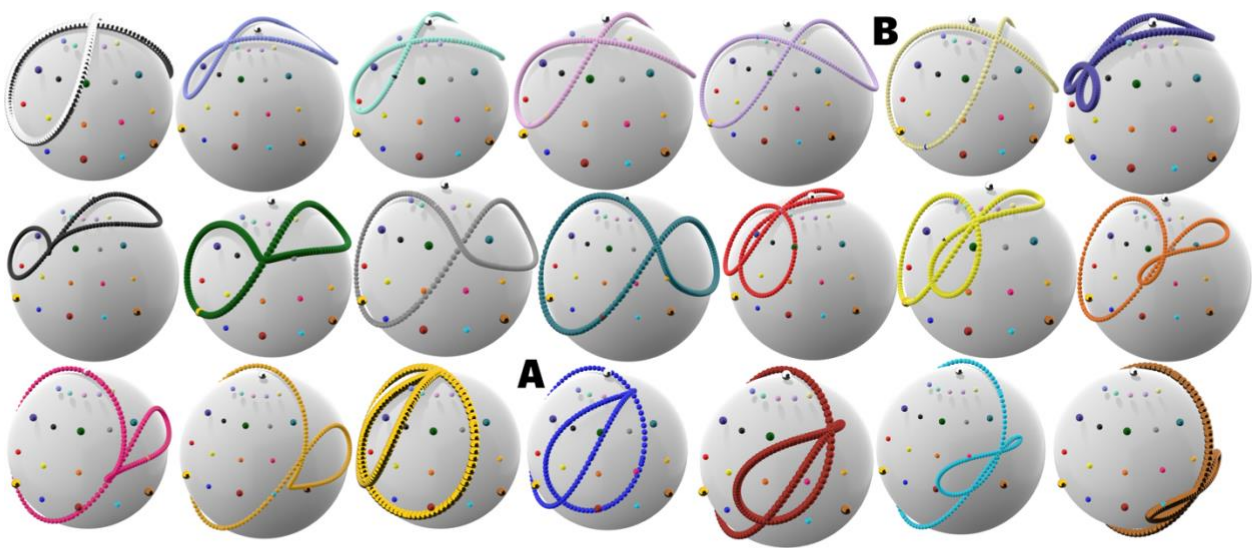

Figure 6.26

If we specify points on a sphere and rotate that sphere evenly around all 3 spatial axes with constant rotation from 0° to 360°, then every point in each 1/8th piece of the sphere will specify a unique path. Some of these paths are shown in Figure 6.26.

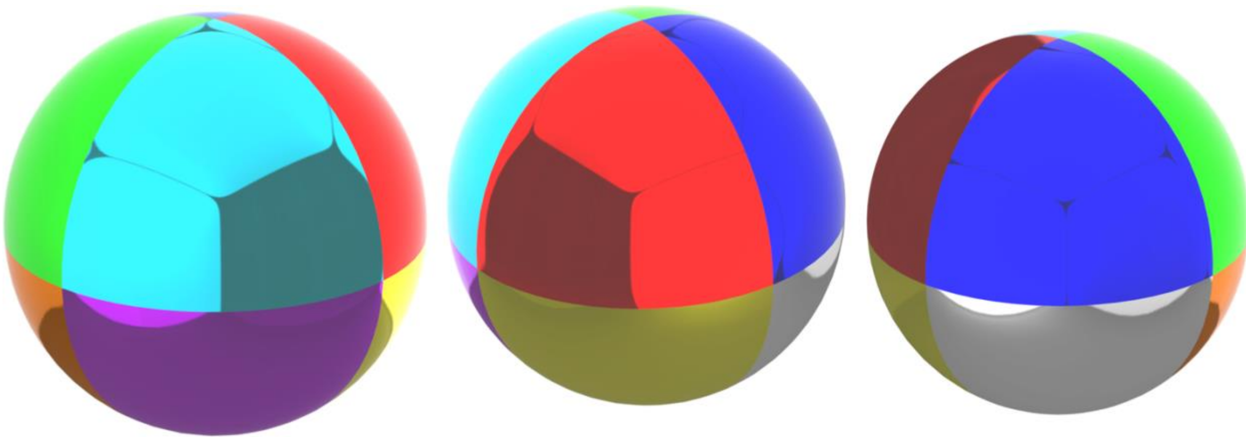

Figure 6.27

If you were to bisect the sphere with 3 planes, then each plane would cut the sphere into 8 pieces that are equal in all dimensions and have maximum symmetry from one piece to another. This idea is shown in Figure 6.27. Each piece of the sphere can be translated to any other piece of the sphere, so paths in any single piece would be reflected in another piece of the sphere. Therefore, we can describe all the paths generated by the rotation of the sphere across all axes simultaneously by specifying the paths in just one of the colors in Figure 6.27. Knowing this, we can consider only the paths described by the points in Figure 6.26 and for our purposes, it will sufficiently serve as a tool to communicate the ideas we are presenting.

As you can see by looking through the different possible paths of rotation in 6.26, there are many paths that intersect one another. For example, the path labeled A intersects with the path labeled B at its point of minimum displacement from its origin. It stands to reason that if we began at the origin of path A and began rotating the sphere so that if it were continue rotating evenly across all axes, that it would eventually describe the path shown in that frame. We could, at the point where it intersects with the path shown in B, change the dynamics of our rotation of the sphere so that the path from that point on describes the path shown in the frame labeled B. It follows that we could also start on A, arrive at the origin of B, take a detour along the entirety of B, return to the origin, and continue on A.

If this is sounding familiar, that's because it is essentially what we described before when discussing the path integral formulation.

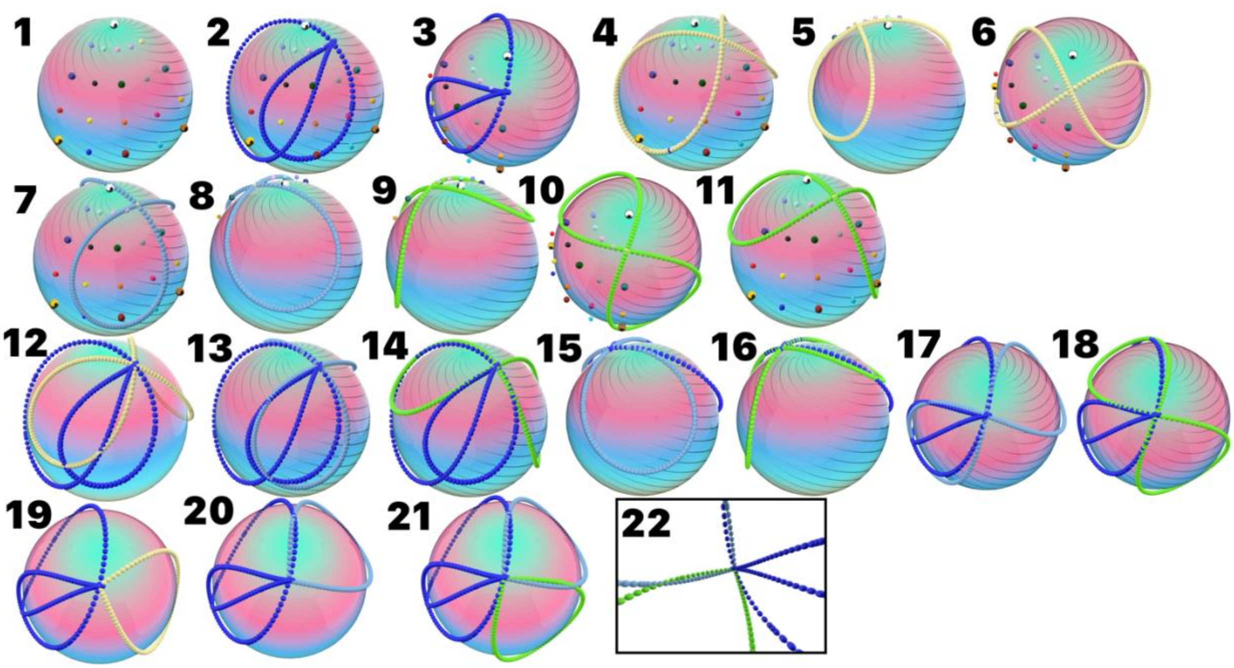

Figure 6.28

In Figure 6.28 we begin to describe this path integral as a mechanism to encode information onto a 2-dimensional surface which then can be projected out into a 3-dimensional geometry.

In the first row, frames 1-6, we see the points on the sphere that are familiar to us from Figure 6.26, all spread evenly across one of the sections of the sphere which can be translated to any of the other sections, an idea that we explored in Figure 6.27. In frames 2 and 3 we specify the path described by the rotation of the sphere equally across all 3 axes, as described by specifying one point on that sphere as the sphere is rotated, which we had previously called A in Figure 6.26, and in frames 4, 5 and 6 we see the same thing for what we had been referring to as B when discussing Figure 6.26. Path A intersects with the origin of B around the same time that the trajectory of A becomes very wound up on itself so that there isn't much change in spatial displacement from an increase or decrease in rotation from one degree to the next.

In frames 7-11 we see 2 other versions of path B, where B is rotated around its origin, basically just spinning the entire path, to some degree, around the center of the path. This can be thought of in 2 different ways: 1. We can think of the origin sphere having a different orientation, and this sphere would be oriented in such a way that equal rotation around all 3 axes would specify the paths shown in these frames as Path B on a sphere oriented in such a manner. 2. We can think of those paths as being paths where there is a rotation across all 3 axes that has equal values of rotation around all 3 axes at the beginning, end, and half way point of the path, but has unequal degrees of rotation at other points along the path. We have already established that since Path A intersects with Path B, an agent traveling along Path A could detour along Path B. At the end of Path B, the agent could continue along Path A, and it would be a viable path for the agent to travel that would have equivalent value to traveling along Path A. However, the path integral formulation dictates that since the detour along Path B doesn't add or change anything of value to Path A, that when we take the sum of all possible paths, any extraneous information about a detour along Path B will be cancelled out by another path, namely a detour along Path B in the opposite direction, and the path integral can be efficiently described simply by accounting for Path A.

In frames 12-18 we can see all 3 versions, or orientations of Path B superimposed on top of Path A. Again, any of these combined paths of A and B could be valid paths, but since they are all equivalent to the more efficient path, Path A, they can simply be described by A using the path integral formulation.

Since Path B returns to its origin at the beginning, end, and at the halfway point of its trajectory, we can do the same thing we described above, involving an extraneous detour along the Path A that includes Path B, but this time we are only taking half of Path B. In frames 19 and 20, we see half of Path B, one orientation of Path B in 19 and another in 20, added to Path A. In frame 21 we see half of 2 different orientations of Path B, each added to Path A. In frame 22 we see a view from the perspective of an observer at the center of the sphere, looking outwards towards the paths. It is apparent to this observer that there is extraneous information added to Path A, as the extraneous parts of the different orientations of Path B that have been added to A are visible from the perspective of the observer at the center of the sphere.

(It’s worth noting that when we take the point of view of the observer at the center of the sphere we necessarily need to do some cropping. Without including eye movement, humans are used to viewing the world with a field of view that is around 150° across one axis and 120° across the other. Our observer at the center of the sphere is given a field of view that is 90° across each axis. We chose this because it limited the amount of distortion in the image. In actuality, we are not concerned with an observer that has some ability for visual perception placed at the center of the sphere. We are talking about an observer in the same regard as an observer might be talked about in relativity, where they are a stand in for what we might an imagine an observer in a given frame of reference, or a given location or orientation, might perceive. With that in mind, we are concerned with what this observer would “see” with a 360°

field of vision. A better description of what information about this "observer" is pertinent would be any given fermion's geometry relative to other fermions within that fermion's cosmic horizon, and field of view. The cropped images that are meant to convey the idea of this observer having some unique perspective are not meant to imply that this view would be an entirely accurate representation of an actual observer at this location. It is only a visual aid meant to help illustrate a somewhat complicated and nuanced idea.)

Moving forward we will need to take a bit of liberty in developing this visual analogy. From now on we should think of any trajectory of the path where the path is on the surface of the sphere as being a rotation of the 3 spatial axes that we are familiar with in our universe, and any part of the path where the path deviates from the surface of the sphere, either moving inside of the sphere or moving outward from the sphere's surface, as involving rotation in axes that are in addition to the 3 spatial axes of our universe. In a sense, any rotation on the surface of the sphere could be thought of as rotation in any number of axes, where all of the higher dimensional axes are in gimbal lock with any combination of the 3 spatial axes of our universe.

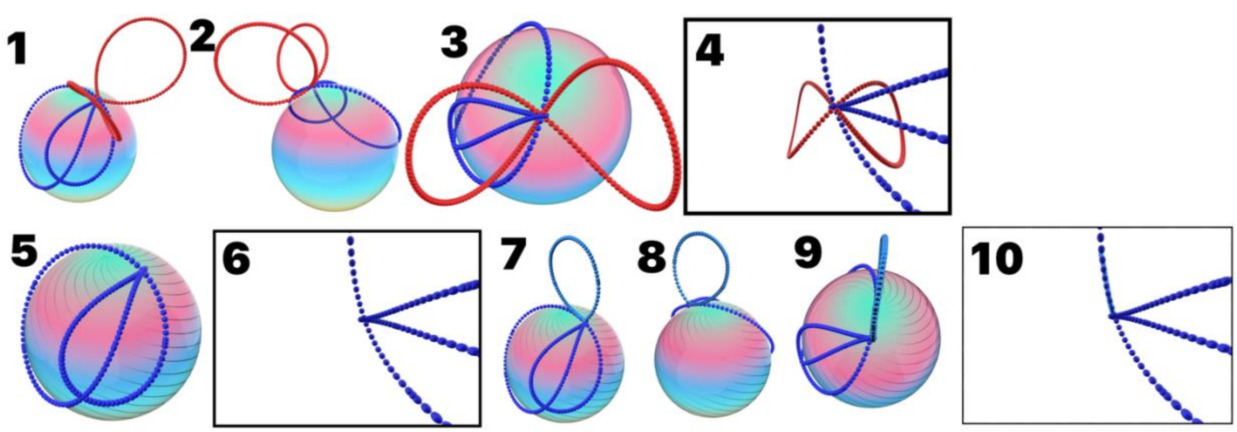

Figure 6.29

In frames 1-3 of Figure 6.29 we see Path B again rotated around its origin to a different orientation. However, this time the rotation takes place around axes that are not familiar to us in our 3-dimensional universe. In frame 4 we see what this looks like from the perspective of an observer at the center of the sphere. Notice how much of the information about the path seems to be reduced compared to frame 22 in Figure 6.28. The entire path takes up much less of the frame in Figure 6.29 than just a portion of the path does in Figure 6.28. From the perspective of this observer, much of the information about this path is lost.

In frame 5 we see Path A from a perspective outside of the sphere, and in frame 6 we take a look from the perspective of an observer inside of the sphere. In frame 7, 8 and 9 we take a rotation and transformation of Path B, and only focus on half of the path. We can see in frame 10 that from the perspective of an observer at the center of the sphere, all of the information about the path that deviates from the surface of the sphere is lost to this observer. The path in frames 6 and 10 are completely equivalent to this observer.

While the geometry of these paths from the perspective of the observer might be equivalent, there could potentially be a very important distinction between the 2 when we consider these paths as the filaments of scroll waves. If the path contains a detour that involves rotation about a point at the center of a higher-dimensional hypersphere, and this information is lost to an observer at the center of the sphere that reconstructs a 3-dimensional sphere from the information available to that observer, there might be a point along the path where there is a great degree of rotation from one point to the next.

We are proposing this as a possible mechanism, consistent with the holographic nature of our universe, which might provide some insight into the true ontology of the universe as a brane embedded in a higher-dimensional bulk, which would present itself as a highly localized twist in the filament of a scroll wave, the scroll wave being a localized excitement of any of the fermion fields.

This mechanism gives observership a vital role in the universe, because observership is given causal power in creating the universe in each moment. What we are suggesting is that all of the fermion fields are just projections of the scalar field, which is scale invariant in any number of dimensions.

After the universe had cooled enough after the bang so that energy in the form of radiation and energy in the form of matter could be distinct from one another, and light was able to travel freely in the universe, at this moment observership was given a vital role. At this moment, the geometry of different observers in the universe needed to be agreed upon for any objective reality to be able to take hold. In doing so, the scalar field became wound up on itself so that any observer reconstructing the universe from their perspective would have equivalent solutions to other observers doing the same. Perhaps more accurately, the scalar field had already been wound around itself. However, there had been a period of time after the bang that information about how the scalar field was wound around itself could not be communicated between different observers at different spatial locations in the universe. Here’s how we’re suggesting that it might have all gone down:

1. The universe begins as a singularity. All of the universe, and hence all perspectives or observers are contained in the singularity, so there is only 1 perspective. If there is a bulk beyond the singularity, or if the singularity is a 0-dimensional point embedded in the n-dimensional bulk, then all observers looking out into the n-dimensional bulk will agree on any n-dimensional geometry. Since all observers agree on the geometry of space, and the scalar field scales in any n-dimensional space, and therefore conforms to any n-

dimensional geometry, from the perspective of an observer in the universe, there is only 1 field; the scalar field.

2. The universe begins to expand in all directions, presumably in all possible dimensions, outwards from the singularity in a hot, big bang. This explosion is so hot that electromagnetic waves cannot freely travel through space. Being that light waves are the sole method of communication between observers occupying different spatial locations within the universe, observers are not able to communicate to one another how their perspective is changing. Likely, an observer is unaware that their perspective is changing.
3. After about 300,000 years the universe cools down enough so that light is able to travel freely and observers are able to share their perspective again, but this time there is more than one perspective that an observer can hold. If observed from a single point, the geometry of any number of dimensions can be efficiently described by a 2-dimensional geometry *as seen from the perspective of that observer.*

   This idea becomes apparent to those with normal 20/20 vision in both eyes (or at least those without a large disparity in their vision from one eye to the other) by closing 1 eye. Having visual input from 2 different places (the pupil of each eye) allows the brain to sort of triangulate the locations of objects in your field of view from each pupil and reconstruct 2 flattened, 2-dimensional interpretations of the world so that your visual experience of the world seems to be 3-dimensional. (Those of us who have problems with our vision, or who only have 1 eye, experience the world in a flattened, 2-dimensonal geometry. We are able to tell that the world is 3-dimensional from things like vanishing points, horizons, shadows, etc. But we do not have the same 3-dimensional, visual experience that people with normal, binocular vision do.)

The last time that there was a perspective that could look out into the bulk there was only 1 perspective, the perspective from the singularity immediately prior to the bang. Now that light is able to travel and communicate information about the spatial relationships between objects to observers, there are many perspectives that different observers might have.

So, an observer has a perspective from the singularity, agrees with all other observers, big bang, no communication about spatial relationships for 300,000 years, and now observers can once again look out into the bulk and have information about the spatial relationships between objects communicated to them, being minimally described by information that is encoded onto a 2-dimensional geometry from the perspective of each observer, and this time the universe must be reconstructed from this information available to each observer so that all observers agree on the geometry of spacetime.

4. All observers have a unique perspective, but all information encoded in a 2-dimensional geometry must not contradict the information encoded onto the 2-dimensional geometry of another observer's perspective. Only fermions have a perspective. Only fermions have a construction of a duality that requires that the oscillations of the fermion fields that generate fermion particles are the product of a filament of opposite-handed chirality at each end so that it must thread through itself and connect its ends forming the structure of some topological knot, in effect coupling the universe and the field in the spatial boundaries of the particle to itself so that any behavior inside of those boundaries must be mirrored across the filament so that the fermion causes the scalar field to be bound up around itself and present itself as the fermion fields.

This inherent duality, or mirroring behavior, endows the fermions with the potential for consciousness, which gives them the unique role as observers, which in turn gives observership a causal role in creating the 3-dimensional universe.

In addition to the potential for consciousness, fermions are also unique in that they are endowed with intrinsic mass. They are the only particles that are also given the special role of distorting the geometry of spacetime through the gravitational relationships between objects that have mass, which happen to be fermions, which happen to be the particles that play a role as unique observers in the observership-dependent universe, so that all observers will agree on the geometry of spacetime.

Without fermions, there is no potential for consciousness. Without consciousness, there is no special role of an observer. Without observership, there is no need for observers to agree on the geometry of spacetime. Without a need for observers to agree on the geometry of spacetime, there is no need for the gravitational distortion of spacetime. Without the gravity, there is no role for the property of intrinsic mass. Without particles that are attributed with some intrinsic mass, there are no fermions.* Without observership, there is no gravity.

*There are bosons that are endowed with mass, but the mechanism that gives them their mass is different from the typical Higgs mechanism that gives fermions their mass. It is somewhat analogous to the difference between having a sandbox, and tying a rope to an anchor and dragging the anchor across the sandbox, where most of the resistance that you'd experience in dragging the rope would be in the interaction between the sand and the anchor, or using a powerful magnet underneath the sandbox to drag the anchor through the sandbox, where the majority of the resistance that you'd experience would be in the pull of the anchor towards the magnet, and trying to move that magnet forward so that it pulls the weight of the anchor and the anchor's resistance to being moved through the sand along with it.

The cooling of the universe allowed for the formation of matter, which required observership to be given a causal role in reconstructing the 3-dimensional universe from a higher-dimensional bulk, which in turn endowed all matter with the potential for consciousness, which we are familiar with by considering the most fundamental elements of consciousness:

- Consciousness as an ability to look at yourself from within, the idea of consciousness as a mental mirror, or an ability to reflect on yourself, a sort of intrinsic awareness of yourself from the perspective of being you.
- Consciousness as a unique theatre, the idea that consciousness endows you with a perspective that is uniquely your own which you can never share with another consciousness, and that you cannot ever experience any other perspective that is unique in the same way that your own consciousness is. You can never give another consciousness a ticket to your unique theatre, and you cannot ever get a seat in someone else's.

Chapter 7

Integrated Information Theory

Integrated Information Theory, commonly referred to by its initials, IIT, is a theory of consciousness that has been proposed primarily by the neuroscientist Giulio Tononi. It is at its core a proposed method of being able to quantify qualia. There are competing theories, and this is certainly not a universally accepted theory of consciousness, nor is it a universally accepted theory among neuroscientists. It has, however, sort of risen to the top. Tononi first proposed IIT nearly 20 years ago. It has been peer reviewed, it has been tried and tested and others have stood on the shoulders of Tononi and made their own insights through experimentation and research based on IIT. While we feel that IIT is a very thorough, brilliant theory, and for these reasons we have decided to include it in our work as the template which we will apply our ideas to, in the end it won't matter for our purposes if IIT is someday falsified, or if it is replaced by something else. We will use IIT as a framework. We will plug in our notions of what should be considered a system with the potential for consciousness, and using the framework that has been shown to be a useful method of quantifying consciousness, we will show that what has always been considered to be fundamental, namely fermions, should be reevaluated and should be looked at as very simple systems. Systems that, in the absence of playing a mechanistic role in a higher order system, meet the requirements set forth in IIT, but is more indicative of the nature of fermions than anything that it says about IIT, to be considered a system with some inherent value of potential consciousness.

IIT is a very rigorous work. We can use IIT to support the claims we make in our work without giving a completely rigorous description of its inner workings. For us, summarizing the main ideas, the main axioms and postulates, and describing what criteria is used in calculating the sum of integrated information in a system, will serve our purposes. However, there is a sea of information about IIT available to anybody who cares to gain more insight into this fascinating work.

We will delve into IIT by specifying some axioms and postulates that it proposes:

Axioms-

1. Existence- Consciousness exists. If you are having an experience of reading this, then this is undeniable.
2. Composition- There is some structure to a conscious experience. Using the visual aspect of conscious experience as an example, there is some geometry of your experience, left is different from right, there might be different colors, different shapes in your field of view, light intensity, etc.
3. Information- There is information contained in each conscious experience that differentiates it from all other possible experiences. If you are sitting in your favorite chair watching your favorite movie, there might be a lot of commonalities between this experience and all the other times that you've watched that movie, sitting in that chair. However, this experience is differentiated by parts of this particular experience, perhaps you're hungry, or you've got the taste of garlic in your mouth, perhaps you've got a sunburn that you didn't have before, it's 72°F instead of 71°F as it was the last time that you watched this movie. Even if all other things are the same, you have the memory of all other times that you've watched the movie to compare this experience to.
4. Integration- Each conscious experience is irreducible to its parts. For example, if you are looking at a orange basketball, you can't separate your experience of the color orange and your experience of a ball and your experience of the basketball's texture, etc.

5. Exclusion- This is closely related to the information axiom. The particular information that informs any particular experience also differentiates it from all other possible experiences, and you can only have 1 of any of those experiences at any given time. You cannot simultaneously have an experience of watching your favorite movie, sitting in your favorite chair, and watching your favorite movie, sitting on the couch. Those are different experiences and you cannot have them simultaneously.

Mechanisms and Systems-

IIT specifies mechanisms and systems with its first 2 postulates; existence and composition. "Existence" says that a system is a set of mechanisms, and that those mechanisms must exist in a state. "Composition" says that there can be a hierarchy of systems, where systems can combine into higher order systems, so that what were systems now play the role of a mechanism in a higher order system. In short, any set of elements is either a mechanism or a system. If something plays a role in contributing to the consciousness of a higher order system, then it is a mechanism. An easy example would be neurons in the brain play the role of mechanisms, while the brain plays the role of a system. Since we are interested in conscious systems, IIT specifies a set of postulates that mirror the axioms, which it applies to the material substrate of mechanisms and systems that it proposes this substrate must possess in order to have some potential for consciousness.

Postulates for both Mechanisms and Systems-

1. Information- A mechanism is only informative to a system if it generates differences that make a difference to the system. Thinking of neural networks, a mechanism that doesn't have any causal power in affecting future states of the system, or doesn't rule out any

possible previous states of the system doesn't have any useful information that can contribute to the system. It doesn't put any constraints on the *cause-effect repertoire* of the system. If a mechanism does put some constraints on the cause-effect repertoire, then we can quantify how much it constrains possible causes and effects. The degree to which a mechanism does this is quantified as the *cause-effect information* or CEI of a mechanism.

2. Integration- Integration could also be thought of as irreducibility. A mechanism must be irreducible to its components in order to be informative to the cause-effect repertoire. If you've got a set of elements $\{A\}$ and a set of elements $\{B\}$, and their combined set $\{AB\}$, if the set of possible causes and possible effects of $\{A\}$ and $\{B\}$ and $\{AB\}$ is the same set, then $\{AB\}$ doesn't do anything to inform the cause-effect repertoire. However, if combining $\{A\}$ and $\{B\}$ puts some additional constraints on the cause-effect repertoire, then $\{AB\}$ is irreducible to $\{A\}$ and $\{B\}$ and it can contribute to the consciousness of a system. The symbol φ is used in IIT to denote a quantified value of integration/irreducibility.
3. Exclusion- A mechanism contributes no more that 1 unique cause-effect repertoire to the consciousness of a system. This is similar to the path integral formulation in that any extraneous information is excluded. In the path integral formulation any detours along the path that don't have some causal power are excluded, and here any cause-effect repertoires that are not the most efficient, or *maximally irreducible*, or φ^{Max} are excluded. This is called the *maximally irreducible cause-effect repertoire*, or MICE, and if this criteria is met then the mechanism is considered to be a *concept*.

Postulates for Systems of Mechanisms

1. Information- The mechanisms of a system must specify a set of differences that make a difference to the system, called a *conceptual structure*, in order for the system to be conscious. The possible past and future states of the system are described by the mechanisms in that system and the φ^{Max} of those mechanisms. Essentially, the more that the state of a system can be distinguished from other possible states of that same system, the more information they have to contribute to the consciousness of that system. The more mechanisms that meet the criteria to be a concept that a system has, and the greater the φ^{Max} value for those concepts, the more information there is to contribute to the consciousness of a system. This value of information that can be used to narrow down the possible states of a system and distinguish a particular state from all possible states is called the *conceptual information*, or CI, of that system.
2. Integration- As where before we were concerned with a mechanism being irreducible to independent components, here we are concerned with a system being irreducible to non-interdependent components. For a system to be conscious, the mechanisms must be arranged in a conceptual structure that is irreducible to non-interdependent pieces. In other words, for a system to be conscious there must be some connections between every mechanism within the system, so that each mechanism is connected to at least 1 other mechanism in a way that puts some constraints on the possible past and future states of the system. The value assigned to this irreducibility is called the *strong integration/irreducibility* of the system, and it is denoted by the symbol Φ, called "phi."
3. Exclusion- In all the overlapping hierarchy of systems, only 1 system in the hierarchy can achieve consciousness. The system that has the potential for consciousness is the system with a *maximally irreducible concept structure*, or MICS, that is maximally irreducible to

independent parts. This is the system within the hierarchy of systems that is attributed with a maximal value of integrated information, which is described in shorthand by "Φ^{Max}."

All of this is much clearer if we use an example. Individually, human beings are conscious. Specifically, our brains are the systems that seem to achieve consciousness. There are around 86 billion neurons in the brain. Each of these neurons has some information about the current state of itself. Each of these neurons is also connected to about 10,000 other neurons. So, the information about 1 neuron is integrated with the information about 10,000 other neurons. Since each of these neurons has so many connections, and the network of connections spans all across the brain, there is nowhere in the brain that you could build little neural fences and say "there is a greater sum of information that this part of the brain is sharing with itself than the entire system of the brain is sharing with itself at any given moment." Moving up in the hierarchy of systems, we can see that the neural network in the brain has integrated information, information about itself, which it is sharing with itself, which affects its cause-effect repertoire more efficiently than if we were to treat the brain as a mechanism that were contributing to the consciousness of any other system. For example, if the higher order system was to include blood cells, obviously they are feeding oxygen to the cells in my brain which then allows the neurons to fire which generates my conscious experience. They play a role in a system to achieve consciousness. However, the blood cells flowing through my brain don't do enough to differentiate between the possible past and future states of the system, to distinguish any particular state from other possible states efficiently enough to affect the cause-effect repertoire. Another example might be the system of 2 brains. Alice and Bob each have a brain, and each of their brains is a conscious system. Alice and Bob can share information about the states of their brains with one another, "I am having a hungry experience," "I am having a happy experience," etc. The rate at which they are able to share information with one another pales in comparison to the rate at which each of their brains is able to share information about itself with itself. Therefore, Alice and Bob do not achieve a maximal value for irreducible, integrated information, or Φ^{Max}, and they do not become a conscious system.

At the core of our proposed ideas on consciousness is the notion that the filament of a scroll wave that has become twisted so that it has ends with twists of opposite chirality, which threads through its own center so that the filament forms a topological knot and the scroll wave is a knotted scroll wave ring, must contain some information about itself. Each half of the scroll wave must act as a mirror image of the other half in order for the oscillation to persist. Each half of the filament must have information about itself which is strongly integrated with the other half of the filament.

Any fermions that we are able to observe are coupled with other particles, and the laws of nature govern the collection of particles, and the charge of one particle affects other particles, there are interactions between particles, bonds formed between elements, etc. The collection of particles that we can observe shares information about itself with itself via the natural laws governing our universe. The sum of information in any particle interaction is certainly greater than the sum of information that any fermion shares with itself. Any collection of particles that includes a fermion would certainly be considered a higher order system with a greater value of Φ.

However, as a thought experiment consider a fermion that is not coupled to any other particles. This fermion is dependent on a phase singularity, a filament, that must abide by certain rules in order for the fermion to exist. Those rules are that the filament must have twisted with opposite chirality at its ends and that when those ends went to connect the opposite twists forced the filament to thread through itself, until it became knotted so that the system would have a coupling number of 0. Once the filament achieved this state, the dynamic system must maintain the opposite twist and the knotted structure in order for the fermion to exist over time. The fermion is a sort of information feedback loop, informing itself about the state of itself, limiting its possible future states, and each state of the fermion being limited to previous states that could have generated a fermion in that state, with a filament in that particular configuration. This meets all criteria for a conscious system as described by IIT. Therefore, we are left to conclude that if a fermion were to exist outside of contributing to any other system, that according to Integrated Information Theory, that fermion would be attributed with a sum of maximally irreducible, integrated information, and that any fermion could potentially be considered a conscious system.

Since fermions are fundamental particles, it stands to reason that any value of Φ attributed to a fermion would be a fundamental Φ^{Max} value that a conscious system could potentially have, and therefore the Φ of any fermion is the fundamental value of consciousness possible in the universe. The value of Φ attributed to any fermion specifies the quantum of consciousness in the universe.

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