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# The Code-Theoretic Axiom: The Third Ontology

Klee Irwin

*Quantum Gravity Research*
*Los Angeles, CA 90290, USA*
*klee@quantumgravityresearch.org*

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A logical physical ontology is code theory, wherein reality is neither deterministic nor random. In light of Conway and Kochen's free will theorem [The free will theorem, *Found. Phys.* **36**(10) (2006) 1441–1473] and strong free will theorem [The strong free will theorem, *Not. Am. Math. Soc.* **56**(2) (2009) 226–232], we discuss the plausibility of a third axiomatic option — geometric language; the *code-theoretic axiom*. We suggest that freewill choices at the syntactically-free steps of a geometric language of spacetime form the code-theoretic substrate upon which particle and gravitational physics emerge.

*Keywords*: Physics; number theory; code theoretic.

## 1. Introduction

### 1.1. *The code-theoretic axiom*

Reality is neither deterministic nor random. Instead, it is code-theoretic, wherein spacetime and particles are discrete and built of a Planck-scale geometric code — a finite set of shape symbols, ordering rules and non-deterministic syntactical freedom.

Broadly speaking, there are three axioms for a physical ontology one can assume. One is the idea that the universe is a deterministic causal chain or algorithm playing itself out. An example of this is the model of the Newtonian clockwork universe,[3] which postulates that if one knew the starting conditions, a powerful computer could predict every event.[4] A second option is the axiom of pure randomness, where a particle can appear anywhere in space and time according to probabilities dictated by quantum mechanics.[5] The third possibility is what we will henceforth refer to as code theory, where, e.g., the Planck-scale fabric of reality operates according to a geometric language with syntactical freedom creating order and preventing the existence of particles at certain spatiotemporal coordinates. Today, deterministic models are widely believed to be false,[6] while the axiom of randomness is generally presumed to be true. This virtual consensus is due to two ideas. The first is the vastly popular Copenhagen interpretation of quantum mechanics,[7] which stipulates that the universe is fundamentally random. The second is the widely accepted opinion that consciousness and freewill are real.

This opinion paper argues for the code-theoretic axiom, a logical alternative to the two older ideas of determinism and pure randomness. Reality would be non-deterministic, not because it is random, but because it is a code — a finite set of irreducible symbols and syntactical rules. Herein, we adopt the popular and reasoned view that freewill is real. Accordingly, we will not focus on deterministic models but instead consider the code-theoretic and randomness axioms.

It is interesting to note that although there is some degree of consensus that nature is random, there is also a general opinion among physicists that they have freewill, which is neither deterministic nor random. The two views are at odds with one another, although it is possible to invent creative solutions.[8] A small minority contend that freewill is not real and that even consciousness does not exist. We will not explore that view here.

Consider the following thought experiment. We start with a universe without freewill animals living in it and that is ideally random. We assume that freewill actors, as self-organized particle systems (e.g., humans), "contaminate" this otherwise perfectly random system with their non-randomness — their freewill. Accordingly, they "steer" or causally influence the particles of their bodies by their creative and strategic freewill choices of thoughts and actions, imparting non-random order on the spacetime and particles in the rest of the universe via gravitational, electromagnetic, quantum entanglement and quantum wave function resonance and damping interactions. This ordering influence is ubiquitous because there is no cutoff on the range of force interactions and because each influenced particle in turn influences others. The *free will theorem* and the *strong free will theorem* of Conway and Kochen states that if we have freewill (i.e., our choices are not a function of the past), elementary particles must have some form of that same freewill quality.[1,2] That is, particles would behave neither deterministically nor randomly. Henceforth, we use the term freewill implicitly meaning Conway and Kochen's sense of freewill.

It is increasingly popular for physicists to presume that a deep implication of quantum mechanics is that reality is made of information versus merely being described by information. This leads one to the deductive conjecture that reality is code-theoretic. A code is an abstract thing. It can be defined as a finite set of objects with organization rules and syntactical freedom that can be exploited for choosing different expressions for the purpose of creating information. In fact, it is difficult to imagine a form of information that does not require a code of some form to express it. The conclusion, which we will develop herein, is that reality is an abstract or information-theoretic code expressing itself. The confusing and often contentious notion of "consciousness" and strategic choice of syntactical selections comes into play with any code. Indeed, the famous measurement problem indicates that somehow consciousness or choices of measurement or observation must be a foundational aspect of a future predictive quantum gravity theory. It has been suggested by many authors that a form of universal consciousness must logically be the substrate for a quantum mechanical reality such as ours.

### 1.2. *Structure of this paper*

In Sec. 2 we argue for an information-theoretic view of reality, and relate information to meaning. In Sec. 3 we acknowledge a well-known candidate ontology in this view, the idea of reality as a simulation, but then propose an alternative ontology based on the concept of nature as a code. We build on this in Sec. 4, arguing for the code-theoretic view with a discussion of information, meaning and non-arbitrary symbolism. The notion of meaning raises the question of consciousness, a challenging but intriguing issue which plays an important role in the code-theoretic ontology. This is discussed in Secs. 5–8. In Sec. 9 we present some predictions of specific features that a fully developed code theory of reality would likely include, and then provide a brief summary and some concluding remarks in Sec. 10. The code-theoretic viewpoint leads us to consider notions of efficiency in the code, and so we have included as an addendum Sec. 11 on the principle of efficient language (PEL).

## 2. Is Reality Information-Theoretic?

An insightful pathway to explore the code-theoretic axiom is to first decide on a related axiom, which can be introduced by the question:

*Is reality made of information or merely described by information?*

Wheeler was one of the first modern physicists to argue that nature is information-theoretic.[9] Today, there are a large number of physicists, such as Wolfram,[10] ‘t Hooft,[11] Fredkin,[12] Schmidhuber,[13] Lloyd,[14] Deutsch,[15] Zizzi,[16] von Weizsäcker[17] and Tegmark,[18] who suggest it is too aggressive to theorize reality is made of something other than information. They contend it is more conservative to accept the logical indication that reality is made of information.

One of the supposed evidential highlights of the information-theoretic argument was first observed by Gates, Jr. He discovered the most fundamental error correction code from computer theory, block linear self-dual error correcting code,[19] embedded in the supersymmetry equation network that unifies all fundamental particles and forces other than gravity.[20]

It is interesting to note that there is not a good counter argument to the information-theoretic ontological axiom. Specifically, when one tries to define energy as anything other than information, they must take a Platonist view that claims energy *just is* — a sort of primordial stuff for which we have no further explanation of how it comes to be and can only know how it behaves. Similarly, this end-of-the-road statement that energy *just is* is identical to the information-theoretic ontology if one stops at the axiom that information *just is* without going further to explain how this information comes to exist or what it is made of.

To simplify, if energy is not information but is the ultimate stuff that *just is*, we know (1) how it behaves but we do not know what it is made of or how it came to be. On the other hand, if we say energy is made of information, then we know (1) how it behaves and (2) what it is. But we do not know what information is made of or how it came to be.

**Information is:** *Meaning conveyed by symbolism.*

The increasingly popular view that "energy is made of information" goes one step further into clarity and explanation than saying "energy just is".[21] But it does not go far enough. An understanding of what information is made of is lacking. How does symbolic meaning — information — come to exist? It is not necessary to stop the scientific inquiry at a premature axiom of "information just is". Stopping at that axiom or not is an important decision, since it would serve as the most foundational scientific axiom underlying all of the physics.

## 3. Is Reality Code-Theoretic?

Some who think reality is made of information suggest it is a simulation.[22] This is known as *the simulation hypothesis*. Like in the movie *The Matrix*, where a quasi-physical reality exists as an information space, one can imagine the universe being a simulation in some large quantum computer. This recently popular view does provide an explanation that goes beyond the axiom information *just is*. However, in some sense, this view is still the antiquated ontology of materialism because it presumes our universe is made of information and that there is some outside universe that is the real non-information-theoretic reality.

A better alternative is to reject the idea of an outside computer and consider a self-organized-simulation, where the symbolic code is simultaneously the hardware, software and the output — the simulation.[23] There may be a more appropriate analogy than these 20th-century computer theory terms. For example, the concept of neural networks is more physically realistic because they self-organize in nature.[24] They are exceedingly efficient at computing, due to their massively distributed non-local architecture.[25] The idea of a mind-like neural network as the basis of an information-only reality is interesting. Here, the neural network can be made of symbolic geometric code in a graph-theoretic architecture operating on a point array in a symmetry space. The information of this symbolic system would live in the emergent pan-consciousness that evolves from the evolution of this physical code. So the code exists or lives within the evolutionary emergent consciousness, which is self-actualized and emerges from the code. The logic of this non-linear causality is explained in Fig. 1. Later, we will explore the physical plausibility of an emergent pan-consciousness.

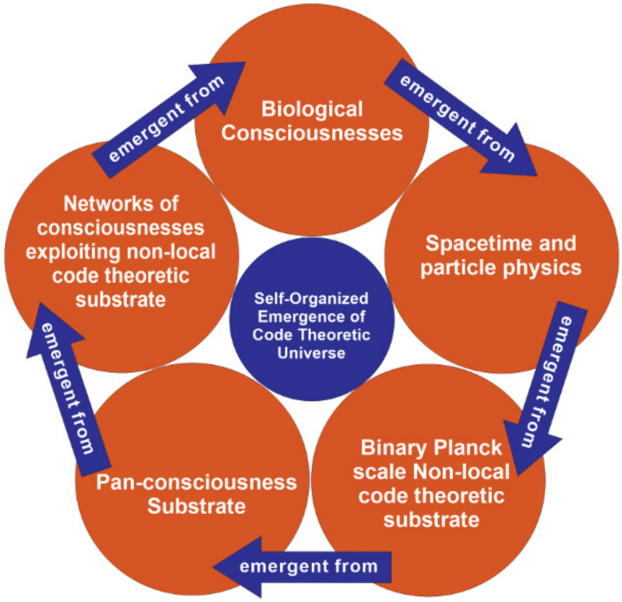


Fig. 1. Here we show the self-organized emergence of all aspects in a code-theoretic universe.

The key idea for now is to establish the explanatory power of this view, which goes further than the previously mentioned *just is* axioms. Here we would have a connected loop of explanations for a physical ontology that gives an understanding of (1) how energy as information behaves, (2) what it is made of (abstract code objects in a pan-consciousness) and (3) how the pan-consciousness itself came to exist. There is a logically consistent and self-embedded causality chain that is less "faith-based" than stopping at the axiom that energy *just is* or information *just is*.

Scientists do not agree how consciousness emerges in neural networks.[26] However, the theoretical and experimental work continue to improve in this area. Scientists discussing the simulation hypothesis[27] are pushing the boundary of understanding in a positive way because they are resisting the status-quo view to accept the energy *just is* axiom.

Although the information *just is* axiom is arguably simpler and more logical than the energy *just is* axiom, it comes with a price, which is implied in the definition of information as meaning conveyed by symbolism. That is, meaning is a quality deeply related to entities capable of ascribing or actualizing meaning. This can be solved by saying that we live in a simulation of aliens in another universe, who in turn live in a simulation of aliens in another word, *ad infinitum*. If we do not accept the simulation hypothesis, due in part to this *Russian-doll* problem, the information *just is* axiom demands a boldly different worldview than the materialistic philosophy of energy *just is*. Materialists can say that God made the energy or the big bang spewed it out. However, scientists contending that reality is information must deal with the fact that information relates to meaning and meaning relates to choice and consciousness.

According to the code-theoretic axiom, the information view means that everything is information — including the abstract neural network-based code-theoretic substrate itself. As long as there are physically realistic syntactical rules guiding how an abstract code self-organizes, it is equally as logical for information to behave physically as it is for the more enigmatic notion of energy as something other than information to behave physically. In this case, the term *simulation* would be confusing because that word is used to distinguish between something real as opposed to something not real. For example, if dreams are unreal and waking reality is real, then we can call the dreams simulations of the real world. However, if reality is information-theoretic, the terms "physical" versus "abstract" and "reality" versus "simulation" must be replaced. We may use terms related to neural networks and emergent consciousness. For example, we might say something is either "chosen" or "not chosen" or "thought" or "not thought". This fundamental action would be identical to the idea of "observe" or "not observe" and "measure" or "not measure". However, in the code-theoretic framework, the idea of syntax comes into play, where the most fundamental freewill action is the expression of syntactically-free steps in the physical code of reality. The chooser in the code, then, can logically (even if some say improbably) be an emergent pan-consciousness as well as emergent subsystems, such as humans.

The scientific deduction that the most fundamental stuff of reality is consciousness is not new.

Werner Heisenberg[28] said:

> Was [is] it utterly absurd to seek behind the ordering structures of this world a "consciousness" whose "intentions" were these very structures?

Wilczek[29] said:

> The relevant literature [on the meaning of quantum theory] is famously contentious and obscure. I believe it will remain so until someone constructs, within the formalism of quantum mechanics, an observer, that is, a model entity whose states correspond to a recognizable caricature of conscious awareness.

Andrei Linde,[30] co-pioneer of inflationary big bang theory, said:

> Will it not turn out, with the further development of science, that the study of the universe and the study of consciousness will be inseparably linked, and that ultimate progress in the one will be impossible without progress in the other?

Wheeler[9] said:

> ... the physical world has at bottom — a very deep bottom, in most instances—an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes-or-no questions...

all things physical are information-theoretic in origin and that this is a participatory universe.

How can this idea of a code and a pan-consciousness be made concrete and mathematical such that we can use it to do realistic physics? To start with, the code would need to use virtually non-subjective symbols that are quasi-physical.

## 4. Quasi-Physical Symbolism

Again, our definition of information is *meaning conveyed by symbolism*. And expressions of code or language are strings of symbols allowed by syntax — ordering rules with syntactical freedom. A symbol is an object that represents itself or another object. And an object is anything which can be thought of. In the universe of all symbols, there is a special class with very low subjectivity. They can be called self-referential geometric symbols. For example, we can represent the meaning of a square with the Latin letters "square". Or we can represent it with the symbol of a square itself, in which case it is a self-referential symbol. Quasi-crystals, such as the Penrose tiling,[31] are examples of geometric symbolic codes. Geometric codes are defined as a finite set of geometric letters or shapes and ordering rules with syntactical freedom. Because the universe is geometric and in 3-space, the logical symbols of an underlying code would be polyhedra. Both the ordering rules and dynamic rules should be based on geometric first-principles, as opposed to arbitrary or invented rules. In Ref. 32, we showed how shape numbers, as geometric symbols for integers, are uniquely powerful. In Ref. 33, we elaborate on quasi-crystalline codes as a logical basis for a quantum gravity framework.

The Standard Model of particle physics is generally considered to be the most powerful physical model we have.[34] It synthesizes quantum mechanics with particle collider data to show how all known fundamental particles and forces (other than gravity) are gauge symmetry-unified according to special algebraic and group-theoretic structures corresponding to higher-dimensional polytopes and lattices. A quasi-crystal is an irrational projection to a dimension $n - m$ of a slice of an $n$-dimensional lattice. The projection preserves (under transformation) key information about the higher-dimensional lattice and its associated Lie algebra. For example, a 3D quasi-crystal derived from the $E_8$ lattice encodes the gauge symmetry unification of the Standard Model of particle physics insofar as $E_8$ and any of its subspaces, such as $E_6$, encodes such unification physics.[35]

We are aware of only one class of non-invented codes that exists via first-principles within the universe of all codes both geometric and non-geometric. That class of codes is the set of all quasi-crystals. Each is generated by an irrational projection of a lattice slice to a lower dimension.[36] The Standard Model of particle physics and associated gauge symmetry models correspond to Lie algebras and associated lattices.[37] The lattice analog starts with the idea that different particles and forces are all equally related to the homogeneously arrayed vertexes or root vectors of certain hyper-lattices, such as $E_8$. In order to make such models physically realistic and dynamic (asymmetric), various symmetry-breaking mechanisms have been proposed. There is poor consensus on what this mechanism is because none are very convincing.[38]

We propose that projective geometry may relate to the correct mechanism. Conveniently, this generates (1) the only known non-invented and first-principles-based codes and (2) an elegant first principles-based symmetry-breaking mechanism. Because the projection is irrational, it preserves under transformation the necessary gauge symmetry unification physics.

One of the most important of the 19 parameters of the Standard Model of particle physics, the Cabbibo angle, can be written in the form $\cos^{-1}(\frac{\phi^2}{\sqrt{2(\phi+2)}})$.[39–42] It corresponds to particle collider experiment scattering angles. As mentioned, various methods have been proposed to explain how it is that reality is not symmetric and why particles are not unified but different, while possessing unification gauge symmetry values corresponding to higher-dimensional lattices.

Interestingly, the angle necessary to break the symmetry of $E_8$ and create the 4D Elser–Sloane quasi-crystal in $H_4$ (the only possible quasi-crystal derived from $E_8$ that possesses $H_4$ symmetry) and the 3D quasi-crystalline spin network in $H_3$ that we work with[51] is this same angle, $\cos^{-1}(\frac{\phi^2}{\sqrt{2(\phi+2)}})$.[43]

Accordingly, we contend that particle collider data and the Standard Model itself are evidences that irrational projection from $E_8$ to lower dimension correlates to the correct symmetry-breaking mechanism. As stated, this generates a geometric code of spacetime and particles — specifically a dynamical quasi-crystal code. This code, like many codes, may require an error detection and correction mechanism. Quasi-crystals naturally correspond to powerful error correction and detection mechanisms, such as Fibonacci error correction code.[44]

## 5. Challenges with the Code-Theoretic Axiom

As discussed, the challenge with the code-theoretic axiom lies in the fact that geometric symbolism requires some notion of consciousness to actualize the information or meaning into existence. Of course, one may take a Platonist philosophy and suggest that these abstract or quasi-physical geometric symbols that constitute reality simply exist without the need of an actualizing entity for the symbolic meaning. In other words, one can decide that the Platonic realism of the symbols is itself the ground of reality and the unprovable axiom — they just *are*. As mentioned, that is identical to the decision to accept that energy *just is* without further explanation.

So the first challenge is the fact that information is meaning and meaning requires consciousness to actualize or recognize it. Certainly, animals such as humans are not likely to be the actualizers of all of this microscopic meaning. The second challenge with the code-theoretic idea is the issue of syntax choice. What chooses the syntactically-free steps in the code? If nature were just a deterministic causal algorithm playing itself out, one could say energy is like a set of falling dominoes with no need for a chooser because there are no syntactically-free steps in the algorithm because it is not a code. One could then stop at energy in the search for further explanations. But with a code, stopping at the axiom that energy is information and information *just is* is not so easy because of this issue of the need for a chooser of the syntactical freedom. If one introduces randomness as the syntax chooser, it is problematic because the meaning output of a code degrades when randomness is introduced. As an analogy, we can take a paragraph of a book to see what happens with the quality of meaning of the English code output when we replace each adjective and noun with randomly chosen adjectives and nouns. The syntax rules will be legally followed but the code conveys much less meaning.

Furthermore, even if we decide that code efficiency is not important and say the ultimate *stuff* of reality is randomness or an unexplainable quantity called energy that randomly operates the code syntax, it would be just one of the other axioms that stop at some level without further explanation — accepting on faith something to be the true base of physical reality, even though there is no explanation for it.

Careful reasoning gives us logical permission to consider that the definition of information as *meaning conveyed by symbolism* should be taken seriously. That is, if reality is information- and code-theoretic, meaning must be involved. And meaning is a substance of minds. A mind chooses (observes) or actualizes information — creates meaning.

So where do we go from there in truly critical scientific inquiry without romantic or spiritual motivations but with only logic and reason to guide us? Are we to seriously consider this notion of pan-consciousness as the substrate of reality — this idea of a *Star Wars*-type intelligent *Force* or some other fictional or religious sounding notion?

There is a rigorously logical possibility with physical evidence that is no less remarkable than big bang theory or the fact that human consciousness emerged from quarks and electrons. And it is certainly less fantastical than the idea that we are living in a simulation of some other real universe.

## 6. The Possible Origin of Pan-consciousness

Consider the non-linear physical logic that event A causes B, which causes C, which completes the loop by causing event A. Many scientific works have put forth theoretical and experimental evidences for retro-causal feedback loops.[45] Radin has done experiments showing retro-causality in the form of human skin conductance changes correlated to computer monitor displayed images not yet selected by a random number generator.[46] The delayed choice quantum eraser experiment has shown how the freewill choice of an experimentalist changes events in the past. Wheeler argued how such choices loop back to retro-causally influence things billions of years ago. Susskind[47] and Maldacena[48] argue that the wormholes or Einstein–Rosen bridges linking non-local regions of spacetime predicted by general relativity are equivalent to quantum-entangled particles predicted by quantum mechanics. And in 2012, physicists in Israel experimentally demonstrated that particles can be entangled to influence one another over time.[49]

There is no evidence retro-causality is unrealistic. There is some evidence suggesting it is a real phenomenon. And there are strong theoretical implications in both general relativity and quantum mechanics that non-locality is a deep aspect of reality. Furthermore, there is no predictive quantum gravity theory of spacetime that includes particle physics whereupon one can make strong statements about what should and should not be possible with respect to retro-causality and non-local connectivity.

We suggest that if it is possible for human consciousness to emerge from finite quantities of energy within some non-local quantum gravity framework, that it is either inevitable or possible that consciousness eventually emerges from all quantities of energy in the universe.

This is an outrageous idea that deserves careful critical thinking. We will deduce via asking and answering a few questions below. Before we begin, the objective here is to look for a logically consistent explanation for how the universe can be self-actualized — a self-emergent neural network that is its own hardware, software and simulation output as one in the same system. We are looking to see if consciousness itself can be the most physically realistic and plausible axiom instead of the imagination that we live in a computer simulation or that energy or abstract geometric symbols *just are* without deeper explanation. We wish to reduce the axiom down to the irreducible idea of Descartes, rephrased here as:

> I don't know what consciousness is, but I know it exists because I have evidence — namely the fact that I am freely choosing to wonder about what consciousness is. And that free choice, neither forced upon me by causality nor merely accidental, is part of the very definition of my consciousness.

Note that some define consciousness as simply being aware, and that it does not require freewill. Others define consciousness as correlating to freewill and choosing what to be aware of or to observe. Notice that to be aware is a slippery notion. What does it mean? Does it mean you are receiving information about something? That would not suffice, since we are constantly receiving information of which we are not aware. So if we adopt the definition of information that does not require freewill or the choice of what to be aware of, we have a blurry enigmatic and therefore imprecise concept of what "to be aware" means.

Conversely, to choose or select is a precise concept. A random action can select A or B. A chooser can select A or B. Embedded deep in the concepts of quantum mechanics is the notion of choice of observation/measurement — position or momentum, for example.

Furthermore, the idea of consciousness being defined only by awareness and stripped of freewill or choice of what to be aware of is the notion of something outside controlling your mind to insert only the thoughts to be aware of that it chooses. In this sense, you would be a copy of their consciousness or its consciousness — merely the river of thoughts defining something or someone else, like a clone of their experience.

Accordingly, we adopt here the more precise concept of choice and freedom as the defining quality of consciousness/awareness. Of course, this is a convenient quality for a code-theoretic ontology which requires a chooser at the syntactically-free steps in a quantum gravity physical code of reality.

We define consciousness as

> Something capable of making non-random and non-deterministic selections — choices — something which can actualize or choose a meaning to recognize.

The reason for the second sentence is because if one has freedom to choose a selection, by definition, one has freedom to choose something to observe, measure, be aware or think of. They have the freedom and the ability to actualize meaning.

The following series of five deductions helps connect some of the elements of this *lesser of evils* approach to the question of the ultimate *stuff* of reality — the quest to find a maximally-reduced axiom of realty with the highest explanatory power possible.

**Deductive Question 1.** *Does consciousness exist in the universe?*

Descartes simplified things nicely by supposing that because he questions whether he exists, he must exist. He said, "I think, therefore I am". He was not specifically speaking of his physical body. It was his inquiry as to whether or not he, as in his self or consciousness, exists.

The answer seems to be, yes we are conscious because we can choose what to think about — what to be aware of and what meaning to give it.

**Deductive Question 2.** *Does physics place an upper limit on what percentage of the universe's energy can self-organize into conscious systems or into a network of conscious systems that is itself conscious?*

To think about this question, let us imagine we are examining the universe four billion years ago. We are considering single-celled organisms and agreeing that we cannot predict their primitive choices of action and behavior. We label them with some primitive notion of freewill and awareness of their environment and their boundary — their selves. We do not have to admit they have the ego-based questions about self that we do. But they do have a sense of their environment, internal structure and the boundary between the two. They chase food, run from predators, reproduce, excrete waste and are absolutely unpredictable in their primitive choices. So, four-billion years ago, we debate whether or not larger magnitudes of energy can self-organize into more highly conscious systems and whether or not the single-celled organisms can self-organize into systems that are of a higher rank of complexity and consciousness. Zooming forward to today, we find that self-organization turns out to allow about 37 trillion single-celled organisms to become the emergent consciousness of a human mind-body system. Clearly, there appears to be no law of physics that would prevent a more sophisticated consciousness than a human to self-organize in the universe. There also seems to be nothing to prevent multiple human consciousnesses from knowingly or unknowingly being part of an uber-consciousness similar to how many single-celled animals self-organize into a larger smarter system like a human without fully eliminating their primitive individual freewill. Notwithstanding classic physical arguments, the only logical or conservative upper limit would be all the energy in the universe in terms of what percentage can self-organize into a system of conscious systems that is itself conscious. There is a mathematical and physical idea that some consider provable:

> Given enough time, whatever can happen will happen.

Based on these carefully reasoned ideas, we may simply say that somewhere forward of us in spacetime, a universal-scale consciousness or global network of consciousnesses that is itself conscious has emerged. One cannot use the separate regimes of quantum mechanics or general relativity to argue for or against this notion. For example, one could use general relativity in a naive attempt to suggest networks across spacetime may not perform well because of the limitation of the speed of light. This does not hold well in light of the experimental and theoretical evidence discussed above. The fact is that without a predictive quantum gravity theory, the two separate place holder models of general relativity and quantum mechanics are incomplete pictures of physical reality and cannot give us an answer as to what is or is not possible with respect to trans-spatial and trans-temporal networks, especially when correlation between two or more nodes in such networks does not exchange information at a finite speed.

Accordingly, the answer to this deductive question 2 here is:

> Theoretically, all the energy in the universe can self-organize into a conscious system. And because it is possible, it may be exceedingly probable that at some point ahead of us in spacetime, it has occurred.

The interesting thing about this deduction is not that it must be correct. It is simply noteworthy as a contrast to other axioms such as randomness, which have very little logical or deductive evidence. Logical evidence is clearly not proof. And of course, there are no proofs in physics at all. But the logical consistency of the idea and the explanatory power is perhaps more scientific than the dead-halt at the unsupported axiom of randomness. It is the lesser of evils. At very least, it is more congruent with the scientific process of searching to go beyond axioms and into deeper and evermore logical explanations.

**Deductive Question 3.** *How many times would the human population have to double to require every atom in the universe to be part of a mind-like system?*

The answer is about 70 doublings. This can happen over thousands of years, as opposed to geological or cosmic time scales. Obviously, resource limitation always halts doubling algorithms in nature, whether that be a bacterium doubling on the surface of an apple or a population of rabbits doubling on an island. An intelligent animal population would have to develop technology to move beyond their biosphere and into the universe at large in order to avoid resource limitations that would prematurely halt the doubling algorithm before all energy in the universe could be converted into a network of conscious systems that is itself conscious. With global violence and pollution decreasing every year for the last 50 years straight and with technology doubling at an even faster rate than the decrease in violence, the probability that humans will move out beyond Earths biosphere has never been as probable as it is today.

**Deductive Question 4.** *Is there any law of physics that would prevent consciousness from self-organizing in the electromagnetic spectrum of space or within emergent patterns of quasi-particles?*

There is no known prohibition by physical laws. In fact, a series of recent breakthroughs in the manipulation of bosons has occurred. We can now completely stop light inside a crystal.[50] We can tie light into knots and braids. Again, the question ultimately depends upon the nature of a possible substructure of spacetime. Our group's quantum gravity and particle unification formalism is called *emergence theory*. The base mathematical object is a quasi-crystalline array of points in $H_3$ symmetry space assumed to be the Planck-scale substructure of spacetime. It is called the *quasi-crystalline spin network*.[51] When acted upon by a certain binary geometric code of "on/off" connections, it acts as a neural network mathematically. The fundamental propagators or quantum particles are called phason quasi-particles, and they are inherently non-local. So we have no theory for how consciousness could emerge from our formalism. However, we do have knowledge of how particle physics and gravity theory can emerge from it. And, of course, it seems true that human consciousness emerged from the self-organization of spacetime and particles — physics that is.

Atmanspacher explains consciousness using quantum field theory.[52] He says, since quantum theory is the most fundamental theory of matter currently available, it is a legitimate question to ask whether it can help explain consciousness. Large systems have less symmetry than nearly-idealized microscopic systems. Goldstone proved that where symmetry is broken, Nambu–Goldstone bosons are observed in the spectrum of possible states; one canonical example being the phonon in a crystal.[53] A phonon is a quasi-particle similar to the idea of a phason quasi-particle propagating in a quasi-crystal. Ricciardi and Umezawa proposed a general theory of quanta of long-range coherent quasiparticle waves within and between brain cells.[54] They showed a possible mechanism of memory storage and retrieval in terms of Nambu–Goldstone bosons. This was later advanced into a theory including all biological cells in the quantum biodynamics of Del Giudice. Jibu and Yasue later popularized these results with respect to consciousness theory.[55] Pockett and McFadden have proposed electromagnetic field theories of consciousness.[56]

The point of deduction 4 here is simply to be aware that there is no strong logical or scientific evidence to suggest consciousness can only exist in atomic or fermionic states of energy. There are only hand-waving theories that can be conjured for why this is impossible, just as there could have been theories by some hypothetical arguers four billion years ago as to why a Wi-Fi signal broadcasting the Internet cannot emerge from a single-celled organism. Of course this turned out to indeed be possible.

**Deductive Question 5.** *If the universe is expanding at faster than the speed of light or at the speed of light, how could consciousness that escapes a biosphere ever move out into all of the universe to create a network of consciousnesses that is itself a higher order of consciousness — a universal consciousness acting as the substrate of an information-only universe?*

The full exploitation of wormholes predicted by general relativity and non-local connections over time and space predicted by quantum mechanics (and experimentally demonstrated) is not likely to be possible without a predictive quantum gravity theory. The conservative scientist should simply be leery of naive claims of impossibility based on general relativity or quantum mechanics alone because the relationship of the two frameworks includes serious conceptual contradictions of one another. Also, both of these place-holder theories will someday be improved upon by a predictive quantum gravity theory that will show how the assumptions of each may be partially flawed or do not apply in special cases, although most aspects of each theory should hold true.

## 7. An Insignificant Force Emerging to Become Everything

An interesting analogy is a few million bacteria on an apple. Intermolecular forces, gravity, the environment, etc. all define the form and behavior of the apple. However, after only a few doublings, the bacteria overtake other factors to become the primary influence determining the destiny of the apple, breaking molecular bonds to return the elements back to the soil. The universe is not old. It is just getting started. An average-sized star, such as our sun, lives for about 10 billion years. This means that from our vantage point "back here" on the 21st-century Earth, the universe is barely 1.5 solar lifetimes or generations old. Like the very beginning of the bacterial doubling algorithm, from this early stage, it appears that consciousness is a trivial influence existing in the tiniest fraction of the overall energy — merely along for the ride while the ordinary physical forces determine everything. However, if a doubling algorithm gets started by a species that has escaped its biosphere and which has discovered a non-local quantum gravity theory, and technologies derived therefrom, trans-temporal forms of consciousness could emerge. In this case, it would not be illogical to entertain the possibility that this "supernovae" of exponentially exploding consciousness defines the future of the universe from our vantage point and is the irreducible foundation of the universe when spacetime as a whole is considered. We might even go so far as to conjecture that this might tie into the observed acceleration of the rate of expansion of the universe. That is, exponential algorithms on increasingly connected networks have an exponential growth curve, wherein the rate of exponential growth itself exponentially increases.

## 8. The Non-computable Substance of Reality

So we have arrived at a seemingly mystical and yet somehow logical and explanatory axiom that the ground of reality is consciousness — an implication of the code-theoretic axiom. It is worthwhile to discuss one important mathematical aspect of this substance. Let us introduce the idea with a surprising party trick. Imagine selecting 17 people from a birthday party and putting them in a room to vote on how many combinations they can form from members of their small group. For example, there can be Linda and Sam and there can be Sam and Linda. There can be Sam, Linda and Gary and there can be Gary, Linda and Sam. We can combine the names and the ordering of the names. Most people unfamiliar with the math would not guess that it is over 355 trillion permutations or about 50,000 times the entire human population. A system of 17 electrons has far more interaction complexity than this, as they interact in various combinations of quantum wave function resonance and damping values and gravitational relationship states. A single human brain has over 100 billion neurons. And each neuron has over 100 trillion atoms, which each contain a quantity of fundamental particles. These interactions, which humans still only partially understand from the equations of the two incomplete pictures of reality, general relativity and quantum mechanics, are the actual physical substance and behavior of reality. The still mysterious and debated ontological nature of the quantum wave function is, in part, the probability space object arrayed in 3-space that partially describes these non-computable interactions.

The emergence of physics and our reality comes from the non-computability of these interactions. That is, they are non-computable in a finite universe, even in principle, and yet they not only exist — they are the most realistic substance of reality itself. Why non-computable? Consider that we live in a finite universe of a finite age. If a computer were made from all the energy in the universe and given, say, 100 trillion times the current age of the universe to compute the interactions of the particles of just one brain cell, it would not be remotely possible. And yet, actual reality is the emergent result of the oscillators in that one cell interacting with all other oscillators in the universe. And below that level, there may exist a theoretical Planck-scale graph-theoretic substructure contemplated in approaches such as ours or loop quantum gravity. The idea is that whatever this substance of "consciousness" as the ground of reality is like, it is non-computable, even in principle. And yet, it is perhaps the most real and foundational stuff of reality.

## 9. Examples of Possible Predictions Indicated by the Code-Theoretic Axiom

Physical ontology is what science is about. Ontology is the study or labeling what is real and what is unreal. Physics is the study of better modeling what is known to be real and discovering new phenomena that are real. Sometimes the models predict things that are not observed at the time, such as black holes or the molecular substructure of water. The code-theoretic axiom can inspire scientific predictions. For example, when a physically realistic quantum gravity code-theoretic framework is discovered, it will…

(1) …be based on an error correction and detection scheme;

(2) …lead to the *principle of efficient language*, which will demand that the universe operate as a relationship between $E_8$, $H_4$ and $H_3$;

(3) … because of the PEL, have as its numerical basis the Dirichlet integers 1 and the inverse of the golden ratio. Dirichlet integers have unique properties which make them suitable for the generation of optimal codes. For example, they are a closed Euclidean ring of quadratic integers, they are dense in the real numbers and possess a unique prime decomposition. They are deeply related to the Fibonacci sequence by their algebraic units which involve Fibonacci numbers. And they are powers of the golden ratio. This links them fundamentally to specific error correction codes, like Fibonacci error correction and detection codes;[57]

(4) …use the angle $\cos^{-1}(\frac{\phi^2}{\sqrt{2(\phi+2)}})$, which is the scattering angle relationship between fundamental particles according to certain particle mixing matrices.[58] This is because in order to generate the densest network of Fibonacci chains in any dimension, one must project a slice of the $E_8$ lattice to 4D along this angle. And this angle too must exist in the 3D space where graph-theoretic formalism would express its dynamical selection patterns;

(5) …because of the PEL, operate in a binary point space as a neural network formalism that exploits the two densest possible networks of Fibonacci chains in any dimension (the quasi-crystalline spin network and the Elser–Sloane $E_8$ to 4D quasi-crystal;

(6) …because of the PEL, use a physical possibility space in 3D that is the quasi-crystalline spin network due to a secondary binary code allowable in 3D that is related to chirality and periodicity;[59] and

(7) …involve an interaction with emergent consciousnesses, such as humans, that actualize *class-II meaning* (see Sec. 11) with respect to experiments such as the double slit experiment. For example, it will cause a change in the interference pattern if a human can in the future or present use the position information of

the measurement to actualize class-II meaning. This will break the symmetry of distribution of frames relative to a formerly equal treatment of the two slits.

## 10. Conclusion

The deductive thoughts above are a string of carefully reasoned choices about what might be more likely than not. Via this deductive approach, which rejects aggressive or non-maximally-reduced axioms, we land on the ultimate axiom; the code-theoretic axiom. This work is an argument for the author's opinion that this leads to a deep ontological conclusion; (1) consciousness exists because we are choosing to wonder if we are conscious. And (2) because we have evidence that our consciousness exists, the argument that emergent consciousness is the foundational substance is better justified than speculations with less evidence, such as the simulation hypothesis. It is also more explanatory than stopping at the axiom that energy *just is* or that some abstract information-theoretic Platonic symbols *just are*.

Axioms are always "religious" in some sense, where that term implies faith or belief in something that cannot be shown to be true. However, good axioms are carefully reasoned. Structureless smooth spacetime is an example of a weak axiom with no reasoned logic or evidence to support it — just as there was no good evidence supporting the belief that water is a smooth continuous substance. Resting comfortably on aggressive physical axioms, such as energy *just is*, prevents exploration of further truth and leads to possibly false scientific ideas. For example, if we accept the axiom that spacetime is smooth, it becomes mathematically logical that a black hole contains an infinity at the center — a singularity. However, if spacetime is quantized, there is no singularity. Clearly, our axioms can be dangerous if they are unsupported by experimental evidence or logical reasoning.

Penrose,[60] Tononi,[61] Koch,[62] Nagel,[63] Dretske[64] and many others have written about the notion of a pan-consciousness being physically realistic and logically necessary. The plausible theory of a pan-consciousness as the substrate for a code-theoretic physical framework is more natural and less fantastical than the popular idea growing in academic circles that the universe is a computer simulation existing in a different universe. It is more realistic because we have physical evidence for the subparts of the idea: (1) Consciousness self-organizes from fundamental particles and forces, (2) there is no upper limit on how sophisticated it can become or how much of the energy of the universe can self-organize into it and (3) neural network formalism, not computer-theoretic formalism, is where and how consciousness emerges physically. Neural networks operate according to codes, not deterministic algorithms.

The plausibility of all energy self-organizing into a conscious system is not logically problematic, given what we know of physics today. What is problematic is the idea of a trans-temporal consciousness and retro-causality, which one would presume is necessary to act as a substrate for the physics of spacetime and particles. That is the concern, not the probability of exponentially self-organizing consciousness. The lack of certainty about this lies in the fact that there is not a predictive quantum gravity theory that can predict the possibility or impossibility of trans-spatiotemporal networks. However, with the recent works of Susskind[47] and Maldacena[48] and the fact that general relativity and quantum mechanics both allow non-local connections, it seems more plausible than not plausible. Accordingly, until a predictive unification theory is discovered, we can realize that there are no "deal killers" to the notion of retro-causality. Indeed, there is some physical evidence for it in the form of Radin's experiments[46] and various delayed choice quantum eraser experiments.[65] And we do know with experimental certainty that nature is inherently non-local, where entangled particles are causally connected over arbitrarily large distances of time and space.

If the universe is code-theoretic, it traffics in the substance of all codes — meaning. Geometric or physical meaning has virtually no subjectivity, while other forms of meaning, such as humor, are highly subjective. Similarly, geometric symbols have very low subjectivity because mathematical meaning is encoded directly into the symbols themselves.[32] For example, the body diagonal of the self-referential symbol of a square is the length times the square root of 2 — intrinsic meaning with very low subjectivity. Such symbols have the ability to act as the quasi-physical symbols/building blocks of a geometric reality.

Figure 1 represents the loop of five causally connected phases of the code-theoretic universe. It shows the self-actualized hierarchical loop of emergence. It is approximately as fantastical as big bang cosmology and the simulation hypothesis.[27] It is physically plausible and logically self-consistent. It rests on the most reduced axiom possible, the deduction of Descartes. We hold it out as the lesser of evils, where all deep fundamental physical and cosmological models are audacious but where a scientist must choose the one with the best explanatory power, logical self-consistency and most irreducible starting axioms.

## 11. Addendum: The Principle of Efficient Language

The code-theoretic axiom leads directly to the principle of efficient language. We provide here a preview summary of it.

One might say that the overarching principle of classic physics is the principle of least action. It directly led to Noether's second theorem about symmetries in nature, which underlies the most powerful physical theory, the Standard Model of particle physics. If the code-theoretic axiom is true, reality is about meaning. There should, therefore, be a more general universal principle of which the principle of least action and Noether's theorem are special cases. Put differently, those two foundational principles would be recast as predictions and manifestations of the overarching principle tied to the code-theoretic axiom, the principle of efficient language, which can be defined thusly:

> Because reality is code theoretic, its purpose is to efficiently express meaning with its ultimate conserved quantity — quantized actions of the evolving pan-consciousness substrate, specifically syntactically free

> binary choices in the self-emergent code theoretic network. Efficiency is achieved by (1) operating as a neural network code that generates maximal meaning from binary actions and (2) strategically places these syntactically free choices in order to generate maximal physical and higher order meaning.

Following is a summary of the ideas necessary to make sense of this otherwise obscure definition.

### 11.1. *Neural network*

A neural network, as opposed to a standard computer, is an array of points distributed in space upon which information can be creatively computed and in which information is exchanged. Computer theory is concerned with efficient creation of information, the solution of problems. Information theory is concerned with efficient transportation and networking of information. Neural network theory is concerned with the efficiency of both. Nature has demonstrated that freewill can emerge in a neural network and act back upon the systems behavior in a feedback loop becoming the emergent behavior of the network.[66]

### 11.2. *Conserved quantum of action*

In a physical neural network, the conserved quantity is energy, which is used to turn a connection on or off. In an abstract or information-theoretic neural network living as information in a self-emergent consciousness, the fundamental binary action is a choice to recognize or register a connection between points/nodes as being on or off. Part of the mathematical formalism of such a neural network theory is graph theory expressed on a spatial graph — a graph *drawing*. If the substrate of an information-theoretic reality is emergent consciousness, the ultimate conserved quantity is syntactically-free choice, which is the fundamental quantum or action of consciousness.

### 11.3. *Quantum of consciousness*

The simplest choice between quantities of identical things is the choice between two things. The simplest thing is either the empty set or the dimensionless point. It is difficult to build a graph-theoretic neural network formalism or make geometric symbols from empty sets. Points, on the other hand, serve both purposes very well. Accordingly, one can have a possibility space of points in some symmetry space, such as $H_3$. When they are chosen to be "on", they connect to other points (nodes) of the network to form geometric pattern — the physical information of spacetime and particles.

### 11.4. *Efficiency*

Efficiency in this context is the greatest ratio of meaning to binary choices. We will now discuss some more concepts to help us better contextualize this definition of efficiency.

### 11.4.1. *Meaning*

Meaning comes in two fundamental classes: (1) Class-I meaning, which is geometric and numerical. This is the physical meaning with very low subjectivity. (2) Class-II meaning, such as irony, appears to be transcendent of geometry and number. The substrate of reality is the point space of the network, which is inherently geometric so if irony exists in this reality it must relate to the code — to geometry. The ordered sets of frozen states forming dynamic physics is numerical. Remarkably, class-II meaning is always built upon class-I meaning. For example, the thought of irony shifts particle positions and dipole orientations in the body. This then changes particles in the universe that are entangled with those particles and also changes other particles via gravitational, electromagnetic and quantum wave function damping and resonance interactions. Accordingly, the class-II meaning of irony cannot transcend its connection to geometry and physicality on the network, even if one supposes it is possible for a consciousness to exist in the gravitational or electromagnetic spectrum.

### 11.4.2. *Conserved and non-conserved quanta of meaning*

Fundamental class-I meaning is conserved and can be reduced to binary choices in the graph-theoretic network. An example would be particle spin states mapping the mass of a black hole to its surface area. However, emergent class-II meaning, such as the complexities of a biosphere, is not conserved. An infinite quantity of class-II meaning can exist on a conserved and finite substrate of binary actions as fundamental class-I meaning. This is due to a simple fact of code theory, where each emergent symbolic object in a code can act as a symbol in a higher-order code. For example, 10 million letters in a novel can be scrambled. The base information of 10 million letters remains conserved. But when ordered as a code, they can form words. The words have an additional rank of meaning beyond the letters. And sentences have an additional rank of meaning above the rank of the words and so on up through paragraphs, chapters, etc. The hierarchy can continue infinitely, such that an infinite amount of higher-order non-conserved meaning can emerge from a finite amount of conserved base meaning.

### 11.4.3. *Special dimensions related to maximally efficient networks*

Because the principle of efficient language requires the universe to operate with the most efficient neural network formalism possible, it implies reality must be based as an interaction between 8D, 4D and 3D according to the following logic, which is only in summary form due to the limited of scope of this addendum.

### 11.4.4. *Two-letter codes*

A Fibonacci chain is a 1D quasi-crystal of the simplest form because it contains only two *letters* or lengths. A two-letter code is generally more powerful than, say, a

50-letter code. All quasi-crystals are codes. The dynamism of the Fibonacci chain code is called *phason dynamics*. It is rule-based and defined by geometric first-principles, where non-locally connected particle patterns with wave-like qualities propagate along it.

### 11.4.5. *Quasi-crystal code possibility spaces*

A Fibonacci chain can be understood as a sequence of binary operations of "on" and "off" on a point space called the possibility space, which is itself a Fibonacci chain of a smaller scale. The points that are on or off are governed by syntactical rules and degrees of freedom in the *phason code*. For example, if we have an infinitely long Fibonacci chain possibility space, and we select some point to be on or off, we will force an infinite number of other points to be on and another infinity of points to be off. This is called the empire of the point that was selected to be on by the code user. Each vertex type in a quasi-crystal has its own empire. The reason for this is based on the trans-dimensional *cut* + *projection* geometric first-principles of quasi-crystals, where a shift in the *cut window* in the higher-dimensional lattice instantly causes many points to enter the cut window that sends points to the 1D quasi-crystal and many to exit the *cut window* — making some points in the possibility space of the quasi-crystal turn on and others turn off. Quasi-crystals are inherently non-local, where a change at one location influences objects at distant locations.

### 11.4.6. *Non-locality of quasi-crystals*

The deep non-locality of quasi-crystals makes them remarkably efficient binary codes, where a single binary choice instantly drives a large number of additional binary choices without having to exercise additional choice actions. If choice is the conserved quantity, this unique feature of quasi-crystals in the universe of all binary codes makes them uniquely powerful.

With this knowledge we can now recast the question of efficiency as:

> In any dimension, what is the most powerful network of Fibonacci chains, where single binary choices generate the largest quantity of automatic binary choices?

To understand this idea, consider the first example, where the registration of one point as being on in the possibility space instantly generates the automatic registration of a large number of other points as being on and off along the chain. If we crossed this 1D possibility space with another Fibonacci chain possibility space that shared the crossing point, a binary action on that point would generate twice as many automatic binary choices, generating changes on both Fibonacci chains.

The second highest density network of Fibonacci chains possible in any dimension is called the *quasi-crystalline spin network*, discovered by our group.[51] It exists in 3D and is derived from the Elser–Sloane quasi-crystal. Accordingly, it encodes $E_8$-based gauge symmetry physics. The interplay between these 4D and 3D quasi-crystals is the basis of our quantum gravity program, called emergence theory.

A quantum gravity code based on the *quasi-crystalline spin network* would be maximally efficient in terms of the ratio of binary choices to class-I and class-II meanings. If consciousness, or something akin to it, is the substrate of an information- and code-theoretic reality, the conserved quantity would be the simplest possible choice, which is a choice of a point or a connection being on or off. And the most efficient binary choices possible in any dimension exist on the 5-compound of the Elser–Sloane quasi-crystal in 4D and, in 3D, the quasi-crystalline spin network. However, our 3D object may indeed be more powerful than the compound of the Elser–Sloane quasi-crystal, even though it may be the second highest density network of Fibonacci chains in any dimension. This is because it possess a second regime of binary codes based upon aperiodic patterns of alternating 3 and 5 periodicities.[59]

### 11.5. *Code power: Restriction of freedom*

A powerful and general code is an ordering scheme of a small number of symbols that is maximally simple. Here we can speak of the restriction of freedom. Restriction of symbol types and restriction of classes of syntax. The ultimate restriction of symbol types is 2. Anything less is not a code. And anything more weakens the power of the code in many cases. A spatial code would be the simplest two spatial objects. Flat 1D is the simplest space and a line is the simplest-dimensional object in that space. So two different lengths would be the simplest two spatial symbols, just as on and off are the simplest two symbols in a computer code.

So an important dictate of the principle of efficient language and the code-theoretic axiom is that reality will use a code with the maximally-reduced number of symbols and simplest syntax necessary for the simulation of physical reality. At emergent scales, such as solid-state physics, the principle of efficient language predicts that when spatiotemporal freedom in a system of oscillators approaches the non-zero restriction, anomalous physics will occur. The non-zero limit is the quasi-crystalline phase, where networks of atoms self-organize into 3D networks of 1D quasi-crystals, which are each composed of aperiodic strings of double well potentials. That is, they organize into strings of energy wells that have a significant fraction of both occupied and unoccupied sites. This freedom at or near the non-zero limit drives high probabilities for quantum tunneling, wherein atomic coordinate changes occur with spatiotemporal coordination over long distances creating wave-like patterns in the material and exhibiting low entropy but high dynamism.[67] This is an example of the principle of efficient language operating at a scale far larger than the Planck-scale origin from which quantum gravity and particle physics emerge.

## References

1. J. Conway and S. Kochen, The free will theorem, *Found. Phys.* **36**(10) (2006) 1441–1473.
2. J. H. Conway and S. Kochen, The strong free will theorem, *Not. Am. Math. Soc.* **56**(2) (2009) 226–232.

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# Toward the Unification of Physics and Number Theory

Klee Irwin

*Quantum Gravity Research*
*Los Angeles, California, USA*

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This paper introduces the notion of *simplex-integers* and shows how, in contrast to digital numbers, they are the most powerful numerical symbols that implicitly express the information of an integer and its set theoretic substructure. A geometric analogue to the primality test is introduced: when $p$ is prime, it divides $\binom{p}{k}$ for all $0 < k < p$. The geometric form provokes a novel hypothesis about the distribution of prime-simplexes that, if solved, may lead to a proof of the Riemann hypothesis. Specifically, if a geometric algorithm predicting the number of prime simplexes within any bound $n$-simplex or associated $A_n$ lattice is discovered, a deep understanding of the error factor of the *prime number theorem* would be realized — the error factor corresponding to the distribution of the non-trivial zeta zeros, which might be the mysterious link between physics and the Riemann hypothesis [D. Schumayer and D. A. W. Hutchinson, Colloquium: Physics of the Riemann hypothesis, *Rev. Mod. Phys.* **83** (2011) 307]. It suggests how quantum gravity and particle physicists might benefit from a *simplex-integer*-based quasicrystal code formalism. An argument is put forth that the unifying idea between number theory and physics is code theory, where reality is information theoretic and 3-simplex integers form physically realistic aperiodic dynamic patterns from which space, time and particles emerge from the evolution of the code syntax.

*Keywords*: Physics; number theory; geometry.

## 1. Introductory Overview

The value of this paper lies in the following questions the following author hopes are provoked in the mind of the reader:

1. Is there a geometric algorithm that predicts the exact number of prime-simplexes embedded within any $n$-simplex?
2. If Max Tegmark is correct and the geometry of nature is made of numbers, would they be geometric numbers like *simplex-integers*?

3. Would this explain the correspondence between number theory and physics and support the conjectures of Freeman Dyson[2] and Michel Lapidus,[3] who posit the existence of a missing link between number theory and fundamental physics?
4. If nature is made of geometric numbers, how would it compute itself into existence and is the principle of least action an indication it is concerned with efficiency?
5. Are quasicrystal codes maximally efficient?
6. If nature is a symbolic language — a code operating at the Planck scale, can it exist without choosing or "measuring" entities at that scale, as is required to put in action the syntactically free steps in all codes?

Ontologically, it seems clear that the fundamental elements of reality are made of information. We define *information* here as "meaning in the form of symbolic language". And we define *language* as "a symbolic code consisting of (a) a finite set of symbols, (b) construction rules and (c) syntactical degrees of freedom. This is in contrast to deterministic algorithms which also use a finite set of symbols and rules but have no degrees of freedom. We define *symbol* here as "an object that represents itself or something else". And, finally, we define an *object* as "anything which can be thought of".

Fundamental particles have distinct geometries and are, in some sense, geometric symbols. For example, at each energy state, an orbiting electron forms a finite set of *shape-symbols* — $p$-orbital geometries composed of the probability distribution of the wave-function in 3-space. There are strict rules on how these fundamental physical geometric objects can relate, but there is also freedom within the rules, such that various configurations are allowed. If we speculate that particles are patterns in a Planck scale geometric quantum gravity code in 3D of quantized space and time, we can wonder what the most efficient symbols would be.

Simplexes are efficient symbols for integers and their set theoretic substructure. The prime simplexes within any bound of simplexes, $n$-simplex to $m$-simplex, are ordered according to purely geometric reasons. That is, the set theoretic and number theoretic explanation is incidental to the geometric one. Accordingly, speculations by Freeman Dyson,[2] Michel Lapidus[3] and others on a hidden connection between fundamental physics and number theory are less enigmatic when considering *shape-numbers*, such as *simplex-integers*. This view brings fundamental physics and number theory squarely into the same regime — geometry — a regime where physics already resides.

As symbolic information, simplexes are virtually non-subjective and maximally efficient when used to express the information of an integer and its set theoretic substructure. A quasicrystalline symbolic code made of simplexes possesses construction rules and syntactical freedom defined solely by the first principles of projective geometry.

All particles and forces, other than gravity, are gauge symmetry unified according to the $E_6$ Lie algebra, which corresponds to the $E_6$ lattice and can be constructed entirely with 3-simplexes. That is, it can be understood as a packing of 6-simplexes, Each simplex can each be constructed from 3-simplexes. More specifically, all particles and forces other than gravity are unified according to the standard model SU (3) × SU(2) × U(1) Lie algebra. The single gauge groups that contain this algebra include SU(5) in the form of Georgi–Glashow Grand Unified Theory (GUT), SO(10)[4] and $E_6$.[5] All three are related by the complex octonion projective plane (C × O)P2 which is $E_6$ divided by SO(10) × U(1) and by the 20-dimensional set of complex structures of 10-dimensional real space $R^{10}$, which is SO(10) divided by SU(5). These algebraic objects are isomorphic to their Euclidean geometric analogues, which are simple higher dimensional lattices constructed as packings of simplexes. So $E_6$ embeds SO(10), which embeds SU(5), which embeds SU(3) × SU(2) × U(1). $E_6$ embeds in $E_8$. In 1985, David Gross, Jeffrey Harvey, Emil Martinec and Ryan Rohm introduced Hetronic string theory using two copies of $E_8$ to unify gravity with the standard model in an attempt to create a full unification theory. $E_8$ can be constructed entirely by arranging, in 8D space, any choice of $n$-simplexes of equal or lesser dimension than the 8-simplex. Other approaches using $E_8$ for unification physics include those of Lisi[6] and Smith and Aschheim.[7]

*Cut + projecting* a slice of the $E_8$ lattice to 4D along the irrational hyper vector prescribed by Elser and Sloan generates a quasicrystal. This quasicrystal can be understood as a packing of 3-simplexes in 4D forming super-clusters 600-cells, which intersect in seven ways and *kiss* in one way to form the overall 4D quasicrystal. Because this 3-simplex-based object derived from $E_8$ encodes the $E_6$ subspace under projective transformation, it also encodes the gauge symmetry unification physics of the *standard model* along with the less well accepted unification of general relativity via $E_8$.

A projection encodes the projection angle and original geometry of a pre-projected object. Consider a copy of a unit length line [yellow] and its projection rotated by 60° [blue] as shown in Fig. 1.

Of course, this is a line living in 2D and rotated by 60° relative to a 1D projective space, where it contracts to a length of $\frac{1}{2}$ (as shown in Fig. 1). Similarly, a projection of a cube (as shown in Fig. 2) rotated by some angle relative to a projective plane is a

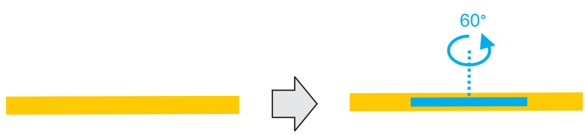



Fig. 1. A unit length line [yellow] & its projection rotated by 60° [blue].

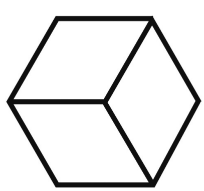


Fig. 2. A cube projected to a plane.

pattern of contractions of the cube's edges, as encoded in the projection, which join to form angles with one another. The total projection is a map encoding the higher dimensional shape plus the rotation of the projector relative to the cube and plane.

One can decode the projection itself to induce the pre-projected cube and the possible projection angles. To form a quasicrystal, more than one cell is projected. A slice of the higher dimensional crystal, called a *cut window*, is projected to the lower dimensional space. The coordinate of the *cut window* can change to generate additional quasicrystalline projections that form animations. These changes can be made by translating and or rotating the *cut window* through the lattice. The coordinates of the various vertex types of the projection will change as the coordinate of the *cut window* changes. The ways these changes can occur are called the *phason* rules and degrees of freedom. This finite set of geometric angles and lengths and the rules and freedom are collectively called the code or language of the quasicrystal. Refer to 'Free Lunch Principles-Forces' in Sec. 5.15 for more on the Cut-and-Project method.

The aforementioned $E_8$ crystal can be built entirely of regular 3D tetrahedra — 3-simplexes. When it is projected to 4D, the tetrahedral edges contract, but do so equally so that the tetrahedra shrink under projection but remain regular, generating a quasicrystal made entirely of 3-simplexes. As will be discussed later, we then generate a representation of this 4D quasicrystal in 3D.

A quasicrystal is an object with an aperiodic pure point spectrum where the positions of the sharp diffraction peaks are part of a *vector module* with finite rank. This means the diffraction wave vectors are of the form

$$\boldsymbol{k} = \sum_{i-1}^{n} h_i \boldsymbol{a}_i^*, \quad (\text{integer } h_i). \tag{1}$$

The basis vectors $\boldsymbol{a}_i^*$ are independent over the rational numbers. In other words, when a linear combination of them with rational coefficients is zero, all coefficients are zero. The minimum number of basis vectors is the *rank* of the vector module. If the *rank* is larger than the spatial dimension, the structure is a quasicrystal.[8] And every aperiodic pure point spectrum in any dimension correlates to some quantity of irrational $cut + projections$ of higher dimensional lattices.

There is an intriguing connection between quasicrystals, prime number theory and fundamental physics. Both the non-trivial zeros of the Riemann zeta function and Eugene Wigner's *universality* signature, found in all complex correlated systems in nature, are pure point spectrums and therefore quasicrystals.[9] However, with 1D quasicrystals that possess many nearest neighbor point to point distances, as opposed to the two lengths in the simple Fibonacci chain quasicrystal, it is very difficult to know what "mother" lattices and projection vectors generate them. In other words, we can know it is a quasicrystal because it is an aperiodic pure point spectrum. But we would have no deep understanding of its phason syntax rules or information about the higher dimensional crystals and angles that generated it.

Andrew Odlyzko showed that the Fourier transform of the zeta-function zeros has a sharp discontinuity at every logarithm of a prime or prime-power number and nowhere else.[10] That is, the distribution is an aperiodic pure point spectrum — a quasicrystal.[2] Disorderly or chaotic non-periodic ordering will not generate an aperiodic pure point spectrum.

Similarly, for any span of $n$-simplexes through $m$-simplexes, the density distribution of simplexes with a prime number of vertices (prime-simplexes) is aperiodic and non-random. Its prime density pattern and scaling algorithm exists for purely geometric reasons. For example, one may consider the 99-simplex. It contains 25 prime-simplexes that have an ordering scheme that drops in density as the series approaches the bound at the 99-simplex. The distribution of the 25 prime-simplexes within this hyper-dimensional Platonic solid is based purely on geometric first principles and is not fundamentally related to probability theory. Of course, it can be predicted using probability theory. The distribution of prime-simplexes, as *shape-numbers*, within any bound is trivially isomorphic to the distribution of digital integers within the same bound. The distribution pattern of digital primes is fundamentally non-probabilistic because the identical geometric distribution pattern of prime-simplexes is not probabilistic.

Interestingly, Wigner's ubiquitous *universality* signature describes the quasiperiodic pattern of the zeta zero distribution.[11] The pattern occurs in all strongly correlated systems in nature. In fact, it shows up in the energy spectra of single atoms. Indeed, nearly all systems are strongly quantum correlated. Terrence Tao and Van Vu demonstrated universality in a broad class of correlated systems.[12] Later, we will discuss more about this pattern, which Van Vu said appears to be a yet unexplained law of nature (see Sec. 4.9).

What could possibly correlate the distribution of primes in number theory to something as ubiquitous as the universality signature? As Dyson recognized, the distribution of prime numbers is a 1D quasicrystal and the universality signature ubiquitous in physics is too.

Each prime-simplex integer is associated with a crystal lattice as a subspace of the infinite A-lattice. For example, the 2-simplex is associated with the $A_2$ lattice (see Fig. 3), which is associated with a crystal made of equilateral triangles and is a subspace of all $A_{2+n}$ lattices.

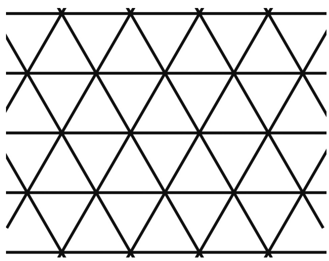


Fig. 3. A triangular lattice.

If we cut + project a slice of this crystal to 1D with the golden ratio-based angle of about 52.24°, we generate a quasicrystal code with three "letters" of the lengths 1, $\varphi$ and $1/\varphi$. As we go up to higher dimensional A-lattice crystals associated with a given simplex-integer and project to 1D, the number of lengths or "letters" of the quasicrystalline code increases. Within any irrational projection of a prime-$A_n$ lattice-based crystal, there exists the projections of all A lattice crystals less than $n$, including a distribution of prime-A-lattices. For example, the projection of the crystal built upon the $A_{99}$ lattice built of the simplex-integer corresponding to the number 100, encodes the distribution of 25 prime-$A_n$ lattice crystals.

This connection can be summarized thus: (a) The distribution of non-trivial zeta zeros and the distribution of prime numbers is a 1D quasicrystal. (b) All 1D quasicrystals can be derived by irrationally projecting hyper lattice slices. A likely candidate lattice is the one corresponding to simplex-integers. (c) Nature is deeply related to mathematics. (d) The foundation of all mathematics, even set theory, is number theory. The appearance of the universality signature in all complex systems and the distribution of primes may relate to the infinite-simplex. That is, the crystal associated with the infinite A-lattice and its projective representation in the lowest dimension capable of encoding information, 1D.

We propose that the missing link between fundamental unification physics and number theory is the study of simplex-integer-based lattices transformed under irrational projection; quasicrystalline code theory.

In Sec. 5, we mention that a general feature of non-arbitrarily generated quasicrystals is the golden ratio. Specifically, any irrational projection of a lattice slice will generate a quasicrystal. However, only golden ratio-based angles generate quasicrystals with codes possessing the least number of symbols or edge lengths. We will discuss how black hole theory, solid state materials science as well as quantum mechanical experiments indicate there may be a golden ratio-based code related to the sought after quantum gravity and particle unification theory. As preparation for that, it is helpful to understand how deeply the golden ratio ties into simplexes.

Of course, the simplest dimension where an angle can exist is 2D. And the simplest object in 2D is the 2-simplex. Dividing the height of a circumscribed 2-simplex with a line creates one long and two short line segments (see Fig. 4). The ratio of the long to the short segments is the golden ratio.

In fact, this is the simplest object in which the golden ratio exists implicitly, since simply dividing a line by the golden ratio is arbitrary and not implied by the line itself. So there is a fundamental relationship between $\pi$ and $\varphi$ in the circumscribed 2-simplex.

Simplexes are the equidistant relationships between an integer quantity of points and, in their lattice form as packings of tetrahedra, they correspond to periodic maximum sphere packings. For example, the maximum sphere packing in 3D includes the FCC lattice, which is a packing of 3-simplexes. The points where the spheres meet generate the lattice associated with the 3-simplex is called the $A_3$

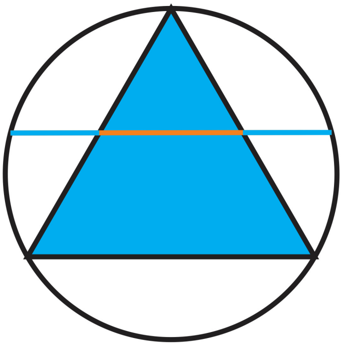


Fig. 4. A triangle in a circle showing the golden ratio as the ratio between the red and the blue edges.

lattice. Similarly, the $E_8$ lattice is a packing of simplexes, and its points are the kissing points of the maximum packing of 8-spheres.

## 2. Proof by Deductive Argument that Simplex-Integers are the Most Efficient Number Symbols for Integers and their Set Theoretic Substructure

### 2.1. *Introduction*

A *number* is a symbol used to measure or label. Generally, a symbol is an object that represents itself or another object. For example, an equilateral triangle (as the delta symbol) often represents the object called "change" or "difference".

However, an equilateral triangle (or any object) can also serve as a symbol to represent *itself*, the equilateral triangle. Symbols can be self-referential and participate in self-referential codes or languages. An example is a quasicrystal, such as the Penrose tiling (see Fig. 5) derived by projecting a slice of the 5-dimensional cube

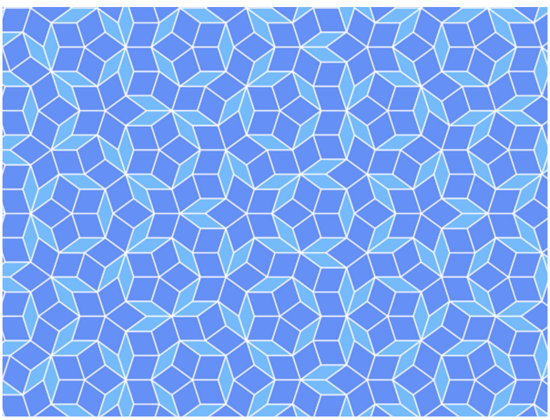


Fig. 5. The Penrose tiling quasicrystal, derived via cut + projection of a slice of the $Z_5$ lattice, is a code because it contains a finite set of geometric symbols (two rhombs), matching rules and degrees of freedom.

lattice, $Z_5$, to the plane.[13] It is a language[14] because it possesses (a) a finite set of symbols, (b) construction rules and (c) degrees of freedom — called *phason degrees of freedom*.

It has two "letters" which are two rhomboid shapes. The rhombus symbols can only be arranged according to specific assembly rules to form seven different vertex geometries that can be thought of as the "words" formed by the two building block geometric "letters". But within the syntax constraints, there are also degrees of freedom, called *phason* degrees of freedom. The quasicrystalline code is a language in every sense of the word, conveying the meaning of geometric form such as dynamical quasiparticle waves and positions. Yet, the geometric symbols, the building blocks of this code, represent themselves, as opposed to ordinary symbols which represent other objects.

It has been shown how 3-simplexes[15] can be the only shape in non-space-filling quasicrystals in 3D or 4D. All quasicrystals are languages, not just the Penrose tiling. And the 3-simplexes, i.e., simplex-integers, in these special quasicrystalline symbolic codes represent themselves.

### 2.2. *Ultra-low symbolic subjectivity*

Generally, symbols are highly subjective, where its meaning lies at the whim of the language users. However, simplexes, as geometric numbers and set theoretic symbols which represent themselves, have virtually no subjectivity. That is, their numeric, set theoretic and geometric meaning is implied via first principles. If space, time and particles are pixelated as geometric code, low subjectivity geometric symbols with code theoretic dynamism such as these could serve as quanta of spacetime.

### 2.3. *Simplexes as integers*

The geometric structure of a simplex encodes numerical and set theoretic meaning in a non-arbitrary and virtually non-subjective manner. For example, the digital symbol "3" does not intrinsically encode information about the quantity of three objects. In fact, any object can serve as a symbol for a number. So, we introduce the notion of *simplex-integers* as virtually non-subjective symbols for integers.

#### 2.3.1. *Symbolic function 1: Counting*

The number of 0-simplexes in a given $n$-simplex indexes to an integer. For example, the 2-simplex has three points or 0-simplexes corresponding to the digital symbol "3". The most basic information of an integer is its counting function. The series of simplex-integers counts by adding 0-simplexes to each previous simplex-integer symbol.

#### 2.3.2. *Symbolic function 2: Set theoretic meaning*

Inherent to an integer is its set theoretic substructure. A simplex-integer is a number symbol that encodes both the counting function and set theoretic substructure of an integer. For example, the quantity of four objects can be communicated by the symbols, 4 or IV. However, when we use a 3-simplex to represent the counting function of the number 4 we also encode its set theoretic substructure:

- Four sets of one
- Six sets of two
- Four sets of three
- One set of four.

This is geometrically encoded in the 3-simplex as four 0-simplexes (points), six 1-simplexes (edges), four 2-simplexes (faces) and one 3-simplex (tetrahedron).

#### 2.3.3. *Symbolic function 3: Binomial expansion*

An $n$-simplex encodes the binomial coefficient corresponding to a row of Pascal's triangle (see Fig. 6).

The coefficients are given by the expression $\frac{n!}{k!(n-k)!}$.

Pascal's triangle is the arrangement into rows of successive values of $n$. The $k$ ranges from 0 to $n$ generate the array of numbers. It is a table of all the binomial expansion coefficients.

#### 2.3.4. *Symbolic function 4: Sierpinski triangle fractal*

Because each simplex is a higher dimensional map of the 2D Pascal's triangle table, it too encodes the same Sierpinski triangle fractal when the positions of the table are coded in a binary fashion to draw out the odd and even number pattern, with fractal dimension log(3)/log(2) (as shown in Fig. 7). This same fractal can be a cellular automaton generated by Rule 90,[16] the simplest non-trivial cellular automaton.[17] Specifically, it is generated by random iterations of the time steps of Rule 90.

#### 2.3.5. *Symbolic function 5: Golden ratio in the infinite-simplex*

Pascal's triangle is analogous to a matrix representation of the sub-simplex sums within any $n$-simplex. Diagonal cuts through Pascal's triangle generate sums that are successive Fibonacci numbers (as shown in Fig. 8). Any two sequential Fibonacci

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1

Fig. 6. The Pascal triangle until the fifth row.

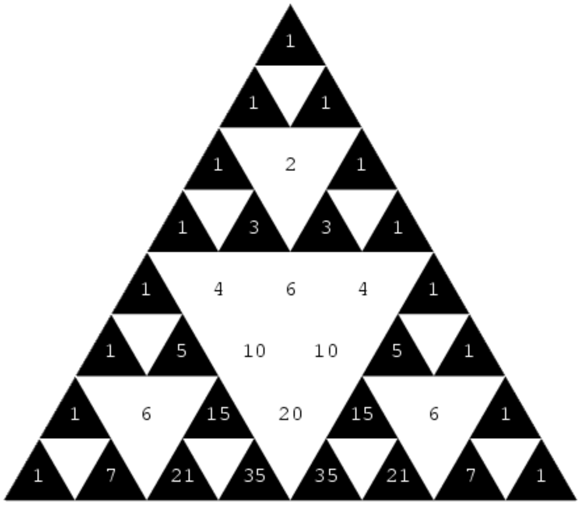



Fig. 7. Sierpinski triangle showing Pascal triangle values.

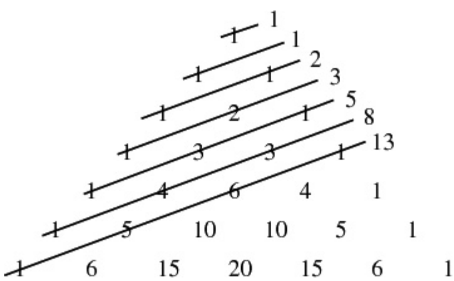



Fig. 8. Fibonacci numbers as diagonal sums of a Pascal triangle.

numbers are a close approximation of the golden ratio. The series of ratios converges to the golden ratio.

### 2.4. *Symbolic power of simplex integers*

In graph theory, one can use a graph drawing as a numerical symbol to count quantities of objects and explore their set theoretic relationships (connections). This makes a graph diagram analogous to the counting function and set theoretic substructure function of a simplex-integer.[18] For example, the complete and undirected graph of three objects expresses the set theoretic substructure implied by the integer 3. The graph drawing symbol is usually the 2-simplex (as shown in Fig. 9).

A key aspect of this symbol is the equidistance between its points — its connections. The complete and undirected network (graph) of three objects has no magnitudes in its connections. To geometrically represent the complete graph of three objects, equidistance symbolizes the notion of equal magnitude of the graph

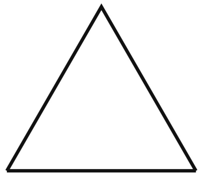


Fig. 9. The two-simplex, a triangle.

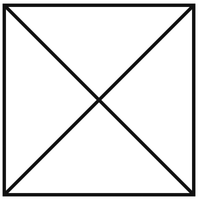


Fig. 10. The three-simplex, a tetrahedron, a complete graph of four elements projected to a square.



connections. So the 2-simplex is an efficient or *waste-free* symbol for the complete and undirected graph of three objects.

The diagrammatic symbol graph theorists typically use for the complete and undirected graph of four objects is given in Fig. 10. It encodes the full set theoretic substructure of the integer 4.

But here, we see a breakdown in efficiency because we have *wasted* information in the drawing or symbol. It does not inherently represent the notion of equal connection magnitude because four connections have one length and two have a longer length. This superfluous information in the symbol must be ignored by the graph theorist. It is wasted.

The only way to have equidistance between four points in a geometric symbol is to extrude an additional spatial dimension — to go to 3D. In this case, the tetrahedron can symbolize in a non-subjective and waste-free manner, the equidistant relationship of four points and their full set theoretic substructure. This is the case for all simplexes where each encodes a positive integer and its full set theoretic substructure in the most efficient manner possible without wasted symbolism and where all connections are of the same length or magnitude.

Of course, we cannot make symbols in spatial dimensions greater than three. However, we can work with higher dimensional simplex symbols in the form of their associated geometric algebras.[a]

Next, let us sketch out a proof that simplex-integers are the most powerful numbers to express counting function and set theoretic substructure.

[a] Each simplex is associated with a Lie group of the series $A_n$ and its Lie algebra $a_n$, which corresponds to geometry because a Lie group encodes geometric operations (mirror reflections and rotations). Each simplex is associated to a Clifford algebra (commonly named *geometric algebra*), while each sub-simplex is a basis element of the same dimension.

### 2.5. *A method for ranking symbolic power*

Here, the term *symbolic power* shall be synonymous with *symbolic efficiency.* Our discussion is concerned only with the efficiency ranking of symbols that can represent the meaning of (a) integers and (b) their set theoretic substructure. The rank of meaning or information content of an integer and its set theoretic substructure increases with size.

The challenge is to logically rank the magnitude of inherent information of a given symbol, then we can consider the set of all symbols which might encode the numeric and set theoretic meaning of integers to see if there is one type with maximal efficiency.

Symbolic efficiency here is concerned with the ratio of:

1. Irreducible sub-symbols
2. Meaning

Because the numeric and set theoretic meaning is established, we are seeking to understand what symbols are the most minimalistic or elegant — the least complex for this purpose. Accordingly, let us discuss the magnitude of a symbol's complexity.

If a symbol can be reduced to irreducible sub-symbols, it is a composition of some quantity of simpler symbols. We will use that quantity as the magnitude rank of symbolic complexity. For example, the sentence "The dog ran fast" is itself a symbol. But it can be decomposed into clauses, words and letters. Indeed, the letters themselves can be decomposed into simpler subparts as points and connections or lines.

Again, symbols are objects that represent themselves or another object. In the universe of all objects, the *empty set* and 0-simplex are equally and minimally simple. There can be no simpler object. These are the only two to possess the quality of being non-decomposable into simpler objects. That is, all other symbols are composites of other objects/symbols.

It is difficult to conceive building composite symbols and a symbolic language out of *empty sets.* Points (0-simplexes), on the other hand, can be arrayed in spaces to form familiar symbols or can be connected graph theoretically without spaces to form non-geometric symbols.

The simplest object in $n$-dimensions is the $n$-simplex.[19] And every $n$-simplex is a composite of irreducible 0-simplexes or vertices $\{\mathrm{v}1,\mathrm{v}2,\ldots,\mathrm{v}n\}$, where every subset in the structure is a simplex of $n$-$m$ dimensions. Subsets with one element are points, subsets with two elements are line segments, subsets with three are triangles, subsets with four are tetrahedra and so on.

The reason a simplex is the simplest object in any spatial dimension is because it is the least number of non-decomposable symbols (0-simplexes) needed to form a convex hull occupying all sub-dimensions of a given spatial dimension. Of course, the simplex need not be regular to possess this quality. However, regular simplexes have only one edge length, one edge angle, one dihedral angle, etc. Irregular simplexes

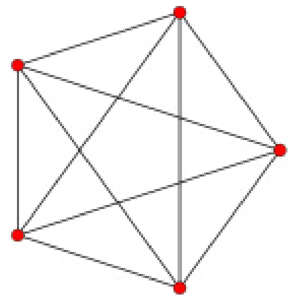


Fig. 11. The four-simplex, a complete graph of five elements projected to a pentagram.



possess far more information, where members of a set must be distinct from one another. Accordingly, irregular simplexes possess more information or sub-symbols.

For this reason, a regular $n$-simplex is the simplest object possible in any spatial dimension.

It is clear that the irreducible 0-simplex is the simplest object that can form composite symbols. It is clear that compositing a set of them to form a series of symbols called simplex-integers non-arbitrarily and inherently encoding the numeric and set theoretic meaning, we are concerned with efficiency and non-arbitrarily symbolizing.

Can we allow, for example, an irregular equilateral triangle to encode the meaning we are interested in and still call it equally simple because it uses the same number of points? It is true that the irregular triangle encodes the numeric and set theoretic meaning. It is also true that a graph diagram in 2D for, say, five objects encodes the same information we need with the name number of points (as seen in Fig. 11).

However, as a symbol, it inherently possesses two different connection lengths. It has additional information not required or needed in our attempt to symbolize the number five and its set theoretic substructure corresponding to equal magnitude of connections. One must ignore that additional inherent meaning of two connection magnitudes is implied by the symbol. We may consider this as an equation, where the right side is the meaning of the quantity of five objects and their set theoretic substructure. The left side is a package of inherent geometric information in the symbol we are considering to equal the right side of the equation. We start by counting the quantity of irreducible 0-simplexes on left side — the symbol side. Counting them gives the value 5. If we allow any irregular 5-simplex, it leaves us with an infinite number of geometric configurations of five points with more than 1 connection magnitude. We wish to minimize the left side further to find the one configuration that is simpler or generates the least amount of unneeded inherent geometric symbolism/information. Specifically, we need all connections between points to be equal. Otherwise, additional information accumulates on the left side of the equation — the inherent information of the symbol itself. Only an $n$-simplex can achieve this task for any quantity of points. Via this logic, simplex-integers are the most powerful numbers to encode the numeric and set theoretic meaning of the integers.

### 2.6. *Section 2. Conclusion*

The simplest object in $n$-dimension is the $n$-simplex. The simplest object in any dimension and the only non-decomposable or non-composite symbol is the 0-simplex. The simplest set of composite symbols is the $n$-simplex series, which adds one 0-simplex to each successive member of the set. The count of 0-simplexes serves as a number — a geometric symbol representing the counting function of an integer and its inherent set theoretic substructure.

Adding more points in some lower dimension, such as 2D, can also serve as a simple counting symbol that also encodes the set theoretic substructure in the form of the connections on a complete graph drawing. However, this symbol deviates from the pure implied meaning in the simplex-integer series because, without extruding an additional spatial dimension for each added 0-simplex, the connections of the graph drawing take on different length values. The implied information and unnecessary complexity of the symbol breaks down with this more mathematically complex object, where the equal set theoretic "connections" are no longer intrinsically implied with virtual non-subjectivity. One must ignore this extra information and subjectively and arbitrarily interpret the various connection lengths as having equal magnitude.

We prove through this deductive argument that the $n$-simplex series is the most powerful set of symbols to represent the integers and their set theoretic substructure. A given simplex embeds the full set of theoretic and numeric information of all simplexes within it, including the distribution of isomorphic prime simplexes to the distribution of prime numbers on the ordinary number line. Accordingly, the infinite simplex is the most powerful representation of the integers, prime distribution and the set theoretic substructure of each integer.

## 3. A Geometric Primality Test and the Prime-Simplex Distribution Hypothesis

### 3.1. *Introduction*

It is generally believed that if an exact expression were found which determines the number of primes within any bound of numbers, it would lead directly to a proof or disproof of the Riemann hypothesis. This is because the non-trivial zeros that fall on the critical line on the complex plane in the Riemann hypothesis correspond to the *error terms* created by using inexact expressions to estimate the number of primes within a span of integers. Inexact expressions are all that have been discovered so far in prime number theory. An exact expression is still outstanding and would lead directly to a proof of the Riemann hypothesis if discovered.

There are 25 primes in the bound of numbers 2–100. However, the prime number theorem expression of Carl Friedrich Gauss of the form $\pi(x) - x/\log x$[20] incorrectly predicts 21.7 primes in the same bound. The expression of Peter Gustav Lejeune Dirichlet of the form Li($x$) - $\pi(x)$[21] incorrectly predicts 30.1 primes.

The delta between these inexact approximations and Riemann's exact function result in error terms that can be written in terms of the non-trivial zeros of the

Riemann zeta function. Number theorists have not proven the Riemann hypothesis because they do not deeply understand these non-trivial zeros. That is, they do not understand how to exactly predict the distribution of primes within a bound of integers.

$$\pi_0(x) = R(x) - \sum_{\rho} R(x^{\rho}) - \frac{1}{\ln x} + \frac{1}{\pi}\tan^{-1}\frac{\pi}{\ln x}. \tag{2}$$

Because an analytical expression for the second term in Equation (1) does not exist, this term quantifies the error in prime counting functions. It is a sum over the non-trivial zeros of the Riemann zeta function ($\rho$) on the critical line. The Riemann hypothesis states that all non-trivial zeros lie on the critical line. Riemann's formula is exact if and only if the Riemann hypothesis is true. Again, mathematicians have not proven the Riemann hypothesis because they do not deeply understand the non-trivial zeros. If an exact form for $\pi_0(x)$ is found that does not depend on the zeros, it could be used to shed light on their nature and should lead to a solution of the Riemann hypothesis.

Mathematics is like an *upside down pyramid*, where sophisticated math is built upon a foundation of simple math, and base math is the counting numbers. For example, before one can think about set theory, one must possess a notion of counting numbers. A huge collection of proofs of potential new theorem exist in the literature. Essentially, they state: "We prove that if the Riemann hypothesis is true, then this theorem is true."[22]

With the current state of prime number theory, we have somehow missed something deep. It is trivially true that within the geometric structure of the infinite-simplex and its irrational projection to 1D, the distribution of prime-simplex and prime digital numbers is encoded. Accordingly, this "deep" aspect of prime number theory, and therefore all mathematics and mathematical physics which we have missed is geometric number theory.

### 3.2. *Geometric primality test*

We introduce a geometric analogue to the primality test that when $p$ is prime, it divides,

$$\binom{p}{k} = \frac{p \cdot (p-1), \ldots, (p-k+1)}{k \cdot (k-1), \ldots, 1} \quad \text{for all } 0 < k < p. \tag{3}$$

Our geometric form provokes the *prime-simplex distribution hypothesis* that, if solved, leads to a proof of the Riemann hypothesis.

**Claim.** *If and only if the quantity of vertices of an n-simplex is evenly divisible into each quantity of its sub-simplexes is that simplex a prime-simplex and associated with a prime A-lattice.*

$$p \text{ is prime } \iff (\forall k \in \mathbb{N}^*, k < p \Rightarrow p|\#\{S_k \subset S_{p-1}\}),$$

$$p \text{ is not prime } \iff (\exists k \in \mathbb{N}^*, k < p, (\#\{S_k \subset S_{p-1}\})[p] \neq 0).$$

$$Note : \#\{S_k \subset S_{p-1}\} \text{ is the binomial coefficient } \binom{p}{k} = \frac{p!}{k!(p-k)!}.$$

We want to prove that $p$ is prime if and only if $p$ divides into $C$, where $C$ is given by Eq. (X). $C = \frac{p!}{k!(p-k)!}$ for any $k$ between 2 and $p-1$. $C$ satisfies this equation: $p! = C\,k!\,(p-k)!$

First, we demonstrate that, if $p$ is prime, $p$ divides $C$.

**Conjecture 1.** *If $p$ is prime, $p$ divides $C$.*

**Proof.** Because $p$ divides $p!$, $p$ also divides one of the three factors on the right side: $C$ or $k!$ or $(p-k)!$

$k < p$ and $k!$ is a product of numbers smaller than $p$.Therefore, $p$ does not divide $k!$. If $k$ is greater than 1, $(p-k)!$ is a product of numbers smaller than $p$. Therefore, $p$ does not divide $(p-k)!$. So, necessarily, $p$ divides $C$. □

**Conjecture 2.** *If $p$ is composite, let $p = a\ b$, where $a \neq 1$, $b \neq 1$ then at least one of the coefficients is not divisible by $p$.*

Next, we demonstrate that, if $p$ is composite, let $p{=}a\,b$, where $a \neq 1$, $b \neq 1$ then at least one of the coefficients is not divisible by $p$.

Take

$$k = a : C = \frac{(a\ b)!}{a!(a(b-1))!}. \tag{4}$$

We can rewrite as

$$C = b(a\ b-1)(a\ b-2),\ldots,(a\ b-a+1)/(a-1)! \tag{5}$$

$C$ is not divisible by $a\ b$, because none of the factors $(a\ b-1)$, $(a\ b\ -\ 2),\ldots,$ $(a\ b-a+1)$ is divisible by $a$, and $b$ is not divisible by $a\ b$.

[*Credit goes to Raymond Aschheim for assistance with the above equations.*]

### 3.3. *Prime-simplex distribution hypothesis*

> *When studied as simplex-integers instead of digital integers, there is a simple formula that separates prime numbers from composite numbers. That is, there is a non-constant polynomial that takes in only prime values.*

There is no known formula that separates primes from composite numbers. However, there exists a purely geometric reason why a given simplex is prime or why there are, for example, 25 prime simplexes embedded in the 99-simplex. The reason is not directly number or set theoretic. Number and set theoretic aspects are merely incidental or secondary to the geometric structure. The reason is based solely on the first principles of Euclidean geometry.

An extension can be made to A-lattices, which correspond to simplexes. For example, the 4-simplex corresponds to the $A_4$ lattice, which embeds the $A_2$ and $A_3$

lattices. Using the 99-simplex example again, the $A_{99}$ lattice, built as a packing of 99-simplexes, embeds 25 prime-$A_n$ lattices and describes their distribution exactly without probability theory based approximations.

The unknown formula expressing the drop in prime-simplex and prime-A lattice density within some bound is also purely geometric. In our future work, we intend to focus on this problem. However, we can state with certainty that the algorithm can be expressed with quasicrystalline formalisms when studied via the irrational projective transformation of a slice of the infinite-A-lattice.

The vertices of a prime-simplex are evenly divisible (without a remainder) into each sum of its sub-simplexes. When one considers what this means in terms of shape analyses, such as symmetry or topology, it becomes clear that there must be special shape qualities present in prime-simplexes that are not evident in non-prime-simplexes. For example, the 3-simplex is the first to fail this geometric primality test. Its sub-simplex quantities are:

4 0-simplexes,
6 1-simplexes,
4 2-simplexes.

Its four vertices does not evenly divide into its six edges. By contrast, when we look at the simplex-integer associated with the prime number 5, we see sub-simplex sets of

5 0-simplexes,
10 1-simplexes,
10 2-simplexes,
5 3-simplexes.

For lack of a better term, there is a *division symmetry* in this simplex with respect to its geometric parts. The "beauty" of five vertices evenly dividing into the sums of each sub-simplex inspires the curiosity about what special volumetric, topological or symmetry qualities this shape possesses.

### 3.4. *Prime number distribution and fundamental physics*

As far as impacting science is concerned, the discovery of the actual algorithm predicting the distribution of prime simplexes within an $n$-simplex may have important implications for fundamental physics, shedding light on an equally monumental outstanding problem: the *theory of everything* that unifies the theory of space and time (general relativity) with the theory of the quantum world (quantum mechanics).

It is certainly true that nature is deeply mathematical, which means its foundation is built upon counting numbers. But nature is deeply geometric as well. So geometric counting numbers, like simplex-integers, are interesting — there is a mysterious connection between physics and the distribution of prime numbers.

Inspired by the Hilbert–Polya proposal to prove the Riemann Hypothesis, we have studied[23] the Schroedinger QM equation involving a highly non-trivial potential whose self-adjoint Hamiltonian operator energy spectrum approaches the imaginary parts of the zeta zeros only in the critical line.

$$S_n = \frac{1}{2} + i\lambda_n. \tag{6}$$

This is consistent with the validity of the Bohr–Sommerfeld semi-classical quantization condition. We showed how one may modify the parameters which define the potential, fine tuning its values, such that the energy spectrum of the (modified) Hamiltonian matches all zeros. This highly non-trivial functional form of the potential is found via the Bohr–Sommerfeld quantization formula using the full-fledged Riemann–von Mangoldt counting formula for the number N(E) of zeroes in the critical strip with imaginary part greater than 0 and less than or equal to E.

Our result shows a deep connection between the most foundational model we have for reality, quantum mechanics, and prime number theory.

Patterns in nature over time or space can only be of three fundamental species:

1. Periodically ordered
2. Aperiodically ordered
3. Random.

There is no solid evidence for randomness in nature. In fact, demonstrating it is impossible because one cannot write it down, as can be done with periodic and aperiodic patterns. An experimentalist can only concede she has not been able to find periodic or aperiodic order. The lack of finding order is not good experimental evidence for the theory of randomness. What does have good supporting experimental evidence is the theory of non-determinism, which fits our *code theoretic axiom*.[24] For example, in 1984, Dan Shechtman reported his observation of code-theoretic aperiodic order in a material *known* by the scientific community to be disorderly-randomly structured (amorphous).[25] The consensus belief was built upon a bedrock of crystallographic mathematical axioms and decades of failure to observe order in this type of material. And yet, Shechtman observed the signature of aperiodic order in the material. A good portion of the scientific community, led by Nobel laureate Linus Pauling, rejected his findings due in part to the popular theory that randomness is real.[26]

Similarly, number theorists have no idea why or how the quasiperiodic spectrum of the zeta zeros possess the *universality* spectral pattern. Some mathematicians think there may be an unknown matrix underlying the Riemann zeta function that generates the universal pattern. Paul Bourgade, a mathematician at Harvard, said, “Discovering such a matrix would have big implications for finally understanding the distribution of the primes”.[27]

So why would proving the Riemann hypothesis help in the search for a *theory of everything*? Because there is a unifying principle in the form of (1) simplex-integers and (2) quasicrystal codes based on simplexes. The notion of randomness in physics would become an old paradigm giving way to the new ideas of aperiodic geometric-language based physics and the *principle of efficient language*.[24] Non-deterministic syntactical choice would replace randomness as the ontological explanation for non-determinism. Discreteness would replace the older notion of smooth space and time. Number and geometry would be unified via the mathematical philosophy of *shape-numbers*, where nature is numerical — simplex-integers forming the substance of reality — geometry, all within a logically consistent self-actualized code-theoretic universe.

### 3.5. *Are digital numbers a dead-end approach to prime number theory?*

Clearly, the *universality* aspect of complex physical systems is deeply rooted in the geometry of particles and forces acting in 3-space. Prime and zeta zero distribution display the same quasicrystalline pattern.

Non-geometric methods, such as probability theory and brute force computational methods, are typical tools for modern number theorists working on prime number problems. If the 2300 years of stubbornness of this prime distribution problem is a deep geometric challenge, then we have been using the wrong tools for a long time.

As mentioned, within, for example, the 99-simplex, there are 25 prime-simplexes, which are simplexes with a prime quantity of vertices. The reasons for why this bound of simplexes 2–99 has a density of prime simplexes of 25 is a purely geometric problem, even though the solution is exactly the same as the unknown algorithm determining the exact quantity of prime digital numbers in the same bound. In other words, the algorithm determining the distribution of prime-simplexes in some bound is the missing and correct algorithm that encodes the *error term*, i.e., it equals the *error term* plus the incorrect result of solutions using the prime number theory algorithm or others.

A fresh and little-focused-on approach is to move prime number theory problems from digital number theory into the domain of simplex-integer number theory — into the realm of pure hyper-dimensional Euclidean geometry and its associated geometric algebras and moduli spaces.

The purely geometric algorithm that determines the number of prime-simplexes within an $n$-simplex is knowable. It would give the exact number of prime numbers within any span of integers. But what is so deeply different about the digital versus simplex-integer approaches? Two core things: (1) non-transcendental convergence and (2) non-homogeneity of sequential number deltas.

### 3.6. *Non-transcendental convergence*

Digital integers do not converge when you add them as a series. And divergences are unhelpful because they tell you little — i.e., they don't give you a number because they explode toward infinity. In order to convert digital integers into a convergent series, one applies the zeta function. For example, we put a power on each integer and then invert it. We do this with the next integer and add to the previous solution. We repeat this with all integers to transform the integers into a convergent additive series that tells us something deep about the integers and their fundamental skeleton, the primes:

$$1/(1^2) + 1/(2^2) + 1/(3^2), \ldots, = \pi^2/6. \tag{7}$$

What is remarkable is that $\pi$ is a deeply geometric number even though integers do not appear to be associated with geometry. It is generally believed that $\pi$ is transcendental, although this is debated.[28] The two most famous transcendental numbers are $\pi$ and the basis of the natural logarithm, $e$.

Both $e$ and $\pi$ and are deeply geometric. The exponentiation is the fundamental operation to transform an angle $\theta$ into a complex number $\mathrm{Exp}(i\,\theta)$ which, multiplied by a vector, also expressed as a complex number, operates the rotation of this vector from this angle. The constant $e$ is defined by the choice of radian as a unit for the angle, which sets $\pi$ to measure a half circle rotation by $\mathrm{Exp}(i\,\theta) = e^{i\theta}$, or $e = \mathrm{Exp}(1)$. This also involves $I = \sqrt{-1}$.

Both $e$ and $\pi$ fundamentally relate to the Riemann hypothesis but only when explored via digital numbers.

Specifically, $e$ is a part of the false error generating algorithms that imperfectly predict the number of primes in a bound — thereby generating the *error term* that maps to the zeta zeros and perhaps preventing a proof of the Riemann hypothesis. And, $\pi$ is related by the convergence of the zeta function itself to $\pi^2/6$. The zeta function process is how we plot the zero solutions related to the errors onto the complex number plane.

It may be helpful to inquire, "If the *error term* generating method using digital numbers relates to the transcendental numbers $\pi$ and $e$, is the inverse true, where in some sense we can say the use of $\pi$ and $e$ generate the *error term*?" Although this question is confusing, it cuts deep. In other words, there is little choice when using digital integers — the zeta function using digital integers converges[b] to $\pi$. And $e$ is deeply related to $\pi$ by similar reasoning associated with the choice to use digital integers — as opposed to simplex-integers.

It is reasonable to realize, though, that $\pi$ and $e$ are deep aspects of the *error term.* And the *error term* is the problem. It is simply the delta between the imprecise temporary "placeholder" prime density prediction algorithm and the currently unknown imprecise ones.

So is it as simple as that? Can we avoid the error term by avoiding digital numbers and, by extension, $\pi$ and $e$?

We will not see $\pi$ and $e$ when we attack the problem via simplex-integers. The true algorithm determining the number of primes within a bound is geometric and related to an algebraic number. Specifically, $\sqrt{2}$. Interestingly, we do see a relationship to 2 in current prime number theory based on digital integers. The non-trivial zeros are all on a coordinate at $\frac{1}{2}$ the length of the strip bounded by $-\frac{1}{2}$ on the left and $\frac{1}{2}$ on the right.

[b] More technically, zeta($x$) converges to 0 when $x$ goes to infinite, but zeta($2n$) for any positive even integer is expressed as a rational fraction multiplied by $\pi$ at the power $2n$.

As mentioned, the zeta function is a method to uncover something deep about the primes by expressing them as a convergent additive series. The additive series of the simplex-integers is naturally convergent without need to invert values. Consider the circumradius of each $n$-simplex and index each successive one to a circumradius generated by an $n$-simplex with a number of vertices equal to that prime number. The circumradius of the 1-simplex is $\frac{1}{2}$. And the circumradius of the infinite-simplex is $1/\sqrt{2}$. The circumradii of all simplexes can be related as a series of concentric circles, each two with a different distance between them than the distance between any other two. The distance between each two corresponds uniquely to a certain prime or non-prime integer such that we may call each delta between sequential circumradii a unique integer. And the sum of all deltas is $1/\sqrt{2}$. Within any span of such rings, there is a subset that are prime based, wherein the pattern of radii are neither periodically nor randomly arrayed. They are arrayed as a quasicrystal.

Here, we see the first example of a radically different form of convergence in simplex-integers, where the convergence value is an algebraic number instead of a transcendental number like $\pi^2/6$.

### 3.7. *Non-homogeneity of sequential number deltas*

A key difference between digital and simplex-integers is the information encoded in the delta between successive numbers. For example, a few of the geometric deltas between two successive simplexes are:

- Dihedral angles (series ranges from ArcCos½ to ArcCos(0).
- Circumradii
- Hyper-volumes

Again, the deltas index to integers. The delta between the circumradius of the 1-simplex and 2-simplex would index to the integer 3 because the 2-simplex corresponds to 3 vertices or 0-simplexes.

The salient point is that the delta between two successive simplex-integer geometric indexes is unique and different than the delta between any other successive pair of simplex-integers.

By contrast, the difference between any two successive digital integers is always 1. Accordingly, it is homogeneous and therefore gives absolutely no number theoretic information. This rich extra information of simplex-integers provides a wealth of geometric clues to fuel a new approach to search for the exact scaling algorithm for density distribution of *geometric primes* as prime-simplexes — the deep reason for why a prime-simplex shows up every so often in a given series of simplexes, and this answer is trivially isomorphic to the distribution of prime digital integers.

### 3.8. *Extensions to lattices and geometric algebras*

Consider a 2-simplex, the equilateral triangle. Around it, there can be an infinite 2-simplex lattice, called the $A_2$ lattice.[29] This is a tiling of the plane with equilateral triangles. The lattice associated with the simplex-integer 4 is the lattice described by a maximum density packing of spheres in 3D — the way oranges are stacked in the supermarket. This is called the $A_3$ lattice and is composed by rotating $A_2$ lattices from one another by ArcCos$(1/n)$, where $n$ is the integer corresponding to the $A_2$ lattice (in this case, 3). This continues *ad infinitum*, where, for example, the lattice associated with the integer 100, the 99-simplex lattice called $A_{99}$, is a stack of irrationally rotated parallel lattices $A_2$ through $A_{98}$.

We can extend the idea of prime-simplex distribution to prime-simplex-A-lattice distribution. Each $n$-simplex can pack to form a crystal of $n$-simplexes — compositing to the $A_n$-lattice for a given dimension. We can then algebraically explore the reasons for why prime A-lattices appear where they do in a given span or *stack*.

A given A-lattice is associated with various geometric algebras, such as Lie and Clifford algebras. The geometric algebra of a given A-lattice contains an *algebraic stack* of sub-algebras associated with each sub-A-lattice. This algebraic space corresponds to a point array and is called a *moduli space*.[30] These geometric algebra tools can be used to work on the geometric problem of finding the actual and precise scaling algorithm for the density distribution of prime-simplex associated A-lattice geometric algebras within a larger stack of algebras — again, an algorithm identical to the unknown precise density algorithm for the distribution of prime digital numbers, which would immediately lead to the proof (or disproof) of the Riemann hypothesis.

The "writing on the wall" seems clear. The 2300 years of searching for the correct prime distribution algorithm via digital numbers and the 157 years of mathematicians trying to prove the Riemann hypothesis via digital numbers are impressive. This apparent roadblock supports the argument that the solution can only be found within the realm of geometry. In addition, the geometric physical connections and the geometry of $\pi$ and $e$ make it even more reasonable to surmise that digital number theory and stochastic approaches will not lead to an answer.

Because only prime simplex vertices divide evenly into all quantities of sub-simplex, there is an aspect of these special prime shapes that is different than non-prime simplexes. This geometric difference has additional aspects other than the pure set theoretic qualities of the divisibility of vertices. It is analogous to the fact that an equilateral triangle contains all the set theoretic information of the complete and undirected graph of three objects. However, it also contains additional shap-related geometric information that goes beyond the set theoretic information of the graph. Prime-simplex-integers possess special group theoretic qualities, topological qualities and various geometric qualities that set them apart from non-prime-simplexes.

### 3.9. *Graph-drawings*

As discussed, one may gain intuition by understanding simplexes and A-lattices via a growth algorithm that generates a graph *drawing*, where the quality of the connection

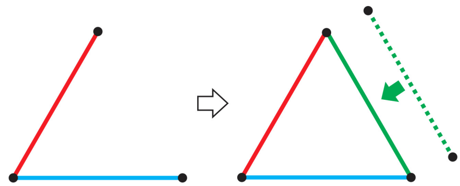


Fig. 12. A blue and a red one-simplex rotated by 60 degrees make a two-simplex.



magnitudes are lengths, making the object a graph drawing because the connection types are geometric line segments. Abstractly, this can be true without admitting a smooth spatial substrate, such as $\mathbb{R}^3$. In other words, the space is discretized such that there exists no information or space between the line segments of the network. This minimalistic graph-drawing space is in some sense a quantized subspace of a continuous space.

Picture a line segment and rotate a copy on one end by $60^\circ$ into another finite 1D spatial dimension to generate the three points of a 2-simplex and its associated A-lattice. We can play with semantics by saying we have rotated a copy of the finite length 1D universe into another finite 1D universe. The objective of the visualization is to disassociate ourselves from the idea of a smooth Euclidean space in a network of finite 1-simplexes, where length is real but restricted to the connections of the network — a graph-drawing made of 1-simplexes.

Or we can index the length value to an abstract graph theoretic magnitude. In any case, the connection relationship between the three points (from the two lines sharing a point) is isomorphic to a 2-simplex (as shown in Fig. 12).

Next, we rotate a copy of the second line (note that we do not need the green line in the diagram in order to generate the 3 points of the 3-simplex) into the third spatial dimension by $60^\circ$ from the previous line to generate the 4 points of the 3-simplex and so on. Again, we reject the assumption of a smooth 3-space in favor of an approach that is graph-theoretic.

Each of these $60^\circ$ rotations from the previous edge is equal to rotating the edge by $\mathrm{ArcCos}[(n-1)/(2n)]$ from the total simplex construct below it, where $n$ is the simplex number.

As mentioned, this iterative process results in the stack of simplexes converging to a circumsphere with a diameter of $\sqrt{2}$ at the infinite-simplex. When the construction of any simplex, such as the 99-simplex, is visualized with $60^\circ$ rotations extruding successive spatial dimensions, one realizes that the lines form a hyper-dimensional discretized *non-Archimedean* spiral.

In other words, the circumradii of the simplex series starts at $\frac{1}{2}$ for the 1-simplex and converges at $1/\sqrt{2}$ at the infinite-simplex. This is in stark contrast to the cubic series of circumradii, which is divergent, converging at an infinite radius for the infinite-cube. So from the simplex-integer 2 (1-simplex) to the infinite-simplex, the increasing radii values must be distributed over a distance of $1/\sqrt{2}-\frac{1}{2}\approx 0.207$.

But in just the distance from the circumradius of the 1-simplex to the 2-simplex, we cover about 0.077 or more than 37% of the total 0.207 distance to convergence — a distance that must be distributed over an infinite number of simplexes.

Of course, this rapid convergence is massively exponential.

The distribution of prime numbers on the digital number line drops with distance. For years, number theorists have used the prime number theory algorithm (and improved versions) related to the natural logarithm number $e$ to predict the number of primes within a given bound. This correlates to a non-Archimedean spiral called the logarithmic spiral because the distances between turnings increase in geometric progression as opposed to an Archimedean spiral.

Is it the natural logarithm number $e \approx 2.718$ that corresponds to the *actual* algorithm for prime distribution — the one that does not generate the *error term*? As mentioned, $e$ is an artifact of the exploration of the problem via digital numbers and is fundamentally part of the *error term*. That is, the algorithm for predicting prime density that is related to $e$ simply does not work. It is the chosen formalism of the approximation itself that generates the *error term* corresponding to the non-trivial zeros. The logarithmic spiral correlated to the distribution of prime-simplexes should logically relate to a hyper-spiral corresponding algebraic irrational $\sqrt{2}$. So, just as the prime number theorem algorithm corresponds to the non-algebraic transcendental number $e$, the simplex-integer prime number algorithm for prime distribution would correspond to the algebraic number $\sqrt{2}$ (and to the golden ratio by arguments beyond the scope of this paper).

### 3.10. *Creation of a prime number quasicrystal*

There is an interesting approach we will explore in a subsequent publication. We will cut + project various A-lattices to lower dimensional quasicrystals and do spectral analyses on the Fourier transform of each. We predict prime-A-lattice associated quasicrystals will possess distinct spectral signatures. If so, a spectral analysis of the superposition of a span of simplex-integer associated A-lattices projected to lower dimensional quasicrystals is expected to reveal the signature of a prime A-lattice distribution scaling algorithm. Such an algorithm would predict the exact prime-simplex density distribution for any bound of projected A-lattices.

### 3.11. *Section 3. Conclusion*

We have established a hypothesis, which should be true by trivial deduction; an exact algorithm for the distribution of primes exists in the realm of pure geometry.

## 4. Simplex-Integer Unification Physics

If nature were a self-organized simulation, it would be a simplex-integer based quasicrystalline code derived from $E_8$.

### 4.1. *Introduction*

The *digital physics*[31] view is the idea that reality is numerical at its core [See work by Ed Fredkin,[32] Toffoli,[33] Wolfram,[34] and Wheeler[35]]. But the numbers need not be digital. They can be *shape-numbers*, such as *simplex-integers*. Because reality is geometric and has three spatial dimensions, one could surmise the following: If nature were built of 3D *bits* of information that are also numbers, the most powerful candidate for a 3D geometric number is the 3-simplex. *Power* in this context is synonymous with *efficiency* in the manner explained in Part 2.

Higher-dimensional lattices, such as E6 and E8 that are associated with unification physics, can be constructed entirely from 3-simplexes. Certain projective transformations result in the 3-simplexes remaining regular but being ordered into a quasicrystalline code that encodes the higher-dimensional lattices and associated gauge symmetry physics.

A hallmark and general characteristic of quasicrystals is the golden ratio. For example, the simplest quasicrystal possible is the two length Fibonacci chain, as 1 and $1/\Phi$. Virtually all 3D quasicrystals found in nature are golden ratio based on icosahedral symmetry.

A self-organizing code on an abstract quasicrystalline substrate is in some sense like a computer but better described as a neural network. Computer theory is concerned with the efficiency of *creating* information in the form of solutions to problems. Information theory is concerned with the efficiency of information *transfer*. Neural network theory [36] is concerned with both the efficient *creation* and *transfer* of information in a network. Neural networks operate via codes, i.e., non-deterministic algorithmic processes — languages. Neural networks in nature are spatial (geometric) arrays of nodes with connections, such as particles connected nonlocally by quantum entanglement or forces. Clearly nature, like a neural network, accomplishes the dual task of (a) creating new information (computation) and (b) transferring information. So the universe as a whole is a neural network in the strictest sense of the term.

A special quality of neural networks that sets them apart from computers is that they are non-deterministic. If one subscribes to the theory of randomness and does not require a theory to explain the generator of randomness, one can decide that the free choices in a neural network code are random. On the other hand, there is a special cases in Physics where human free will emerges in a biological neural network, which itself emerges from fundamental particle physics and presumably some unknown quantum gravity theory. In this case, the free will can act on the syntactical choices in the code-theoretic neural network, providing an explanation for the syntactical choices that might be more explanatory than stopping at randomness as the unprovable axiom. It is generally known that physical reality is: (a) non-deterministic and (b) that it creates the emergence of non-random *free will*, at least in the case of humans. As this is not a philosophical paper, we will simply say that whatever *free will* is, it is non-deterministic. It behaves similar to the concept of *randomness* insofar as being non-deterministic. The difference is that *choices*, as the *actions* of *free will*, are made with a blend of subjective meaning, perceptions or opinions combined with logic and choices of strategy. So symbolic language and meaning are deep principles embedded in the theory of free will. Conway and Kochen proved that if free will is real, fundamental particles have some form of non-random free will.[37]

Another fundamental feature of nature is that, as a network, it is concerned with *efficiency* in the form of the *principle of least action* and similar laws.[38] In fact, efficiency may be the most fundamental behavior of reality — leading directly to *Noether's second theorem* about conservation and symmetries in nature,[39] conservation laws and from there to the modern gauge symmetries unification physics, such as seen in the standard model of particle physics.

### 4.2. $E_8$ in nature

The most foundational symmetry of nature unifies all fundamental particles and forces. It can be described as:

> *All fundamental particles and forces, including gravity, are uniquely unified according to the gauge symmetry transformations encoded by the relationships between vertices of the root vector polytope of the* $E_8$ *lattice – the Gosset polytope.*[6]

We have also shown cosmological correlations to $E_8$ in *Heterotic Supergravity with Internal Almost-Kahler Configurations and Gauge SO,*[32] *or* $E_8$ *x* $E_8$*, Instantons.*[40] However, our general approach is to exploit projective geometry as the symmetry breaking mechanism in a quantum gravity plus particle physics approach, which recovers particle gauge symmetry unification.

The simplest polytope in eight dimensions is the 8-simplex. The $E_8$ lattice is the union of three 8-simplex based lattices called $A_8$. This lattice corresponds to the largest exceptional Lie algebra, $E_8$. That is, the simplest 8D building block of the Gosset polytope and $E_8$ lattice is the 8-simplex — the most powerful number that inherently encodes the counting function of $3^2 = 9$ and its full set theoretic substructure. Nine, incidentally, is the first odd number that is not prime.

### 4.3. $E_8$ derived quasicrystal code

In *Starobinsky Inflation and Dark Energy and Dark Matter Effects from Quasicrystal Like Spacetime Structures*[41] and *Anamorphic Quasiperiodic Universes in Modified and Einstein Gravity with Loop Quantum Gravity Corrections*,[42] we show how quasicrystalline codes can relate to quantum gravity frameworks.

A 4D quasicrystal can be created by projecting a slice of the $E_8$ crystal.[43] This 4D quasicrystal is made entirely of 600-cells, which are each made of 600 regular tetrahedra. So the fundamental 3D *letters* or symbols of this quasicrystal are 3-simplexes. The allowable ways these geometric number symbols can spatially relate to one another is governed by cut + project-based geometry,[44] which generates the *syntax* of this non-arbitrary quasicrystalline code. The term *code* or *language* applies because the syntax allows various legal configurations that are determined by the size, shape and position of the cut-window in the hyper-lattice from which the Quasicrystal is cut and projected from. A language or code must have degrees of freedom within the rules and a finite set of symbols that must be arranged by a *code user* in order to create meaning. Geometric codes, such as quasicrystals, generate geometric meaning, such as waveform and quasiparticle position. The *code user* may emerge from the evolutionary complexity of the system itself and can be as sophisticated as a human consciousness and beyond. Or it can be simple, like the guiding tendency of a tornado to preserve and grow its dynamical pattern for as long as possible in a new physical ontology based on code theory instead of randomness.

Furthermore, how two or more syntactically legal quasicrystals can be ordered in a dynamic pattern or animation has a separate syntax scheme based on how the cut-window moves through the hyper-lattice. That is, all behaviors and rules are part of a code based solely on geometric first principles with no arbitrary *ad hoc* mathematical contrivances.

The caveat is that a free will chooser of some form must execute the free choices in the code. This is the case with all codes, whether that be a computer language or song-language of birds. A general quality of codes is that meaning is not maximized and breaks down when strategic choices in the syntax are replaced by, for example, a pseudo random number generator.

Discovering a fundamental unification model of all particles and forces based on such a geometric first principles code is a worthy but formidable challenge. It would be a *microscopic first principles theory of everything*. Currently, there exists no first principles explanation for the fine structure constant, the speed of light, Planck's constant or the gravitational constant. In other words, there is no known *first principles* unification theory. In fact, the fundamental constants $h$ and G and c are only known to about four places after the decimal. The CODATA values, which go out to a few more places after 4, are an averaging of six established experimental methods that all disagree at the 5th place after the decimal.

Syntactically legal configurations of these quasicrystal-based *simplex-letters* form simplex-based *words* and *sentences*. In other words, groups of simplexes have emergent geometric meaning — shape and dynamism. Sets of these inherently nonlocal quasicrystalline *simplex sentence* frames can be ordered into *animated* sequences and interpreted as the physical dynamic geometric patterns of space that have both wave and particle like qualities, a well understood dualistic quality of phason quasiparticles in quasicrystal codes.[45]

While this part of the discussion is a mix of fact and conjecture, the reader may agree that, if nature is a code or simulation based on *maximally efficient* symbolism, the following three ideas may be at play:

(1) Nature must be an efficient symbolic code capable of simulating a 3D reality. Accordingly, the most powerful symbol in 3D — the 3-simplex — may be exploited because it is the simplest and most efficient 3D quantum of information.

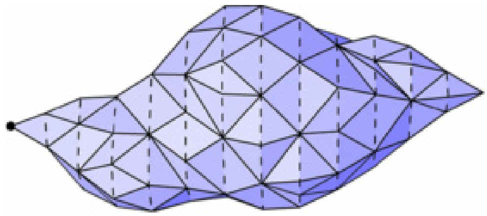


Fig. 13. Causal triangulation of a surface. The vertical dotted lines are the timelike edges.

(2) Spacetime would be discrete. While in quantum mechanics the spin is quantized (the quantum of action is the Planck's constant), energy is quantized (the photon is the quantum of energy), and here we also propose spacetime which itself is quantized. Nature must have an efficient geometric "pixel" or foundational symbol, just as a dynamic image on a high-resolution video monitor is composed of invisible microscopic building-block pixels or just as a binary computer code is made of irreducible elements symbols, where bytes can be further decomposed into bits but no further. In our proposed framework, the simplex-integer is the irreducible and non-transformable "pixel" in the *simulation* that composes our 3D reality. It is the fundamental shape-symbol in a geometric code/language. In short, simplex-integers "switch-hit" as both numbers and spatial building blocks.

(3) It must be a symbolic code derived from $E_8$, which encodes the gauge symmetry unification of all fundamental particles and forces. We have generated a 3D quasicrystal language of 3-simplexes derived from $E_{8(15)}$.

The *causal dynamical triangulation* program of Amjorn and Loll[46] is encouraging evidence that fundamental physics can be modeled with aperiodic configurations of 3-simplexes as the only building-block element (see Fig. 13). They have generated very close approximations of Einstein's *field equations*.[47]

### 4.4. *Quasicrystals as maximally efficient codes*

Just as simplex-integers are the most powerful numbers to express counting function and set theoretic information, quasicrystals are the most efficient codes possible in the universe of all codes.

This is a major claim. To understand it, we should first establish the fact that an $n$-dimensional quasicrystal is a network of quasicrystals in all dimensions lower than it. For example, the Penrose tiling, a 2D quasicrystal, is a network 1D quasicrystals. A 3D Penrose tiling, called Ammann tiling[48] is a network of 2D quasicrystals, which are each networks of 1D quasicrystals.

So the building block of all quasicrystals are 1D quasicrystals. Reducing further, we should understand that there are an infinite set of 1D quasicrystals. The "letters" of a 1D quasicrystal are lengths. A 1D quasicrystal can have any finite number of *letters*. However, the minimum is two. The Fibonacci chain is the quintessential 1D quasicrystal. It possesses two lengths related as the *golden ratio*. In order for a quasicrystal greater than 1D to have only two letters, the letters must be 1 and the inverse of the golden ratio. Interestingly, this simple object has a deep relation to $E_8$. When a slice of $E_8$ is projected to 4D according to a non-arbitrary golden ratio-based irrational angle,[43] the resulting quasicrystal is made entirely of 3-simplexes and is the only way to project that lattice to 4D and retain $H_4$ symmetry. The angle between adjacent 3-simplexes is $60^\circ + \mathrm{ArcCos}([3\varphi - 1]/4)^\circ = \mathrm{ArcCos}(1/4)$, where $\varphi$ is the *golden ratio*. This quasicrystal, fully encoding gauge symmetry unification physics, can be described as a network of Fibonacci chains. These are the most powerful 1D quasicrystals for two reasons. As mentioned, the power of a code relates to how many building block symbols it has. This definition of power relates to the discussion earlier, where we spoke of the left side of the equation as being the magnitude of simplicity of the symbolic system. But a code cannot have fewer than two fundamental symbols for obvious reasons. This is what makes binary codes so powerful. Secondly, Fibonacci chain quasicrystal codes are based on the Dirichlet integers 1 and $1/\varphi$, which possess remarkable efficiency characteristics, such as error detection and correction abilities and multiplicative and additive efficiencies. For example, they are closed under multiplication and division. As with all quasicrystals, Fibonacci chains are fractal.[49]

The function of division stands out in the arsenal of powers that the golden ratio possesses because it relates to measurement, which is the deepest and most enigmatic aspect of quantum mechanics that is not yet fully understood.

Physics Nobel laureate, Frank Wilczek of MIT said,[50] "The relevant literature [on the meaning of quantum theory] is famously contentious and obscure. I believe it will remain so until someone constructs, within the formalism of quantum mechanics, an *observer*, that is, a model entity whose states correspond to a recognizable caricature of conscious awareness."

Wilczek is speaking of the need to build measurement into a new quantum mechanics mathematical formalism that incorporates an operator capable of measuring at the Planck scale. His motivation is on solid ground. Quantum mechanics indicates that the ontology of physical reality must be based on measurement, where all that exists is that which is measured. Certainly, it is extreme to postulate that physical reality needs humans to measure it in order to be real. A physical formalism based on the premise that reality is made of information in the form of a code would require a quantum-scale mathematical operator capable of actualizing information via measurement.

A measurement of any form is ultimately a spatial relationship between the measurer and two additional points in space. This is the case with any detector, such as a human eye or a Geiger counter. Waveforms are reducible to quantum particles. All detectors are reducible to component particles that interact with signal particles, such as photons, that are emitted from another particle being measured at a distance. For example, a camera takes a photo of a tree by receiving rays of photons that trace to the camera lens. The irreducible measurement, however, is the relationship between a detecting particle and two other particles at two other coordinates. This forms a triangle, where the detector is one vertex and the two measured coordinates are the other vertices. The fundamental information being registered by the detector is a transformation via contraction of the edge length of the triangle that is not connected to the detection particle. For example, you observe two friends in the distance. We can conceptualize you and the two friends as three points in space. There is an actual distance length between your two friends, which we will call $L$. Because it is impossible for you to have a perfectly equal distance between you and each of your friends, you observe or measure the information of $L$-$l$, where $l$ is some contraction value on $L$.

Your transformation of $L$ gives you information about the relationship of your two friends and their relationships to you. If they are standing one car length apart but your angle relative to them is such that you perceive it as ½ a car length, then you intuitively know how to decode that information to tell you their actual distance as one car length plus your position relative to them. Similarly, when you look at the complexity of, say, a tree, the massive package of information from that measurement/observation is merely a composite of these individual length transformations between pairs of points and the measuring detector, forming a transformation of the pre-transformed triangle.

So $L$ and $l$ form a relationship in your mind as a ratio. The meaningful information of your measurement is not $l$ it is the ratio of $L$ to $l$, which tells you information about the relationship of the two measured points to one another (their actual length relationship) and their length relationship to you from your vantage point.

Consider this set of three points that are equally spaced in a line in 3-space. If you measure them with your eye from a golden ratio-based vantage point equal to a rotation of the line of three points by a golden ratio angle, then you can divide the total length into two parts as 1 and $1/\varphi$ (as shown in Fig. 14). This is true only in perspective projection, never in orthogonal projection where the segment sizes would stay equal.

To review, all measurements are divisions or ratios. And a choice of measurement (observation) is necessary to actualize or make-real any information. If we consider that reality is information theoretic or code-based, we must model a mathematical measuring operator, as discussed. So why would the golden ratio obey the *principle of efficient language* better than any other ratio? Why would it be more powerful in terms of the ratio of symbolism to meaning?

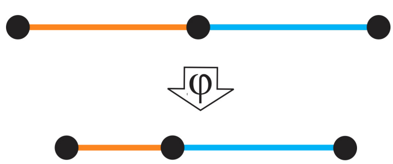



Fig. 14. Two segments of equal lengths rotated by an angle and seen through perspective projection. Blue is nearest to the observer and looks bigger than the red segment. The ratio is the golden ratio (beware–that will not be the case with the orthogonal projection).

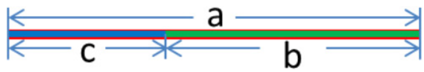



Fig. 15. The golden ratio: B is to A what C is to B.

For golden ratio divisions, going down from long to short, the ratios between successive pairs is the golden ratio. Going up, it is the inverse of the golden ratio. This quality is known as inflation and deflation and the golden ratio achieves it with only two symbols or numbers 1 and $1/\varphi$.

But for divisions other than the golden ratio, going down needs two ratios (3/2, 2/1 for example); going up also requires two ratios. Consider the idea that Planck scale measurement operators in the quantum gravity code use abstract *observation actions* in the $E_8$ derived quasicrystalline point space to actualize compact symbolic objects that are themselves ratios — simply ordered arrays of the two Dirichlet integer values 1 and $1/\varphi$. This binary pair of values is maximally efficient in terms of the symbolism to meaning ratio.

For the $\varphi$ (golden ratio) division, there is only one ratio needed for encoding the relationships of the consecutive segments going down in length (as shown in Fig. 15).

$$\frac{\boldsymbol{a}}{\boldsymbol{b}} = \frac{\boldsymbol{b}}{\boldsymbol{c}} = \varphi, \tag{8}$$

Or going up in length

$$\frac{\boldsymbol{c}}{\boldsymbol{b}} = \frac{\boldsymbol{b}}{\boldsymbol{a}} = \frac{1}{\varphi}. \tag{9}$$

For example, any other division, such as dividing into thirds, requires two ratios and therefore more symbolic information to express

$$\frac{a}{b} = \frac{3}{2}, \frac{b}{c} = \frac{2}{1} \quad \text{or} \quad \frac{c}{b} = \frac{1}{2}, \frac{b}{a} = \frac{2}{3}. \tag{10}$$

The other aspect of the golden ratio that is powerful and may be important for a simulation code of reality is its fractal nature. In the last 37 years, fractal mathematics has been found to be at play at all scales of the universe from cosmic to the sub-atomic scales.[49] Dividing a line by the golden ratio, if we take the short length and place it on top of the long length, we are left with a section of the long length that is left over. That length is even shorter than the short length of the first division and the ratio of this new short length to the original short length is the golden ratio. This process can continue to infinity in the smaller direction with the ratio of the remainder to the previous length always being the golden ratio. Furthermore, this process can be applied in the other direction, where we add the long piece from the original division to the undivided length. The ratio of the new combined length to the long length from the first division is the golden ratio. This also continues to infinity. The golden ratio is the ultimate recursive fractal, generating the most information for the least amount of symbolic symbolism and *measurement action*.

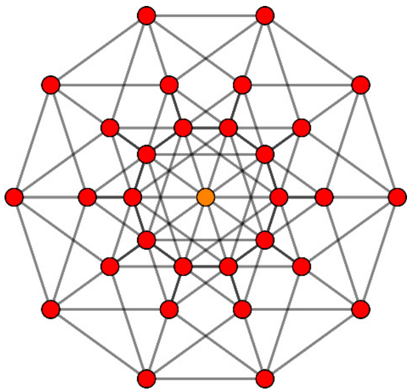


Fig. 16. The projection to 2D of a five dimensional cube with 32 vertices projected to 31 giving possibility space of Penrose Tiles.

A *phason flip* in a quasicrystal is a binary state change of a point, where it is registered as being *on* or *off*. If it is *on*, it is an active node with a connection to other points in the quasicrystal. The syntax rules allow legal choices of whether a point can be *on* or *off*. One can call the total set of points the *possibility space*. The points that are chosen to be *on* by the code user, are active in that *frame* of the dynamic quasicrystal. Active or *on* points have connections and are syntactically legal selection configurations of the possibility space. For example, this is a projection of the 32 vertices of the 5-cube to the plane, where we see 31 total points with an overlapped 32nd point hidden in the middle. Note that the Penrose tiling is made by projecting a slice of the 5-cube lattice to the plane. These 31 points are a small section of the *possibility space* that the dynamical phason code of the Penrose tiling operates on (see Fig. 16).

The Penrose tiling is a tiling of two types of selection patterns of 16 of the 31 point decagonal *possibility space*. The two decagons can overlap other decagons in two ways or kiss without overlapping. In Fig. 17, we highlight those two selection

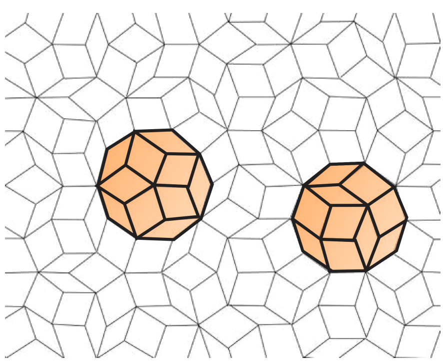


Fig. 17. Two types of selection pattern of 16 of the 31 point decagonal possibility space, as they exist in a larger Penrose tiling Quasicrystal.

patterns, as they exist in a larger Penrose tiling quasicrystal. You can easily visualize how to select one of the two 16 point combinations by looking at the projection of the full 31 point *possibility space* (shown in Fig. 16).

The *empire of a given point* consists of points that are forced to be *on* by the given point. For example, look again at the 31 points in Fig. 16. Note that if you select the center point to be *on*, you are forced to have a certain 15 additional points also be *on* and another 15 to be *off*.

Those 15 points that were forced to be *on* are the *empire* of the one point which you, the language user, chose to be *on* in a *phason flip* binary action.

Why is this interesting in terms of efficiency? In computer theory, we try to conserve binary actions. It costs electricity and time to open or close logic gates in a computer. So efficiency is important. We want codes that achieve maximal information with as few actions as possible.

Changing a single point to be *on* or *off* in a Fibonacci chain 1D quasicrystal forces an infinite number of additional points throughout the *possibility space* of the 1D chain to also change state. This global or nonlocal "spooky action at a distance" is very powerful in terms of the ratio of *action* to *meaning*.

If we live in an information theoretic universe, then, abstractly, the action we are trying to conserve is binary *choice*. Speculation of what the substance or entity or action is that makes the choices in the code is flexible. Our frame work deals with the math and behavior of the code, not so much who or what the operator of the code must be. The *principle of efficient language* requires the operation of the code to tend toward maximal meaning for the least number of *on–off* choices.

Resources are always used to make a choice in any physical model. For example, in the neural network of a human brain, choices cost calories and time. In an artificial neural network, choices require time and electricity. So efficient neural networks generate as much meaning as possible with a given number of connection actions — they generate maximal information for as few binary choices as possible.

Each Fibonacci chain is isomorphic to a *Fibonacci word*, which is a string of 0s and 1s that encodes a unique integer.[51] Of course, the larger the integer, the greater the magnitude of the information. For example, a one millimeter Fibonacci chain with Planck length tiles is isomorphic to a *Fibonacci word* with $10^{31}$ 0s and 1s and corresponds to an equally enormous integer. Changing one point on the Fibonacci chain *possibility space* from *off* to *on*, changes the state of points along the entire chain, thereby changing the *Fibonacci word* to a different integer. The principle of *empires* in artificial neural networks consisting of networks of Fibonacci chains involves enormous efficiency when one is interested in conserving binary actions or choices. If nature is a computational language based on neural network theory and globally distributed computation and connectivity, quasicrystal codes are the most efficient possible.

When a network of Fibonacci chains is formed in 2D, 3D or 4D, a single binary state change at one node in the possibility space changes the Fibonacci chains throughout the entire $1 + n$ dimensional network of chains.

### 4.5. *DNA and quantum computers as examples of 3D neural networks*

Manmade computer code symbols are, in some sense, minimally efficient. That is, the binary symbols encode an instruction to do one binary state action in a logic gate to express only one bit of information. DNA is not quite a computer. It is a neural network in the sense that it both computes information using its code rules and it transfers information within its structure. Like a neural network, it achieves its computations and information storage in a distributed manner within 3-space. A single position in the DNA *possibility space* of coordinates where one of the four molecules in the code can exist serves as information in more than one 1D string of code. For example, an adenine molecule can exist at some location in the DNA coordinate space. This then forces certain states of the 4-letter code for other positions in the string, according to syntactical rules of the code. That string of code is wrapped around the double helix and has an *empire* of forced coordinate identities from the four letter code. But the *empire* is not just in 1D along that single string. Information relative to that one molecule selection of adenine is also encoded into strings that run in-line with the axis of the double helix and also diagonal to the axis. It is similar to the analogy of the game *Scrabble*, where a choice of a single letter on the grid of the possibility space of the game can encode information in more than one word. So the choice of the adenine molecule at that coordinate achieves a great deal of efficiency by (a) playing a role in multiple 1D strings and (b) by forcing other syntactically controlled actions of coordinates in the empire of that single registration of adenine in the DNA *possibility space*.

DNA has quasicrystalline structure. In fact, Erwin Schrodinger first deduced that DNA has a quasiperiodic structure in his book *What is Life*, published nine years prior to Watson and Crick's discovery of DNA in 1953.[52] His deduction is in-line with the theme of this paper. Specifically, crystalline structures are deterministic and have no degrees of freedom in terms of their abstract construction. They are not inherently languages because they are too rigid in their construction rules.

On the other hand, amorphous or disorderly materials do not have structural rules and can have a virtually infinite number of microscopic geometric relationships – *geometric symbols*. The lack of rules and lack of a finite set of geometric symbols prevent a dynamic code from evolving within amorphous materials. The "sweet spot" between order and disorder, where a language or code can emerge, is in quasicrystalline order. Only within aperiodically-ordered structure is there a true code with a finite set of geometric symbols, rules and syntactical freedom.

The most powerful codes are based on the golden ratio because the ratio of symbolism to geometric meaning output is maximal. For example, DNA is made of two helices that have pentagonal rotational symmetry, which is based on the golden ratio. The two helices themselves are then offset from one another by a golden ratio related value called a Fibonacci ratio, which is a rational approximation of the irrational golden ratio.[53]

Quantum computers are another example of systems where one node serves multiple roles in various relationships. 3D clusters of atoms, often with golden ratio-based icosahedral symmetry[54] in a quantum correlated state interact with one another in various combinations to process and create information as a group — a spatial network of nodes very different than the ordinary notion of a 1D computational system.

### 4.6. *Symbolic power of Fibonacci chain networks*

It is well known that Fibonacci codes have unique and powerful properties in terms of error correction and detection.[51]

For example, all sequences in a *Fibonacci word* end with "11". And that sequence appears nowhere else in the data stream of that symbolic group object. Changing a bit corrupts the sequence (the symbolic group object). However, within a few more symbols, the pattern "11" will appear again, which indicates the end of the string or group symbol.

The system or user can then simply resume coding with only those few symbols felt to be incorrect. The power in this is that one bit can only corrupt up to three symbols. No other code shares this property. Error detection is fast, and errors are limited in how much damage they can do. Error correction is similarly powerful and unique. Let us say that a 0 is erroneously changed to a 1 that is adjacent to a correct 1. A 1 that is part of the data stream gets changed to a 0. A 1 that is part of the ending 11 gets changed to a 0 and so on.

When an error occurs in ordinary codes, it will exist uncorrected in the string forever.

The power of 3D networks of Fibonacci chains relates to the spatial dimension of the quasicrystal being able to host objects with icosahedral symmetry. For example, the 4D analogue of the icosahedron is the 600-cell.[55] The icosahedron is one of the five regular polytopes in 3D — the *Platonic solids*. Three of the solids correspond to crystal symmetries because their combinations can tile space. These are the square, octahedron and tetrahedron. The other two are correlated with quasicrystal symmetry, the 600-cell and the 120-cell. These correspond to the quasicrystal-based Platonic solids called the icosahedron and dodecahedron, each possessing icosahedral symmetry. Again, in 3D there are five regular polytopes. In 4D, there are six. And in all dimensions higher than 4D, there are only three — the analogues of the tetrahedron, octahedron and cube — the crystal-related polytopes. The quasicrystal-related regular polytopes are exclusive to dimensions less than 5D. So the special dimensions for Fibonacci chain-related quasicrystals are 1D, 2D, 3D and 4D. Of these dimensions, 4D can host the quasicrystal with the densest network of Fibonacci chains, where 60 Fibonacci chains share a single point at the center of the 600-cells in the $E_8$ to 4D quasicrystal discovered by Elser and Sloane.[43] In other words, a binary state change in the *possibility space* for this quasicrystal changes the state of many other Fibonacci chains associated with that point. And numerous other points in the possibility space also change state, not just the ones in the Fibonacci chains connected to the aforementioned point. All this binary state change — the *empire* — occurs due to the geometric first principles via the state change of a single node in the possibility space.

If the universe is a neural network interested in maximal efficiency, this would use a substrate like this. The fact that this quasicrystal and its 3D analogue discovered by our group called the *quasicrystalline spin network* (QSN) encodes gauge symmetry unification physics may be evidence for the trueness of the conjecture. And this would be more likely if the universe is a neural network code concerned with expression of maximal meaning for the minimum number of binary state choices/actions.

The *principle of efficient language* guides the behavior of the code choices in this framework, where binary actions in the code are chosen such that maximum information or meaning is generated for the least number of binary choices.

Meaning comes in two categories:

(1) Physical or ultra-low subjectivity geometric information — the prototiles of the quasicrystalline code, wherein all particles and forces can be simulated such that the simulation are one and the same and are themselves in physical reality.
(2) Emergent or virtually transcendent and highly subjective information, such as Mathematics and Humor. This form of information can never be separated from the geometric physical information and quasicrystalline code. For example, the abstract thought of "love" comes with a package of memories and associations that trigger countless changes in the nonlocal waveform domain of quantum mechanics, gravity and electromagnetism.

At a physical level, evidence for this tendency toward efficient code use would exist in the form of the *principle of least action* and similar principles and conservation laws. At a non-physical level, evidence for this would exist in the form of the delayed choice quantum eraser experiment[56] and Bem's retro-causality experiments[57] in addition to well-known experiments of quantum entanglement over space and time. As engines of abstract meaning generation and perception, humans would be a special case in a universe obeying the *principle of efficient language*, where our perceptions of meaning and information far exceed the brute simple geometric meaning expressing physical phenomena in the quasicrystalline code.

The degree 120 vertices of the $E_8$ to 4D quasicrystal appear to be the maximum possible density of Fibonacci chains in a network of any dimension and therefore the most powerful possible *possibility space* for a neural network. 3D quasicrystals ordinarily have a maximum of degree 12 vertices with six shared Fibonacci chains. Fang Fang of Quantum Gravity Research discovered how to create a 3D network of Fibonacci chains with degree 60 vertices.[15]

This quasicrystal is made entirely of 3-simplexes, the simplest possible "pixel" of information in 3D (see Fig. 18). It encodes $E_8$ unification physics and is derived from the aforementioned $E_8$ to 4D quasicrystal. Refer to Fang Fang's *et al.* paper *An Icosahedral Quasicrystal as a Packing of Regular Tetrahedra*[103] regarding the

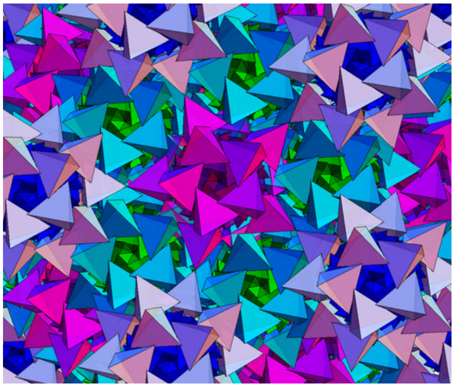


Fig. 18. A chiral quasicrystal derived from $E_8$ – a tetrahedral decorated $E_8$ to 4D then to 3D quasicrystal.

construction of a dense, quasicrystalline packing of regular tetrahedra with icosahedral symmetry.

### 4.7. *Is the error correction code found in gauge symmetry physics a clue that nature computes itself into existence?*

James Gates, the John S. Toll Professor of Physics at the University of Maryland and the Director of The Center for String and Particle Theory found the widely used *doubly-even self-dual linear binary error-correcting block code* embedded in the network of relationships of the gauge symmetry unification equations of fundamental particles.[58] These are the exact same codes used in web-browsers and peer-to-peer network simulations to ensure the consistency of information transfer from client to client. Furthermore, he found that the error correction codes relate specifically to geometric symbols, called adinkas,[59] which encode the relationship of particle gauge symmetry equations. This astounding finding is one of the most powerful pieces of evidence in support of the *digital physics* view that is growing in popularity in academic circles — the view that reality itself is a computation, essentially a simulation.[60] Gates himself commented, "We have no idea what these things are doing there".[61]

### 4.8. *Is there evidence for a golden ratio code in black hole equations, quantum experiments and solid state matter?*

Other compelling evidence used to support the *digital physics* view includes black hole quantum gravity theory and an idea known as the *holographic principle*, which is derived from the mathematical proof called the *Maldacena conjecture*.[62] It states that the total amount of binary information from all the mass and energy pulled into a black hole is proportional to its surface area, where every four Planck areas of its surface encodes the state of a fundamental particle that fell into it.

It is a distinctly binary code-based framework that comes directly from the first principles application of general relativity and quantum mechanics at the limit of both theories — the environment of a black hole. Black hole quantum gravity equations are one of the best clues we have about what a theory of everything might look like.

As stated, quasicrystals generally relate to five-fold symmetry and the golden ratio. The pentagon is the 2D analogue of the icosahedron and the quintessential 2D quasicrystal is the Penrose tiling with its 5-fold symmetry related golden ratio structure. Virtually all of the 3D quasicrystals discovered in nature have icosahedral symmetry. That symmetry is possessed by any object having the combination of 2-fold, 3-fold and 5-fold rotational symmetry. The E8 to 4D quasicrystal has these symmetries and is fundamentally based on the golden ratio.

Black hole physics relates deeply to the golden ratio. It is the precise point where a black hole's modified specific heat changes from positive to negative.[63]

$$\frac{M^4}{J^2} = \phi. \tag{11}$$

It is a part of the equation for the lower bound on black hole entropy.

$$e^{\frac{8\pi S l_P^2}{kA}} \geq \phi. \tag{12}$$

The golden ratio even relates the loop quantum gravity parameter to black hole entropy.[64]

$$2^{\pi\gamma} = \phi. \tag{13}$$

In 1993, Lucien Hardy, of the Perimeter Institute for Theoretical Physics, discovered that the probability of entanglement for two particles projected in tandem is[65]:

$$\phi^{-5}. \tag{14}$$

In 2010, a multinational team of scientists found an $E_8$-based golden ratio signature in solid state matter. Cobalt niobate was put into a quantum-critical state and tuned to an optimal level by adjusting the magnetic fields around it. In describing the process, the researchers used the analogy of tuning a guitar string. They found the perfect tuning when the resonance to pitch is in a golden ratio-based value specifically related to the geometry of E8. The authors speculated that the result is evidence in support of an E8-based theory of everything.[66]

Xu and Zhong's short paper,[67] *Golden Ratio in Quantum Mechanics*, points out the connections to the golden ratio in various works — linking it to particle physics and quantum gravity (quantized spacetime). The short piece is worth reprinting here, and we have included their citations in our bibliography.

*The experimental discovery of the golden ratio in quantum magnetism*[68] *is an extremely important milestone in the quest for the understanding of quantum mechanics and E-infinity theory. We full-heartedly agree with the explanation and discussion given by Prof. Affleck*[69] ... ... *For this reason, we would like to draw attention to a general theory dealing with the noncommutativity and the fine structure of spacetime which comes to similar conclusions and sweeping generalizations about* *the important role which the golden ratio must play in quantum and high energy physics. Maybe the most elementary way to explain this point of view is as follows: Magnetism is just one aspect of the five fundamental forces of nature. In a unified picture where all the five forces melt into one, it is reasonable to suspect that the golden ratio will play a fundamental role. This fact immediately follows from the work of the French mathematician Alain Connes and the Egyptian engineering scientist and theoretical physicist M.S. El Naschie. In Connes' noncommutative geometry, his dimensional function is explicitly dependent on the golden mean. Similarly, the bijection formula in the work of El Naschie is identical with this dimensional function and implies the existence of random Cantor sets with golden mean Hausdorff dimension as the building blocks of a spacetime which is a Cantor set-like fractal in infinite dimensional but hierarchal space. Invoking Albert Einstein's ideas connecting spacetime to geometry with energy and matter, it is clear that these golden mean ratios must appear again in the mass spectrum of elementary particles and other constants of nature. There are several places where this work can be found.*[70–72]

### 4.9. *Wigner's universality*

The *universality* pattern is another fundamental clue about what a theory of everything should look like. It is aperiodic but ordered — liberally defined as a quasicrystal. It was first discovered by Eugene Wigner in the 1950s in the energy spectrum of the uranium nucleus.[73]

In 1972, number theorist Hugh Montgomery found it in the zeros of the Riemann zeta function, so it deeply ties into the distribution of prime numbers.[11] In 2000, Krbálek and Šeba reported it in the complex data patterns of the Cuernavaca bus system.[74] It appears in the spectral measurements of materials such as sea ice[75] and human bones. In fact, it appears in all complex correlated system — virtually every physical system. *Wigner's hypothesis* states that the universality signature exists in all complex correlated systems.[9] Van Vu of Yale University, who has proven with coauthor Terence Tao that *universality* exists in a broad class of random matrices, said, "It seems to be a law of nature".[12]

Why something as fundamental as the *universality* signature would relate to both the distribution of primes and complex physical systems is a mystery — unless somehow number theory and an unknown theory of everything are deeply related. Of course, that is trivially true since the entire edifice of mathematics is built upon the counting numbers. And the foundational "skeleton" of the counting numbers are the primes. Eugene Wigner famously said that nature is unreasonably mathematical.[76] So the ultimate foundation of both complex mathematics and nature herself reside in number theory.

Freeman Dyson defines a quasicrystal as "a [aperiodic] pure point distribution that has a pure point spectrum". He said, "If the Riemann hypothesis is true, then the zeros of the zeta-function form a one-dimensional quasicrystal...".[2] Andrew Odlyzko published the Fourier transform of the zeta-function zeros. It showed sharp peaks at the logarithm of the primes and prime.[10] This demonstrated that the distribution is not random but is aperiodically ordered. By the same definition, the *universality* signature is a quasicrystal. Quasicrystals in nature generally correspond to the golden ratio. So how might the *universality* signature correspond to it?

*Universality* relates fundamentally to matrix math. It defines the spacing between the eigenvalues of large matrices filled with random numbers. This is interesting because the four-term two-by-two binary matrix is the most fundamental of all matrices. 14 of its 16 possible combinations of 1 and 0 have either trivial or simple eigenvalues as 0, 1 or 2. However, the remaining two eigenvalues are golden ratio based as

$$\lambda_+ = \phi \quad \text{and} \quad \lambda_- = -\frac{1}{\phi}. \tag{15}$$

Quantum systems, such as the hydrogen atom, are governed by matrix mathematics. Freeman Dyson said, "Every quantum system is governed by a matrix representing the total energy of the system, and the eigenvalues of the matrix are the energy levels of the quantum system."[80]

Based on work done by Suresh and Koga in 2001,[77] Heyrovska[78] showed the atomic radius of hydrogen in methane to be the Bohr radius over the golden ratio.

$$r_H = \frac{a0}{\phi}. \tag{16}$$

The random matrix correspondence to physics is not an indication that actual randomness occurs. The matrices of some correlated systems, like a hydrogen atom, can be worked out precisely. However, more complicated systems, such as a uranium atom, are non-computable by current methods. The values of its unknown matrix become super-imposed like the blur of voices in a crowded conference hall. Although, there is no randomness in the conversations of the people in the crowd, the super-position of soundwaves behaves exactly like the solutions to a matrix with random numbers.

Scientists are still trying to figure out why *universality* has the exact pattern that it does. Vu said, "We only know it from calculations". Because this pattern also matches perfectly to the distribution of the non-trivial zeros in the Riemann zeta function, the distribution of primes must relate to a strongly-correlated matrix. Dynamically, quasicrystals obey random matrix statistics.[79] And they are strongly correlated and nonlocal, due to the *empire* concept discussed above.

The distribution of prime numbers is encoded in the spectral pattern derived by an irrational projection of a slice of an $A_n$ lattice to 1D. The cell types of $A_n$ lattices are simplex-integers, $n$-simplexes, where each $A_n$ lattice and its $n$-simplex cell type embeds the stack of all $A_n$ lattices with dimensions lower than it. That is, the series of simplex-integers, including prime-simplex-integers, are encoded in the projection of a slice of an $A$-lattice to 1D.

The salient point for now is that the distribution of primes and, accordingly, the zeta zeros corresponds to geometric-number theory — simplex-integers and their associated $A_n$ lattices. We conjecture that our quantum gravity framework based on a quasicrystal projected from the 8-simplex based $E_8$ lattice will explain why the quasiperiodic *universality* pattern appears both in nature and prime number theory. That is, the matrix analogue of our quasicrystal may be the missing matrix correlated to the *universality* signature.

Like all quasicrystals, the dynamical behavior of our $E_8$ derived quasicrystal is described by a complex matrix.[79] Because its complex phason code is strongly and nonlocally correlated, it will obey random matrix statistics and map to the *universality* signature. But the random matrix and universality pattern would be secondary. We agree with László Erdös of the University of Munich, who said "It may happen that it is not a matrix that lies at the core of both Wigner's *universality* and the zeta function, but some other, yet undiscovered, mathematical structure. Wigner matrices and zeta functions may then just be different representations of this structure".[80]

### 4.10. *Section 4. Conclusion*

This section began with the conjecture:

*If nature was a self-organized simulation, it would be a simplex-integer based quasicrystalline code derived from $E_8$.*

We have defended the reasonableness of the conjecture. Now it is up to our institute and the scientists who work here continue to publish a series of theoretical and experimental papers that transform the toy framework into a rigorous formalism worthy of attracting a community of collaborators. The approach is certainly outside the box. However, an outside the box approach may be what is needed. String theory is now 50 years old and it has not made a successful prediction. We believe that a fresh but rigorous new approach such as ours is overdue. It is possible there are bridges to aspects of the string theory approach. In fact, the most foundational string theory was first introduced by David Gross *et al.* in 1985, *heterotic string theory.* It exploits the power of $E_8$.[105]

However, our primary approach achieves symmetry breaking in an intuitive manner via projective geometry to lower dimensions, where full recovery of hyper-dimensional unification physics can be achieved. The resulting spacetime and particle code is a simulation, much more similar in form to *loop quantum gravity*, where the code itself is the structure of dynamical spacetime.

## Appendix A. Overview of Emergence Theory

*Emergence theory*, developed by our institute over the last eight years, exploits the ideas discussed above. The program is at an intermediary stage of development.

### A.1. *Foundational papers*

Fang Sadler *et al.* published the foundational tetrahedral golden ratio rotational relationships and helical behavior in 2013.[81] In 2012, Kovacs *et al.* introduced the *sum of squares law*[82] and in 2013, Castro-Perelman *et al.* proved the derivative *sum of areas and volumes law.*[83] In 2014, Fang *et al.* derived the golden ratio rotation from the first principles approach of the *icosagrid* method. In 2016, she and coauthors published the construction rules of the 3-simplex based quasicrystalline possibility space and introduced the term *golden matrix* ("GM") to describe it along with its $E_8$ derived sub-spaces.[15]

### A.2. *Conceptual overview*

Our program is an *Occam's razor* approach to physics, where we aim to start with irreducible first principles and relentlessly question *status quo* assumptions. Because nature seems to be governed by rules and beautiful math, it is safer to say that there exists an analytical expression for the fine structure constant, the Planck constant, the magnitude of the speed of light and the gravitational constant than it is to say there is not. Put differently, either there exists a first principle theory of everything that explains these values or there is not. However, no such theory has been discovered yet. All theories start with those values and then create equations relating them and their composite objects.

It is helpful to understand the difference between a *unification theory* and a *simulation theory.* A *unification theory* is a network of equations that show how different things transform into one another. A *simulation theory* uses geometric building blocks as the mathematical operators that themselves *are* physical reality — the simulation — instead of merely describing it. Such a framework would spit-out the unification equations while also serving as the "pixels" or functional building blocks of reality. We want to know what reality is, not just the equations that tell us how it behaves or how it is unified. *Loop quantum gravity* is the most popular simulation theory.

Because reality appears to have three spatial dimensions, we start there and inquire whether or not it is possible to simulate physics using the simplest building block or pixel of 3D information, the 3-simplex. The idea is known as a *background independent* model because it starts with spacetime building blocks and makes particles the propagating patterns in that system. The second part of our basic idea is that we use a quantized irreducible unit of measurement at the Planck scale substructure of our model. We call this operator a *quantum viewer.* The building block simplex-integers are made of information. But, they are ontologically real because they are being actualized by quantized units of primitive measurement — the *quantum viewers.*

We will now highlight a few of the key components of our framework.

### A.3. *Ontology and symbolic language* — "*All that exists is that which is measured*"

We would agree with Ilija Barukčić's statement:

> "Roughly speaking, according to Bell's theorem, *there is no reality separate from its observation*".[84]

Classical physics indirectly defines energy as information in the form of an abstract quantity called the "potential for work". Spacetime is permeated with energy, where different energetic potentials within it, are equal to local densities of curvature.[101] Einstein's mass-energy equivalency reduces matter to the notion of bound up energy.[85] Quantum mechanics is more clearly information theoretic, dividing reality into the abstract possibility space of the wave function and the actualized collapse into a particle coordinate in the form of measurement data.[86] J. A. Wheeler was one of the first to point out that reality is made of information.[35] Max Tegmark and many other modern physicists hold this view today. Information is real, so ontologically, there is a division between the potential for information, which is not real, and information as a product of measurement/observation, that is real.[87] The *measurement problem* associated with quantum mechanics relates in large part to the choice of ontological interpretations of what the equations and experiments mean. It is a topic of hot debate with no broad consensus. Einstein and many others have said that there is something we are missing and that the formalism is incomplete.[88] Some have taken the bold position that humans or entities at our level must measure something to actualize it into physical existence. Einstein was one of the first to take issue with this idea, saying, "I like to think that the Moon is still there even when I'm not looking at it". So we take the more conservative position that there is some self-actualizing measurement operator at the Planck scale, where the quantized *pixels* of reality exist. We call this operator a "*quantum viewer*". Its function is to generate a trinary state change in the 3-simplex quanta of space in a *possibility space* of such objects. The possibility space is called the QSN.[15] It is an $E_8$ derived space of 3-simplexes, wherein the trinary state selection actions create syntactically legal quasicrystalline subspaces of the QSN that are physically real frames of space with particle patterns embedded within it. The trinary quality state choices are: (1) on right, (2) on left and (3) off. For example, if a 3-simplex is in the "on right" state in one quasicrystalline frame and is "on left" in the next frame of a dynamical sequence, the formal action is a Clifford rotor or spin operation on the possibility space. However, there is an ontological requirement to manifest these actions with an irreducible measurement/observation operator — the *quantum viewer* action. To understand this, visualize the idea of standing to the left of a friend and taking a photo. Next, walk to her right and take a second photo. Each photo is a transformation-symbol. The ordered set of two photos express the physical information of a discretized rotation of your friend changing orientation relative to your camera if you are stationary and she rotated between the two orientations. So as each *quantum viewer* performs its operation, it captures symbols which are projective transformations that are equal to a state change of a tetrahedron as either on-right, on-left or off. The *quantum viewers* actualize, via observation/measurement, the action of a Clifford rotor or spin operation on the QSN.

As mentioned in Sec. 4.4, the 3-simplex network can be decomposed as a network of 1D Fibonacci chains with line segments in the golden ratio proportion. The *quantum viewers* generate either a right or left-handed rotation of a tetrahedron, which divides a given edge by the golden ratio on one side or the other (as shown in Fig. A.1).

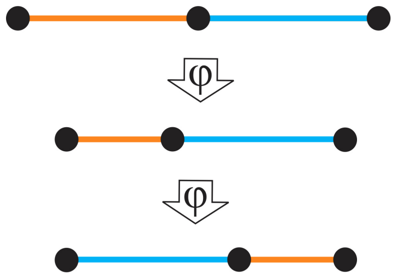



Fig. A.1. Golden division of tetrahedral edges with twisting.

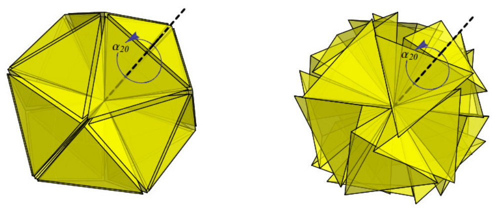



Fig. A.2. (a) An icosahedron divided into regular tetrahedron which are spaced from the inside symmetrically so there is space between the faces. (b) The same tetrahedron with a common vertix in the center rotated with face kissing.

Mathematically, the coordinates of the *quantum viewers* — the camera positions — are the edge crossing point set of the QSN. A key geometry of the network can be understood by taking 20 evenly spaced 3-simplexes that share a common vertex at the center of the cluster. Rotating each either right or left on an axis running from the outside face center through the shared inner vertex by the golden ratio based angle $\frac{1}{2}\left(\cos^{-1}\left(\frac{1}{4}\right) - 120\right)^{\circ}$ creates a 20-group that is either twisted to the right or left (see Fig. A.2). This is an absolute chirality not relative to one's vantage point.

In summary,

(1) The *quantum viewers* are the observation or measurement operators.
(2) They make projective transformations based on their position, just as a camera transforms a 3D image to a 2D image, which is really a network of transformations of 1D actual lengths (lines) between pairs of points to contracted or transformed lines. So the irreducible measurements are 1D phason flips that divide a line into the golden ratio with the long side on one side of the line or the other.
(3) The transformations are information. They are observations that are equal to symbols. Because those symbols are ontologically real due to actualization via observation, they compose the next frame or state change in that region of the QSN — a physically real region of space and time with particle patterns in it.
(4) Formally, the system is a spin network on a discretized moduli space, where the operators are primitive measuring entities generating physically real information.

(5) Its rules and syntactical degrees of freedom are derived by the geometric first principles of *phason cut + project* dynamics related to the movement of a *cut window* through the Elser and Sloan $E_8$ to 4D quasicrystal.

### A.4. *Quantized space and "Time"*

As explained above, space is quantized as 3-simplexes. And time is quantized like a 35 mm film, as ordered sets of individual quasicrystalline frames of 3-simplexes generated by ordered sets of trinary selection choices of the *quantum viewers* in the QSN. Of course, this concept of a universal frame rate is anathema to key assumptions in special relativity — the invariance of the speed of light and the notion of smooth spacetime. The old relativistic notion is that, because spacetime is smooth and structureless, nothing can have intrinsic time or motion but only relative time and motion. The relativistic concept is well supported by experiments, which show that, no matter how fast an observer chases a photon, it always seems to elude him at the speed of light. Our solution to this is the electron clock model.

### A.5. *Electron clock intrinsic time*

We reject the assumption of structureless space. The Michelson–Morley experiment of 1887 was not designed to test for a structure as described herein or any of the other *loop quantum gravity* type theory, where spacetime has a discrete substructure. Prior to 1887, the scientific community presumed a specific fluid type material called the *aether* filled space.[89] When experiments did not demonstrate this substance, a new axiom was established — that there is no substructure to space. Of course, without substructure, there can be no logical motion relative to space. An object would not have intrinsic motion but only motion relative to another object floating in the ocean of the structure less vacuum. This key axiom undergirds relativity theory. The second modern assumption is that fundamental particles, like the electron, have no substructure and are instead dimensionless points. If this were true, such a particle could not have an internal clock or any concept of rotation. All time or *change* that would be ontologically real would be changed relative to another object changing — another clock.

Louis de Broglie first conceptualized the notion of the electron possessing an internal clock.[90] Later, David Hestenes made this idea more rigorous.[91] In the *emergence theory* framework, massive particles, like electrons are composites of multiple Planck length 3-simplexes chosen as ordered sets in frames of the QSN. There are two forms of dynamic pattern:

(1) *Stepwise toroidal knot* — This is a knot pattern much like a 3D trefoil knot that has an asymmetric region that cycles around the geometry of the knot (as shown in Fig. A.3). Multiple quasicrystal frames are required in order to complete a full cycle around the knot — a *tick* of the internal electron clock.

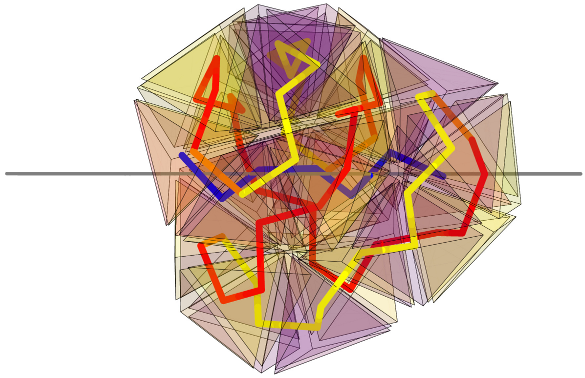


Fig. A.3. A Hamiltonian path cycle through the 57 centers of 57 tetrahedron.

(2) *Helical propagation*: For simplicity, let us imagine it takes 10 frozen quasicrystal states chosen by the *quantum viewers* to compose an animation of one knot cycle. The entire knot can remain at one coordinate in the QSN or it can propagate helically forward in a certain direction. However, if any of the 10 frames are used to propagate the pattern forward, there will be fewer frames available to complete time cycles of the internal toroidal knot-like clock. There must always be a rational fraction of frames used for propagation and frames used for clock time. The two patterns of "time" and propagation would be inversely proportional to one another. And there would always be an absolute and intrinsic ratio of internal clock-time to propagation with respect to the global frame rate of the QSN.

A photon in this model is a pattern of tetrahedra in the QSN that is only helical, not toroidal. So the ratio of propagation to clock time in a given number of frames will always be 100:0. That is, any non-massive particle (particles without internal knot structure) will always propagate in an invariant manner with the same distance covered over a given quantity of frames.

The traveler in a spacecraft moving at 99% of the speed of light will shift their intrinsic clock cycles (as a ratio of total frames) to a very slow rate. This will include all massive particles moving with it, including the measurement apparatus and the operation of the brains of the scientists onboard the craft. The clock cycles or experience of change on the craft will be very slow and the photon will move at the speed of light from the projector on the ship and will go to a mirror at some distance before reflecting back to the measurement apparatus to be compared to some quantity of clock cycles. Very few clock cycles will have elapsed because time for these travelers and their massive equipment will slow to a near halt. Accordingly, the comparison of the distance traveled by the photon to the number of clock cycles will indicate that the photon moved relative to the traveling craft at the same speed it moved when the experiment was done while the vehicle was moving at 1% of the photon's rate of propagation. However, the intrinsic or actual difference between the speed of the vehicle moving at 99% of the speed of light and photon moving at 100%, would in truth be 1% of the speed of light. Clearly, this viewpoint is far less enigmatic and geometrically pleasing than the ordinary interpretation of these experiments via the smooth spacetime ontology of special relativity.

### A.6. *Chirality*

The conjecture that fundamental particles are dimensionless points without structure causes intuitive geometric confusion with other indications that particles deeply relate to handedness or chirality. For example, a current of electrons has a well understood geometric chirality feature. The right-handed rule of how a magnetic field is wrapped around the current in a chiral fashion tells us something deep about handedness in nature. However, the notion of a right-handed or left-handed individual particle is replaced by an abstract non-geometric sign value that is distinctly non-geometric due to the conjecture of the dimensionless point particle identity of the particle. For example, the point particle mathematical abstraction is one where helicity is the sign of the projection of the spin vector onto the momentum vector, where left is negative and right is positive. It is an outstanding mystery as to why the *weak interaction* acts only on left-handed fermions such as the positron and not right-handed ones like the electron.[92]

Quasiparticle patterns in the QSN have a fundamentally different feature that relates to chirality. In Fig. A.4, a left-handed group of 20 3-simplexes, where the states of the tetrahedra by the quantum viewers on the simplexes are all "on-left" is shown.

Ordinarily, a helix made of 3-simplexes, as shown on the left in Fig. A.5, will have no periodicity because of the irrationality of the dihedral angle. However, in the QSN, tetrahedra can only be related by the golden ratio-based angle:

$$\frac{1}{2}\left(\cos^{-1}\left(\frac{1}{4}\right) - 120\right)^{\circ} = \mathrm{ArcCos}\left[\frac{\phi^2}{2\sqrt{2}}\right]. \tag{A.1}$$

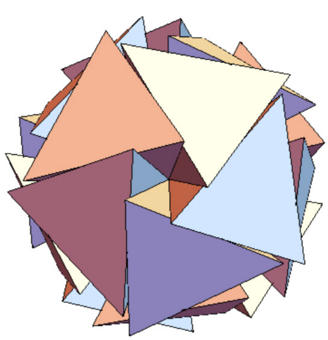
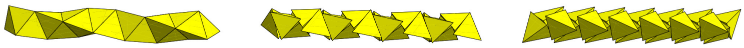


Fig. A.4. A left-handed group of 20 3-simplexes, where the states of the tetrahedra by the quantum viewers on the simplexes are all "on-left".



(a) (b) (c)

Fig. A.5. (a) The Boerdijk–Coxeter helix showing no Periodicity. (b) The Boerdijk–Coxeter helix showing 5 Periodicity by same-handed golden twisting. (c) The Boerdijk–Coxeter helix showing 5 Periodicity by opposite-handed golden twisting.



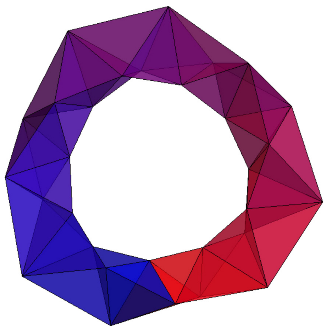


Fig. A.6. 3D projection 30 tetrahedral ring from 600-cell.

The helix on the left is right-handed. So when the rotation of the golden ratio angle is of opposite chirality, in this case, rotated by that value — right-handed — the periodicity become 5-fold. And when it is rotated left, it becomes 3-periodic. The deep reason for these two periodicities corresponds the $E_8$ to 4D Elser–Sloan quasicrystal, wherein the projection of the Gosset polytopes in the $E_8$ crystal generates 600-cell made of 600 3-simplexes. Each simplex is part of a rings of 30 simplexes, as shown in this diagram.

The periodicities of the tetrahedra ring in Fig. A.6 are a superposition of 3-fold and 5-fold, where the orientation of 15 tetrahedra repeats 3-periodically and 15 repeat 5-periodically. The dihedral angle between any two adjacent tetrahedra is $\frac{1}{2}\left(\cos^{-1}\left(\frac{1}{4}\right) - 120\right)^{\circ} + 60^{\circ}$. In 4D, there is vectorial freedom for the $60^{\circ}$ component of the angle. When the relationships of 3-simplexes are represented in the QSN, we cast out the $60^{\circ}$ component because it is the portion related to the construction of a simplex series, where each $60^{\circ}$ of a new edge on an $n$-simplex to generate an $n+1$ simplex is $60^{\circ}$ into an additional spatial dimension.

Realistic physics would not be able to be done if we projected the $E_8 \rightarrow$ 4D to 3D or projected $E_8$ directly to 3D. The key feature of the QSN is that, by making the tetrahedra regular by taking a 3D slice of the 4D QC with regular tetrahedra and then rotating copies of that slice by the same angle that relates adjacent tetrahedra in the 4D QC but minus the $60^{\circ}$ component, we introduce three crucial elements into the object:

(1) It generates an additional sign value necessary for Physics.
(2) It significantly increases the degrees of freedom in the code. In other words, it transforms the code from a binary on/off code to a trinary code of "on right",

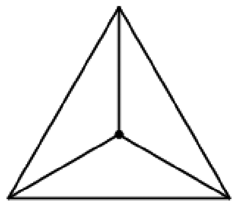


Fig. A.7. Projection of a tetrahedron.



"on left" and "off" in terms of the registration possibilities for a given tetrahedron in a frame of the QSN.

(3) It improve the ratio of symbolism to meaning by reducing all of the tetrahedra to the simplest possible 3D pixel of information, the 3-simplex. If the 3D QSN were generated by projecting the E8 lattice or the 4D QC to 3D, it would generate seven different shapes of distorted 3-simplexes. It would change the ratio of symbol simplicity rank to meaning in the code (see Part 3).

### A.7. *Conservation and the sum of squares law*

Conservation is an inherent quality of irrational projection-based geometry. For example, consider a tetrahedron with four lines running from the centroid to each vertex. Assuming the edge length of the tetrahedron is one, we can project the four inner lines to the plane with an infinite number of projection angles, such as in in projection in Fig. A.7.

The sum of squares of each contracted length in the projection is always conserved as 4 or the integer corresponding to the simplex-integer, in this case the 3-simplex corresponding to the integer 4. The sum correlates in a mysterious way to the spatial dimension of a projected polytope, as reported in two Quantum Gravity Research papers, Julio Kovac's *The Sum of Squares Law*[82] and Carlos Castro Perelman's *et al.* The sum of the squares of areas, volumes and hypervolumes of regular polytopes from Clifford polyvectors.[83]

Based on this same conservation principle, the "letters" or geometric symbol types of a quasicrystal are conserved. For example, there are seven different vertex geometries in a Penrose tiling, as shown in Fig. A.8.

Each of their frequencies of occurrence are conserved as follows:

$\mathrm{A} = 1$
$\mathrm{B} = \varphi$
$\mathrm{C} = \varphi$
$\mathrm{D} = \varphi^2$
$\mathrm{E} = \varphi^3$
$\mathrm{F} = \varphi^4$
$\mathrm{G} = \varphi^5.$

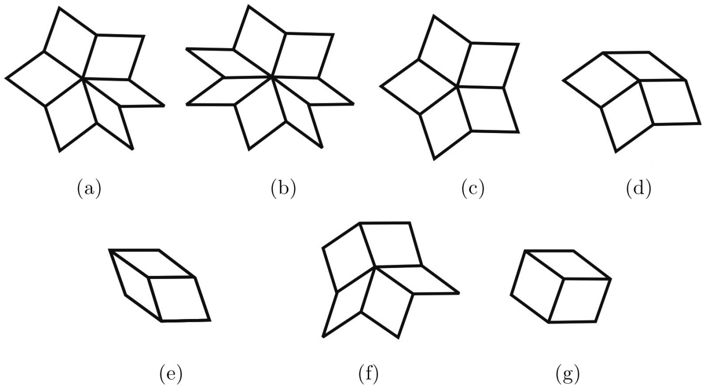



Fig. A.8. The seven vertex configurations of the Penrose tiling.

Similarly, the various legal particle configuration patterns made of relationships between 3-simplexes chosen on the QSN have conserved quantities. We suggest that the deep first principles-based explanation for Noether's first theorem, gauge symmetries and conservation laws in nature is hyperdimensional projective geometry, where the full encoding and richness of hyperdimensional structure is transformed into lower dimensional geometric symbolic code — quasicrystal language.

Quasicrystals have the fractal quality that any shape, such as the seven vertex geometries in the Penrose tiling (see Fig. A.8), repeat according to a scaling algorithm, typically the power series of the golden ratio, $\varphi$, $\varphi^2$, $\varphi^3 \ldots$.

## A.8. *Alternative expression of geometric frustration*

The term geometric frustration can be thought of as "trans-dimensional pressure" resulting from a projection of an object to a lower dimension. For example, in 3D, there is vectorial freedom or space for 12 unit length edges to be related by 90° in the form of a cube. When projected along an irrational angle to 2D, the reduction of vectorial freedom compresses or transforms the information into a 2D representation that requires edges to contract and angles to change. The 2D projection or *shape-symbol* is a map encoding (1) the information of the pre-projected object and (2) the angular relationship of the projection space to the pre-projected object. The trans-dimensional tension or pressure is immediately released or transformed into the transformed lengths and angles of the projection.

An alternative form of transformation or transdimensional pressure expression is rotation and translation. For example, consider the transformation of a 20-group of tetrahedra sharing a common vertex in the 600-cell in 4D space. If we project it to 3D along a certain angle, we can generate a group of 20 distorted tetrahedra with a convex hull of a regular icosahedron and 12 inner edge lengths contracted by

$$\frac{\sqrt{\phi\sqrt{5}}}{2} = \cos 18^\circ. \tag{A.2}$$

We can understand the difference of dimensions as a curvature of one dimension into a higher dimension. For example, a flat piece of paper can be curved into the 2nd dimension such that it is a curved 2D object that requires three spatial dimensions to exist in.

So if we take our 4D 20-group, we can realize that it is bounded by a 3-sphere (4D sphere), which is a curved 2-sphere (ordinary sphere). And we can slowly de-curve or flatten the 3-sphere of space containing the 20-group until it is "flat", at which point it is an ordinary 2-sphere. In this case, the 20 regular tetrahedra living in 4D that have unit edge lengths would need to distort such that the 12 shared inner edges contract to $\cos 18^\circ$ (see Eq. A.2). This result is identical to the aforementioned projection of the 4D object to 3D. An alternative method of encoding the projection or uncurving action is to anchor the 20 tetrahedra around their common shared vertex and rigidify them, such that they are not allowed to encode the geometric frustration via edge contraction and angle change. This will force the tetrahedra to express the information of their hyperdimensional relationships in lower dimensional space by rotating along each of their 3-fold axes of symmetry that run through face centers to opposing vertices (the shared center vertex).

Each of the 20 tetrahedra in the 4D space lives in a different 3D space related to the adjacent 3D space by $\mathrm{ArcCos}([3\varphi - 1]/4)^\circ + 60^\circ = \mathrm{ArcCos}(1/4)^\circ$. If we visualize this as a gradual uncurving of the 4D space toward flat 3D space, we begin with zero rotation of each tetrahedron.

As we initialize the uncurving, the faces will begin to rotate from one another such that their 12 shared inner edges "blossom" into 60 unshared inner edges. As we do this, we are gradually intersecting or converging the twenty separate 3D spaces into a single 3D space. At the point where the 3-sphere bounding space is completely flattened to an ordinary 3D sphere, the rotation value between the kissing inner faces of the 20-group is $\mathrm{ArcCos}([3\varphi - 1]/4)^\circ$, which is the angular relationship between kissing 3D spaces containing tetrahedra in the 4D space of the 600-cell, minus the $60^\circ$ component that there is no room for in 3D (see '$60^\circ$ *Construction*' in Sec. 5.9).

Now, we have a curvature value of 0 and a rotational value of $\mathrm{ArcCos}([3\varphi - 1]/4)^\circ$ and have encoded the relationships of the 20 tetrahedra living in 4D into a geometric symbol in 3D via rotation instead of edge contraction. We have converged 20 tetrahedra from 20 individual 3D spaces related to the other by $\mathrm{ArcCos}([3\varphi - 1]/4)^\circ + 60^\circ$ into a single 3D space where they are related by the same fundamental irrational

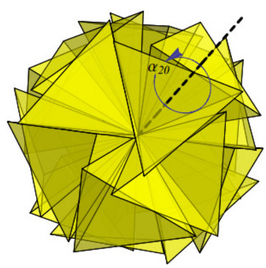



Fig. A.9. The 20 group with the axis of rotation through the center of the face.

component of their former relationships but without the 60° component that was used to construct them by extruding successive spatial dimensions by a process of rotating edge copies into the next spatial dimension by 60°.

We can now reverse the process and slowly curve the flattened 4D object that is now a 3D object back into a perfect 4D 20-group. As we do, the rotational value decreases and the space curvature value increases. At the point in which the 2-sphere and its rigid tetrahedra are curved into a perfect 3-sphere, the rotational value is 0 and the curvature value is $1/\varphi$. So, there is an inverse proportionality between the curvature limit and the rotational limit as 0 rotation $\rightarrow 1/\varphi$ spatial curvature and $1/\varphi$ spatial curvature $\rightarrow$ 0 rotation.

In the QSN, every adjacent tetrahedral relationship is $+/-$ ArcCos$([3\varphi - 1]/4)^\circ$, which is the 4D angular relationship between tetrahedra in the $E_8$ to 4D quasicrystal minus the 60° component not related to 3D.

This special non-arbitrary rotational value is powerful for modeling quantum gravity and particle patterns for four reasons:

(1) It encodes the relationships of tetrahedra in a 4D space, which can be useful for modeling 4D spacetime in three spatial dimensions.
(2) It encodes the relationships of tetrahedra in an E8 derived quasicrystal, which can be useful to model gauge symmetry unification of gravity and the *standard model* particles and forces.
(3) It introduces a binary sign value, chirality. The edge distortion method of encoding geometric frustration does not generate the chirality value. This may be useful for fundamental physics which uses three binary sign values (1) polarity, (2) spin and (3) charge.
(4) The chirality sign value servers as an important degree of freedom in the quasicrystalline code, as opposed to a more restrictive ordinary quasicrystalline. This degree of syntactical freedom makes the geometric language more powerful.

This fundamental rotational value is the basis of action on the QSN. That is, the Clifford rotor spin operations are this rotation, which will serve as the new $\hbar$, the reduced Planck constant or Dirac constant, in our emerging geometric first principles approach to fundamental physics.

There are three ways to visualize operations on the QSN:

(1) **Graph theoretically:** The QSN is a network of points and connections (edges). It is simply an extended construction of the 20-twist discussed below. The 180 possible connections on the 60 points derived via any of the construction methods discussed are part of the possibility space. So when graphed theoretically, we can picture the 180 connections as a graph diagram in 3-space. And then we can do graph operations to turn edges "on" or "off" in order to make patterns.
(2) **Trinary code:** We can turn entire tetrahedra "on" or "off" in which case we can think of a centroid of a tetrahedron as being selected and designated as either the

right-rotated or left-rotated version or not on at all, for a total of three possible choices.

(3) **Clifford rotor/spin network:** We can conceptualize the tetrahedra to rotate smoothly in a classical sense, such that it is rotated from a left to a right position via the $\mathrm{ArcCos}([3\varphi-1]/4)^\circ$ rotation value. We can further decompose these rotations into individual edge rotations.

### A.9. *Simplex construction by* $60^\circ$

As mentioned in Sec. 3, the simplex series is constructed by starting with an edge, a 1-simplex, and rotating a copy on a vertex by $60^\circ$ into the next spatial dimension to form a 2-simplex or three equidistant points on the plane. A copy of one of those edges is then rotated by $60^\circ$ into the 3rd spatial dimension to form an equidistant relationship of four points and a dihedral angle of $\mathrm{ArcCos}(1/3)$. The dihedral angle series ranges from $60^\circ$ in the 2-simplex to $90^\circ$ in the infinite-simplex, spanning a total of $30^\circ$ and where each dihedral angle in the series between $30^\circ$ and $90^\circ$ is irrational as the ArcCos of a successive fraction from the harmonic series $1/2$, $1/3$, $1/4\ldots$.

We can think of the $60^\circ$ component of each dihedral angle as being tied to the action that extruded an additional spatial dimension necessary for the next point to be added in such a manner that all points are equidistant. The remaining irrational component of each dihedral angle is the more "meaningful" part, carrying the key information of the given simplex-integer. For example, in the case of the 4D simplex, the two parts of its $\mathrm{ArcCos}(1/4)^\circ$ dihedral angle are $\mathrm{ArcCos}([3\varphi-1]/4)^\circ \approx 15.522^\circ$ and the $60^\circ$ component correlated to the extra-spatial rotation that extruded out the next spatial dimension in the buildout process from 3D to 4D. The relationship between kissing 3-simplexes in a 4D space is $60^\circ + 15.522^\circ$. Accordingly, when one uses the irrational component of this angle in a 3D construction of regular tetrahedra, such as in our approach, it encodes the relational information between tetrahedra as they would have existed in, for example, the 4D Elser–Sloan quasicrystal derived from $E_8$.

And because $15.522^\circ$ is inversely proportional to the $1/\varphi$ curvature value, as explained above, it is most deeply a transformation of the information of a finite 4D spaces (a 3-sphere of radius 1) into a finite 3D space — a 2-sphere of radius $\cos 18^\circ$ (see Fig. 18).

This same construction approach can also be used to build out the $E_8$ lattice, which is a packing of 8-simplexes that leaves interstitial gaps in the shape of 8D orthoplexes.

### A.10. *Specialness of* 3*D and* 4*D*

In 2D there are an infinite number of regular polytopes, but they all have rational angles and are trivial in some sense except for the ones based on the angles $60^\circ$, $72^\circ$ and $90^\circ$ as the equilateral triangle, pentagon and square. These are the polytopes corresponding to the five Platonic solids, the only regular polytopes in 3D.

For example, the equilateral triangle is the polytope in 2D corresponding to the tetrahedron. Only the equilateral triangle and square can tile the plane, making them the "crystal"-based 2D analogues of the platonic solids. The pentagon cannot tile the plane and corresponds to the icosahedron and dodecahedron. Of the five platonic solids, three are based on the crystal group, the cube, tetrahedron and octahedron. The remaining two, the icosahedron and octahedron, are the quasicrystal regular solids. That is, they cannot tile space alone or in combination with other Platonic solids. Virtually all quasicrystals discovered physically have the symmetry of the dodecahedron and icosahedron called *icosahedral symmetry.* As we go to 4D, we have four crystal symmetry polytopes, the 4D tetrahedron, 4D cube, 4D octahedron and a crystal based polytope called the 24-cell. We also have two quasicrystalline polytopes, the 4D icosahedron called the 600-cell, and the 4D dodecahedron called the 120-cell.

With this, the quasicrystalline symmetry ends. It never appears again in any dimension after 4D. In every higher dimension, the only regular polytopes are the hyper-tetrahedron ($n$-simplex), hyper-cube and hyper-octahedron.

Some have wondered why 3D and 4D appear especially related to our physical universe. If reality is based on quasicrystalline code, then this would perhaps be the reason.

### A.11. *Principle of efficient language*

The *principle of efficient language* is the guiding law or behavior of the universe in the *emergence theory* framework. The old ontology of randomness and smooth spacetime is replaced by a code-based ontology where symbolic information and meaning become the new first principles basis of our mathematical universe. As discussed in Symbolic Power of Fibonacci Chain Networks in Sec. 4.6, meaning comes in two fundamental categories: (1) ultra-low subjectivity physical meaning, which is purely geometric and (2) ultra-high subjectivity or virtually transcendent meaning, which includes things such as the meaning of irony and the myriad layers of meaning imposed by an experimenter about, say, the notion of a particle being measured as going through one slit or the other in a double-slit experiment. Interestingly, it is impossible to imagine an instance of ultra-high subjective meaning being disconnected from the underlying geometric code at the Planck scale. For example, the experience of humor is always associated with countless changes in particle position and alterations to the quantum, gravitational and electromagnetic fields associated with that event. All forms of meaning are ultimately composed of actions of the quantum *viewing actions* that animate the code. The inherent nonlocal connectivity and distributed decision making actions of this neural-network like formalism allow various emergent patterns of intelligent choice and actualization of abstract meaning to be registered and considered within the degrees of freedom of the code. Choices will be made in such a manner as to create maximal associations and meanings where, in systems such as human beings, meaning is highly subjective.

Consider for example, how a joke can be told and one individual will react with massive levels of neural activity and associated meaning, while another person may barely comprehend it. The first person generates a much higher degree of correlated and physically meaningful actions when considered at the Planck scale level of the code operations. This feedback between the overall system (the universal emergent neural-network) and the person generating a larger amount of meaning from the joke plays a role in syntactically free choices of the code. We call these free choices the *hinge variable* steps in the code. On average, physical laws and actions are preserved because the physical meaning of the code (forces and physical laws) are the emergent and non-first principles manifestations of the underlying waveform language of the quasicrystalline quasiparticle formulism.

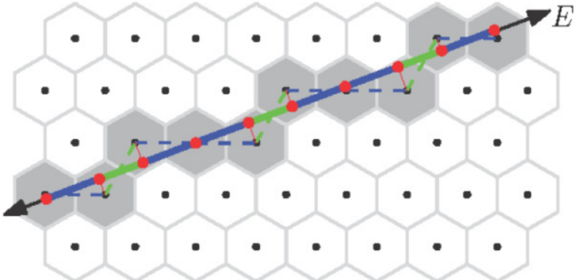
## A.12. *Phason code*

Phason quasiparticles have both a nonlocal wavelike quality and a local particle-like propagation aspect called a *supercell* in crystallographic parlance. As mentioned previously, there are three general ways matter can be organized: (1) Amorphous or gaseous materials that have massive degrees of freedom and are therefore not naturally codes. Geometric codes require a finite set of symbols, strict syntactical rules and minimal degrees of freedom. (2) Crystalline materials have no degrees of freedom unless there are local defects or phonon distortions. There are ultrafine scale vibrations allowed, but not organized code-based larger scale oscillations. (3) Quasicrystals are maximally restrictive without being ultimately restricted like in the case of a crystal. For example, unlike a crystal, the assembly rules for a quasicrystal allow construction choices within the rules that are not forced. A crystal allows only one possible type of relationship between atoms. For example, all vertex types in a cubic lattice are identical. In an amorphous or gaseous material, atoms can have a virtually infinite number of relational objects or vertex types. In a quasicrystal, as with any language, there is a rather small set of allowed combinations. For example, in the Penrose tiling, which is found in nature, atoms form seven different allowed vertex geometries and the construction rules allow a very minimal level of freedom within the construction syntax.

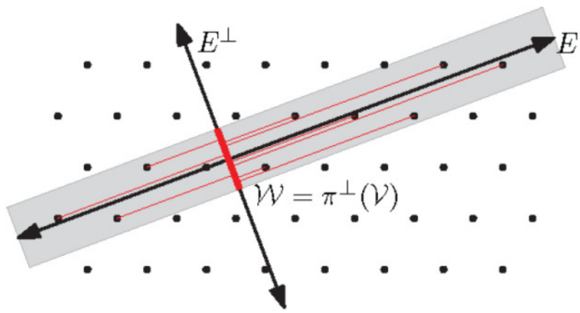
## A.13. *Empires and phason flips*

Because all quasicrystals are networks of 1D quasicrystals, understanding a phason flip and empires should start with how a quasicrystal is made via the *cut* + *project* method. An irrational projection of a *cut* or slice of any crystal to a lower dimension produces a quasicrystal.

For example (see Fig. A.10(b)), one can select a rectangular cut window rotated with an irrational angle to the 2D crystalline pointset. One projects the points captured in the *cut window* to the 1D projection space to generate our 1D quasicrystal. In the second image, we translate the *cut window*, which projects a different set of points to the 1D space. When the *cut window* moves to a new coordinate, points




(a)




(b)

Fig. A.10. A schematic diagram showing two ways of interpreting the cut-and-project method for generating a quasicrystal from a higher dimensional lattice. (a) shows that the points are selected for projection as long as there is non-trivial intersection between their Voronoi cell and the quasicrystal space. The black points are the lattice points, and the hexagons are their Voronoi cells, $E$ is the quasicrystal space, $E \perp$ is the orthogonal space, and the solid blue and green segments are the projected tiles in the quasicrystal space; (b) shows that the points are selected for projection as long as their projection on the orthogonal space falls inside of $W$.

instantly jump in or out of possible positions in the 1D space that we call the *possibility space*. This instant change from one coordinate to the other in the *possibility space* is called a *phason flip*.

When one point is captured in the *cut window*, there are an infinite number of other points along the length of the *cut window* (if considering an ideal infinite point space) that are also captured in the *cut window* at its new coordinate. This creates an infinite number of *phason flips* in the 1D possibility space. An arbitrarily large but non-infinite quasicrystal can be built according to assembly rules instead of the *cut + project* method. In this case, a user of the assembly language must choose a single *phason flip*, which is simply the designation of a point from the *possibility space* to be "on" or "off".

In Fig. A.10 note that, when the *cut window* changed location, some points in the 2D space (1) remained in the window, (2) some departed from the window and (3) some entered the window. When a quasicrystal code user chooses a point to be "on" from the possibility *point space*, it causes a certain group of other points in the possibility space to also be turned on and other points to say on. These two sets of points are called the *empire* of the selected "on" point.

A key concept is conservation. The number of points captured in the *cut window* is conserved. As points enter the window, an equal number of points exit. A second key concept is non-locality, the *empire* of forced points determined to be "on" or "off" by a single point selection of a code user is very large. A third key idea is discrete and instant coordinate change. When the points are a model for particles, an ontology of instant coordinate change in the "physical" projection space is recognized, much like the notion of virtual particles in the *Dirac sea*, where particles are conserved such that when one is annihilated, another instantly appears.

Quasicrystals in dimensions higher than 1D are more complex because they are networks of 1D quasicrystals. So a *phason flip* and *empire* of a single 1D quasicrystal will have a massive empire that influences every other 1D quasicrystal in the network. Figure A.11 shows an image from Laura Effinger-Dean's thesis, which shows the *empire* of one of the *vertex types* of the Penrose tiling. We can see that the density of the *empire* drops with distance from the vertex being designated as "on" at the center. One can think of the possibility space as an aperiodic point space where any point can be selected to be one of the allowed *vertex types*. In the Penrose tiling, there are seven different vertex geometries. As mentioned, once one *vertex type* is selected for that vertex on the *possibility space*, it forces other vertices in the space to be "on" or "off" the *empire*. A key point for physics modeling, where forces drop with

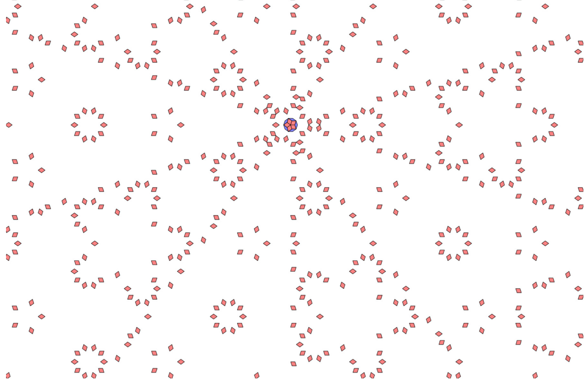


Fig. A.11. The empire of a vertex configuration in Penrose tiling.

distance, is that some *empires* drop in density with distance. We will connect this with the idea of *empire waves* and the *free lunch* principle shortly.

Another key idea for physics using this formalism would be that the *minimum quantum of action* notion of quantum mechanics would be replaced by the action of a point being registered as "on" or "off".

Phason quasiparticle behavior in any quasicrystal has two distinct sets of construction rules:

(1) Quasicrystal Assembly Rules: These construction rules govern how a single frozen state of selections on the *possibility space* can exist. The rules are defined by the angle, size and shape of the *cut window* in the higher-dimensional lattice.
(2) Ordering Rules for Two or More Quasicrystals: These rules govern the creation of dynamical patterns generated by ordering two or more different selection states on the *possibility space* into a stepwise frame-based animation. The rules are defined by the way that a *cut window* can translate or rotate through the higher-dimensional lattice and whether combinations of those actions is discrete or continuous.

### A.14. *Empire waves*

Just as the 2D Penrose tiling quasicrystal has *empires* (see Fig. A.11) that are circular, with radial lines of higher density tiles evenly distributed from the *empire* center point, a 3D quasicrystal has *empires* with radial lines of higher tile density penetrating evenly distributed points on a sphere. As explained in *Electron clock Intrinsic Time* (Sec. 5.5), a massive particle in our framework is composed of a vertex type (a *supercell* of 20 3-simplexes) that dynamically animates over many coordinate changes or frames to form (1) a toroidal knot cycle internally in the QSN and (2) a propagation pattern through the QSN that changes coordinate along a stepwise helical path. The interaction of these two forms of stepwise internal toroidal cycling and forward propagating helical cycling generate a richly complex dynamical pattern of empire waves — waves which extend to the end of the universal space of the QSN but drop in density with distance. These waves are the geometric first principles key to modeling forces in this framework. However, it is helpful to explain that quantum mechanics does not require the assumption of Bohr's conjecture known as *complementarity* — the core of the Copenhagen interpretation of quantum mechanics. This is the view that a fundamental particle, such as an electron, is either a wave or particle but never both. Neither experiment nor the mathematical machinery of quantum mechanics compel this interpretation. The Broglie-Bohm theory states that an electron, for example, is always a wave and particle at the same time and that the wave aspects guides the particle coordinate, like a pilot wave. The *cost* of this absolutely rigorous but less popular interpretation is the requirement of the assumption of inherent nonlocality in nature. Empire waves are nonlocal according to the non-enigmatic geometric first principles of projective geometry.

### A.15. *Free lunch principle — forces*

With this general overview of *empire waves* established, it is now possible to understand how forces can be modeled via geometric first principles. Let us begin with the analogy of the game *Scrabble*, where you gain points by making multiple words diagonally, vertically or horizontally using letters from one or more other words already on the game board. When you do this, you get "free lunch" by earning points for each word your letter(s) played a position in. The *Scrabble* board is analogous to the QSN possibility space. And the 26 Roman letters are like the finite set of geometric relationships or *vertex types* in a quasicrystal — the geometric-symbols of the language. The rules and freedom of English are like the rules and freedom of the phason code in a quasicrystal language. In *Scrabble*, the commodity that is to be conserved and used efficiently is the number of turns each player gets. Each turn needs to generate as much meaning as possible. In *emergence theory*, the same principle applies. There are a certain number of quasicrystal frames or "turns" that a system of, say, two particles can be expressed in over some portion of a dynamical sequence. Let us consider that it takes 10 frames to model a cycle of electron internal clock action or some total length of discrete transitions through the space. The patterns of this object in the QSN always need some integer ratio of the given number of total frames used for internal clock cycle steps versus helical propagation steps.

The physical pattern is expressed as the trinary selections of 3-simplexes in the QSN: on-right, on-left or off. And just as the words "cat" and "rat" can share an "a" for greater efficiency and synergy, the system of two such patterns moving through the QSN allow us to save steps. We can model *free lunch* in this geometric code thanks to the *empires*. When the first propagating electron is moving near the second electron, the two begin to benefit from one another's *empire waves*. In the simplest example, consider that it would ordinarily take two remotely separated electrons 10 frames each to express a certain amount of clock cycling and propagation. However, the closer they are to one another, the more *free lunch* they will enjoy. The system saves frames when a selected tetrahedron from one particle's empire is in the necessary right or left "on" state to that matches the state necessary to fill a position in the geometric pattern of a second electron, thereby saving a frame in the way that we saved an "a" in our *Scrabble* game example.

The result is that the particles require fewer phason flips or frames of trinary selections on the universal QSN to express their clock cycles and their given number of propagation steps along some direction. The physical meaning of this is that they have advanced a further distance than they would have otherwise with 10+10, where no *free lunch* is enjoyed. And because the density of *free lunch* opportunities increases with approaching distance, the two particles will accelerate toward one another as their separation decreases.

The *empire wave* around a massive particle in this framework is distinctly chiral and behaves according to the *right-hand rule*, where the direction of propagation determines the direction of the chiral *free-lunch empire wave* system around it. A "train" of these objects, such as electrons in the QSN, will fall in-line behind one another and form a current because that positioning ensures the maximum amount of *free lunch*. By all moving along the same helical path, a group empire wave system, in the form of the chiral magnetic field, emerges around them. However, most electron models are in either groups of free electrons or are in atomic systems that are arranged with many different orientations, such that the emergence of a chiral magnetic field does not occur. In other words, picture our model of the electron approaching Earth. As it accelerates closer, the probability of finding *free lunch* frame savings increases. Again, the *empire wave* field of every massive fundamental particle on Earth has no general similarity in their various orientations or directions of propagation. And they are not strongly correlated. Accordingly, around Earth, there is an enormous superposition of *empire waves* from every massive particle. One can say that it is a noisy quantum field of *empire waves* on the dynamical QSN. There is a high degree of non-coherence, as compared to a current of electrons, where there are coherent group patterns in the *empire waves* — like combed flowing hair as opposed to tangled hair. Nonetheless, there will still be some opportunities for *free lunch* around the tangled array of *empire waves* surrounding large groups of massive particles for any approaching electron from outer space to enjoy as it nears Earth. But it will be exponentially less than the *free lunch* around the current of electrons. Gravity would logically be orders of magnitude weaker than electromagnetic forces. And it will be distinctly non-chiral, due to the fact that the average chirality is null, with an approximately equal quantity of right and left-handed empire waves states on the QSN around Earth (other than the Earth's magnetic field).

### A.16. *A non-arbitrary length metric*

The nearest neighbor lengths between points in the QSN are the Dirichlet integers 1 and $\frac{1}{\phi}$. So if our framework is generally correct, it would more deeply explain why black hole physics corresponds to the golden ratio and why quantum mechanics does in the form of the $\varphi^{-5}$ entanglement probability discovered by Lucien Hardy.[65] Accordingly, a new length system based on golden ratio values would simplify many equations in physics. For example, the three most fundamental constants are the speed of light, $c$, the gravitational constant, $G$, and Planck's constant, $h$. The only number that unifies all three is a length called the Planck length, $l$, which happens to be about 99.9% of the golden ratio in the metric system.

$$l = \sqrt{\frac{\hbar G}{c^3}}. \tag{A.3}$$

If spacetime had substructure built on our Planck length scale QSN, planetary systems might evolve overtime to energetically favorable cyclical and length ratios that approximate simple golden ratio fractions. And if we based our measuring system on a physical valued tied to a planet, it would be less arbitrary than, for example, the yard, which was based on the distance from King Henry I of England's nose to thumb distance.

Indeed, the metric system is less arbitrary because it is based on $\frac{1}{4}$ the circumference of Earth, where the distance from the Equator to the North pole is 10,002 kilometers, making the metric system unit value of 1, a full 99.98% of that distance (disregarding where the decimal is). When the system was established, they could not achieve the full accuracy of measuring this distance on Earth. So today, the metric system unit is almost that distance. It is not well known, but the metric system deeply relates to approximations of golden ratio values. The Earth and Moon system is approximately a quarter of the age of the universe. So it has had a long time to self-organize into optimal ratios that approximate the golden ratio. To an accuracy of 99.96%, the dimensionless ratios are

$$\left[\frac{\text{radius of Earth}}{\text{radius of Earth}}\right]^2 + \left[\frac{\text{radius of Moon} + \text{radius of Earth}}{\text{radius of Earth}}\right]^2 = \varphi^2, \tag{A.4}$$

or

$$\left[\frac{\text{radius of Moon}}{\text{radius of Earth}}\right] = \sqrt{\varphi} - 1. \tag{A.5}$$

In other words, this is a double coincidence. It is not just that the sum of the Earth and Moon diameters in the metric system are almost exactly the golden ratio 1.618..., but the breakdown of the two diameters that sum to that value is $\varphi - \sqrt{\varphi}$ for the Moon and $\sqrt{\varphi}$ for Earth.

The master dimensionless ratio of fundamental physics is the fine structure constant, $a$. Interestingly, it is also closely approximated with golden ratio expressions as

$$a = \varphi^2/2\pi, \quad \varphi^2/360 \text{ [to an accuracy of about 99.7%]}. \tag{A.6}$$

### A.17. *A non-arbitrary "Time" metric as ordered quasicrystal frames*

Much of the data we present in this paper includes time-based or planet and moon cycle "coincidences" that seem to match far too closely to the golden ratio to be explained away by anything other than the presumption of some unknown substructure of spacetime in a new quantum gravity framework.

By combining both time and length-based values, the critical reader can perhaps be interested in the following impressive number.

The gravitational constant, G, ties time and length based values together as

$$\mathrm{G} = \chi c^2/4\pi. \tag{A.7}$$

$h\chi = 1.0000026$ of the golden ratio as $0.6180382(10^{-59})$ cubic meters per second [note $1/\varphi = 0.61803\ldots$ and $\varphi = 1.61803\ldots$ are the same ratio]. This deviation at the millionth place after the decimal is remarkable.

Now, having put forth an argument why it is plausible that spacetime can have a golden ratio-based substructure as a natural result of the projection of $\mathrm{E}_8$ to a lower dimensional quasiperiodic point space, we can speculate on the idea that the metric system is deeply related to $\varphi$ and consider the idea of a first principles analytical expression of the constants c, G, h and $a$. But clearly, there is a problem. The first three constants are dimensional and tie into the speed of light. And the speed of light is based on a length metric and a time metric. The length metric is being proposed as nonarbitrary, according to this speculative argument related to our projective approach to $E_8$ unification physics.

However, the speed of light playing into these corresponding equations appears at first to be based on an arbitrary metric for time, the second. The QSN is based on the numbers 2, 3 and the golden ratio because the 3-simplex building blocks are regular or non-distorted. And the golden ratio is deeply related to 5 geometrically in the form of the pentagon and to 5 algebraically as $\frac{1}{2}$ of $\sqrt{5}+1$. From the analytical expressions of the 3-simplex volume to its length values, such as height and centroid to vertex distances, it is fundamentally built of the numbers 2 and 3 and their square roots. So the QSN is deeply related to 2, 3 and 5. Incidentally, these are the symmetries that define anything with icosahedral symmetry. And nearly every quasicrystal found in nature (over 300) possesses icosahedral symmetry. It is interesting, then to note, therefore, that the constant $c$ (in the metric system) is 99.93% of the number 3, disregarding where the decimal is placed. And the distance of the Earth to the Sun is 99.73% of 3/2.

The number of (presumably) $\varphi$-based meters traveled by a photon in vacuum in one second is a close approximation of 3/2. Assuming hypothetically, that $E_8$ quasicrystalline physics is a good approach, why is this the case if the second is arbitrary?

The second is not arbitrary, of course. It is based on a cycle of the fundamental Earth clock system, which itself is fundamentally based on $\varphi$, as argued above. It is based on the clock cycles of the Earth rotating once on its axis, which is gravitationally and electromagnetically tied to the Earth, Moon, and Sun system as a whole. The number, of course, is 86,400 seconds in one of these non-arbitrary physical cycles of the Earth clock. That is, $60\,\text{s} \times 60\,\text{min} \times 24\,\text{h}$. Remarkably, the modern precise average Earth day is 86,400.002 s. So the old number is unexpectedly close to the accurate measurement. Again, we disregard where the decimal place is in the context of thinking about the fundamental aspect of a number — its factorization. Accordingly, 86,400 becomes $864 = 2^5\,3^3$, a number deeply related to 2, 3 and 5.

Have we missed anything obvious? Yes, the Earth distorts along the equator. So if we adjust for the meter to assume a non-rotating Earth with no distortion, we can see if our number gets closer or further from the golden ratio being the Planck length. Realizing that the pole-to-pole diameter of Earth is 12,713 km, and simplifying the value by moving the decimal to 1.2713, we can calculate that a $\frac{1}{4}$ of a circle intersecting a non-distorted sphere of this diameter is 0.9984766. This then is normalized to 1. Note that this approach is not based on a metric. It is based on the ratio of the Moon to Earth, where we get the dimensionless value. And here, we are not using the ideal Phi values mentioned. We are using the actual values in their ratio. So this gives the dimensionless ratio value of 0.9984766 in the manner just described. We can then normalize this to a standard unit of 1. Again the justification is the conjecture that the substructure of space is based on a dimensionless ratio of one part being 1 and the other part being $1/\varphi$. Now, what this means is that the Planck length now changes slightly from the current value of 1.616199, which is based on the meter that is measured from a distorted Equator to the normalized value based on the new dimensionless ratio-based length and based on the actual measurement of the Earth's pole through pole diameter (not plugging the golden ratio approximation of that diameter). We get a logically adjusted Planck length of 1.6183412... or 1.0002 of the golden ratio.

### A.18. *Mass in the quasicrystalline spin network*

We will now combine the following ideas in order to understand mass in the *emergence theory* framework:

(1) Free lunch and empire waves
(2) Massive particle clock time to propagation inverse relationship
(3) Principle of efficient language

Obviously, our vision of a geometric first principles unified quantum gravity theory, as explained thus far, reduces everything to length. Our formalism is Clifford rotor operations on a spin network made of the two Dirichlet integer values 1 and $1/\varphi$.

Mass is the degree of resistance to a change in direction or acceleration of a massive particle. If space and time are discretized, where space is divided into positions like on a checker board and time is divided into turns of the players, where a piece can only move to a connected square, an intuitive understanding of mass emerges.

In Fig. A.12, we see that putting a particle in motion along some direction in spacetime as the square grid achieves an efficient diagonal progression across

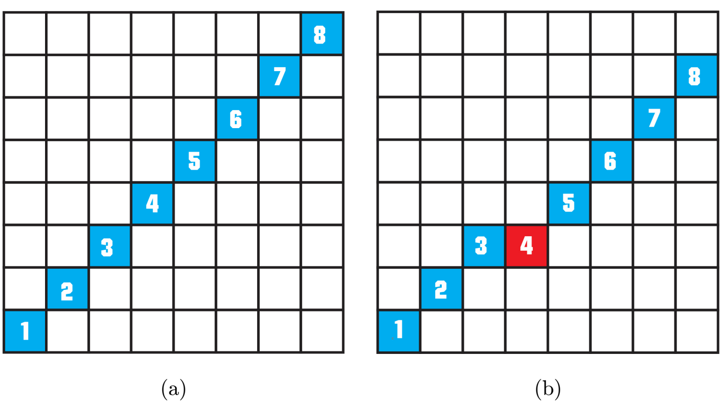



Fig. A.12. Two paths in a spacetime grid. (a) Shortest, most efficient path between position 1 and 8. (b) Seven efficient paths of which one is illustrated.

the board, using the shortest path between position 1 and 8. In the left grid (Fig. A.12(a)), there is only one shortest path. In the right grid (Fig. A.12(b)), there are seven paths of which one is illustrated.

As explained in Sec. 5.3, mass is connected to curvature. In our framework of discretized spacetime, curvature is derived from the angle 15.522° as explained in Fang's *et al.* paper '*Encoding Geometric Frustration*'.[104]

## A.19. *Generation of the quasicrystalline spin network*

### A.19.1. *A fang methods*

In Method 1, Fang Fang initially constructed the QSN by modifying the *icosagrid* with Fibonacci chain spacing to make it a quasicrystal. In doing this, the alternative Method 2 was discovered. Packings of tetrahedra in the form of the FCC lattice are Fibonacci chain spaced. Then five copies are rotated from one another by the 15.522° angle.

#### A.19.1.1. Method 1. Fibonacci icosagrid

This approach is inspired by the *pentagrid* method of constructing the Penrose tiling. A 3D analogue is the *icosagrid* construction method for icosahedrally symmetric quasicrystals. 10 sets of equidistant planes parallel to the faces of an icosahedron are established with periodically repeating parallel planes in each set that, together, form the icosahedrally symmetric *icosagrid*. The intersecting planes segment the 3-space into an infinite number of 3D cell sizes. The *icosagrid* is not a quasicrystal due to the arbitrary closeness of its edge intersections and the resulting infinite number of prototile sizes. We converted it into an icosahedral quasicrystal by changing the equal spacing between parallel planes to have a long and short spacing, L and S with L/S = golden ratio and the order of the spacing follow the Fibonacci sequence. Therefore, we call this kind of spacing the Fibonacci spacing. This Quasicrystal turned out to be a 3D network of Fibonacci chains and we would like to name it QSN.

#### A.19.1.2. Method 2. Golden composition of the fibonacci tetragrid

Similar to the *icosagrid*, a *tetragrid* is made of four sets of equidistant planes that are parallel to the faces of a tetrahedron. Applying the Fibonacci spacing to this structure will also give us a quasicrystal with tetrahedral symmetry (Fibonacci *tetragrid*) — again we focus mostly on the regular tetrahedral cells. In order to obtain icosahedral symmetry, we need to implant the 5-fold symmetry. We applied a Golden Composition process to this Fibonacci *tetragrid* and achieved the same QSN structure.

The Golden Composition is described as follows:

(1) Start from a point in a Fibonacci *tetragrid* and identify the eight tetrahedral cells sharing this point with 4 in one orientation and the remaining 4 in another orientation.
(2) Pick the four tetrahedral cells of the same orientation and duplicate another four copies.

Put two copies together so that they share their center point, the adjacent tetrahedral faces are parallel, touching each other and with a relative rotation angle of $\mathrm{ArcCos}([3\varphi - 1]/4)^\circ$, the *golden rotation*. Repeat the process three more times to add the other three copies to this structure. A twisted 20-tetrahedra cluster, 20G, is formed in the end. Now expand the Fibonacci *tetragrid* associated with each of the 4-tetrahedron sets by turning on the tetrahedra of the same orientation as the four, an icosagrid of one chirality is achieved. Similarly, if the tetrahedral cell of the other orientation are turned on, an icosagrid of the opposite chirality will be achieved. In either case, there is a 20G at the center of the structure.

### A.19.2. *Clifford rotor induction method*

As explained in the paper 'Emergence of an Aperiodic Dirchlet Space from the Tetrahedral Units of an Icosahedral Internal Space'[102] an inductive framework has been established to link higher-dimensional geometry from the basic units of an icosahedron using spinors of geometric algebra and a sequence of transformations of Cartan sub-algebra. Spinors are linear combination of a scalar and bivector components defined (see Eq. A.8).:

$$s = \kappa_D + \alpha_D \mathbf{e}_{12} + \beta_D \mathbf{e}_{23} + \gamma_D \mathbf{e}_{31}. \tag{A.8}$$

The subscript $D$ denotes that the spinorial coefficients live in a Dirichlet coordinate system, i.e., $\alpha_D := \alpha_1 + \phi\alpha_2$, where $\phi$ is the *golden ratio*. This approach presents, for the first time to our knowledge, a direct inductive and Dirichlet quantized link between a three-dimensional quasicrystal to higher-dimensional Lie algebras and lattices that are potential candidates of unification models in physics. Such an inductive model bears the imprints of an *emergence* principle where all complex higher-dimensional physics can be thought to emerge from a three-dimensional quasicrystalline base.

### A.19.3. *Dirichlet integer induction method*

The need for quasicrystalline coordinates brought us naturally to consider a class of number which are more rich than the rational integers (useful for crystals), but more constrained than the real numbers, the quadratic integers. From this class, the five-fold symmetry of our quasicrystal guides our choice to the ring living in the quadratic field associated to 5, which is sometimes noted as $\mathbb{Z}[\varphi]$, the quadratic ring of "Dirichlet integers" referencing to their use in Dirichlet's thesis and following works, or in short $\mathbb{D}$.

Then we use a digital space $\mathbb{D}^3$, to host triplets of Dirichlets integers, and a digital spacetime $\mathbb{D}^4$, to host quadruplets of Dirichlets integers. $\mathbb{D}^4$ could have a quaternion structure, and written $\mathbb{H} \otimes \mathbb{D}$. Where $\mathbb{D}^3$ the space part, is the imaginary part. Furthermore, the structure can be complexified to biquaternion, and also put in bijection with octonion and sedenion.

Each point can also be seen as a 4 by 4 matrix of integers, a digital tetrad, $M^4(\mathbb{Z})$, or as $\mathbb{H} \otimes \mathbb{H} \otimes \mathbb{Z}$.

The 16 numbers are integers.

$$1 \quad i \quad j \quad k \cdot \begin{matrix} a_w & b_w & c_w & d_w \\ a_x & b_x & c_x & d_x \\ a_y & b_y & c_y & d_y \\ a_z & b_z & c_z & d_z \end{matrix} \cdot \begin{matrix} 1 \\ \varphi \\ I \\ I\varphi \end{matrix} .$$

There is one line per dimension, and the first dimension, indexed by $w$ is hidden in the space construction. $a$ and $b$ are combined to make the real part of the Dirichlet complex.

The generators satisfies $ijk = i^2 = j^2 = k^2 = I^2 = \varphi - \varphi^2 = -1$. In a first approach, the imaginary part will be set to 0 (so all $c$ and $d$ are null). A point in the realized space will just show three coordinates:

$$a_x + \varphi b_x,$$
$$a_y + \varphi b_y,$$
$$a_z + \varphi b_z,$$

...where $\varphi = \frac{1+\sqrt{5}}{2}$, and is equivalent to the non-golden part made of the $a$, and the golden part made of the $b$.

In a Euclidian spacetime, $a_w$ and $b_w$ can correspond to time, while it is $c_w$ and $d_w$ in a Lorentzian spacetime, and all four are used in a Kaluza–Klein model.

A set of eight integers, (the $a$ and $b$, or the $c$ and $d$), can encode a position in an $E_8$ lattice (with a doubling convention).

Let us focus on how these numbers emerge. Our model is from the first principle built from regular tetrahedral in an Euclidian 3D space, because the simplex is the simplest geometric symbol, and the space is observed as tridimensional.

We ask the question: *which sets of vertices in $\mathbb{D}^3$ can hold regular tetrahedra of the same size having one vertex in the center (0,0,0)?* The equation is the equation of the sphere, written in $\mathbb{D}^3$, which holds two equations by separating the golden and the non-golden parts. From this, the result is

- A maximal possibility space bigger than the QSN but smaller than Dirichlet space.
- Vertex figure: New polyhedron with 108 vertices and 86 faces.
- Tetrahedron centers figure: New polyhedron with 32 vertices which is not the icosidodecahedron.
- 72 possible tetrahedra around a vertex (see Fig. A.17).

Having built a first-principle version of Dirichlet space where 20G emerge naturally (but as 4 copies), I have the intuition that $E_8$ physics can also emerge naturally as encoded by the possible tetrahedron configurations. We will focus on rule emergence.

Some come from Physics, like the hadronic rule saying that the combined color of three quarks in a neutron or photon is neutral, also known as the SU(3) symmetry, quantum chromodynamics; some from information theory and mathematics; some from matching with quasicrystal study when importing CQC simulation with dynamic window and observing phason occurrence, to deduce phason rules.

(The Dirichlet Integer Induction Method was introduced in an internal communication from Raymond Aschheim to Klee Irwin via email on May 19, 2016).

A.19.4. *Projection and graph diagram method*

To illustrate the correspondence of the 20G twist to the $E_8$ lattice, I developed the following method:

(1) Project $E_8$ to 4D to generate the Elser–Sloan quasicrystal. It is made entirely of 600-cells. Alternatively, we may project one of the 240 vertex root vector polytopes of $E_8$ to 4D to generate two 600-cells scaled by the golden ratio.
(2) Select 20 tetrahedra sharing a common vertex in a 600-cell and project the cluster to 3D such that the outer 12 points form the vertices of a regular icosahedron.
(3) Induce its dual, the dodecahedron, which has 30 points.
(4) Use the 30 points to create a graph diagram by connecting points separated by a distance of $\varphi$ (Sqrt2) times the dodecahedral edge length. This creates a 3D graph diagram equal to two superimposed tetrahedron 5-compounds, one right and one left-handed.

    In Fig. A.13, the right chirality 5-compound is shown. The Cartesian coordinates of the 30 vertices are the cyclic permutations of:

$$(\pm 1, \pm 1, \pm 1)$$
$$(0, \pm 1/\varphi, \pm\varphi)$$
$$(\pm 1/\varphi, \pm\varphi, 0)$$
$$(\pm\varphi, 0, \pm 1/\varphi).$$

(5) Select either the right or left-handed tetrahedron 5-compound. And from it, we select one tetrahedron and translate a copy of it away from the center of the cluster along one of its 3-fold axes of symmetry by a distance of Sqrt(3/8) times its edge length — the distance necessary to translate one of its vertices to be coincident with the center of the tetrahedron 5-compound. We do the same

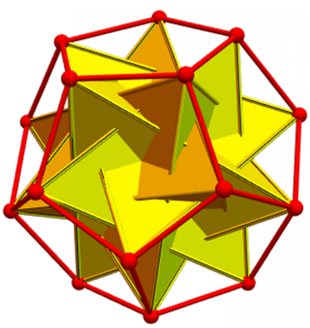


Fig. A.13. Compound of 5 tetrahedron with right chirality.

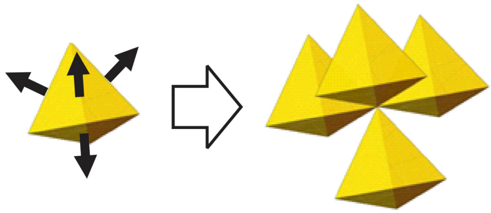


Fig. A.14. One tetrahedron is translated along each of three edges sharing a vertex to give four tetrahedras.

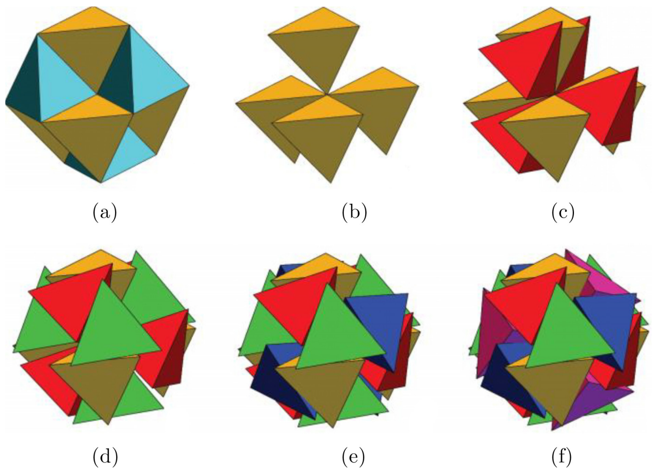



Fig. A.15. (a) A small tetragrid local cluster with eight tetrahedral cells, four "up" and four "down". (b)–(f) The golden composition process: (b) 1 tetragrid. (c) 2 tetragrids, shown in red and orange. (d) 3 tetragrids, shown in red, orange and green. (e) 4 tetragrids, shown in red, orange, green and blue. (f) 4 tetragrids, shown in red, orange, green, blue and purple.

copy-and-translate action along the other three of the selected tetrahedron's 3-fold axes of symmetry. This generates four new tetrahedra that share a common vertex with the centroid of the cluster. Their 12 outer vertices form the points of a cuboctahedron (as shown in Fig. A.14).

We repeat this 4-step process with the remaining four tetrahedra from the initial tetrahedron 5-compound (see Fig. A.15). We then remove the original five tetrahedra as well as the dodecahedron.

Thus far, this induction process generated 20 tetrahedra sharing a common vertex at their group center. It is the 20G twist with 60 outer vertices equal to a cuboctahedron 5-compound. It has Cartesian coordinates that are the cyclic permutations of

$$\begin{gathered}(\pm 2, 0, \pm 2),\\ (\pm\varphi, \pm\varphi^{-1}, \pm(2\varphi - 1)),\\ (\pm 1, \pm\varphi^{-2}, \pm\varphi^{2}).\end{gathered}$$

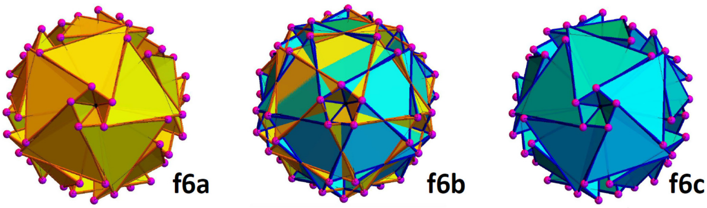



Fig. A.16. (f6a) The right twisted 20G. (f6b) The superposition of the left-twisted and right-twisted 20G. (f6c) The left twisted 20G.

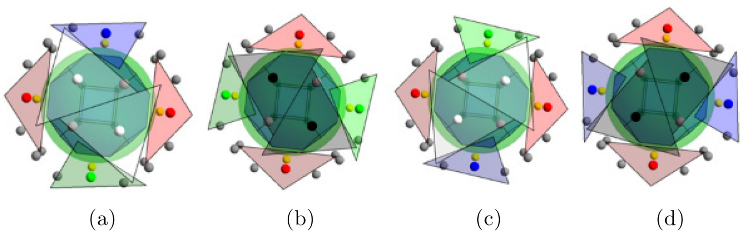



Fig. A.17. Seventy two possible tetrahedra around a vertex. Four combinations of non-intersecting tetrahedron subsets of the 72. (a) 2 left twisted tetrahedra (see Fig. A.16 f6c). (b) 2 right twisted tetrahedra (see Fig. A.16 f6a). (c) 2 right twisted tetrahedra rotated 90 degrees compared to (b) (see Fig. A.16 f6a). (d) 2 left twisted tetrahedra rotated 90 degrees compared to (a) (see Fig. A.16 f6c). From left to right, the 2 tetrahedron facing left, right, right, left chirality. Here you see we can mix chiralities.

(6) Finally, in Fig. A.16, we repeat the entire process with the starting tetrahedron 5-compound of the opposite chirality. The right-handed 20G twist [f6a] and left-handed one [f6c] are superimposed in the QSN to form the basic building block set of possibilities from 60+1 points and 180 possible 3-simplex edges or connections [f6b].

### A.20. *Hyperdimensional information encoded in* 3*D*

One of the principles of the *emergence theory* approach is simplicity. We question the physical realism of hyperdimensional spaces implied by models such as general relativity and string theory.

However, it is clear that the gauge symmetry unification of all particles and forces of the *standard model*, which is everything except gravity, are described by the six-dimensional root vector polytope of the $E_6$ lattice. Full gauge symmetry unification with gravity seems to be possible with the eight-dimensional $E_8$ lattice, which embeds $E_6$. This unification can be achieved with or without geometry by selecting either the pure algebraic Lie algebras or the geometric analogues of hyperdimensional crystals and geometric algebras. Even without considering the gauge theory implications of hyper geometry, general relativity alone relies on a 4D geometric structure.

Clearly, fundamental physics implies a deep tie to hyperdimensional math. But we have never measured any geometric dimensions beyond 3D. So the Occam's razor approach is to see if we can derive all the hyperdimensional information from a purely 3D framework without having to adopt the ontological realism of, for example, curled up spatial dimensions or the 4D spacetime of general relativity.

Because we can measure reality to be 3D and because it is simpler than hyperspaces, we seek to model the implied math of hyperdimensional geometry while restricting ourselves to Euclidean 3-space.

The quintessential example of a lower-dimensional object encoding the information of a higher-dimensional object is irrational angle-based projective geometry-quasicrystallography.

The vertex Cartesian coordinates are the cyclic permutations of

$$\begin{gathered}(\pm 1, \pm 1, \pm 3)\\ (\pm\varphi^{-1}, \pm(-\varphi^{-2}), \pm 2\varphi)\\ (\pm\varphi, \pm(-2\varphi^{-1}), \pm\varphi^{2})\\ (\pm\varphi^{2}, \pm(-\varphi^{-2}), \pm 2)\\ (\pm(2\varphi-1), \pm 1, \pm(2\varphi-1)).\end{gathered}$$

### A.21. *Emergence of a self-actualized code operator*

Frank Wilczek challenged physicists to develop a conscious measurement operator that comports with the formalism of quantum mechanics.[50] This is daunting for social reasons. Discussions of consciousness in academic circles of physicists is generally scorned, with few exceptions. And many physics journals reject such notions under the unwritten premise that philosophy and physics should not be combined.

However, blunt logical deduction, free of social fears, points to the idea that consciousness is a fundamental element, as though it is the substrate of reality. J.B.S. Haldane[93] said:

> *We do not find obvious evidence of life or mind in so-called inert matter...; but if the scientific point of view is correct, we shall ultimately find them, at least in rudimentary form, all through the universe.*

Erwin Schrödinger[94] said:

> *For consciousness is absolutely fundamental.*

Andrei Linde,[95] co-pioneer of inflationary big bang theory, said:

> *Will it not turn out, with the further development of science, that the study of the universe and the study of consciousness will be inseparably linked, and that ultimate progress in the one will be impossible without progress in the other?*

David Bohm[96] said:

> *The laws of physics leave a place for mind in the description of every molecule... In other words, mind is already inherent in every electron, and the processes of human consciousness differ only in degree and not in kind.*

Freeman Dyson[96] said:

> *That which we experience as mind... will in a natural way ultimately reach the level of the wave-function and of the 'dance' of the particles. There is no unbridgeable gap or barrier between any of these levels... It is implied that, in some sense, a rudimentary consciousness is present even at the level of particle physics.*

Werner Heisenberg[97] said:

> *Was [is] it utterly absurd to seek behind the ordering structures of this world a* consciousness *whose "intentions" were these very structures?*

The growing credibility of the digital physics argument still leaves one with the sense of audacious improbability. These scientists claim that the universe is a simulation in the quantum computer of an advanced being or society. Although they could be correct, this has a similar level of outlandishness as the idea that a creator *God* from outside the universe is the source of everything. Of course, this is a popular religious view. But the idea that something from outside the universe created the universe implies a new definition of the term *universe*. That term is supposed to mean *everything*. The idea of a self-actualized universe may be more sensible.

The mounting evidence that the universe is made of information and is being computed includes the aforementioned mathematical proof of the *Maldacena conjecture* and the discovery of error correction codes. There are many other pieces of evidence that add to the argument. But for those new to the thought process, here is a simple way to deduce that something like a computer or mind is needed: Everything we know about physics, including classic physics, indicates that reality or energy is information. And information cannot exist without something to actualize it. It is abstract and relates deeply to a mind-like entity, whether that be a biological neural network or an artificial intelligence.

However, there is a more plausible explanation than the digital physics computer simulation hypothesis. In his submission to the FQXi Essay contest, mathematical physicist, Raymond Aschheim,[7] a scientist at Quantum Gravity Research, said:

> *Can reality emerge from abstraction, from only information? Can this information be self-emergent? Can a structure be both the software and the hardware? Can it be ultimately simple, just equivalent to a set? Can symmetry spontaneously appear from pure mathematical consideration, from the most symmetric concept, a Platonic "sixth element"? Would this*

> *symmetry be just structuring all the particles we know? Can all this be represented? Can standard physics be computed from this model? Eight questions: eight times yes.*

The notion of a self-emergent computational but non-deterministic neural-network universe is more plausible than the idea of a simulation creator from outside the universe. In fact, the emergence of free will and consciousness need not be a speculation. It is proven to exist, at least in humans. So it is one of the interesting behaviors of the universe locally in the region of our physical bodies. In my paper, *A New Approach to the Hard Problem of Consciousness: A Quasicrystalline Language of "Primitive Units of Consciousness" in Quantized Spacetime*,[98] I discuss in detail the plausibility of a self-emergent mind-like universe. The first question is to consider whether or not physics imposes a limit on self-organizing evolution of consciousness. In other words, are humans the limit or can intelligence tend toward infinity? From what we know about classic and quantum physics, there is no limit. It can tend toward infinite awareness and intelligence. The next question is, "What percentage of the energy in the universe can self-organize into conscious systems and networks of conscious systems?" Of course, the answer is the same as the first question. Physics imposes no upper limit. So the answer is that, in principle, 100% of the energy of the universe can self-organize into a conscious network of conscious sub-systems. The final consideration in the deduction relates to the axiom:

> *Given enough time, whatever can happen will happen.*

By this axiom, somewhere ahead of us in spacetime, 100% of the universe has self-organized into a conscious system. It certainly need not be anthropomorphized. We can leave the detail of what this entity would be like out of the deduction. For example, there is no reason to presume that it cannot exist trans-temporally and have an extremely different quality than what we conceptualize as consciousness. The next step of deduction is to question whether or not trans-temporal feedback loops are disallowed by current physics paradigms.

Stephen Hawking of Cambridge and Thomas Hertog of the European Laboratory for Particle Physics at CERN say that the future loops back to create the past.[99] The *delayed choice quantum eraser* experiment also indicates that the future loops back to create the past. And Daryl Bem of Cornel has published several experimental results demonstrating retro-causality.[57] In 2014, Brierley *et al.*[100] demonstrated quantum entanglement of particles across time. In fact, there is an *old wives tale* that general relativity prohibits trans-temporal feedback loops. This is not true. General relativity simply states that communication between events cannot occur via photon mediation. In fact, general relativity predicts wormholes through time and space. The inherent non-locality of quantum reality does not require signals for things to be connected; any more than rotating a penny while looking at the heads side requires time to transmit the torque to the other side of the penny. It is a simultaneous or null-speed correlation. The truth is that until we have a predictive first principles theory that unifies general relativity and quantum mechanics, one cannot aggressively invoke interpretations of either of these two *place-holder* theories to say with confidence what can and cannot occur. Both will turn out to be flawed or incomplete in certain ways when a full theory of everything is discovered.

So for now, let us develop the most conservative argument as follows:

(1) Like the exponential explosion of any doubling algorithm, high-level forms of consciousness and networked consciousnesses will envelope the universe. There are no hypotheses that can reasonably challenge this idea. We have hard evidence that consciousness emerges because our minds are sharing the words of this sentence. The idea of consciousness exponentially spreading throughout the universe is plausible due to the extraordinary behavior of doubling algorithms. For example, if we doubled a penny as fast as we can hit the "x2" button on an iPhone calculator in 30 s, we would have more pennies than all the atoms in the entire universe. The reason we do not see doubling algorithms in nature go more than a few iterations because resources halt the doubling algorithm very early.

(2) The question is whether or not a species with high consciousness and evolving consciousness can leave their biosphere and continue doubling and staying non-locally networked. Humans made it to another cosmological body in 1969, when we landed on the Moon. It is only a matter of time before technology and our built-in compulsion to explore takes us out into the universe, where resource limitation halting will not occur until all the energy of the universe is exhausted. Again, the challenge is not to argue why this will occur. That is established by the axiom "Given enough time, whatever can happen will happen". The onus of logic falls on those who guess humans will destroy themselves or that society will collapse or and that all other potential species in the universe will have the same fate.

(3) Now, if the universe is expanding faster than the speed of light, then exponentially expanding consciousness can never sequester all energy into a universal scale conscious neural network of quantum entangled conscious sub-systems. As mentioned, general relativity allows wormholes, and quantum mechanics is inherently non-local. So until a predictive *theory of everything* is discovered, it is not clear whether or not non-local information exchange or teleportation can occur, where a consciousness can relocate trans-temporally or trans-spatially in instant-time (perhaps without atomic form) to influence matter and energy in distant regions of the universe. However, it is worthwhile to play the *what-if* game to see where the idea leads. If a new first-principles quantum gravity theory inspired a technology that allowed consciousness to project into spacetime coordinates non-locally, where would we go first? *What if* you were given 100 free airline vouchers to fly anywhere in the world? Would you explore ballistically by first traveling 100 miles from your home, then 200 miles and so on until you explored the far reaches of the world? Or would you make a *favorites list* and bounce around arbitrarily depending on whether Beijing, Sydney or Rio made it near the top of your wish list? If humans or any other intelligent life in the

universe discovers non-local information exchange that a consciousness can exploit, we will bounce around the universe and plant consciousness in various parts of the cosmos. At first, the transplanted consciousness outposts will have the sparse pattern of a sponge — or neural network — throughout the whole cosmos. So the expansion rate of the universe would not be a problem for the deduction that, given enough time, high consciousness will eventually envelop all energy in the universe. The sparse sponge-like pattern of *outposts* of networked consciousness will fill-in as they approach maximum density at 100% of the energy of the universe.

(4) What would this high consciousness be like? It is hard to say. But it would not be very much like us. We are related to snails and horses and dinosaurs, but we are not very much like them. However, the one thing we would share in common is that we would understand the first-principles theory of everything that would be a prerequisite for the exploitation of non-local mental and physical technology. When a first-principles theory of everything is discovered, it will not be replaced by something else. To say otherwise indicates a misunderstanding of what the term *first-principles* means in this context. The Pythagorean Theorem is based on first principles. It will not be replaced. We are not talking about a model of how the universe works. We are speaking of discovering the simulation code of geometric symbolism itself and interacting with it.

So, we have told an audacious story, even though it may be logically inevitable. However, it should be noted that the *big bang* theory is audacious and probably true at the same time. The emergence of this very conversation, dear reader, and the human consciousness that it exists within is audacious. And so too is the notion of the universe being a simulation from a creator outside the universe. So if audaciousness is evil, then we are seeking the lesser of all evils. The deduction herein is in fact conservative. And yet it is audacious at the same time. It is not just plausible. It is inevitable.

The punchline of the deduction is this: Because this is an inevitable outcome, the simplest answer on how an information theoretic universe can exist and what its substrate would be if it self-actualized is the entire system — reality — is a mind-like mathematical (geometric) neural network. Just as our now limited consciousness can hold within it the notion of a square, we can allow a self-organizing game or language of squares to emerge in our mind. A far greater neural network could hold within it the relatively simple geometry of $E_8$ and the 4D and 3D quasicrystals we have discussed. Primitive quanta or measuring entities (*quantum viewers*) at the Planck scale substructure of the imagined *possibility space*, which are essentially vantage points of the universal emergent consciousness, would actualize geometric symbols by *observations* (projective transformations) within the quasicrystalline *possibility space*. Each observation of a Planck scale *quantum viewer* generates a projective transformation equal to a rotation of the 3-simplex it is associated with. These primitive geometric binary choice states on the *possibility space* are part of a code that forms a neural network based on 3D simplex-integers in an $E_8$ derived quasicrystal. By geometric first principles, the code has a free-variable called the *phason flip*. And the universal consciousness operating the details of the code obeys the *principle of efficient language*, taking instructions from conscious sub-systems like us, who are engines of emergent meaning.

The universe would not exist if it weren't for intermediary emergent entities like us. It would also not exist if it weren't for the maximally simple golden ratio-based quasicrystalline $E_8$ code that self-organizes quarks and electrons into 81 stable atoms and into countless compounds and planets and people and societies and overly-wordy sentences and on up through to the collective consciousness of the universe. And that primitive starting code and the simplex-integers and the *quantum viewer* operators needed to animate the whole thing would not exist without the collective emergent consciousness. Retrocausality allows the whole idea to be logically consistent, where the future creates the past and the past creates the future. The simple creates the complex and the complex creates the simple — a cosmic scale evolving feedback loop of co-creation. This framework is both explanatory and conservative. And it requires no magical moments that are unexplainable, like the moment of the *big bang* or a creator-*God*. It uses first-principles logic where A co-creates B, which co-creates C, which co-creates A. Non-linear causality is mathematically and logically rigorous. The entire framework is based on two fundamental and inarguable behaviors of nature: (1) emergent complexity and (2) feedback loops.



## References

1. D. Schumayer and D. A. W. Hutchinson, Colloquium: Physics of the Riemann hypothesis, *Rev. Mod. Phys* **83** (2011) 307.
2. F. Dyson, Birds and frogs, *Not. AMS* **56**(2) (2009) 212–223.
3. M. L. Lapidus, *In Search of the Riemann Zeros: Strings, Fractal Membranes and Noncommutative Spacetimes* (American Mathematical Society, Providence, R.I., 2008).
4. H. Georgi and S. L. Glashow, Unity of all elementary-particle forces, *Phys. Rev. Lett.* **32** (1974) 438.
5. F. Gursey, P. Raymond and P. Sikivie, A universal gauge theory model based on E6, *Phys. Lett. B* **60**(2) (1976) 177–180.
6. A. G. Lisi, An exceptionally simple theory of everything. 2007. Available at https://arxiv.org/abs/0711.0770 (accessed 21 August, 2017).
7. R. Aschheim, Is reality digital or analog. 2011. Available at http://fqxi.org/community/forum/topic/929 (accessed 21 August, 2017).
8. Online Dictionary of CRYSTALLOGRAPHY Available at http://reference.iucr.org/dictionary/Aperiodic_crystal (accessed August 21, 2017).
9. E. P. Wigner, On the distribution of the roots of certain symmetric matrices, *Ann. Math.* **62**(2) (1958) 325–327.
10. A. M. Odlyzko, Primes, quantum chaos and computers, Number Theory, in *Proc. Symp. National Research Council*, Washington DC, 1990, pp. 35–46.
11. H. L. Montgomery, The pair correlation of zeros of the zeta function, in *Proc. Symp. Pure Math.* **24** (1972) 181–193.
12. T. Tao and V. Vu, Random matrices: The universality phenomenon for Wigner ensembles. Modern aspects of random matrix theory, *Proc. Symp. Appl. Math.* **72** (2014) 121–172.

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# The Self-Simulation Hypothesis Interpretation of Quantum Mechanics

**Klee Irwin** *, **Marcelo Amaral** and **David Chester**

Quantum Gravity Research, Los Angeles, CA 90290, USA; marcelo@quantumgravityresearch.org (M.A.); davidc@quantumgravityresearch.org (D.C.)
* Correspondence: Klee@QuantumGravityResearch.com

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**Abstract:** We modify the *simulation hypothesis* to a *self-simulation hypothesis*, where the physical universe, as a strange loop, is a mental self-simulation that might exist as one of a broad class of possible code theoretic quantum gravity models of reality obeying the *principle of efficient language* axiom. This leads to ontological interpretations about quantum mechanics. We also discuss some implications of the self-simulation hypothesis such as an informational arrow of time.

**Keywords:** simulation hypothesis; philosophy of mind; quantum mechanics

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## 1. Introduction and Background

The simulation hypothesis [1] is a materialistic view, which argues that our universe is most likely a simulation in a physical universe. In *Are you living in a computer simulation?*, Nick Bostrom discusses how sufficient evolution of future technology leads to lifeforms capable of producing a large quantity of high fidelity simulations, called ancestor simulations. These simulations express an evolutionary process leading to humans and on up through higher levels of biological and technological evolution. The simulation hypothesis explains where the information that is our reality comes from. However, it does not offer an explanation for where the physical stuff of the real universe comes from. Because there would be more simulations than the one real universe, the deduction is that it is more likely that we are in one of the simulations than the real universe.

We discuss a non-materialist view called the self-simulation hypothesis, wherein everything is information, which we define as thought. The universe self-actualizes itself into existence via self-simulation using a mathematical code and a simulation *game rule* called the principle of efficient language. The salient idea is "timeless emergentism", wherein the total simulation run can be viewed as one grand thought. Herein, the presumption of time does not exist, and, instead, a nested hierarchical order in the total self-simulation thought as an ordered set exists. Emergentism in this context is where the self-simulation grand thought has various sub-thoughts in a nested hierarchy that synergistically composite to higher-order sub-thoughts and eventually composite to become the grand thought of the self-simulation run itself. An early sub-thought in the ordered set is the base mathematics of the self-simulation code. Another important early sub-thought is the principle of efficient language, which is the idea of economizing sub-thoughts, called code-steps or actions, for the purpose of economically expressing the meaning that emergent sub-thoughts, such as humans, choose to experience, such as a measurement. One important sub-thought early in the ordering of the nested hierarchy is a fundamental particle.

*Materialism* is an axiom that says matter and other physical things, such as light and spacetime, are the fundamental substances of reality. In this view, the terms "abstract" and "physical" are juxtaposed, where abstract, i.e., not real, information merely describes the real physical things. The axiom offers no explanation for where the physical stuff comes from. It just is.

Digital physics [2–11] is a non-materialistic view, which says there is no physicality but only abstract information as the fundamental building blocks of emergent informational structures of reality, such as atoms. One advocate was John Wheeler, who discussed how entities capable of observing and thinking influence how physical information behaves. The digital physics view is non-dualistic in that it does not juxtapose the terms "abstract" and "physical", since everything real is information and therefore abstract. However, just as the materialist view does not explain where the physical stuff comes from, the digital physics view does not offer an explanation for where the information comes from. It just is.

Idealistic holistic panpsychism [12] (herein, panpsychism) is related to ontological idealism [13]. It says that everything is thought or consciousness. Panpsychism philosophy does not explain how the panpsychic substrate comes to exist. It just is. We propose a panpsychic self-simulation model, which attempts to describe the origin of the panconsciousness.

In Reference [14,15], one of the authors discussed the idea of the self–simulation. (After release of our preprint, Christopher Langan contacted us to point out that some of our independently derived ideas are similar to some of his. Upon review of his work [16–18], we acknowledge some similarities, such as the use of the term "self–simulation" [17]. Where "simulation" is defined as something representing something else, a self-simulation is a case where something simulates, i.e., represents or creates itself. The universe creating itself is a rather ancient idea. To our knowledge, the modern idea of reality as a code–in–action was first introduced in 1969 by Finkelstein in *The Space–Time Code* [19]. In essence, the work of both Langan and ourselves is a synthesis of three general ideas: (1) reality is made of information in the form of code/language [2,3,19–23], (2) reality is a transtemporal system, where things from one time can influence things in other times [24–26] and (3), the substrate of this information is panconsciousness [12] that emerges from itself, as the creator or simulator of itself. Differences in our synthesis include our connection to self-referential vs non-self-referential symbols, strange loops, a finite possibility space for physical information, a unified free energy principle, quasicrystalline codes and details on the nature of retrocausality, to name a few). In 2017, he put forth the idea that a digital physics–based quantum gravity theory can be based on simplex–integers or shape as number [27]. A unification of the numerical aspect of the digital physics view and geometric aspect of the materialistic view was proposed, where the shapes that form reality are equivalent to numbers. In Reference [15], he discussed how these shape–numbers as physical information can act as the elements of a quasicrystalline mathematical code. This view provides an origin for the panpsychic substrate of reality, where nothing "just is" and where there is a logically self–consistent origin story for the panpsychic substrate as a self–simulation strange loop. The logic is based on evidence that consciousness can evolve to increase in magnitude, as it has done here on Earth from early lifeforms to humans. Human minds can run primitive simulations, such as dreams. Sufficiently large minds can be networks of smaller minds and can, in principle, evolve to enormous levels in the future to run fully realistic universal self–simulations. A panpsychic self–simulation unifies notions from emergentism and panpsychism by showing that panconsciousness can emerge from or self–simulate itself.

One of the goals of this paper is to stimulate debate by providing critical thinking options for those interested in comparing the simulation hypothesis to the self-simulation hypothesis. We have evidence today that computers are getting more powerful, along with the resolution of the physical systems they can simulate. We also have evidence that self-simulations, i.e., dreams of one's physical form, have gotten extremely powerful as consciousness has evolved here on Earth. If it were a competition for resolution and detail, human dreams are today more realistic than computer simulations. Some have had lucid dreams, wherein one realizes they are dreaming. What is most remarkable is the ultra-high-fidelity resolution of these mind-based simulations and the accuracy of the physics therein. Upon investigating the quality of these simulations, it is typical for lucid dreamers to report that these mind-based simulations are generally indistinguishable from ordinary reality. In fact, most people who dream are usually not aware they are dreaming because the simulation is so realistic that one tends not to question it. The reader might take their experience now, as they read these words, and notice that they have not suspected they are in a dream at this moment. Why would they? The experience has a very high resolution—but so does a dream. The physics of dreams can be impeccable insofar as how light triangulates off glasses of water, how gravity behaves, etc. More powerful minds can simulate more fine-grained physics, perhaps down to the Planck scale, as the self-simulation hypothesis predicts. We are not saying that human dreams are a physical reality, however, since the physical reality is the dream of the panconsciousness, not a human.

In the simulation hypothesis, as opposed to the self-simulation hypothesis, the first consciousness emerges out of a physical realm. This then leads to those consciousnesses creating technology that leads to ancestor simulations, where more consciousness emerges from the pure information of the simulation. If we presume that the probability of our reality being an ancestor simulation is likely, this same logic implies that each ancestor simulation is likely to be inside another ancestor simulation. While the self-simulation hypothesis can have mental simulations within mental simulations, all simulations are made of the same stuff—thought. Specifically, one might question, in a simulation hypothesis ontology, if they are physical, i.e., real, or if they are merely information in one of the nested simulations within simulations. However, because the self-simulation hypothesis is based on panpsychism, where everything is thought, it does not require a physical universe with computers to run the mental self-simulation. The difference here is that physical information can emerge out of a conscious realm rather than just physical information emerging from a physical realm. Accordingly, the question "Which is the real universe?" is resolved because all information that is thought of is real and there is nothing outside of thought or consciousness. In the simulation hypothesis, the simulations are a fake reality. In the self-simulation hypothesis, they are real.

As mentioned, panpsychism does not explain the origin of the fundamental thing—the panconsciousness itself. It just is. Materialism does not explain the origin of the fundamental thing—the physical stuff itself. It just is. Digital physics does not explain the origin of the fundamental thing—the information itself. It also just is. Similarly, the simulation hypothesis is based on materialism. Thus, it does not explain the material stuff. It just is.

The self-simulation hypothesis explains the origin of the fundamental thing—the panconsciousness—and does not say, "It just is". The universal mind self-actualizes itself into existence via the strange loop of self-simulation. As mentioned, this requires the assumption that reality, i.e., the panconsciousness, is outside of time. Notions of quantum gravity, such as the Wheeler–de Witt equation and Rovelli's insights, suggest that time is not real [28,29]. Furthermore, as opposed to the ontology of digital physics, the self-simulation view offers an explanation for where the information that is reality comes from, including the information of the panpsychic computational substrate itself. The computational mental substrate emerges from its own self-simulation as thought. The idea is that the physical simulation of spacetime and particles is mathematical thought, which emerges from the evolution of mind in the simulation in a logically consistent loop or whole. Loops or circles do not necessarily mean that an argument is faulty circular reasoning. The self-simulation hypothesis is a strange loop, a term introduced by Hofstadter, who claimed that the self is an inherently circular structure with no grounding [30,31]. Strange loops that describe creation are paradoxical if one assumes linear time. We can ask: "How did the panconsciousness come to exist?" The creationist who thinks panconsciousness is fundamental with no origin story, i.e., "Panconsciousness just is", will say that is a false question. The self-simulation hypothesis ontology would answer, "The panconsciousness self-actualizes itself in a strange loop via self-simulation."

The only price to pay is that one must reject the false question: "Which came first, the chicken or the egg?" or "what came first in time, the simple math of the self-simulation code or the complex emergent panconscious substrate that thinks of the simple math?" We move away from classical ideas of time and causality. This suggests that the universal mind self-actualized itself through a grand thought of a complex system (a thought that is itself the universal mind) that has evolutionary hierarchical nested complexity that provides explanation for each level in the hierarchy as emerging logically from all the others.

We claim above that materialism, panpsychism, and information theoretic ontologies do not explain the origin of the fundamental stuff and that the self-simulation hypothesis does. Those three ontologies do not try to explain the origin of the fundamental things. Similar to most religions, all three are creationist insofar as saying there is one fundamental thing that creates all others but which itself has no creator. The self-simulation hypothesis recognizes that: (1) thoughts called choices of what to think; and (2) thoughts called the experience of those chosen thoughts are fundamental and that one explains the other via the self-simulation creative process of self-actualization. Materialism does not say that fundamental physical stuff created itself. Digital physics does not say fundamental information created itself. Panpsychism typically does not say that the universal consciousness created itself. They say that fundamental things "just are" with no explanation. In this paper, we build a logical thesis that does not contradict the parts of these other three ontologies that claim the fundamentality of "physical = materialism", "information = digital physics", and "consciousness = panpsychism". For us, all three things, physicality, information, and consciousness, are fundamental. We show how they are equivalent and discuss a categorization and origin scheme that simply goes further into the process of relating and explaining than those more limited ontologies that stop at "it just is". Instead, using code theory, we provide theoretical structure suggesting how reality self-simulates. We provide various forms of evidence-based rationale.

As discussed, panpsychism is the idea that all of reality exists within a mental substrate, where everything is thought. Physicists, such as Roger Penrose, discuss versions of panpsychism in relation to quantum mechanics [32]. Shan Gao [33,34] discusses how conscious beings can distinguish definite perceptions and their quantum superpositions, while systems without consciousness cannot distinguish such non-orthogonal quantum states.

Interpreting quantum mechanics (QM) places one at the nexus where the philosophy of what is real (ontology), experimental physics and mathematics converge. More physicists subscribe to the Copenhagen interpretation than any other, which requires entities capable of observation to collapse wavefunctions. While some interpret Copenhagen to not refer to consciousness, this obscures the role of consciousness in measurement, since it is typical to recognize that observers must be conscious or are defined with consciousness. Derivative off-shoots, such as Wigner and Stapp's *consciousness causes collapse* interpretation [35,36] and Qbism [37,38], also postulate that consciousness is the fundamental quantum operator or actualizer of reality. If we assume that we possess consciousness and freewill and follow the many-worlds interpretation, it is conceivable to imagine that freewill leads to decoherence, similar to outcomes of measurement. Consider an electron that is spin up in the z-direction. We flip a coin; heads leads to a spin measurement in the y-direction, while tails leads to a spin measurement in the x-direction. This would lead to four universes of equal probability: spin up y, spin down y, spin up x, and spin down x. The random coin flip can be replaced with a conscious choice, suggesting that all freewill choices could be combined as a mixed state within the many-worlds interpretation, such that a conscious choice is a type of decoherence (One objection may be that it is simpler to create an infinite ensemble of coin flips, rather than an infinite ensemble of conscious freewill choices, but we do not look to model probabilities associated with freewill). Not all interpretations of many-worlds must lead to this, but this is one possibility. For clarity, we interpret freewill choices as a form of wavefunction collapse, but note that a self-consistent many-worlds interpretation may also be valid.

Practically minded physicists often minimize the scientific importance of dealing with the philosophical meanings of what QM is trying to tell us. If they are not trying to push the bounds of fundamental physics, such as developing a quantum gravity theory, then it is true they can, in the words of David Mermin, "Shut up and calculate!" [39]. However, for those of us looking to understand nature more deeply or working on quantum gravity theories, we cannot shut up. We must critically think about consciousness and certain aspects of philosophy that are uncomfortable subjects to some scientists. When physicists trivialize those working on such crucial issues, it helps limit the probability of advancements in fundamental physics. Accordingly, we share a few encouraging remarks from titans of modern physics about the importance of this study.

**Erwin Schrödinger**: *Consciousness cannot be accounted for in physical terms. For consciousness is absolutely fundamental* [40].

**Arthur Eddington**: *The stuff of the world is mind stuff* [41].

**J. B. S. Haldane**: *We do not find obvious evidence of life or mind in so-called inert matter...; but if the scientific point of view is correct, we shall ultimately find them, at least in rudimentary form, all through the universe* [42].

**Julian Huxley**: *Mind or something of the nature as mind must exist throughout the entire universe. This is, I believe, the truth* [43].

**Freeman Dyson**: *[M]ind is already inherent in every electron, and the processes of human consciousness differ only in degree and not in kind from the processes of choice between quantum states which we call "chance" when they are made by electrons* [44].

**David Bohm**: *It is implied that, in some sense, a rudimentary consciousness is present even at the level of particle physics* [45].

**Werner Heisenberg**: *Was [is] it utterly absurd to seek behind the ordering structures of this world a "consciousness" whose "intentions" were these very structures* [46]?

**Andrei Linde**: *Will it not turn out, with the further development of science, that the study of the universe and the study of consciousness will be inseparably linked, and that ultimate progress in the one will be impossible without progress in the other* [47]?

**John Bell**: *What is much more likely is that the new way of seeing things will involve an imaginative leap that will astonish us* [48].

**Frank Wilczek**: *The relevant literature [on the meaning of quantum theory] is famously contentious and obscure. I believe it will remain so until someone constructs, within the formalism of quantum mechanics, an "observer"; that is, a model entity whose states correspond to a recognizable caricature of conscious awareness* [49].

Other notable authors interpreting that physical reality requires consciousness to choose to do measurements in order to actualize states of reality include von Neumann [50], London and Bauer [51], Wigner [52], Stapp [53,54], and Penrose and Hameroff [55–59].

*Definitions*

Because discussions of consciousness are philosophical, it is necessary to establish the following definitions for key terms used in this document.

**Strange Loop**: A hierarchical structure that is wrapped back upon itself, where the simplest object is embedded in the whole or the most complex emergent part and where all parts depend upon all others and where the emergent whole is dependant upon the synergy of parts.

**Thought**: The process and result of choosing or creating meaning, where "meaning" is always a relationship.

**Meaning**: A relationship between two or more objects recognized or created by an entity capable of doing so. For example, if we think of the compound self-referential symbol of a square, we may recognize the relationship between two vertices as a meaning. However, if we think of the symbol of a heart, we may create, via relationship, the symbolic meaning of love, as opposed to recognizing some inherent self-referential meaning implied in the symbol of the heart. An entity capable of deciding that this is like that or this is like this is an entity capable of generating meaning, i.e., thought. Meaning can be recognition of inherent relationships or the creation or assignment of arbitrary ones.

**Object/Symbol**: Defined as in set theory, an object is anything that can be thought of. All objects are symbols because all thoughts are symbolic, i.e., have meaning.

**Symbolism**: A case where an entity capable of perceiving meaning relates or equates one object with another object—a relationship within thought, where X = anything; either itself or something else.

**Self-referential Symbolism**: A special case of symbolism, where an object represents or relates to itself; "this means this" or X = X. For example, one can use a square to self-referentially symbolize a square or its body diagonal to represent the number $\sqrt{2}$ or the quantity of vertices of a square to represent the quantity 4.

**Non-self-referential Symbolism**: A special case of symbolism, where an object represents or relates to something other than itself; "this means that" or $X =$ anything other than $X$.

**Mind/Conscious Entity/Consciousness**: A system capable of choosing to perceive and create meaning. For example, if one were to feed all thoughts or meaning into your mind, at the expense of you being able to choose your own thoughts, you would be a clone or mirror of their consciousness. According to our definition, the discretion to choose what to be aware of or what to think cannot be disassociated from the term consciousness.

**Information**: Symbolic meaning, which implies thought. Put differently, all thoughts can be reduced to symbolism in the mind of an entity capable of actualizing information. While this is a different notion than quantum information, our mathematical program (beyond the scope of this paper) is to find code theoretic simulations that lead to the emergence of quantum information.

**Emergent Physical Thought (EP)**: Information as self-referential symbolic thought (number and shape) that forms the basis of physical reality; spacetime and particles.

**Emergent Consciousness Thought (EC)**: Information as non-self-referential symbolic thought, such as freewill decision to observe, the sense of self, humor, etc. that forms the basis of consciousness reality emergent from physical reality in the strange loop.

**Code/Language**: A finite set of symbols with relational or ordering rules that include syntactical freedom. Codes may be used by entities capable of strategically exercising syntactical choices for the purpose of expressing meaning.

**Freewill/Choice**: A non-random and non-deterministic action or state that ontologically exists and that is a member of a set containing at least one other such possibility that does not ontologically exist because it has not been actioned, recognized, observed, thought, chosen, or any other suitable term that separates the subset from the super-set. Freewill or choice may be significantly influenced by other things/thoughts but not fully controlled. In order for the choice to be non-random and non-deterministic, there must be reason, strategy, whim, theory, or some other process of thought. Put differently, if the action occurs due to thoughts, it is by definition non-random and non-deterministic. It is sometimes suggested that freewill is an illusion and that everything is deterministic or that everything is a combination of determinism or randomness. While possible, it is far-fetched when one considers, for example, the idea that an Emily Dickson poem was a result of such a deterministic process combined with randomness, an accidental process. While reductio ad absurdum proofs are not strong, they can be instructive for choosing the lesser of evils when no good proof is available.

**Measure/Observe**: The choosing of symbolic meaning. For example, you observe an experiment and creatively generate, i.e., choose, meaning in your mind about the experience, which includes influence or interaction. The choice may be conscious or subconscious.

Interestingly, all 14 of the above terms are forms of "thought" in our ontology, wherein everything is thought.

## 2. The Self-Simulation Hypothesis

### 2.1. Axioms and Principle of Efficient Language

The self-simulation hypothesis (SSH) allows for an application of the *principle of efficient language* (PEL) [15]. The SSH is built upon the following axioms:

1. Reality, as a strange loop, is a code-based self-simulation in the mind of a panpsychic universal consciousness that emerges from itself via the information of code-based mathematical thought or self-referential symbolism plus emergent non-self-referential thought. Accordingly, reality is made of information called thought.
2. Non-local spacetime and particles are secondary or emergent from this code, which is itself a pre-spacetime thought within a self-emergent mind.
3. The panconsciousness has freewill to choose the code and make syntactical choices. Emergent lower levels of consciousness also make choices through observation that influence the code syntax choices of the panconsciousness.
4. The desire or decision of the panconscious reality is to generate as much meaning or information as possible for a minimal number of primitive thoughts, i.e., syntactical choices, which are mathematical operations at the pre-spacetime code level.

These four axioms can be briefly summarized by the notions of (1) the strange loop of the emergent self-simulation that includes (2) emergent spacetime, (3) emergent freewill sub-entities and (4) the PEL. The last axiom leads to an energetic model, where the behavioral statistics of the code are based on a least computational principle and where those statistics can change over the evolution of the self-simulation—depending upon what choosers decide what information/meaning the PEL should economized for. Due to this economy principle, the code used will be a member of the set of maximally economical codes capable of generating the physical reality we observe, such as a universe with particles possessing the spin and charge values shown in experiments. Here, "economy" is defined as the amount of consciousness-based resource used for the fundamental mathematical actions (thoughts) in the code for the purpose of expressing some chosen meaning, such as a particle's pattern of propagation through space and internal time. Accordingly, the SSH, which subsumes the PEL, is applicable to any code-theoretic quantum gravity theory that is a member of the most economical set of codes simulating reality.

The SSH is non-deterministic and yet posits that there are hidden variables or a sub-quantum mechanics that also define a quantum gravity theory, where spacetime and particles are patterns therein.

To work in an efficient manner, the panconsciousness breaks down all freewill choices into a binary decision tree, as this is the most efficient way to to express possibilities. This leads to a trivalent graph network. Quantum gravity as an effective quantum field theory has been riddled with infinity problems due to infinite graviton vertex diagrams. However, recent advances in scattering amplitude computations find that trivalent (cubic) graph representations lead to more efficient computations [60–62]. Similarly, Wolfram conjectures that reality is a cellular automata built upon an ideal trivalent graph code [9]. The *quasicrystalline spin network* [63–66], used in our program at Quantum Gravity Research, is a trivalent graph. A corollary of the PEL is, therefore, that the panconsciousness chooses a trivalent graph network because it is maximally economical for simulating quantum spacetime.

### 2.2. Information

Before elucidating the SSH, some pre-discussion about information, i.e., symbolism, is called for. The Copenhagen-like interpretations divide things into two ontological categories—unreal information and real physical "stuff"—which is an epistemological view. For example, the probability distribution of the wavefunction is considered unreal because it is merely information, while a measurement updates the wavefunction to a state more closely resembling the post-measurement physical reality and also actualizes some physical reality into existence—that part correlated to an observation. In other words, it defines realism as physical stuff and something unreal as information or abstractness. However, another popular view, digital physics, is that all of reality is made of information or abstractness, which Wheeler described as "it from bit". Since reality is real, they say information is real. Materialism is monism. Copenhagen is, in some sense, dualist because, unlike materialism, it places abstract information at a fundamental status in the form of the wavefunction, and thus it has the dualism of information and physical stuff playing two juxtaposed fundamental roles.

The SSH is monistic in that it views reality as information defined as thought. If the SSH were to suppose reality uses a wavefunction, it would say that both it and physicality are made of the same stuff—thought. It relies on the PEL, which posits that there are two fundamental forms of thought or symbolic information:

1. Self-referential symbolism that is part of a mathematical spacetime and particle code based on the thought of number and geometric symbols or pixels of spacetime information (the case of $X = X$)
2. Non-self-referential symbolism ($X =$ *anything other than* $X$, such as the thought of humor, love or a decision of purpose to observe/measure a physical system)

Unlike the Copenhagen interpretation and other ontologies assuming physical stuff to be the opposite of information or thought, the code theoretic ontology of the SSH traffics only in information or thought. Ontology is the study of what is real and what is not, so it is binary. The binary ontology of the materialism-based Copenhagen view is to say that information is unreal and physicality is real. We invert part of this. We set up our binary ontological system to be (See also [67]):

1. The unreal potential information as thought that could exist.
2. The information actualized by thought (by observers including the panconsciousness substrate) selected from the possibility space of nonexistent potential information.

For example, imagine thinking a thought that is so strange and complex you can assure yourself no thinker in the universe previously thought it. Before you thought of it, it was not actualized information. However, it was information that could have existed if you thought of it earlier. Accordingly, we have potential self-referential information that could exist if thought of. Furthermore, we have physical states that could exist as physical thought made of self-referential symbolism along with states that have been thought of by the universe through our observations and so do exist because thought of. We also have thoughts as a form of information that can influence measurements (e.g., decisions to measure) and, in so doing, influence the physical information via wavefunction collapse or something akin to it.

As discussed in [15,27] and following our definitions, symbols are objects of thought that represent themselves or something else. As mentioned, any symbol use fits into one of these two categories: $X = X$ and $X =$ *anything other than* $X$. The $X = X$ category is that of self-referential symbolism. This symbolic meaning is special because it possesses non-arbitrary or non-subjective truth. For example, via mathematical first principles, the numerical properties of a triangle, such as its area, may be deduced non-subjectively from the symbol itself. One may use an equilateral triangle to represent the meaning of itself—an equilateral triangle. In this case, the meaning of the symbol is not subjective. Alternatively, subjective meaning can be chosen for the triangle, such as the notion of change symbolized in physics by the triangular delta symbol. Quasicrystals can be created by projectively transforming self-referential symbols called Lie algebraic root lattices. Some of these lattices encode gauge symmetry physics via their associated Lie algebras. Our program of code theoretic based physics, derived from quasicrystalline root lattice transformations, is the $X = X$ case, i.e., self-referential symbolism. Unlike lattices or crystals, quasicrystals are self-referential symbolic codes, where their syntax rules are non-invented, i.e., are implied by mathematical first principles.

Languages, i.e., codes, are systems that have an irreducible class of symbol types called "letters" and syntactical rules. Users can steer the syntax degrees of freedom in choices of how to order of the symbols to create semantic form, i.e., meaning, that can exist in nested hierarchies of emergent symbolic meaning, including spatiotemporal or geometric meaning. Letters can be combined to form the emergent meaning of "words". Words can be combined to form the meaning of "sentences" and so on. One can recognize this as synergistic meaning, where the emergent meaning is greater than the sum of the irreducible symbols or letters and where no additional base symbols are needed for the extra synergistic meaning—only the strategic ordering of the symbols.

Our approach is to build a physical ontology based on a finite set of self-referential geometric symbols that map to formal algebras. We call this level of thought or information $i$, where the lower case represents the idea that it is base or letter-level information. Because it is a discrete spacetime code, our pixels of self-referential symbolism are shapes such as quasicrystalline prototiles or, alternatively, entire quasicrystal *inflation* [63,68] states. These geometric objects map to various isomorphisms and bijections in the form of mathematics that are not geometric. For a finite quasicrystal possibility space, there is a finite set of N different inflations that can be performed. This results in a superset of $N!$ possible ordered sets or dynamic patterns that can be generated from N. Quasicrystals are proper codes, which require freewill choices of syntactical degrees of freedom or code action to form meaningful expressions. Codes or languages do not organize themselves. They require action—the decision of a syntactical chooser—for the addition of each new symbol in a sequence. This is in contrast to crystals, which are not codes and where the positioning of one tile determines all others. With quasicrystals, "fundamental" particles may emerge as phason quasiparticles that can be created as ordered sets of inflations, wherein the order may be chosen by the panconsciousness as it gets "instructions" from its sub-part consciousnesses, e.g., humans, called observations/measurements.

How would such "instructions" from a human observer to the panconsciousness syntactical chooser occur? Clearly, we are suggesting mathematical actions that the panconsciousness operates that relate to the Planck scale, but humans are at the meter scale. We are not sure of the mechanism. On the one hand, we may presume that since the panconsciousness is a great mind and we are subminds of it, it knows our thoughts of observation as its own sub-thoughts. This should be true. However, perhaps it is also true that there is a deep mathematical connection between the panconsciousness substrate and our $EC$ thoughts to measure and think other things. After all, our thoughts emerge from Planck scale $EP$ information and up through higher-order spatiotemporal $EP$ physical symbolism, such as DNA and biological structure in a fully connected continuum. Penrose theorizes that there is an ideal Platonic substrate at the Planck quantum gravity scale that interacts through structures in our body called microtubules. He believes that there is a panconsciousness at the Planck scale that interacts with us through these structures in our body near the angstrom scale, according to he and Hammeroff's *orchestrated objective reduction* (Orch-OR) theory [55]. This is related to our quantum gravity program because of two similarities. The first is that our quasicrystalline mathematical substrate is built of 3D tiles based on the five Platonic solids, which we derive via rigorous means from the transformation of certain Lie algebraic root lattices. These structures include Fibonacci sequence numbers and various rational and irrational numbers useful for gauge symmetry physics. Accordingly, our mathematical formalism is built upon an ideal Platonic substrate. The second similarity is that microtubule structures encode Fibonacci numbers and are better described technically as quasicrystalline, not crystalline atomic motifs. Quasicrystalline mathematics, materials quasicrystal science, and the very term quasicrystal are arcane with fewer than 100 physicists and mathematicians funded to work full time in these areas. Microtubules behave as a binary code as implied by sequences of coherent patterns of charge sign value changes to their dimer substructures.

Paola Zizzi extended the Orch-OR framework into cosmology, using a quantum computational paradigm, showing how the universe became conscious at the end of the inflationary period [69]. Her view is different from ours in terms of how we use evolutionary biology, where we see evidence that consciousness has emerged in at least humans. We take this forward and assume that, just as simple lifeforms, as cells, self-organize collectively to exhibit emergent human consciousness, lifeforms such as humans can self-organize to exhibit collective emergent super-consciousness that is far greater than the sum of the parts. One can think of a human mind–body system as a percentage of spacetime and energy in the universe that self-organized to exhibit emergent consciousness. In principle, all spacetime and energy in the universe can self-organize to form an uber emergent consciousness. Accordingly, it seems that our process of explanation through evolutionary hierarchical processes may be able to converge mathematically with aspects of Penrose and Zizzi's views insofar as all of spacetime becoming a quantum net capable of thought. As opposed to our view, where, from our vantage point, panconsciousness emerges forward of us in the hierarchy we call "time", Zizzi's view is related to a universal consciousness emergence event in our "past" at the end of the inflationary period driven by "dark energy".

We believe that, until a predictive quantum gravity theory is discovered, it is premature to speculate on the nature of dark energy and matter. What we appreciate about Zizzi's idea is that reality itself can be a quantum net capable of quantum computation. In general, neither Penrose and Hammeroff nor Zizzi focus on topological quantum computation but instead on standard quantum computation. At low temperature, atomic quasicrystals are topological phases of matter. Mathematically, our Planck scale based quantum gravity program is based on topological quantum computing. Criticisms by Tegmark and others about Penrose's Orch-OR mathematics are often centered on the contention that microtubules in the human body cannot quantum compute to describe consciousness because the body is not at a low enough temperature. The high temperature leads, in these objections, to decoherence times that are too short for the Orch-OR model to make sense. Penrose and Hameroff have certain arguments to rebut this. However, one way to resolve it is to switch from the notion of quantum computing to topological quantum computing, which allows local thermally induced decoherence events without the destruction of the global quantum superposition state—the global qubit.

With respect to the collection of all ordered sets within the superset $N!$ mentioned above, it is a statistical possibility space with probabilities governed by an energetic scheme we use based on a least computation principle built into the PEL. As mentioned, our interpretation of QM is general and can be applied to other spacetime codes or code theoretic quantum gravity models. However, we use this quasicrystalline interpretation of reality as an illustrative example of the PEL, since our interpretation of QM is related to a class of quantum gravity models and axioms such as ours.

Computer simulations endowed with a random number generator to represent the non-determined choices to measure can implement a form of a *game of life*. A random number generator may select actions from a deterministic unitary evolution that weighs the selection probabilities of different orderings, i.e., phason quasiparticle random walks, via their computational economy for expressing paths of extremal action. The fundamental particles, as patterns emerging from self-referential geometric symbols, such as 3-simplices, are themselves emergent self-referential spatiotemporal symbols built of simpler symbols that reduce to on/off states of 0-simplices (points) in the possibility pointset that we build our graph actions on. This discrete point set and the internal structure of the quasiparticles are made of such geometric self-referential symbolism, which encode both fundamental and emergent numerical values. Similarly, higher-order emergent spatiotemporal patterns emerging from these, such as "atoms" and "molecules", are also self-referential symbols or what we call *emergent physical symbols*, but where our physicalism is information/thought-theoretic. Because the possibility space is discrete, the degrees of freedom are finite, i.e., the random walks such quasiparticles can take are of a finite quantity of possibilities. These emergent strata of higher-order physical symbolism above the level of $i$ are ranked in terms of compound complexity.

Tononi et al. have a similar idea for a ranked complexity measure, where, at some critical magnitude, the complexity can be defined as consciousness or thinking. His approach is called *integrated information theory* (IIT) [70–72]. IIT posits that many physical systems intrinsically possess consciousness, which, in this context, is defined as a measure of a subsystem's ability to affect the rest of the system, i.e., causal reality [72]. His notion of consciousness and freewill is comparable to ours in the sense that a highly conscious entity would be able to make more freewill choices, which increases its ability to influence the syntactical degrees of freedom in the code. In this sense, the emergent consciousness of the universe—the simulation substrate—would be the most conscious entity. However, subsystems of this conscious mind may emerge within the self-simulation and possess consciousness once such subsystems become complex enough to create meaning, i.e., observe or think. Such perceived meaning of a subsystem is also a perceived meaning of the panconscious substrate and so is a form of distributed workload of choice actions to think, i.e., generate meaning/information.

This connectivity of our consciousness to the substrate instructs the panconsciousness to make fine grained mathematical code choices that comport with our more coarse-grained thoughts called observations. In other words, there are a large number of different choices of mathematical action at the quantum gravity level that the panconsciousness can choose from in order to map to a given approximate experience of an observation that a human or other thinking entity does, thus we provide: (1) the instructions for when the panconsciousness does a mathematical choice/thought/action; and (2) a coarse-grained constraint on what those choices can be in order to equate with the meaning we thought of in the form of the observation itself.

Our approach is different from IIT insofar as using language theory, where we see a nested hierarchy of code-theoretic information referred to as $EP_1$, $EP_2$, $EP_3$, …, $EP_N$, with $EP$ standing for *emergent physical* information. Since $EP$ or physical information is geometric and numeric, and therefore non-subjective, all forms of higher-order $EP$ are emerging from base-level self-referential symbols. However, not all self-referential symbols need to be EP, since we can think in our minds of $EP$ objects such as triangles without it existing as physical information. The different levels represent different strata of complexity emerging from simpler strata in the same sense that a molecule is emerging from atoms, which are emerging from fundamental particles, which may be emerging from self-referential geometric symbolic Planck units of spacetime information/thought. To account for all information, we must sum the total amount of $i$, which, in our case, is the quantity of on/off state selections in the quasicrystal inflation possibility point space, with the sum of total information in the emergent hierarchy of $EP_N$. Physicists are generally trained to think only in terms of base or $EP_1$ information, such as spin states. Accordingly, an analogy would be helpful to emphasize the informational power of higher-order or emergent information.

Consider a book with $N$ letters and randomize them. If we have a value of 1 unit for the meaning or information of each letter, the magnitude of $i = N$ units. We notate the total information of the system as $I$. In this case of random ordering of $i$, we have that $i = I$. However, if we allow the letters to be organized into words, we have more information than $N$. It is not easy to agree on the magnitudes of the emergent information. However, at the same time, it cannot be ignored because the emergent information in a complex physical system is statistically causal on all parts of the system in a force-like manner, as with the notion of *entropic force* [73] or Tononi's notion of complex system information influencing the behavior of the system. For example, we may randomize the letters in a string of DNA code, which leaves only the information of the sum of the molecular letters. However, if we allow them to be ordered in a meaningful way, they encode a protein folding algorithm, which is an immense statistically causal package of information influencing lower entropy systems that surround it that must be credited with some unknown value of causal information that is over and above the sum of the letters. Accordingly, we have

$$I = i + EP_1 + EP_2 + \cdots + EP_N. \tag{1}$$

In this notation, $EP_{j+1}$ denotes the additional emergent information in relation to the synergistic meaning created from combining multiple elements of $EP_j$.

At some point in the nested $EP$ hierarchy of this emergent physical information, something enigmatic occurs that may be related to something very similar to the Orch-OR model. Consciousness emerges from the regime of $EP$ to form a new system of information that is itself unbounded in possibilities over a finite set of $EP$ based $i$. Let us call this regime $EC$ for *emergent consciousness*-based information, i.e., non-self-referential thought. As mentioned, all non-self-referential symbols are forms of EC, but $EC$ may also include non-physical self-referential symbols, such as the thought of a square. We propose that $EC$ also exists in a nested stratification of $EC_1, EC_2, EC_3, \ldots, EC_M$, each built upon previous strata in the hierarchical stack. This regime is capable of generating additional information over and above the emergent physical $EP$ information. We argue that the potential of its possibilities is infinite, as it is the universe of all things which can be thought of. Since all forms of emergent information must fit in one of these meta-categories, $EP$ or $EC$, we have that

$$I = i + EP_1 + EP_2 + \cdots + EP_N + EC_1 + EC_2 + \cdots + EC_M, \tag{2}$$

for the total system information $I$. Again, the $EP$ physical information is self-referential geometric and numerical symbolism, such as spacetime quanta with quasiparticle patterns representing fundamental particles with their quantum numbers, spacetime quanta geometric numerical values, and the statistical numerical values relating to the economy rule of the PEL.

To appreciate the scientific importance of the $EC$ enigma, we reference some unresolved problems and some experiments. First, there is no consensus on the definition of "consciousness". Thus, herein, we mean the definition we provided in the definitions section, which reduces down to thought or meaning. One might think issues of consciousness are solely the purview of psychologists and philosophers, as opposed to physicists. A second problem is the measurement problem, which relates to the difficulty of reconciling the completeness of the wavefunction, linear evolution, and the Born rule with respect to measurements. If consciousness relates to measurement, then consciousness is relevant for quantum mechanics. The third problem is the question of how consciousness emerges from things that are not conscious. This is called the *hard problem of consciousness* [74,75]. The SSH starts with the notion that consciousness is fundamental and self-emerges as a strange loop in a cosmological holism ontology that requires abandoning the idea that time is fundamental or even real.

The SSH is novel in how we use the $EP$ information of numerical and geometric mathematical thought to create high-order compound $EP$ physical thought that evolves to $EC$ thought eventually capable of self-actualizing itself in one grand thought that is itself the strange loop $i \rightarrow EP \rightarrow EC \rightarrow i \rightarrow EP \rightarrow EC \rightarrow \ldots$, where $i$, $EP$, and $EC$ are part of the overall self-simulation thought. However, unlike other attempts to resolve the last two problems above by saying panconsciousness is the ground of reality without explaining how it emerges or why consciousness would influence physical things, such as collapsing wavefunctions, our approach goes further by providing an origin explanation for panconsciousness that, similar to humans, can think in both the $EP$ and $EC$ regimes.

The empirical evidence is that physical systems change when conscious minds choose to observe them. This is reminiscent of how a video game player with a VR headset has a relationship with the code processing computer, where she instructs the CPU and GPU to compute and render simulation landscapes according to what she observes. For the most part, it is the physical evidence for and the inexplicability of observers changing physical reality which leads to all of the interpretations of QM, such as the Copenhagen version. These interpretations, whether they call it "observer" or "consciousness", often place measurement in the role of collapsing wavefunctions (or decoherence), as evidenced, for example, by the change to the interference pattern in a double slit experiment. Simply having knowledge of which slit a photon goes through dramatically changes the physical system.

At early stages of 20th century physics, there was more debate about whether it was the conscious knowledge of the observer or some physical interaction within the experimental apparatus, such as in the detector, that caused the physical changes in the interference pattern. However, as experimental physics and discussion advanced, it became more widely agreed that it is consciousness, i.e., knowledge or thought about the measurement that generates the physical change and not a physical interaction between an artificial or biological detector and system being observed. Our model implies that, if a consciousness were to somehow be able to have awareness of a physical system without using ordinary means, such as photons or sound, that it would collapse wavefunctions without need of any form of physical detector. Radin et al. reported evidence of this, showing a 4.4 sigma deviation above the null effect [76–78]. Tremblay independently analyzed the results to confirm the statistical significance but also identified lesser magnitude statistical anomalies in the control data [79]. The implication of our model would caution that even the control data might be contaminated by EC-thought based human influence. This is because the entire experiment should be permeated by opinions and thought about the meaning of the endeavor, even the control aspect but with a less focused or less potent degree of statistical modulation from the baseline statistics of QM.

Semantic confusion can enter these discussions. For example, we used certain words above emphasizing the term "consciousness". Other authors use terms such as "measure" and "observe". However, these terms are inextricably linked with words such as "awareness", "knowledge", "consciousness", and "thought". For some Copenhagen-like interpretations of quantum mechanics, at some point of demarcation in a self-organizing system, such as a human, consciousness emerges, which is capable of collapsing the quantum wavefunction and changing physical systems via awareness or knowledge from and about observations [53,80]. This seemingly mystical phase transition is often referred to as the *Heisenberg cut*. For us, the thinking needs to be able to create $EC$ information, which requires an emergent mind capable of abstraction. We believe the most sophisticated and plausible mechanism to date for the Heisenberg cut is the Penrose and Hameroff view.

In conclusion of this section, the hierarchical stratification of our $EP$ and $EC$ information does not allow for a limit on the magnitude of total $I$ that a system can have because the $EC$ information possibility space is unbounded. The SSH resolves the measurement problem by showing that codes use choosers of syntactical freedom. Choices themselves are thoughts, thus there are choices being made by emergent entities, such as humans, that generate $EP$ and $EC$. Stephen Hawking asked: "What is it that breathes fire into the equations and makes a universe for them to describe?" The SSH posits that it is observers that animate the syntax expressions of the code, which then map to the statistical equations of a post-quantum mechanical quantum gravity formalism that includes a set of gauge symmetry equations. In this sense, the foundational thought is the observation choice thought/action, which maps to mathematical choices corresponding to quantum gravity code syntax choices, that is the irreducible building-block thoughtform of the universe. When such choices are made to observe and think about physical systems, this generated thought informs the panconsciousness of the meaning created by observation, which defines the degrees of freedom for mathematical choices it can make at the spacetime code level.

The SSH resolves the hard problem more weakly than the Orch-OR model by recognizing that consciousness, i.e., information or thought, is the only thing that exists but without disagreeing with the basic premise of Orch-OR. However, it does this in a very different manner than typical idealist panconsciousness approaches, which say "Consciousness just is". The SSH offers an explanation for how consciousness comes to exist via self-emergence through the logical strange loop of the $i \rightarrow EP \rightarrow EC \rightarrow i \rightarrow EP \rightarrow EC \rightarrow \ldots$ simulation, where we do not need to say that consciousness "just is". There is an origin story. The panconsciousness requires the thought of physical mathematical symbolism to self-emerge from. This is because only through simple-to-complex information or language theoretic structure can the free bonus information or synergy of emergent information exist, where the whole is greater than the sum of the parts. In the universe of all thoughts, mathematical information may be the simplest of all. For example, an object is a thought, and the simplest object is either the empty set or dimensionless point, depending upon how one argues it. Thus, the grand self-simulation thought is a nested hierarchy of thoughts, mostly of the synergistic emergent form, starting with the dimensionless point, in a state of on, off, or undecided, and ending with the thought of the entire self-simulation thought, which is equal to the panconsciousness substrate itself.

### *2.3. Nonlocality of the Self-Simulation*

At its deepest level, we interpret the measurement problem as being related to questions of how consciousness can perform measurements. It should be noted that decoherence is not the same as wavefunction collapse. Quantum systems in nature can decohere without measurement because non-measurement based decoherences exist in the unitary evolution of off equilibrium systems that are not perfectly isolated. In some systems near a tipping point of decoherence, a measurement can change the physical system enough to cause it to decohere. It is difficult to imagine having a completely satisfying explanation for the measurement problem without a consensus definition of consciousness.

We know that consciousness is thought and awareness and the other terms in the definition section that are equivalent to thought. However, we still cannot deeply explain consciousness other than our experience of it and recognition of its synonyms.

The *simulation hypothesis* proposes that reality could be a computer simulation, which implies it is made of code [1]. Physicists Beane, Davoudi, and Savage propose this can be experimentally constrained [81]. Simulations typically run with a finite number of resources. This may be accomplished by discretization of spacetime, as in several quantum gravity theories, such as ours (emergence theory). One of the proposed experimental signatures to look for would be an anisotropy in the distribution of cosmic rays that is consistent with the simulation hypothesis. Campbell et al. have proposed experimental tests for the simulation hypothesis [82]. These same tests could be applied to the SSH if it turns out these experiments suggest that we are in a simulation.

Again, the simulation hypothesis is based on the dualistic idea that there is a physical reality and various non-physical or information theoretic simulated realities. The SSH rejects this dualism and suggests that it is more probable that we are in a mental self-simulated universe, which may be less far-fetched than the idea that we are in a simulation living in a different physical universe. One reason is Occam's razor and another is evidence. Specifically, in [14,15,27], one of the authors discusses a cosmology that allows for a code-theoretic universe to self-simulate or self-actualize itself into existence from the "future". A similar cosmology was discussed by [17]. Consciousness that emerges at late stages of the self-simulation eventually evolves to a magnitude sufficient to hold, abstractly in pure informational thought space, the quantum gravity code necessary for its own self-simulation run or self-evolution starting at the big bang. This strange loop is similar to a mind running a simulation from an initial condition and where that simulation becomes the mind itself after a long run-time. Of course, the self-simulation idea requires time to be an emergent illusion, as discussed by Rovelli [29] and in different terms by Susskind and Maldacena [83].

Advanced waves have been interpreted as being related to consciousness or measurement in multiple QM interpretations. Aharonov was inspired by Feynman to create an independent advanced wavefunction, leading to the two-state vector formalism [25,84]. This is also compatible with the transactional, many worlds and Bohmian interpretations. Sutherland has generalized Bohmian mechanics, which leads to a notion of post-quantum mechanics and introduces new nonlocal dynamics [85,86]. The evidence for non-locality is sufficient enough to presume spacetime, whether fundamental or not, is non-local [87–90].

Accordingly, we may adopt a physical logic: A influences B influences C influences A influences B, and so on. That is, an emergent mind-like substrate of the universe in the future can self-actualize itself by creating the code and initial conditions to run its own simulation—all within the abstraction of pure self-simulated information in the form of choice, observation or awareness as a strange loop with hierarchical order but not time. We may think of this with time and presume it to be non-local or presume time to be illusionary, emergent or non-fundamental. The substrate, then, is made of information called thought or consciousness. Its evolutionary self-simulation run is also made of the same abstract information, i.e., *meaning* within thought or mind-stuff [12,32–34,36,91–93]. Sarfatti's interpretation of Sutherland's extension of Bohmian mechanics [94] suggests that the wavefunction is itself a property of consciousness, while the particle is the domain of material reality. In this dualistic view, dividing reality between physical stuff and consciousness, advanced waves allow for consciousness to have new retrocausal dynamics on the physical stuff. From this perspective, consciousness of the future can influence the past so long as freewill is not violated.

Our view is similar to Sarfatti's interpretation, except that we do not take a Bohmian approach and divide things into physical stuff and consciousness. It is all information in the self-actualized strange loop of panconsciousness, where the physical information is *EP* thought and the non-physical information is *EC* thought. Our approach is also different in that we subscribe to a discretized spacetime view. Bohmian mechanics does not.

It is noteworthy that if the large scale causal structure of the universe is a strange loop, instead of having some beginning for which we have no explanation, then perhaps there would be empirical implications, which may ultimately be observed.

With this ontological background in place, let us discuss the regime of *EC* information. When we think of the idea of love or politics, is this self-referential symbolism? Is it information? Of course, these are not cases of self-referential symbolism. However, they are indeed two networks of compound information. These packages are not physical information, such as the self-referential geometric information of the base-code elements in the simulation that can be organized into emergent levels of self-referential *EP*, e.g. a biosphere or solar system. However, *EC* is equally as real and causal as *EP* information and so must be considered part of the universe's total information along with i and the regime of *EP*. Each conserved stratum of *EP* information is built upon the conserved strata under it. To be more precise, the choices of *EP* configuration are conserved over a finite simulation run time because the degrees of freedom in a discrete possibility space-based code, such as ours, are finite. There are a finite number of possible animations or ordered sets of on/off state selections on the finite quasicrystal possibility space. The quantum states therefore exist in a finite-dimensional space.

This is not the case for the possibility space of *EC* information that can be created over a finite simulation run. The *EC* category is the regime of non-self-referential symbolism, where we can say $X =$ *anything other than* $X$, and where both $X$ and *anything other than* $X$ are members of the set *anything which can be thought of*. Put simply, we may think about anything from an infinite set of things to create in our mind. Again, in an information only universe, this form of *EC* information—thoughts—is equally as real and influential as the self-referential physical information that the universal consciousness self-simulation substrate can hold. Thus, the regime of *EP* possibilities is a set of selections or relationships in a finite possibility space. It is discrete and may lead to a quantum gravity formalism with a discretized probability density distribution. The regime of *EC* possibilities is the infinite set of all possible symbolic relationships and combinations thereof, i.e., meaning that one can choose to think of from the infinite universe of possible thoughts. Unlike the *EP* space, the *EC* possibility space is smooth and continuous—infinite. Sequential choices in the regime of thought or consciousness of what and when to measure create reality by coding a concatenation network of wavefunction collapses—forming a completely different universe than the highest probability path(s) through the unitary evolution if no measurements had occurred. It creates a network of short-lived unitary evolutions between measurements defined by the freewill choices of conscious entities to strategically order sequences of measurements. A measurement itself is a thought in the mind of the observer, which prematurely kills off or terminates the deterministic unitary evolution that existed prior to the measurement and after the last measurement by creating a new function that will live until the next observation and thought about it. All functions exist in the possibilities of the Hilbert space. The choices of when, where, and what to measure are *EC* thoughts that can be chosen to change the unitary evolution of the *EP* information.

As shown in Figure 1, conscious humans are part physical information (made of the numerical and geometric spatiotemporal information/thought in the *EP* regime) and part abstract non-self-referential symbolic thought from the *EC* regime. The commonalities between the *EP* and *EC* regimes include the following:

1. They are both mutually dependent upon one another for their origin and existence. They each interact with one another.
2. They are both made of pure symbolic information in a language-theoretic informational paradigm, where relationships between two or more symbols of meaning at one stratum form synergistic meaning, and therefore higher-order symbols of meaning that form a new higher-order symbolic stratum.

In order for the SSH to be causally consistent, *EC* must emerge to be complex enough to allow for a self-simulation. This is what allows for the completion of the causal circle or emergent whole.

If $EC$ were to never emerge, the system would never gain any consciousness, and the SSH would be illogical. Relativistic time as we know it is irrelevant in relation to the panconsciousness because the self-simulation strange loop is created as a whole or grand thought, which, from a wavefunction perspective, includes advanced and retarded waves. Since the self-simulation requires emergent consciousness to run in the first place, this makes the likelihood of emergent life to be inevitable. Driven by the PEL, the panconsciousness can send advanced waves that encourage emergent structures, such that additional observers can emerge.

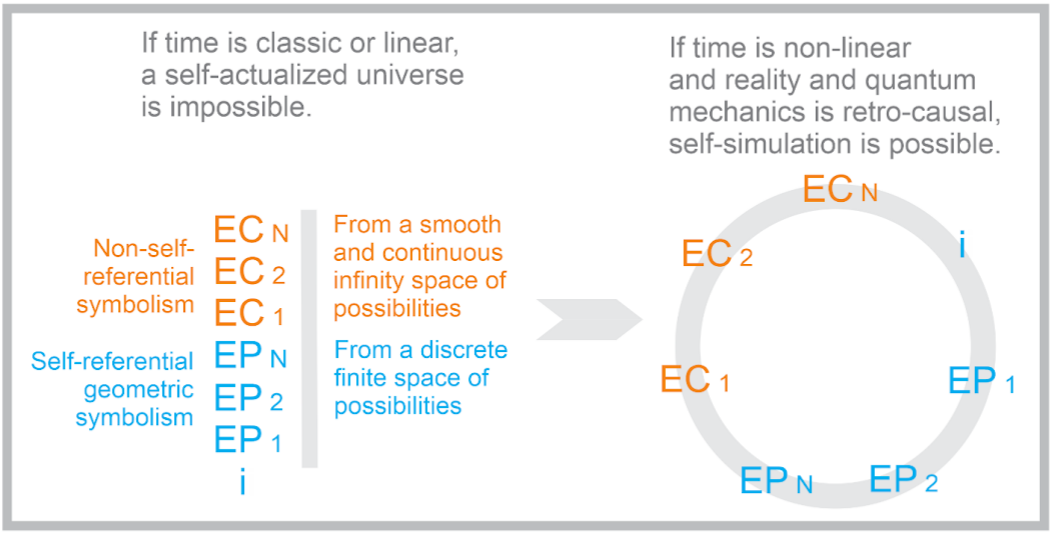


**Figure 1.** Self-Simulated Universe: Humans are near the point of demarcation, where $EC$ or thinking matter emerges into the choice-sphere of the infinite set of possibilities of thought, $EC_\infty$. Beyond the human level, physics allows for larger and more powerful networks that are also conscious. At some stage of the simulation run, a conscious $EC$ system emerges that is capable of acting as the substrate for the primitive spacetime code, its initial conditions, as mathematical thought, and simulation run, as a thought, to self-actualize itself. Linear time would not permit this logic, but non-linear time does. Furthermore, rejecting the conjecture of time and seeing it as an illusionary aspect of our perception permits it. This model may be more scientifically satisfying than the materialist statement, "Mass, energy and spacetime *just are* without explanation". Here, we may ask: "Where does the mind-like universal substrate of self-simulation thought come from?" We get a scientifically satisfying answer or at least a logically consistent one. It emerges, just as human consciousness did from simpler thoughts. Even without knowing exactly how, we need not accept that it just magically appeared. We can ask: "Where did the Planck scale information theoretic $EP$ building blocks come from and where do they live?" In our view, they are information in a simulation run in the mind of the emergent panconscious universe—the self-emergent substrate as a strange loop.

Of course, there are systems in the $EP_1$ regime of fundamental particles, such as a rock, that do not contain meaningful $EC$ information. There can also be emergent consciousnesses in the $EC$ regime that, unlike humans, are not partially in $EP$ and $EC$. For example, coherent patterns of pure $EC$ information can allow the emergence of higher-order collective consciousnesses that is not at the level of the panconsciousness but that is, in some sense, a higher level than human animal-level consciousness. Furthermore, there can be coherent patterns of mathematical information, such as topological information, at the quantum gravity regime that can be understood as consciousness but which is not made of fundamental particles. There may be topological consciousnesses that can emerge that are trans-temporal in nature, which, of course, would be an entirely different form of thought than we are familiar with. However, the $EP$ and $EC$ regimes cannot be disassociated, since the hierarchical stack of information based symbolic systems is interactive, non-locally connected and self-embedded.

As mentioned, this model posits that our consciousness instructs the panconsciousness to project the wavefunction to a new state upon measurement. Our thesis does not imply that the panconsciousness must always follow what we currently label as the laws of physics or QM. If this were true , it would be something that can be tested for using humans who envision things that violate physics or influence the statistics of QM [76–78]. Because emergent conscious entities, such as us, instruct the panconsciousness substrate to perform mathematical operations in the $EP$ regime that comport with our $EC$ thoughts about our surroundings or things non-local to us, such violations of canonical physical theories appear to be allowed.

Other than the consciousness activated collapse of the wavefunction, there is another way to recognize how $EC$ or consciousness is physically causal. The following thought experiment is instructive. Consider a system of particles that is organized as a conscious human at the bottom of a deep energy well, such as the base of a mountain. The human may create an abstract story in her mind that climbing out of the energy well every day is a good and strategic thing to do. Only because of that abstract belief and choice, living in pure $EC$, the probability for all the particles of her body to do this each day will be close to 100%. Quantum statistics would never predict this because it is not the statistics of the behavior of conscious systems. Consciousness, via observation, is what kills off the deterministic unitary evolution of the wavefunction in a manner not described by the Schrodinger equation. QM merely describes statistical fluctuations that lead to emergent classical conservation laws. QM discusses statistical dynamics between measurements. Consciousness determines a process of sequential measurements via self-reflection and external observation.

On the other hand, we can imagine a woman at the bottom of the hill being devoid of consciousness, such as with a brain-dead state but with all the particles in her body in the same states as when she was not brain-dead. In this case, devoid of consciousness, the probability of her climbing a macroscopic hill approaches zero and reproduces the statistics of classical mechanics, as she does not have enough consciousness to influence causal reality via free will to expel energy. That is, the evolution of her system would follow the unitary evolution of a wavefunction, where the probability to go up the hill would comport with QM and be very close to zero.

It is trivially true that freewill or the conscious ability to choose to go against the statistics of classical and quantum physics is a fact relating to some unknown foundation beyond QM. Consciousness causes a deviation from the statistics as a type of non-ergodic causal entropic force. For example, the desire for a human to experience novelty may affect the statistics to prefer a less likely path and motivate her to climb a mountain. This claim is also supported by the fact that the canonical interpretations of QM hold a special place for consciousness insofar as it uniquely being capable of actualizing reality into existence from a non-real space of quantum possibilities into the space of physical realism.

## 3. Informational Arrow of Time Based on Measurement

One can think, at time-1, of the idea of a person leaving their home. At time-2, they can think of the person moving from there to a store. These are two thoughts. However, if one did not accept the idea of time, they can think of a single thought as an ordered set of elements in pure information or thought space. The total information of the ordered set is a single thought or object without need for time but relying on order or pattern to express the information formerly labeled as "time". For convenience of language, we use terms such as "first", "then", "before", "after", and so on. Here, those terms mean the notion of "order within a set", where the set is the self-simulation thought of the universe. For example, one can watch a movie and have the laser reading head of their DVD player relate to each bit on the disc one moment at a time in an ordered set. Conversely, one may look at all the bits in one moment with no notion of a flow of time. In either case, there is order in the set of bits.

Keeping in mind how we use "first" above in the thought of the person leaving their home, the SSH stipulates that the "first" measurement, i.e., thought, is by the emergent panconsciousness substrate. It chooses the thought of the mathematical code, quasiparticle construction, a function corresponding to the initial variables, and other mathematical thought necessary for the total thought of the self-simulation "before" the measuring sub-thinkers such as us take the load of choice actions in a form of distributed computing or distributed thinking.

To simplify, let us focus on the idea of a function. By way of metaphor, consider the Mandelbrot set fractal and a quadratic map that could create it with enough computational resources. The fractal and the quadratic map are different objects. The second object, as a primitive algorithm, is a much simpler thought than the first. That is, more symbolism and mathematical operations are necessary to create the first object than the second. One possesses more information and takes more thought than the other. There is a class of functions that describe objects such as series. Some of these functions allow one to access the $n$th element of a series without knowing the $n-1$ preceding elements. One example is the Binet formula $fb(n)$ that allows one to know the $n$th Fibonacci number without knowing any of the earlier ones,

$$fb(n) = \frac{(1+\sqrt{5})^n - (1-\sqrt{5})^n}{2^n\sqrt{5}}. \tag{3}$$

The unitary evolution of the wavefunction gives, for example, the probabilities for measuring a particle's position at time-2, time-3, and so on. We may take the position coordinates for each time and order them by probability magnitude in a column. We can do the same for time-2, time-3, and so on to create a table. Each row of the table would be a series of complex values. The key here is that, according to QM, the series has order and is not random. For example, it is known that the spectral lines of the hydrogen atom have quasiperiodic order. Our emergence theory quantum gravity formalism has probability tables such as this. However, the statistics emerge from the Fibonacci number-based underlying mathematics that we derive via the transformation of Lie algebraic root lattices. We are currently exploring functions and algorithms that will allow us to "dial in"to one column in the table without having to calculate all the other columns. Herein, let us call this function $F_n$.

Let us return to the idea of the initial thought about the starting mathematics of the simulation. Let us call this $F_n$, where the function is not the same object as the table or information of the unitary evolution. It is exceedingly simpler thought/information. Based on the initial conditions as variables to the function that define it as being $F_n$ and not $F_m$, we have at some evolution of the non-computed function a high probability for a measuring or computing entity to emerge, just as we have in the ordinary quantum formalism with a single universal wavefunction expressing a deterministic unitary evolution from the big bang to the first computing or measuring entity.

Early in the series corresponding to this function, the quality of order in the unreal possibility space described a universe too hot for life to form. That is, the probabilities for a measuring/computing entity—a thinker—were very low. Somewhere in the unitary evolution, the first measuring life statistically appeared at the $N$th column of the aforementioned table with a high probability for existing. The first measurement occurred; the first moment of conscious awareness in the super-thought of self-simulation as a strange loop. However, we must be careful here to think about what this means with our $EP$ and $EC$ labeling scheme. What was created, $EP$ or $EC$, or both? What was the nature of the $EP$ information? Measuring entities create coarse grained $EP$ and more fine-grained $EC$ information. For example, when we do a position measurement, we are creating numbers and geometry. We elaborate. First let us return to the previous idea of self-referential symbolism. We used examples in geometry, such as a triangle representing a triangle. However, numbers are also an example. There is self-referential non-subjective truth in the idea of a square's body diagonal being $\sqrt{2}$ of its edge length. There is also non-subjective truth in the number 5 being prime or the factorial set combinatorics of the number 120. As mentioned, our previous work elaborated on the notion of self-referential numerical symbols called simplex-integers.

Again, when we do a position measurement, we are doing very coarse-grained measurements of numbers and geometry. Presuming Planck time and volume pixelization of spacetime, our position measurement creates some of the $EP$ information in the form of number and geometry that is a spread of positions in a geometric coordinate space, since we do not have the ability at this stage to do position measurements with Planck scale resolution. We are also spreading this over the geometry of ordered sets of spatial selections that we call "time" because we do not have time based resolution finer than the attosecond level. This same measurement "blur" we create as real geometric *EP* information is associated with pure numerical *EP* numbers, as probabilities, attached to each of the various geometric coordinate values in the blur that we call a position measurement. Put differently, our notion of a position measurement is really a statistical spread in a region of spacetime that is far smaller than our assumptions of where the particle might be prior to the second measurement based upon the prior measurement that we extrapolate from. In addition to the *EP* information, the observer may generate some non-self-referential information or story about the experience of measurement, such as "beauty" or an idea related to some physical theory the observer holds in their mind.

When we consider the aforementioned table of rows and columns, we can understand that a column correlates to a "random walk" for a particle, where the column itself is not in a single Planck moment. It is a short animation that we can call the random walk and the column has the probabilities for all such random walk animations at that coarse-grained level of time we are measuring at. Each box on the column is a brief animation or ordered set that describes a given minimal random walk and its statistical probabilities, which map to how many computational actions are needed for that minimal walk. A walk of distance X may take more or less computational actions than another walk of distance X. Let us say that the quantity of boxes on the column prior to the measurement is N. Next, we have the measurement. As explained, the *EP* level measurement information that is created is not precise down to the Planck level. Accordingly, it is smeared out in a blur of uncertainty. However, it is not as smeared out as the probability distribution prior to the measurement. The measurement can be interpreted in this framework as lensing or concentrating the probabilities into a much smaller set of squares in the column, such that most of the previous squares now have zero probability values and where the remaining squares have much higher probabilities than if no measurement occurred to define the approximate time and space resolution of information created by the observer.

According to the PEL, the panconsciousness substrate would have to have a reason for computing or simulating a precise position and time value down to the Planck level. The SSH view is that the panconsciousness, as an emergent consciousness, leaves the heavy lifting of new thoughts to the conscious measuring entities within it. That is, its emergent consciousness grows on the substrate of the network of all conscious thoughts of *EP* and *EC* within it. However, after this first course grained measuring entity does this very first measurement, additional measuring entities emerge. Today, we have 7.7 billion human measuring entities on Earth and it should be true that many other living things on this planet, at least, can also measure to create *EP* information, even if they are not generating as much *EC* information as humans are. We can see now that we have an informational "arrow of time" or pattern in the ordered set. More measuring entities create more total information. In addition, the quality of measurement can increase. A human has a conscious moment of awareness about once every $10^{41}$ Planck moments. However, in principle, this frequency can greatly increase with evolution, especially with artificial evolution via technologies such as CRISPR gene editing. We can see here a picture in our table, where the density of contracted or probability lensed columns is increasing, as the quantity of measuring entities increases. We can also see that the resolution toward the Planck scale of space and time can improve, which increases the degree to which a column is probability lensed. The limit of contraction for a given column is measurement at the Planck scale of time and space that lenses the probabilities onto a single box, leaving the other boxes with zeros. The evolutionary nature of the SSH implies that the magnitude of *EP* and *EC* information increases exponentially as one goes deeper into the ordered set of the self-simulation super-thought of the universe. It has appeared enigmatic to some as to why there seems to be a sense of directionality or flow to the experience we call "time", considering the equations of canonical physics are generally time reversible. This evolutionary view of increasing information is certainly one aspect of empirical observation. We see a universe starting with a quark gluon plasma with low degrees of complex information in the *EP* regime to a more complex universe of hydrogen atoms to a universe with over 100 elements to solar systems, biospheres, DNA, and up through massive amounts of $EC$ information being generated by mankind at this stage. This observed directionality of complexity is the informational arrow of time, where the term information is not restricted to quantum information, i.e., $EP_1$.

One form of this complexity is measuring entities. Some readers may wonder what happens in this self-simulation picture when measuring entities become so numerous and can measure at the Planck scale, such that all columns are collapsed to single boxes. Would the simulation end because no further choices can be made via measurement? Would that imply a "game reset" reset for another simulation run? Of course, if the answer is "yes" to both, the SSH would imply a cyclic cosmology model. For now, we would answer this question with the response, "Perhaps". Our model is at a mid-level stage of development, and our focus at this time is on reproducing quantum statistics from first principles and deriving gauge symmetry equations for a new quantum gravity and particle physics model.

*A Free Energy Principle from the PEL*

The emergence of biological life and its ability to preserve nonequilibrium states has puzzled many. Schrodinger introduced a term called negative entropy [95], which was later shortened to negentropy. Later, Schrodinger explained how he was actually referring to free energy. Entropy maximization corresponds to free energy minimization. While there is a notion of thermodynamic entropy and thermodynamic free energy, it has been realized for roughly a century that the total entropy includes information entropy, suggesting the same holds true for free energy. Friston introduced a free energy principle in the field of neuroscience as a mechanism to have complex biological systems preserve a nonequilibrium thermodynamical state [96]. Friston's free energy principle includes a free energy function of the internal state of a biological system that makes decisions of belief about its environment. It essentially states that life attempts to model reality and minimize the difference between its mental model and reality.

Considering our notion of $EP$ and $EC$, it is plausible that the thermodynamic free energy principle and Friston's free energy principle can be combined into a single free energy principle based on $I$. The emergence of intelligent life can be thought of as an equilibration of consciousness. Initially in the timeless strange loop, the panconsciousness is highly conscious, yet the emergent information is not very conscious. In other words, the panconsciousness is modeling itself by spreading its consciousness and free will nonlocally in a manner reminiscent of distributed computing or decision making. The emergence of $EC$ and more intelligent life may allow for physical information to stay in non-equilibrium states because the emergence of additional consciousness is also part of the equation.

There are a few self-consistencies in assuming that $EC$ relates to Friston's free energy principle. $EC$ has been related to the measurement problem. In order to talk about Friston's principle, a complex biological system must model reality, which is a type of quantum measurement. Friston's principle seems to implicitly motivate the evolution of consciousness, as more highly conscious entities and greater quantities of such entities would be able to more accurately model reality at ever finer resolutions relative to the *pixelation* at the Planck scale. Friston's free energy principle has been connected to consciousness [97], although they do not adopt our nuanced panpsychic view. Connecting $EC$ to Friston's free energy principle may be helpful for the development of a mathematical formulation of consciousness in terms of variational Bayesian methods.

From the perspective of the panconsciousness as the largest source of EC, it would prefer to model itself with increasing accuracy. To do this efficiently, it helps to provide EP, which is more grounded and universal as a self-referential language. Rather than modeling the abstract realm of EC, it can learn more about itself by creating some primitive notion of EP. This process continues until $EP$ emerges to a regime of complexity where it can form thoughts and model aspects of its reality. It may be conceivable to envision emergent $EC$ via $EP$ as an efficient code running on multiple parallel processors. Rather than the panconsciousness completely modeling itself, it can let the emergent information model reality and create fundamentally new interactions of physical information, which leads to a deeper understanding of the panconsciousness as a whole.

## 4. Unification of Emergentism and Panpsychism

It is widely believed that panpsychism is incompatible with emergentism [98]. We have defined panpsychism above. Emergentism is the belief in emergence, particularly as it involves consciousness and the philosophy of mind. Its antithesis is reductionism, because emergentism is the property where the emergent whole is greater than the sum of the properties of the system's parts. Theories of consciousness generally fall under one of these two categories: Consciousness is present at a fundamental level of reality (non-self-simulation-based panpsychism) and has no explanation or origin or it emerges from simple physical processes that exist primordially with no explanation (non-self-simulation-based emergentism). As articulated, the transtemporal interactive nature of the SSH requires emergentism to explain the existence of the panpsychic computational thinking substrate of reality to run its own self-simulation. Accordingly the SSH resolves the conflict between emergentism and panpsychism—unifies the two views.

Emergentism typically subscribes to the philosophy of materialism. While our panpsychic view is opposite from materialism, our model nevertheless has the notion of emergent consciousness ($EC$) from emergent physicality ($EP$), both of which are forms of thought in the strange loop of the self-simulation. In this sense, our view is philosophically different than emergentism, yet effectively accomplishes the same goals, as a type of consciousness emerges from physical information, which emerges from the panconsciousness, and so forth.

## 5. Spiritualism

Whether one appreciates the term "spiritualism" or not, aspects of the SSH and our emergence theory program include aspects of spiritualism if we follow these definitional excerpts from *Encyclopedia Britannica.*

> Spiritualism, in philosophy, a characteristic of any system of thought that affirms the existence of immaterial reality imperceptible to the senses. So defined, spiritualism embraces a vast array of highly diversified philosophical views.
>
> Furthermore:
>
> Less obviously, it includes belief in such ideas as finite cosmic forces or a universal mind, provided that they transcend the limits of gross Materialistic interpretation. Spiritualism as such says nothing about matter, the nature of a supreme being or a universal force, or the precise nature of spiritual reality itself.

The ideas laid out in this document as a whole cannot be defined as spiritualism because, as the above definition states, spiritualism says nothing about matter, the nature of the supreme being or a universal force, or the precise nature of spiritual reality itself. Our thesis does indeed say several things about those ideas, as we focus on issues such as mathematical physics, symbolism, and the finite but evolving nature of the supreme being and its origin story, i.e., the emergent panconsciousness substrate as a strange loop. We have not used the term "God" in place of panconsciousness in this document because that is an ambiguous and confusing term. It has many meanings. Two of the most general meanings associated with that word are ideas anathema to this thesis. The first is that God is infinite. This is not the case in the SSH model. Our panpsychic substrate evolves. The second is the popular idea in many religions that God creates everything. Our panpsychic self-simulation is everything and is collectively created by everything within it. It is unitary and interdependent, where the panconsciousness cannot exist without evolving through us and everything else that can make decisions.

Creationist ideas are non-unitary and non-interdependent. That is, the thing that creates everything is not itself created by those things. This is not just an idea of religion. It is general, as the idea that there is one thing fundamental, such as God or spacetime and energy or information. Furthermore, the one underlying fundamental thing does not require other things to exist or other things to create it. Those things may only emerge from or be created by the fundamental thing. Modern materialism is one such view, where spacetime and energy just are, and they evolve according to eternal primordial physical laws to create us and the rest of reality. All interpretations of QM mentioned above are creationist views in this same sense. Panpsychism and digital physics are also creationist views. The SSH is not a creationist view. It is the philosophy of holism, which is the idea that properties of a system are synergistic and can only be explained by the emergent whole and where the whole influences and creates the parts and vice versa—mutual co-creation of all.

When such a philosophy can fit within a logical or mathematical model of reality that makes predictions and explains things with reasoning, a scientifically minded person may choose to ask questions that are not "allowed" by today's status quo scientific views. For example, one can ask whether or not such a new physics would support the possibility that a consciousness can exist across time and without having to be dependant on systems of atoms, as with biology. The SSH allows this. One might ask whether thoughts can interact in a manner that comports with ideas such as "communicating with a higher form of consciousness including one's future evolution or even the panconsciousness substrate" or "communicating with another consciousness non-locally without requiring propagating signals in spacetime". For both questions, the non-fundamental nature of time in the SSH allows this possibility.

## 6. Conclusions

We introduce the self-simulation hypothesis as a modification of the simulation hypothesis. We consider the assumption of mental simulations to be more plausible than computer simulations because, as with lucid dreams, they are currently more precise. Furthermore, humanity's recent hacking of evolutionary biology, via CRISPR gene editing, is likely to allow rapid evolution of consciousness in the future—*designer consciousness*—that can make mind-simulations even more powerful. Future non-local quantum gravity theories and deeper understanding of what consciousness is may allow new forms of mind to emerge from networks of biological consciousnesses or that do not require matter in the first place. The upper limit of energy in the universe that can self-organize into conscious systems and networked systems of conscious systems is 100% of the energy.

As an overall takeaway message throughout the document, we also state that mental simulations are a better fit for what quantum mechanics and the measurement problem seem to be implying. Our overall theme that bridges ideas ordinarily at odds has been the notion of code theory or hierarchical inter-nested symbolic systems in a strange loop and how we recognize thought and the universe itself as such.

We contrast our holism viewpoint with the "it just is" viewpoints of panpsychism, materialism and digital physics and point out that it is more true to the scientific spirit of demanding origin stories for everything, even those things that are supposedly fundamental. We speak in limited terms of the program worked on at Quantum Gravity Research, called emergence theory. We also discuss various interpretational aspects of QM. We end with some controversial but hopefully stimulating ideas about spiritualism and the possible importance of humanity's role.

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