# Elementary Particles as Local Deformations of a Universal Lattice

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**Abstract**

A new model of space in the form of a Planck scale, deformable, discrete lattice is proposed. The local deformations of the lattice, which are limited in number and precisely defined in structure, are identified with the standard model's elementary particles. The lattice is proposed as the ground from which quantum field theory's vacuum state and relativity's spacetime both arise simultaneously as *emergent* theoretical frameworks. We refer to the framework that encompasses these ideas as *synergetic lattice field theory*: *synergetic* because of its roots in Buckminster Fuller's synergetic geometry and *lattice field theory* because of its description of an all-pervading, *discrete* field within which all the observed phenomena of the universe arise. We refer to this universal lattice as *the synergetic field*.

## 1. Introduction

*1.1. Overview*

The 20th century American architect, inventor, and philosopher, Buckminster Fuller, speculated that his synergetic geometry [1, 2] could help explain some of the observed properties of elementary particles [3, 4, 5, 6, 7] and that it might someday provide the foundation for a unified field theory [8, 9]. *Fuller's central conjecture was that his synergetic geometry defined the actual "coordinate system of nature"* [10]. Fuller never explicitly proved this conjecture, and he never demonstrated a complete and comprehensive application of synergetic geometry to modern physics' core problems. He did, however, encourage others to do so [4]. Nystrom, for example, proposed a synergetics-based model of cellular automata as a theoretical framework for calculating an "emergent" physics [11].

Synergetic lattice field theory, which for brevity we will refer to as SLFT, attempts to investigate the possible validity of Fuller's central conjecture and his related ideas regarding the potential relevance of synergetic geometry to foundational problems in modern physics. It does so by using synergetic geometry, with some natural modifications and extensions, as the starting point for constructing a self-consistent model of physical reality. These modifications and extensions of synergetic geometry, which are defined in subsequent sections, are necessary for successfully building a bridge between synergetic geometry and modern physics. SLFT describes a Planck scale model that includes a precise mapping of the standard model's elementary particles to various geometric elements of this modified and extended version of Fuller's synergetic geometry [1, 2]. If such a model can be constructed that has a reasonable level of concordance with the physical universe's known properties, it can be argued that Fuller's conjectures are at least plausible possibilities, if not actual realities.

The paper starts with a very general conceptual introduction to SLFT. This is followed by several sections describing the specific structure and dynamics of the synergetic field *as a whole*. (We refer to the lattice described by SLFT as the synergetic field.) This is then followed by a number of sections discussing the structure, motion, and properties of the elementary fermions within the synergetic field. These sections also introduce the concept of negative-mass fermions. These negative-mass fermions arise naturally in SLFT directly from the specific structure of the field. The next sections discuss gauge bosons, which SLFT models as composite particles constructed from bound states of pairs of positive-mass and negative-mass fermions. Several sections follow that discuss the possible reconciliation of SLFT with the core pillars of modern physics, including quantum theory, special relativity, general relativity, and modern cosmology. These sections include discussions of SLFT's relationship to relativistic ether models and to nonlocal, contextual hidden variables models. The paper concludes with a brief discussion of the possible experimental consequences of SLFT.

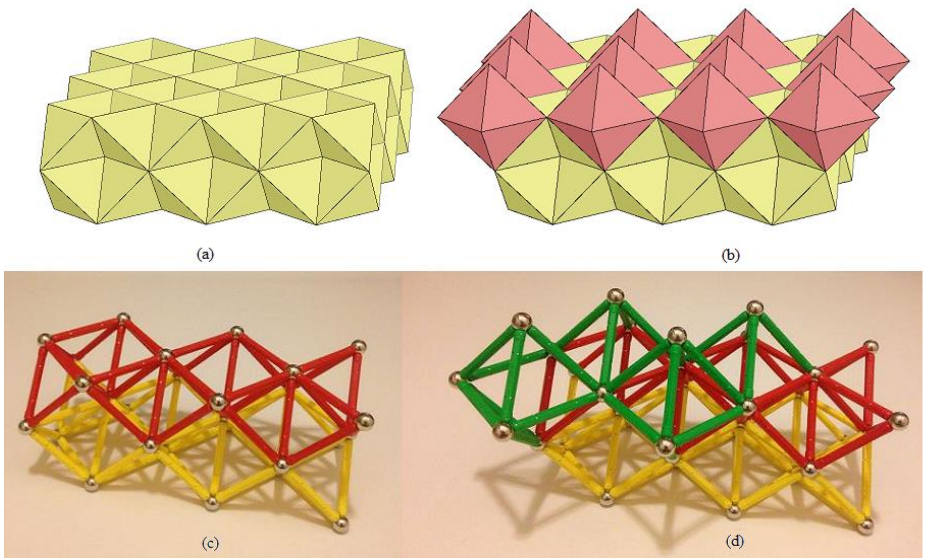



Figure 1: Synergetic geometry's isotropic vector matrix ("IVM") consists of the struts of a set of tetrahedrons and octahedrons stacked together to fill space. Figure 1(a) shows a small set of two layers of tetrahedrons stacked together. This stacking of tetrahedrons includes empty pyramid-shaped regions between the tetrahedrons. Figure 1(b) shows a set of octahedrons nested into some of the empty pyramid-shaped regions in Figure 1(a). This combined stacking of tetrahedrons and octahedrons can be extended indefinitely to span arbitrarily large spatial extents. Figure 1(c) and Figure 1(d) show similar geometries as Figure 1(a) and Figure 1(b), respectively. Figure 1(c) and Figure 1(d) show these geometries constructed as "real world" lattices, with an emphasis on the struts (or "vectors") that define the edges of the stacked tetrahedrons and octahedrons.

The model proposed by SLFT is based on a Planck scale, locally deformable lattice derived from Fuller's "isotropic vector matrix" [12]. Fuller's isotropic vector matrix (IVM), shown in Figure 1, can be understood in terms of packing space with two of the five Platonic polyhedra: the tetrahedron and the octahedron. The edges of the tetrahedrons and octahedrons define a rigid, three-dimensional, jungle-gym-like structure of interconnected triangles. Fuller believed that the isotropic vector matrix is a fundamentally important structure in nature, and he built much of his synergetic geometry around it.

The following sections will delineate a physical approach to deriving a close variant of the isotropic vector matrix. SLFT identifies this close variant as the universal field that forms the foundation of physical reality. SLFT calls this derivative field the "*isomorphic* isotropic vector matrix" (IIVM) or simply *the synergetic field* (Figure 2). The synergetic field can become deformed in different ways such that it contains various well-defined, localized, geometric deformations. SLFT identifies these localized deformations of the field with the standard model's elementary particles. The synergetic field itself is constructed from an "atomic" unit which SLFT calls the *isomorphic vector equilibrium*.

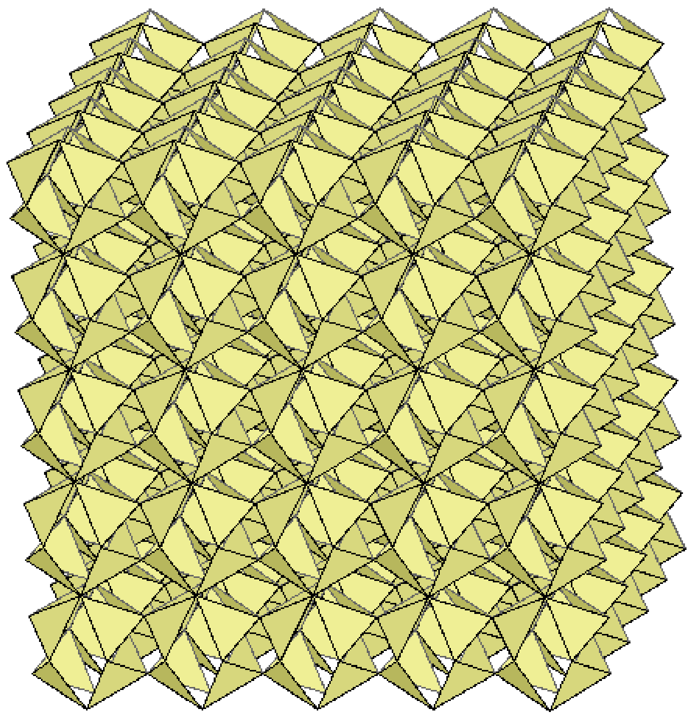


Figure 2: A small section of SLFT's *isomorphic isotropic vector matrix* (IIVM) showing a "5 X 5 X 5" three-dimensional array of 125 Planck scale *isomorphic vector equilibriums*. As will be explained in Section 5.4, the isomorphic vector equilibrium defines the *atomic unit* of the IIVM. The IIVM is constructed from equal numbers of interwoven *left-handed* and *right-handed* isomorphic vector equilibriums. For visual clarity, this figure only shows 125 left-handed isomorphic vector equilibriums. An additional 125 right-handed isomorphic vector equilibriums can be woven into the interstitial spaces that exist between the 125 left-handed isomorphic vector equilibriums.

The derivation of the synergetic field presented in subsequent sections takes the form of a plausibility argument based partly on well-established facts regarding known properties of the Universe and partly on the fundamental and universal symmetries of three-dimensional space itself. The resulting argument is not proposed as a proof of the correctness of SLFT but rather as a support of its plausibility. Its plausibility is further supported by the natural explanations it provides for a number of fundamental properties of the Universe. These explanations, which will be discussed further in subsequent sections, include geometric motivations for the standard model's specific spectrum of elementary fermions (and bosons), quark flavors, the quarks' color charges and fractional electric charges, some of the unique properties of neutrinos, and geometric motivations for the existence of precisely three generations of elementary particles.

### *1.2. Elementary Particles as Local Field Deformations*

The first key assumption used in the derivation of the synergetic field is the idea that *elementary particles are nothing other than localized deformations of the field itself.* This is not a fundamentally new idea. Various physicists have proposed it at various times and within various contexts. In *The Evolution of Physics*, Einstein and Infeld proposed just such an idea that was consistent with general relativity's *conceptual* model of spacetime, but that also transcended it [13]. They proposed that matter and gravitational fields *both* consist of curved spacetime. They identified gravitational fields with the curved spacetime surrounding elementary particles, and they further identified the elementary particles themselves with even more extremely curved spacetime. In this model, the curved spacetime surrounding matter was continuous with, and seamlessly connected to, the even more tightly curved spacetime that *defined* elementary particles themselves. Several other twentieth century physicists, including Louis de Broglie [14, 15] and Erwin Schrödinger [16], expressed similar ideas within different theoretical contexts.

The above ideas can be further understood using a rubber sheet as a conceptual model of general relativity's spacetime. This model, often used as an analogy to explain general relativity, includes an extended, stretched rubber sheet and one or more weighted balls resting on the rubber sheet. The weight of a single ball creates a dimple in the rubber sheet. The rubber sheet models spacetime and the weighted ball models matter, for example, an elementary particle, such as an electron. The presence of an elementary particle (or any matter) within spacetime causes a local curvature, or warping, of the spacetime surrounding the particle, just as a weighted ball causes a local dimple in a two-dimensional rubber sheet.

If *two* weighted balls are placed on a rubber sheet simultaneously, they will tend to roll towards each other to minimize the sheet's total distortion. Similarly, when two particles are in close proximity in spacetime, they will be attracted to each other gravitationally. This mutual attraction will cause them to move towards each other, thus reducing spacetime's *net* curvature in their immediate vicinity. In general relativity's model of spacetime, gravity, and matter, there is a clear distinction between the particles (the weighted balls) and spacetime (the rubber sheet). The weighted balls are separate elements external to the rubber sheet that cause the rubber sheet to form gravitational "dimples".

What general relativity lacks that Einstein attempted to provide is a deeper understanding of the relationship between matter and spacetime. Einstein felt it was insufficient to simply define how spacetime curved in the presence of matter, and how that curvature, in turn, affected the motion of matter, without also explaining the actual mechanism by which spacetime and matter act upon each other. Einstein wanted to know how and why a piece of matter caused spacetime to curve and how the curved spacetime "reacts back" [17] on matter to guide its motion.

Einstein and his fellow researchers proposed solving this problem with an approach analogous to using a rubber sheet that creates its own dimples without any external agency. In such a model, the dimples themselves *define* the particles, and the distinction between particles (just self-created dimples now, instead of weighted balls) and spacetime (the rubber sheet) dissolves—the particles are nothing more nor less than extreme local distortions of spacetime itself, resulting in a deep and fundamental unification of matter and spacetime.

These ideas, grounded in general relativity and its logical extensions, led Einstein to think of spacetime in terms of a universal, all-pervading medium or *ether* and to think of matter (i.e., elementary particles) as nothing other than areas of extremely localized distortions of this medium [13]. In this model, Einstein imagined that these localized areas of extreme distortion (i.e., elementary particles) continuously merged into the surrounding spacetime and naturally induced lesser degrees of distortion in the spacetime surrounding them. In Einstein's model, these areas of distorted spacetime simultaneously define *and* surround elementary particles and are themselves the ultimate sources of gravitational fields.

SLFT's *isomorphic isotropic vector matrix* (IIVM) is analogous to Einstein's proposed field. The synergetic field itself is a universal, *discrete*, spatial medium, or substratum, that spans the entire Universe. The field's well-defined, local deformations are associated with elementary particles. The field's deformations, which extend continuously outwards from these localized elementary particle deformations, give rise to gravitational fields surrounding the particles.

Although the synergetic field is analogous to Einstein's proposed field, there are significant differences between them. For example, SLFT is a theory of space, not spacetime. The IIVM is a model of three-dimensional space, not of the four-dimensional spacetime described by general relativity. Because the IIVM is an ether-type model, there is one universal time that stands separate from three-dimensional space. As will be explained in Section 9.2 and Section 20, the IIVM is, nevertheless, a *relativistic* ether. Within this relativistic ether the rules of special relativity and general relativity still apply, but they ride on top of it as *mathematical* and *observational* frameworks. They are *emergent* theoretical frameworks, not fundamental realities.

The synergetic field is *discrete* in contradistinction to the *continuous* field proposed by Einstein. *This difference defines the second key assumption used in the derivation of the synergetic field.* The idea that space is discrete is not fundamentally new. Various physicists have proposed the idea at various times and within various contexts. Einstein himself did not embrace this idea, but in his later years, he speculated on the possibility that it might ultimately be necessary to adopt it [18].

Many other physicists have since speculated on the possible necessity of adopting some form of discrete space. This has been motivated by the need to reconcile general relativity's description of spacetime and its gravitational fields with the discrete realities of quantum mechanics. Although there is no current experimental proof that space is discrete, this idea has been more seriously considered in recent years. Various researchers have proposed variations of the idea that space can be loosely thought of as a three-dimensional array of pixels, or more accurately, *voxels* (i.e., small, regular, discrete, three-dimensional *volumes* (e.g., tiny *cubes*)).

## 2. A Discrete Substratum

If one accepts the idea of a universal, *discrete* substratum, then it is natural to ask what specific geometry describes the substratum at its finest levels. One may wonder if some type of regular lattice defines the substratum or whether it has a more irregular structure, even including random geometric perturbations, as is assumed in some theories of quantum gravity. It is part and parcel of the substratum model proposed by SLFT that elementary particles are formed within the substratum as localized deformations. Suppose we combine this *assumption* that elementary particles are nothing other than deformations of an underlying substratum, together with the *observation* that elementary particles can be created or destroyed *at any point* in the Universe and always have the *exact* same properties. These combined considerations draw us to conclude that the substratum that contains and defines those deformations is always and everywhere the same. More specifically, they draw us to conclude that *the substratum has a regular and uniform (versus random) underlying structure*.

In other words, it can be argued that the regular and well-defined nature of the substratum's local deformations (i.e., the regular and well-defined nature of the standard model's elementary particles) implies that the underlying substratum itself is also regular and well-defined. Within such a picture, in which elementary particles are local deformations of an underlying discrete substratum, an irregular or random lattice does not make a great deal of sense. Such a picture rather strongly implies that the discrete substratum has the form of a well-defined, regular, but *deformable* lattice. Adopting the assumption that space is a regular lattice ensures that the substratum's localized particle-deformations will always and everywhere be the same.

Regular lattice structures exist throughout nature. Whenever fundamental systems are brought to their ground states, their lowest energy states, they often tend towards configurations that display regular, repetitive, geometric patterns. This tendency is seen most clearly in configurations of atomic arrays. When groups of atoms come together under the right circumstances and proportions, in a state of low energy, they often tend to form crystalline structures. At these atomic and subatomic levels, nature employs strategies of discreteness and spatial regularity. Therefore, it would not be surprising to find nature employing these same strategies at even deeper levels, including at the Planck scale, in the discrete structure of a universal substratum.

If we accept the idea of a universal, discrete substratum as a working hypothesis, and if we also accept the idea that it has the form of some sort of regular lattice, then the next question that naturally arises is, *"What is the specific geometric structure of this lattice?"*. Finding a reasonable answer to this question can be approached using certain natural constraints. Specifically, the constraints provided by the symmetries of three-dimensional space itself, and the constraints provided by the *specific* set of fundamental structures that manifest within that space (i.e., the standard model's elementary particles), can be used *together* to explore possible answers to this question.

## 3. The Shape of Space

### *3.1. The Inherent Symmetries of Three-Dimensional Space*

We can borrow specific ideas from the study of crystallography to better understand the possible regular, discrete lattices that can form within three-dimensional space. It turns out that the limited set of regular crystal lattices that can exist, *in principle*, can be traced back to the geometric structures of the regular and semi-regular polyhedrons. These polyhedrons can themselves, in turn, be traced back to certain fundamental symmetries of space itself. These fundamental symmetries of space can be said to define a sort of *shape of space.*

The idea that three-dimensional space has some implicit *shape* may at first seem strange and counter-intuitive, but this idea contains a profound truth. At first glance, space seems to be a passive and empty vessel—a formless and structureless container for all manner of shapes and structures that exist within it. Such a perception of space is understandable, but it is not the true reality. In a very abstract sense, space has an *implicit* shape that can be discovered by exploring the *explicit* symmetries of the most basic shapes that can, *in principle*, exist within it. Amy Edmondson, one of Buckminster Fuller's students, explored these ideas in her book, *A Fuller Explanation: The Synergetic Geometry of R. Buckminster Fuller* [19]. In support of these concepts, Edmondson references Arthur Loeb's work, *Space Structures*, which also discusses these ideas. Loeb held that space imposes inherent geometric constraints on all structures that exist within it and that space is not just a passive container for those structures [20].

### *3.2. Regular and Semi-Regular Polyhedra and the Atomic Unit of Space*

If space does, in fact, consist of small, regularly shaped, voxel-like units, it is natural to ask, *"What specific forms do these voxels take?"* In other words, "*What is the specific form of the "atomic unit" of space?"* The "powerful constraints" on the "shape of space", described by Edmondson and Loeb, limit the possibilities of the form that an atomic unit of space can take. Mathematically, these constraints are expressed as the minimal set of simple spatial symmetries that can, in principle, exist in three-dimensional space. These symmetries are externally *explicated* in the forms of the five Platonic (regular) polyhedra and the thirteen Archimedean (semi-regular) polyhedra. They are further explicated in the forms of the uniform, convex *honeycomb* structures (i.e., three-dimensional space lattices) that can be constructed by stacking together various combinations of the Platonic and Archimedean polyhedra [21].

The "shape of space" itself puts hard constraints on the number of simple, symmetric polyhedrons that can exist, *in principle* (i.e., the Platonic and Archimedean polyhedra). The shape of space puts further constraints on which of these polyhedrons can stack together with themselves, or with one another, to construct regular space lattices. The regular and semi-regular polyhedra define, in a sense, a sort of *alphabet of space*. In the next section, we will use certain constraints of the physical Universe itself (i.e., the standard model's elementary particles) to determine which of these polyhedrons are the best candidates to construct a regular lattice that can be used to model space.

## 4. Atoms of Space

### *4.1. Elementary Particles as Local Constraints*

Certain *local* constraints supplied by the Universe itself can be used to help identify the specific Platonic or Archimedean polyhedron(s) from which SLFT's space lattice is constructed and that define its “atomic” unit(s). These *local* constraints are the elementary particles themselves. Suppose that elementary particles, which are well-defined in number, are nothing other than local deformations of an underlying lattice. In that case, it is natural to conclude that the underlying lattice must have the ability to become deformed at any given point in a similar, well-defined number of ways. It *might* then be possible to map these locally deformed states of the medium back to the elementary particles themselves.

To simplify this mapping, at least initially, we can make some *temporary* reductions in the number of particles being considered. The first reduction will be to consider only the elementary particles themselves and not the forces between them, i.e., we will *initially* consider only the fermions and not the bosons. If we initially confine ourselves to just the first generation of elementary particles, and if the symmetries of charge, spin, quark color, and quark flavor are also ignored, then only three particles remain. The remaining three particles are the neutrino, the electron, and the quark. This implies that the space lattice must support the existence of three states of deformation, each associated with greater rest masses. These three fundamental particle states must simultaneously exhibit a high degree of stability *and* transformability—they must be able to persist in time and *also* be able to be created or destroyed at any point in space. This approach assumes that the temporarily ignored symmetries of these three fundamental particles (as well as the gauge bosons) can be later recovered based on various geometric considerations.

Using the above ideas, we would like to identify one or more polyhedral structures from the set of five Platonic (regular) and thirteen Archimedean (semi-regular) polyhedrons that define *the atomic unit of space*. This atomic unit must be able to pack with itself to define a regular lattice. In addition, the identified atomic polyhedral unit must have the ability to become deformed to form other polyhedrons in order to support the formation of the known elementary particles. In our simplified three-particle universe consisting of neutrinos, electrons, and quarks, this second constraint requires that the polyhedral candidate(s) collectively support three *structurally stable* states of deformation. In the next section, we will explore the geometric implications of the requirement that the states of local deformation must have structural stability. We will start by more deeply exploring the geometric meaning of “structural stability”.

### *4.2. Elements of Structural Stability and Structural Flexibility*

In his study of spatial forms, Fuller realized that when the triangle is realized as a *real-world* structure, it is uniquely stable among all possible two-dimensional polygons. Among two-dimensional triangles, the equilateral triangle, whose three edges have equal lengths, has the highest degree of strength and structural stability because of its symmetry. Fuller further realized that the three Platonic polyhedra constructed solely from equilateral triangles, i.e., the tetrahedron, the octahedron, and the icosahedron, share the structural stability of their constituent triangles. It turns out that these are the only "omni-triangulated" polyhedrons among the regular and semi-regular polyhedrons [22].

These three "omni-triangulated" polyhedrons are inherently structurally stable when realized as real-world systems. Fuller illustrated these observations regarding the structural stability of omni-triangulated polyhedrons with real-world physical models, like those shown in Figure 3.

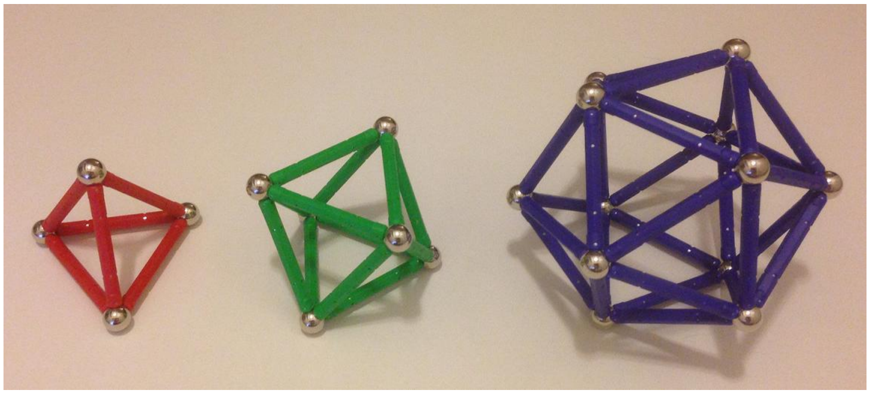


Figure 3: The tetrahedron (left), the octahedron (middle), and the icosahedron (right) are three of the five Platonic or regular polyhedra. These three polyhedra are the only "omni-triangulated" (constructed solely from equilateral triangles) polyhedra among the regular and semi-regular polyhedrons. By virtue of their "omni-triangulation," these polyhedrons have inherent structural strength and stability when they are realized as "real world" structures, as shown in the figure.

The cube's inherent instability provides a good counter-example to the inherent stability of the three omni-triangulated polyhedrons. Although a cube appears perfectly stable and solid when viewed as a figure on a printed page, a cube constructed as a real-world object from rigid struts and flexible connecting vertices demonstrates no such stability or definite shape. Such a cube can flip-flop around and take on innumerable configurations [23] (Figure 4). Fuller observed that this was true for all polyhedrons that do not consist solely of triangles [24]. Of the regular and semi-regular polyhedrons, only the "omni-triangulated" polyhedrons—the icosahedron, the octahedron, and the tetrahedron—are fixed and completely stable when realized as actual three-dimensional structures in the real world (Figure 3).

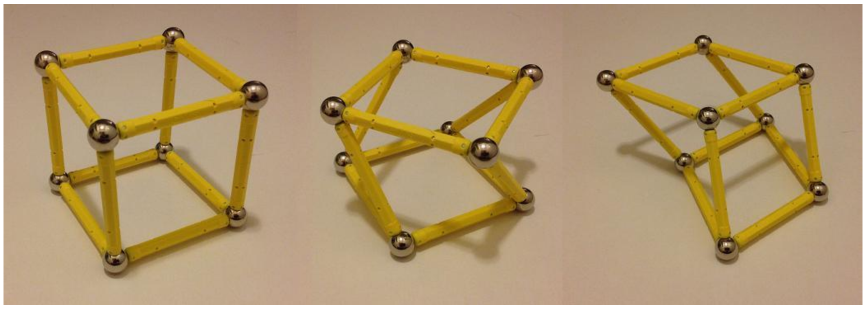


Figure 4: "Real-world" physical cubes, constructed from rigid magnetic rods bound together at their vertices by the attraction of the magnetic rods to small steel spheres. The left figure *appears* to be a solid and symmetrical "cube". However, the other two cubical "nets" immediately to its right, demonstrate the reality: the inherent instability of real-world cubes. Such cubical nets can take on an innumerable number of different configurations.

*4.3. Mapping Particles to Polyhedra*

The three omni-triangulated polyhedrons' stability makes them good candidates for modeling the fundamental stability of the three elementary particles: the neutrino, the electron, and the quark. As a preliminary working hypothesis, SLFT maps the icosahedron, octahedron, and tetrahedron to the neutrino, electron, and quark, respectively. We have already concluded that the synergetic field is constructed from one or more of the regular and semi-regular polyhedra. We have also concluded that the various deformations of the field's "atomic" polyhedron define elementary particles. It is reasonable to assume then that these deformations must themselves be regular or semi-regular polyhedrons. Given the requirement that elementary particles display a high degree of stability, it is natural to map these particles to the most structurally stable of the regular and semi-regular polyhedra. The fact that that there are three elementary fermions (i.e., in our simplified three particle universe) combined with the fact that there are exactly three "omni-triangulated", most stable polyhedra, leads SLFT to the above working hypotheses that associates the quark, electron, and neutrino with the tetrahedron, octahedron, and icosahedron, respectively.

When these polyhedrons are embedded within the synergetic field, the mapping between elementary particles and elementary polyhedrons is a bit more complicated. More specifically, looking forward to Section 6.3, we will see that neutrino-icosahedrons, *embedded within the synergetic field*, are actually associated with *pairs* of symmetric and asymmetrical icosahedrons. Similarly, electron-octahedrons will be found to be associated with *pairs* of octahedrons and cuboctahedrons, and quark-tetrahedrons will be found to be associated with *pairs* of tetrahedrons and octahedrons. Consequently, terms such as electron-octahedron or electron-octahedron-cuboctahedron will sometimes be used to describe electrons. Similar nomenclature will sometimes be used to describe neutrinos and quarks.

The reason for these particular associations will be further explained in Section 6, which discusses the local and global structure and transformations of the synergetic field. For now, suffice it to say that when these three polyhedral *pairings* (i.e., icosahedron-asymmetrical icosahedron, octahedron-cuboctahedron, and tetrahedron-octahedron) are embedded *within* the synergetic field, *as a whole*, they will be found to create sequentially greater *local* contractions of the field. SLFT ties these three sequentially greater local contractions of the field to the sequentially greater rest masses of their associated elementary particles.

*4.4. Requirements of the Atomic Unit of Space—A Summary*

Recapping, we have determined that the substratum proposed by SLFT should be a regular lattice. We have further determined that it should be a locally deformable lattice. Since we want to identify the lattice's local deformations with elementary particles, the deformations should be structurally stable. This has led to the working hypothesis that the three fundamental elementary particles (i.e., quarks, electrons, and neutrinos) should map to the three structurally stable, omni-triangulated polyhedra (the tetrahedron, the octahedron, and the icosahedron). Taken together, the above considerations lead to the conclusions that the atomic unit of space must be able to pack together with itself to span space *and* must also be able to locally deform into tetrahedral, octahedral, and icosahedral configurations.

Now we want to determine which regular or semi-regular polyhedron best fulfills these requirements. It turns out the Fuller's synergetic geometry already provides an answer to this question. The cuboctahedron, one of the semi-regular polyhedra, is the best (and possibly only) fit to these requirements. Fuller called the cuboctahedron the "vector equilibrium" and he defined it as a dynamic, transformable, geometric "system" versus a static "solid" [25]. Importantly, he discovered a set of "jitterbug" transformations of the vector equilibrium [26] that are central elements of both synergetic geometry and SLFT. Fuller arrived at the conclusion that the vector equilibrium (VE) is central to synergetic geometry's proposed "coordinate system of nature" by a thread of reasoning grounded in general systems theory [27]. More specifically, the thought processes that led him to this conclusion were guided by considerations of structure [28], triangulation [29], and closest packing of spheres [30].

*4.5 Identifying the Atomic Unit of Space—A Process of Elimination*

Section 4.6 provides an in-depth introduction and description of Fuller's vector equilibrium and its "jitterbug" transformations, but we would first like to provide an alternative motivation for adopting the cuboctahedron (i.e., synergetic geometry's vector equilibrium) as the synergetic field's atomic unit. We will do this following a different path than Fuller followed—a path that is congruent with, and a natural extension of, the line of reasoning developed in the preceding sections. We want to determine which of the regular and semi-regular polyhedra best fulfills the requirements of an atomic unit of space, if any. We will approach this problem through a logical *process of elimination* until we are left with the best candidate. Happily (and not completely coincidentally) we will discover that the best candidate is, in fact, the cuboctahedron (i.e., Fuller's vector equilibrium).

In order to integrate the three omni-triangulated particle-polyhedrons described above into SLFT's lattice, it will be necessary to construct the lattice from a polyhedron that can undergo structural transformations to form these three omni-triangulated polyhedrons. This polyhedron must also be able to pack with itself in a regular and orderly way to form a space lattice. The candidate polyhedron cannot be omni-triangulated since it would then be completely structurally stable, and it would not have the flexibility required to undergo deformations and transformations. The candidate polyhedron should contain *some* triangles, however, since it has to transform into the three omni-triangulated polyhedrons. *Therefore, the candidate polyhedron should be constructed partially from triangles, with the addition of some non-triangular faces to provide a degree of structural flexibility.* The candidate polyhedron cannot be one of the five Platonic polyhedra since each of these polyhedrons is constructed from a single type of polygonal face. Instead, the candidate polyhedron must be selected from one of the thirteen Archimedean polyhedra since these polyhedrons all have at least two different types of polygonal faces.

The candidate polyhedron must also be able to stack together with copies of itself to create a regular space lattice. Six of the thirteen Archimedean polyhedra do not have this capability because of their five-fold spatial symmetries. These five-fold symmetries preclude their ability to stack together in a regularly repeating, uniform lattice structure. This leaves just seven possibilities from the set of thirteen Archimedean polyhedra. Of these seven, two can be immediately eliminated from the set of *likely* candidates since they do not contain any triangles—the truncated octahedron and the great rhombicuboctahedron. This leaves just five Archimedean polyhedra as *likely* candidates.

The polyhedron defining the synergetic field’s atomic unit must have *some* degree of flexibility in order to allow it to undergo deformations. The simplest component that can give structural *flexibility* to a polyhedron is the square. Of the remaining five candidate polyhedrons, three are constructed solely from triangles and squares: the cuboctahedron, the small rhombi-cuboctahedron, and the snub cube. While the other two remaining Archimedean polyhedra, the truncated tetrahedron, and the truncated cube, *do* each contain triangles, they *do not* contain any squares. Instead, they contain higher-order polygons—hexagons and octagons, respectively. These higher-order polygons would likely support *too much* structural flexibility, making their associated polyhedrons less than ideal candidates.

Based on the above considerations, the three candidates that seem to warrant further investigation are the cuboctahedron, the small rhombi-cuboctahedron, and the snub cube—the three Archimedean polyhedra constructed solely from triangles and squares. The cuboctahedron has fourteen sides, eight of which are triangles and six of which are squares. The small rhombi-cuboctahedron has twenty-six sides, eight of which are triangles and eighteen of which are squares. The snub cube has thirty-eight sides, thirty-two of which are triangles, and six of which are squares.

Given these characteristics, the cuboctahedron appears to be a sort of "Goldilocks" candidate. It has the best balance between its number of structural components (i.e., triangles) and its number of flexible components (i.e., squares) of the three polyhedrons being considered. Therefore, we will further investigate the cuboctahedron to determine if it fulfills the two previously identified requirements: *the ability to transform into the three structurally stable, omni-triangulated, polyhedrons and the ability to stack together with multiple copies of itself to form a space lattice*.

### *4.6. The Cuboctahedron, the "Jitterbug" and the Vector Equilibrium*

We will first investigate whether or not the cuboctahedron can transform into icosahedral, octahedral, and tetrahedral configurations. Buckminster Fuller discovered that the answer to this question is "yes." Fuller believed this was one of the more important discoveries of his life [31]. He called this transformation the "jitterbug" after a famous swing dance of the era [26]. Fuller's choice of this playful name can probably be traced back to the circular swinging motions of the cuboctahedron, and its constituent triangles, as it folds and unfolds upon itself. Physical models of the cuboctahedron undergoing this motion have an abstract similarity to a dancer's body swinging to-and-fro. Coxeter contemporaneously and independently identified the *static* set of symmetries traversed by Fuller's dynamic jitterbug transformation [32]. There have also been a number of other investigations generalizing Fuller's "jitterbug" transformation to an extended family of regular and semi-regular polyhedra [33, 34, 35, 36, 37, 38]. Fuller named the jitterbug transforming cuboctahedron the "vector equilibrium" (VE) [39]. We will follow Fuller's nomenclature going forward.

The VE can be viewed as a set of eight interlocking triangles connected to each other at twelve shared vertex points. These eight triangles are inherently stable, but the six squares defined by the spaces between the triangles are not. They can hinge and fold to form other geometric shapes. These deformable squares provide the VE with the flexibility required to undergo its various jitterbug transformations, while the triangles supply a complimentary degree of structural stability. The structural stability supplied by the triangles constrains the VE's jitterbug transformations to a small set of well-defined, symmetric configurations. The ways in which the VE transforms to its icosahedral, octahedral, and tetrahedral configurations are described below.

The "jitterbug" transformation pathway connecting the vector equilibrium's cuboctahedral phase to its icosahedral and octahedral phases is illustrated in Figure 5. This figure shows a vector equilibrium in its most expanded, cuboctahedral phase on the left, followed by subsequently more contracted phases, culminating in its octahedral phase on the right. During this contraction, the VE passes through its icosahedral phase, followed by various asymmetrical icosahedral phases, culminating in its octahedral phase. During this transformation, the VE's original square faces fold along imaginary "ridge lines" formed between two diagonally opposite corners of each square. As these squares fold, they form bent diamond shapes that become thinner and thinner as the VE progresses from its cuboctahedral phase to its octahedral phase.

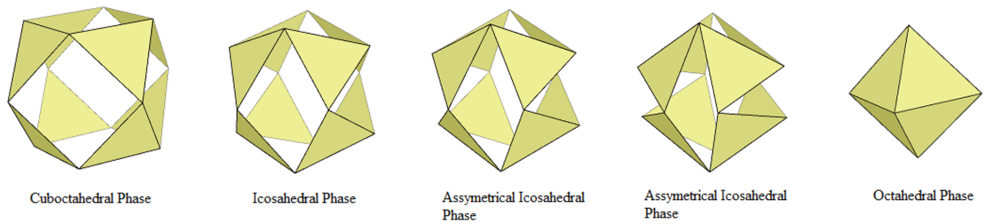



Figure 5: This figure shows the sequential contraction of the vector equilibrium (VE) from its cuboctahedral phase (far left) to its octahedral phase (far right). During this contraction, the VE also passes through its icosahedral phase (second from left) and various asymmetrical icosahedral phases (two illustrated).

As previously mentioned, Fuller discovered that the VE can also contract to a tetrahedral configuration [40]. The VE's contraction to a tetrahedron follows a slightly different pathway shown in Figure 6. During this contraction, two oppositely oriented square faces of the VE's cuboctahedral phase progressively pinch together in orthogonal directions while the other four square faces progressively transform into diamond shapes that each become equivalent to two coplanar equilateral triangles when the VE reaches its tetrahedral phase. The resulting tetrahedron is a *two-frequency* tetrahedron, i.e., its edge lengths are twice the edge lengths of the vector equilibrium's octahedral and icosahedral configurations.

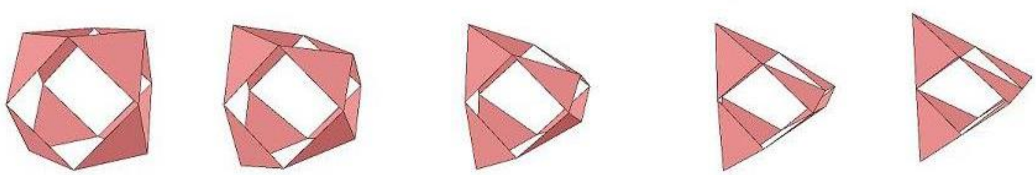


Figure 6: This figure shows the VE's sequential contraction from its cuboctahedral phase (far left) to its tetrahedral phase (far right). During this contraction, two oppositely oriented square openings in the VE progressively pinch together in orthogonal directions until the tetrahedral phase is reached. In this instance, the two square openings that pinch together are the left and right facing openings. The left opening pinches together parallel to the page's vertical axis. The right opening pinches together parallel to an axis that runs in-and-out of the page.

## 5. The Synergetic Field

### *5.1. A Jitterbug Lattice – The Isotropic Vector Matrix*

The previous section detailed the VE's ability to dynamically transform into the three stable, omni-triangulated polyhedrons—the icosahedron, the octahedron, and the tetrahedron. We will now investigate the second requirement for an *atomic unit* of space—can multiple copies of the VE be woven together to form a lattice spanning three-dimensional space? The answer to this question is also "yes." It is well known that many cuboctahedrons can pack together to symmetrically span three-dimensional space. This is shown in Figure 7. It will be noted that there are spatial voids or gaps that remain between neighboring cuboctahedrons. As is also shown in Figure 7, these gaps can be filled with octahedrons.

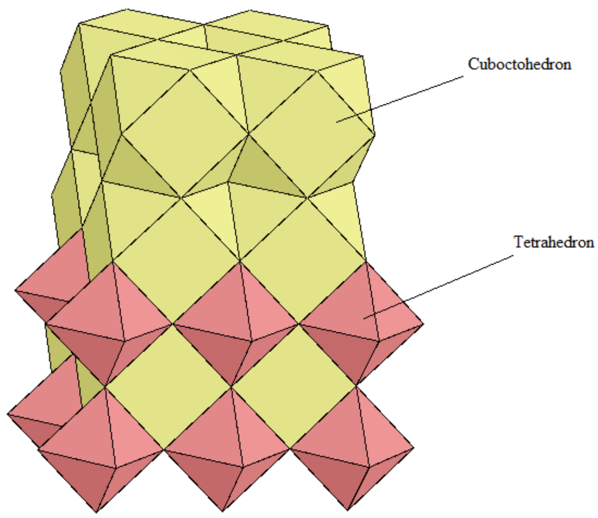



Figure 7: Cuboctahedrons and octahedrons can be packed together to fill arbitrarily large spatial extents.

Having confirmed that the candidate atomic unit of space, the VE, can be packed together to form a three-dimensional space lattice, it is also necessary to confirm that such a lattice still has sufficient flexibility to undergo geometric transformations. In other words, can the transformational properties of its component units, the VE, be carried over to the IVM matrix as a whole? Such transformational flexibility is required of any lattice that models elementary particles as local deformations of its structure. Fuller discovered that such *global* transformations of the IVM do exist [41]. In addition to these *global* transformations of synergetic geometry's *IVM*, SLFT identifies certain *local* deformations of its *IIVM*. We will first describe the *IVM's global* transformations as a segue to describing the *IIVM's local* deformations. These local deformations are important elements of SLFT.

### *5.2. Global Transformations of the IVM*

Consider two sets of VE, in which the members of one set are in their cuboctahedral configurations, and the members of the other set are in their octahedral configurations.

Given this scenario, it is possible to completely fill space by stacking these two sets of VE together in a one-to-one ratio. With this construction, the global transformations of the IVM can be tied back to the previously described jitterbug transformations of its individual VE.

As described above, the IVM's constituent VE can be divided into two sets. The VE in one set are in their cuboctahedral phases, and the VE in the other set are in their octahedral phases. The VE in the set that are in their *cuboctahedral* phases have the potential to *contract* to their *octahedral* phases. The VE in the other set, which are in their *octahedral* phases, have the potential to *expand* to their *cuboctahedral* phases. It turns out that the IVM's two sets of individual VE can respectively expand or contract together through their various phases in perfect synchrony. As they do so, the entire IVM goes through a global transformation. Fuller discovered this transformable version of the IVM during his development of synergetic geometry [42]. Figure 8 shows very small sections of the IVM undergoing this transformation.

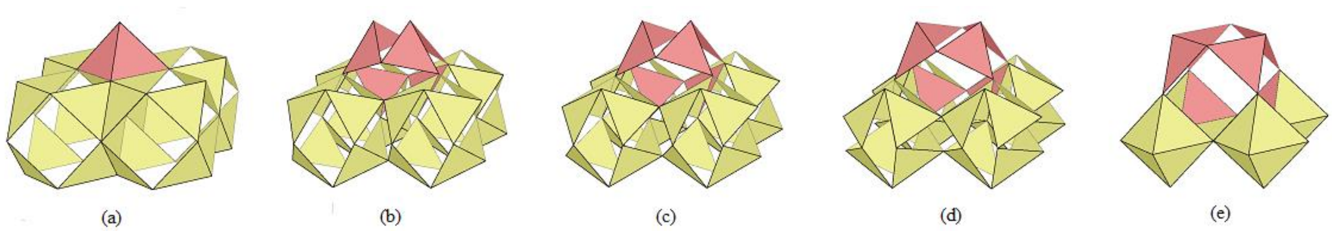



Figure 8: Figure (a) shows four VE in their cuboctahedral phases plus one additional VE in its octahedral phase. The upper octahedral phase VE is situated in a half-octahedral "nest" formed by the four lower cuboctahedral phase VE. Figures (b) through (e) illustrate the global transformation of this small subset of the IVM. The four VE in their cuboctahedral phases all contract to their octahedral phases, while the one VE in its octahedral phase expands to its cuboctahedral phase. Purely by convention, SLFT refers to the four lower VE as *left-handed*, and it refers to the single upper VE as *right-handed*. This convention is associated with the orientation of the VE's bent diamond shapes facing the viewer. If these bent diamonds are oriented vertically, the VE is referred to as *left-handed*. If they are oriented horizontally, the VE is referred to as *right-handed*.

Purely by convention, SLFT refers to the four lower VE in Figure 8 as *left-handed*, and it refers to the single upper VE as *right-handed*. The application of the terms *right-handed* and *left-handed* to these VE is arbitrary. There is nothing *inherently right-handed* or *left-handed* about their structural transformations. In order to make a right/left distinction between these VE, we arbitrarily choose one of the VE's external triangles as a point of reference. For example, the upper right triangles in the lower four VE shown in Figure 8 rotate in a clockwise, left-handed sense during the contractions illustrated in the global transformation.

Figure 9 shows two rows of VE illustrating the VE’s sequential contraction from its cuboctahedral phase to its octahedral phase. The left-most VE in each row are both in their cuboctahedral phases. Progressing from left to right, the VE in both rows are shown contracting towards their octahedral phases. The top row of VE contract in a *left-handed* sense and the bottom row of VE contract in a *right-handed* sense. Moving from left to right in the upper row, one can see that the upper right triangle in the left-handed VE is rotating in a clockwise sense, while the upper right triangle in the right-handed VE is rotating in a counter-clockwise sense. In fact, all of the *corresponding* triangles in the left-handed and right-handed VE rotate in opposite senses.

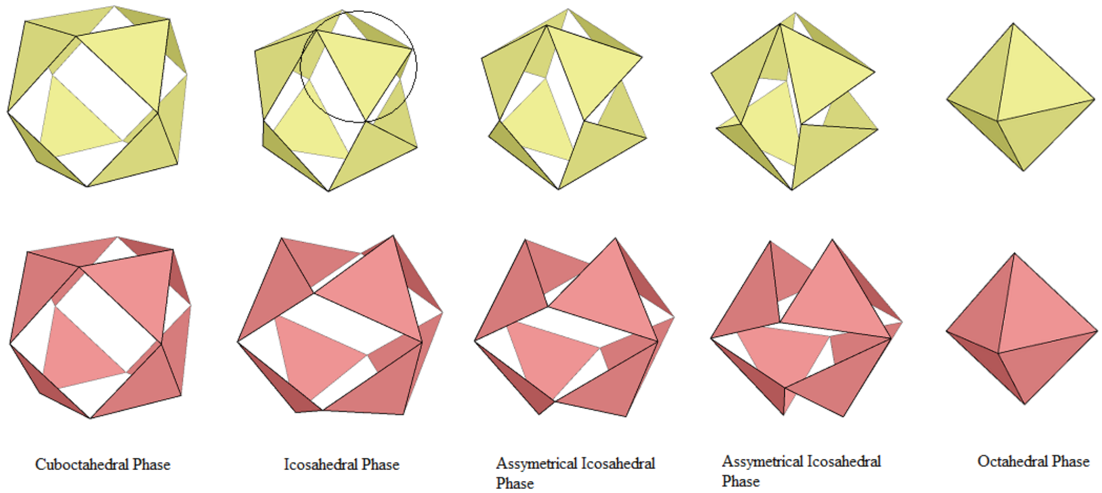



Figure 9: The upper row shows a VE contracting from its cuboctahedral phase (far left) to its octahedral phase (far right), in a "left-handed" sense. Similarly, the lower row shows a VE contracting from its cuboctahedral phase to its octahedral phase in a "right-handed" sense. The upper right triangle in each VE (circled in the second from the left VE in the upper row) is *arbitrarily* selected as a reference point for determining the handedness of the VE's contraction. In the upper row, this triangle is rotating in a left-handed, clockwise sense as the VE's contraction progresses from left to right. In the lower row, this triangle rotates in a right-handed, counter-clockwise sense as the VE's contraction progresses from left to right. As the left-handed and right-handed VE progressively contract from their cuboctahedral phases to their octahedral phases, *all* of their *corresponding* triangles rotate in opposite directions.

This left-handed and right-handed nomenclature is just a convenient convention used to distinguish between the two sets of VE. In point of fact, in both left-handed and right-handed VE contractions, half of the VE's triangles rotate in a left-handed sense and half rotate in a right-handed sense. This convention is also associated with the orientation of the "bent diamond" shape (Figure 8) facing the viewer. If the diamond is oriented vertically, the VE is referred to, by convention, as *left-handed*. If it is oriented horizontally, the VE is referred to as *right-handed*.

Figure 9 illustrates that the internal *rotations* of the individual triangles that make up the VE are intimately and inextricably connected with the simultaneously occurring all-directions-pulling-inwards *contraction* of the VE as a whole. Even though the left-handed and right-handed VE contract by the same amount, their component triangles rotate by *equal* and *opposite* amounts, with *opposite* senses. When embedded within the IIVM, the VE *contractions* are associated with the *field's curvature*, while their component triangles' rotations are associated with the field's positive and negative *torsion*. Section 8 and Section 21 will explain the central importance of these concepts relative to SLFT's introduction of negative mass and SLFT's potential relationship to certain extensions of general relativity.

*5.3. The Equilibrium State of the IIVM*

Figure 10, below, shows the same transformation illustrated in Figure 8 but now with equal numbers of left-handed and right-handed VE—eight of each. As this small local section of the IVM goes through the global transformation illustrated in Figure 10, the entire lattice starts to expand. At the midpoint of the transformation, the lattice reaches a point of maximum expansion and then contracts back to its original dimensions. When the transformation is complete, the cuboctahedral phase VE and the octahedral phase VE have traded places—the VE that were initially in their cuboctahedral phases are now in their octahedral phases, and vice versa.

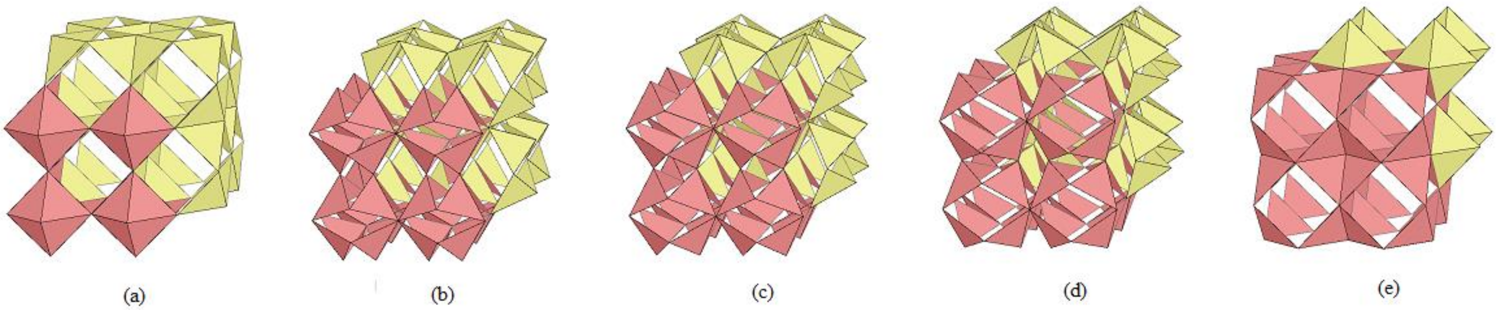



Figure 10: A group of 16 VE traversing the same global transformation illustrated in Figure 8. The eight upper VE are left-handed, and the eight lower VE are right-handed.

The point of maximum expansion of the IVM that occurs at the midpoint of its global transformation plays a crucial role in SLFT. At this point of maximum expansion, all of the VE, in both the left-handed and right-handed sets of VE, take on the same shape. This shape has the form of a very specific asymmetrical icosahedron. Before this point is reached, the VE in one set take the form of asymmetrical icosahedra closer to the cuboctahedral phase, while the VE in the other set take on the form of asymmetrical icosahedra closer to the octahedral phase. At the point of maximum expansion, the "trajectories" of the morphological transformations of both sets of VE cross. At this point, all of the VE are in the same configuration—all of the VE are isomorphic to one another.

This configuration of the IVM represents a state of dynamic equilibrium—a state of balance between the opposing contractive and expansive tendencies of the two sets of VE that jointly constitute the IVM. SLFT refers to this state as the "isomorphic" phase of the IVM or, simply, the "isomorphic isotropic vector matrix" (IIVM)). In this phase, all of the VE within the IVM are isomorphic to one another. We will refer to the associated phase of the IVM's constituent VE as their "isomorphic" phase. As a matter of convention and in the manner explained above, we will refer to one set of such isomorphic VE as "left-handed" and to the other set as "right-handed".

Although the *isomorphic* vector equilibrium and the *isomorphic* isotropic vector matrix defined by SLFT are both *implicit* in the continuum of jitterbug transformations discovered by Fuller, he never *explicitly* described them—these particular configurations of the vector equilibrium and the isotropic vector matrix were never explicitly identified or described in Fuller’s works. The author therefore assumes that the identification of these specific, *isomorphic* configurations of the vector equilibrium and the isotropic vector matrix, and their significance, are new contributions to synergetic geometry. These new elements are part of SLFT's modifications and extensions to synergetic geometry referenced in Section 1.1.

*5.4. The Structure of the Synergetic Field*

The deformable polyhedron defined by the isomorphic VE (Figure 11) is the "atomic" unit—the basic building block—of the universal, discrete, space lattice proposed by SLFT. SLFT refers to the isomorphic isotropic vector matrix (IIVM), constructed from innumerable isomorphic VE, as *the synergetic field*. The IIVM defines the least contracted, "ground state" of the synergetic field.

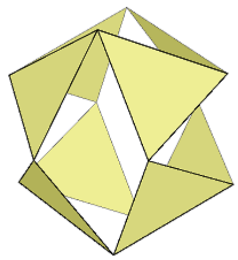


Figure 11: A single, left-handed, Planck scale, isomorphic vector equilibrium (VE). The isomorphic vector equilibrium is a very specific configuration of synergetic geometry's vector equilibrium. The isomorphic vector equilibrium defines SLFT's *atomic unit of space*. Its external shell consists of eight equilateral triangles. It also has 24 internal faces that, for simplicity, are not shown in this diagram. (Note: The isomorphic vector equilibrium has a direct morphological relationship to Jessen's orthogonal icosahedron. Although it is different from Jessen's icosahedron, it shares the same set of *exterior* vertex coordinates as Jessen's icosahedron. It is also noteworthy that the external shells of the isomorphic vector equilibrium *and* Jessen's icosahedron can *both* be derived from a specialized truncation of the only space-filling, semi-regular polyhedron: the truncated octahedron.)

Closer examination of the isomorphic VE reveals a couple of interesting geometric properties. The isomorphic vector equilibrium has a direct morphological relationship to Jessen's orthogonal icosahedron [43]. Although it is different from Jessen's icosahedron, it shares the same set of exterior vertex coordinates. It turns out that the external shells of the isomorphic vector equilibrium *and* Jessen's icosahedron can *both* be derived from a specialized truncation of the truncated octahedron. The truncated octahedron is one of only two space-filling polyhedra within the family of regular and semi-regular polyhedra. The other space-filling polyhedron within this family is the cube.

Another important characteristic of the isomorphic VE is that if it is rotated by 90 degrees about one of its symmetry axes, it can be perfectly connected to a non-rotated copy of itself along one of its triangular faces (Figure 12). This ability of VE to connect with rotated copies of themselves allows many isomorphic VE to be stacked together to form an extended space lattice. This is a conceptually useful, alternative way to understand the manner in which many VE can be connected and woven together to form the synergetic field. Any subarea of the synergetic field consists of two sets of isomorphic VE—a left-handed set and a right-handed set. Each set has an equal number of VE, and all of the VE in one set have been rotated by 90 degrees about one of their bi-lateral symmetry axes relative to all of the VE in the second set. This construction yields a field consisting of interpenetrating and interlocking sets of left-handed and right-handed isomorphic VE.

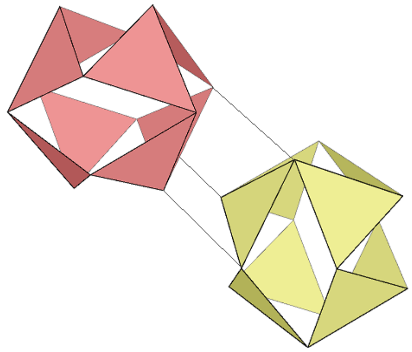


Figure 12: An exploded view of two inter-connected isomorphic VE. The isomorphic VE on the right has been rotated by 90 degrees about one of its symmetry axes relative to the isomorphic VE on the left. It can be linearly translated in space towards the non-rotated VE on the left, following the path indicated by the connecting diagonal lines between the two VE. The two VE can then be exactly joined with each other across a pair of conjugate triangular faces. The VE on the left is a right-handed isomorphic VE. The VE on the right is a left-handed isomorphic VE.

Figure 13 illustrates an extension of the process of connecting isomorphic VE to one another beyond just the two VE shown in Figure 12. Figure 13 shows five isomorphic phase VE stacked together. There are four left-handed VE on the lower level of Figure 13, and there is a fifth, right-handed VE slightly above them that can nest in the depression formed by the lower four. The fifth nested VE has been rotated by 90 degrees relative to the four lower VE that form its nest. The four lower VE and the one upper VE are thus members of two separate and distinct, interwoven, and interlocking left-handed and right-handed sets of VE that taken together form a small section of the synergetic field.

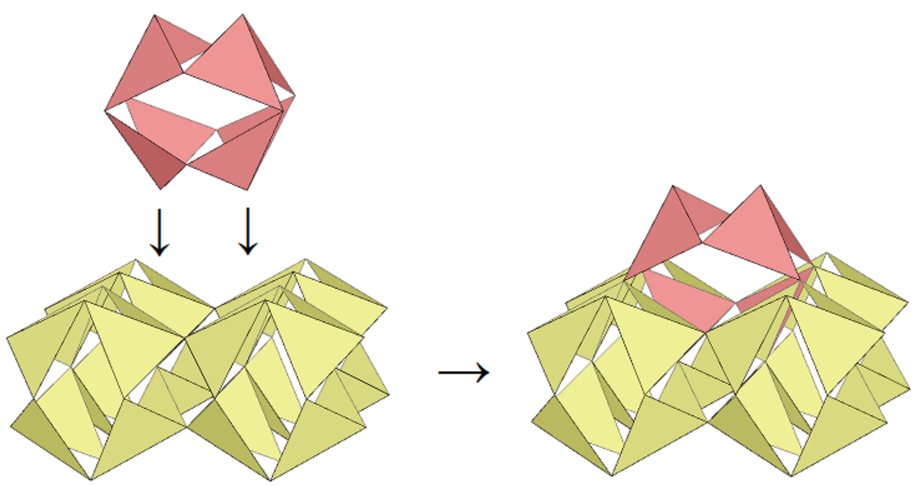
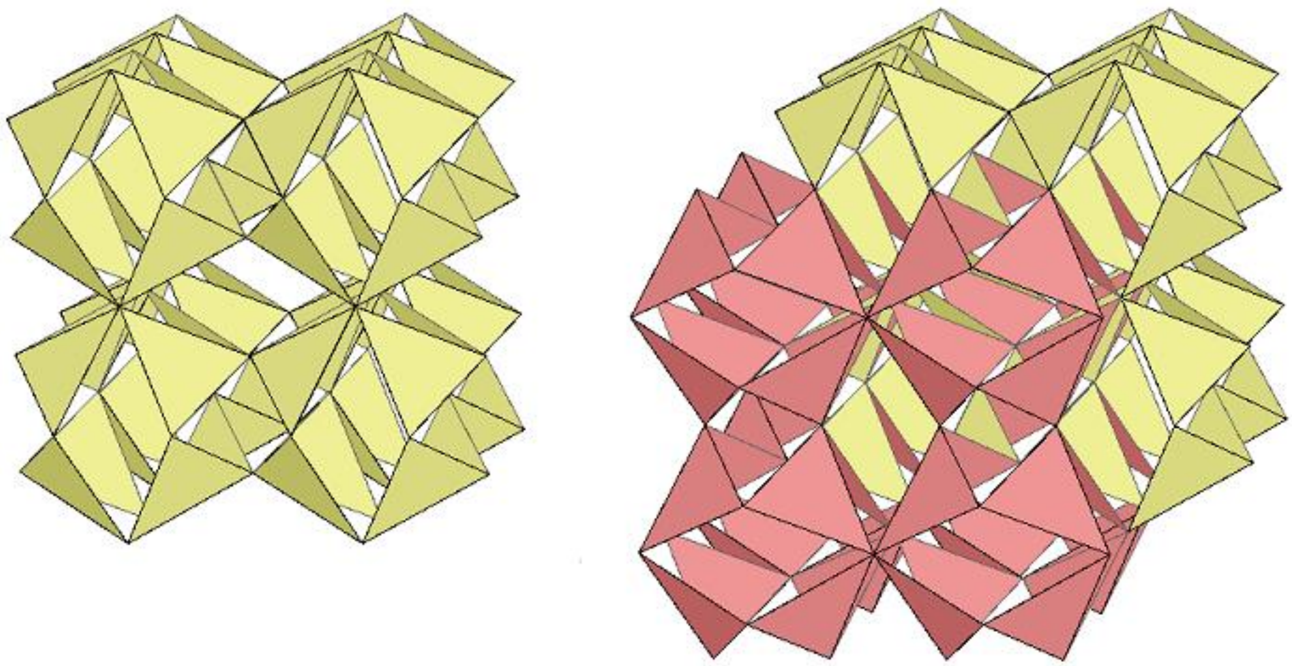


Figure 13: The left image shows an exploded view of five isomorphic phase VE stacked together. In both the exploded view on the left and in the merged view on the right, there are four left-handed VE on the lower level and a fifth right-handed VE nested within a depression formed between the lower four VE.

Figure 14(a) shows eight left-handed, isomorphic VE defining a 2x2x2 cubic array of VE joined together at neighboring vertex points. When such a left-handed set is combined with a similar set of eight right-handed VE, the members of one set fit precisely into a set of interstitial spaces defined by the members of the other set. The two sets fit snuggly together so that the triangular faces of one set coincide exactly with the triangular faces of the other set. Figure 14(b) shows a total of 16 VE, consisting of eight left-handed, isomorphic VE interwoven with eight right-handed, isomorphic VE positioned exactly within the two sets' respective interstitial spaces.



(a) (b)

Figure 14: Figure 14(a) shows one set of eight left-handed VE in a "2 X 2 X 2" cubic array. Figure 14(b) shows the same eight VE shown in Figure 14(a), but with the addition of a second set of eight right-handed VE nested in the interstitial spaces lying between the first set of left-handed VE. In Figure 14(b), the eight upper VE are left-handed, and the eight lower VE are right-handed.

Figure 15, below, shows a three-dimensional lattice of 1000 isomorphic VE stacked together to span a tiny region of space. For the sake of visual clarity, Figure 15 shows only the left-handed set of VE instead of two interwoven sets.

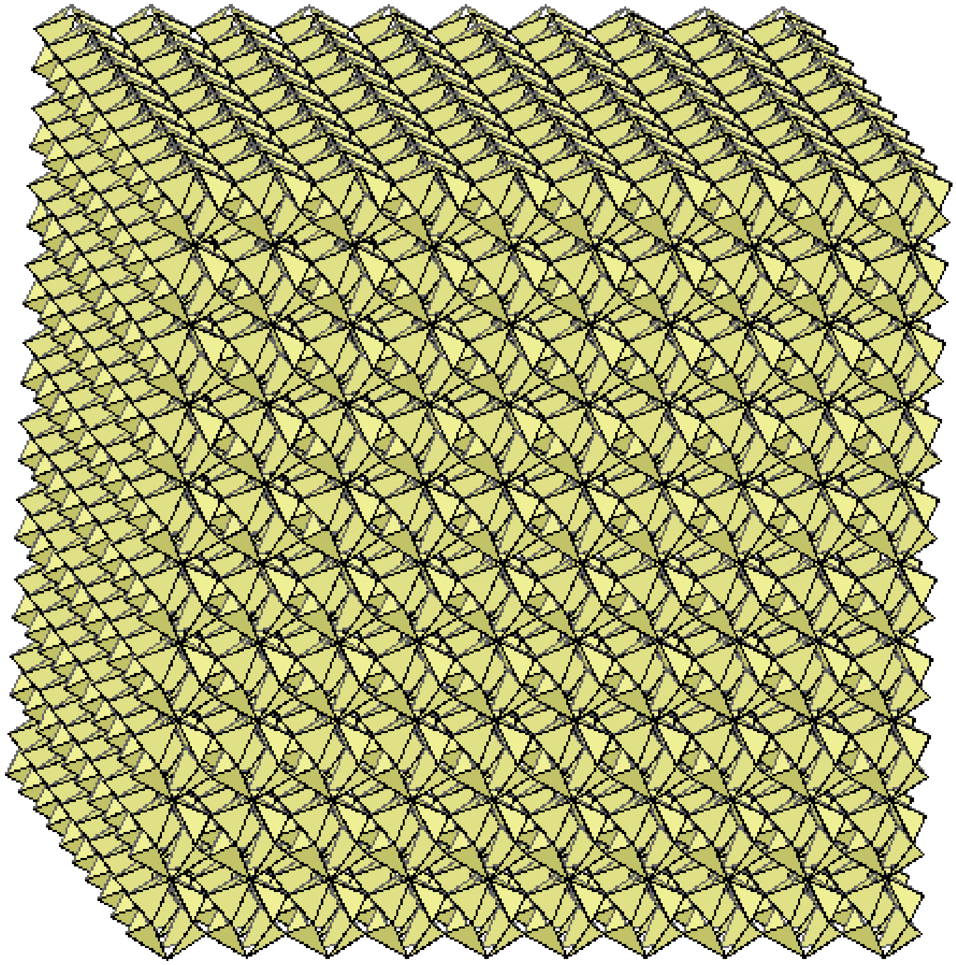


Figure 15: A "10 X 10 X 10", three-dimensional array of 1000 left-handed, Planck scale, isomorphic phase VE. For visual clarity, the second set of 1000 right-handed VE, situated in the interstitial spaces between the 1000 illustrated left-handed VE, are not shown.

An *innumerable* number of alternating left-handed and right-handed, Planck scale, isomorphic VE, woven together, define the synergetic field. The *relaxed*, balanced, *maximally expanded* state of the IVM, constructed from such isomorphic VE *is* the synergetic field. SLFT proposes that the synergetic field is the universal substratum underlying both the *flat* space of general relativity completely devoid of matter and energy, as well as the vacuum state of quantum field theory. As is discussed in Section 19 and Section 21, SLFT assumes that the gravitational and quantum fields arise as mathematical formalisms lying on top of the synergetic field. General relativity and quantum theory describe the *dynamics* of space and elementary particles, while SLFT describes their *structure*. Having completed a first-order description of the synergetic field focusing on its most expanded configuration, which is defined by the IIVM, we will now explore the *local* deformations of the synergetic field used to model elementary particles.

## 6. Fermions in the Synergetic Field

### *6.1. The Formation of Particles*

Certain *localized* variations of the global transformations described in Section 5.2 allow the synergetic field to support *localized* deformations, specifically in the form of *localized* contractions of the field. These localized contractions are *three-dimensional* analogs to the nominally *two-dimensional* rubber sheet dimples, previously discussed in Section 1.2. The synergetic field, however, does not need any external agents, such as weighted balls, to form its three-dimensional dimples. As will be explained in Section 11.1, the synergetic field has a *self-contained* mechanism that supports the formation and persistence of these localized contractions. Because of the very specific and discrete geometric structure of the synergetic field, these local contractions are well-defined and limited in number. *SLFT maps these local contractions to the elementary fermions, which are also well-defined and limited in number.*

We will now examine the specific details of how these localized, three-dimensional dimples form within the synergetic field. We will explore how these dimples are incorporated into the synergetic field as individual particles. We will explore how the synergetic field can exist in its most relaxed, fully expanded state, *globally* (i.e., the IIVM), while supporting localized areas of contraction (i.e., elementary particles) that can move freely through it.

### *6.2. The Structure of Electrons within the Synergetic Field*

To illustrate how such localized elementary particle contractions form within the synergetic field, we will first consider the electron. SLFT associates the electron with the VE's octahedral configuration (paired with the VE's cuboctahedral configuration). Suppose we start with the synergetic field in its isomorphic phase and let one of its VE contract toward its octahedral phase. In that case, there will be a tendency (especially if the synergetic field consists of a relatively small number of VE) for the *entire* field to undergo the *global* transformation described in Section 5.2, in which one set of VE contracts to octahedrons and the other set expands to cuboctahedrons. This does not give an image of a clearly defined *localized* particle.

To understand how a truly *localized* particle forms within the synergetic field, it is essential to understand two conflicting tendencies of the field. The first tendency, which will be discussed at greater length in Section 6.2, is the tendency for the synergetic field to remain in its equilibrium state—its state of maximal, global expansion in which all of its constituent VE are in their isomorphic configurations. The second tendency, which will also be discussed at greater length in Section 6.2, is the tendency of individual VE to contract to configurations corresponding to elementary particles, such as the octahedron-electron or the tetrahedron-quark configurations.

An accurate picture of an elementary particle arises when the synergetic field's global tendency to maintain its most expanded equilibrium state (i.e., the IIVM) is reconciled with its local tendency to contract to form elementary particles. The reconciliation of these two tendencies occurs in the limit in which the number of VE making up the synergetic field is very large. In this case, the contraction of a localized, individual VE in the synergetic field to its octahedral phase, for example, creates a tug-of-war between the two previously described opposing tendencies within the synergetic field.

The first tendency is the tendency of local contractions to induce the formation of a sea of electrons in the form of spatially alternating octahedrons and cuboctahedrons. The second tendency is the *global* tendency of the field to remain in its isomorphic, most expanded state. The resolution of the tug-of-war between these two tendencies results in a *local sea* of octahedrons (and their associated cuboctahedrons) embedded within, and gradually merging with, a surrounding *ocean* of approximately isomorphic VE (Figure 16). Within this local sea of octahedron-cuboctahedrons, there is only one VE contracted completely to its octahedral phase. This is the VE at the very center of the sea. This is the *center* of an electron.

An essential part of resolving these two opposing tendencies within the synergetic field is the existence of a "transition zone" between the central, octahedrally contracted VE and the surrounding synergetic field that is nominally in its isomorphic state. In this transition zone, the surrounding VE are only approximately in their octahedral (and cuboctahedral) configurations and *approach* their isomorphic configurations as the distance from the central VE increases. It is this locally extended sea of octahedral-cuboctahedral contractions, including both the central, maximally contracted VE, as well as the VE in the surrounding transition zone, that SLFT identifies as an elementary particle—specifically as an electron.

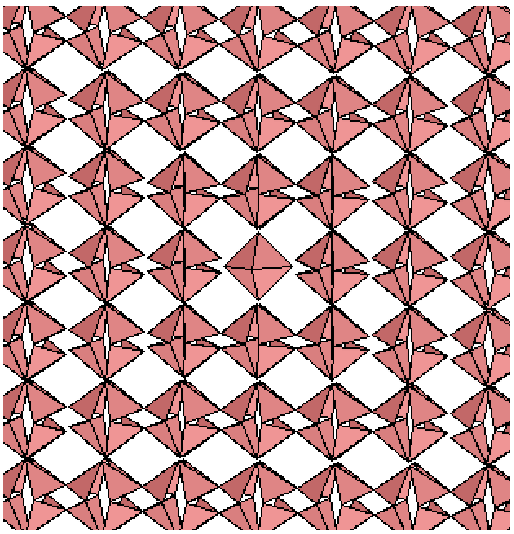


Figure 16: A nominally, two-dimensional cross-section through the synergetic field in the area of a localized octahedral contraction. The central most VE in the illustration is contracted to its octahedral configuration. The VE surrounding the central most VE are also contracted *towards* their octahedral configurations. SLFT identifies such areas of local contraction with elementary particles. The octahedral contraction is identified with the electron. For the sake of visual clarity, the rate of change in contraction between neighboring VE is greatly exaggerated in this illustration. The VE in the second set of interstitial, cuboctahedral phase VE are not shown in this illustration, also for the sake of visual clarity. (See Figure 8 in Section 5.2 and Figure 10 in Section 5.3 for illustrations of octahedral phase VE interwoven with cuboctahedral phase VE.)

Figure 16 reveals small gaps between the individual, neighboring VE. This implies that the left-handed and the right-handed sets of VE are not perfectly well connected. This is not explicitly illustrated in Figure 16 because it only shows the left-handed, octahedral set of VE. However, it is nevertheless the case—the left-handed set of octahedral VE and the right-handed set of cuboctahedral VE are no longer well connected to one another in the vicinity of the synergetic field's local contractions. In the case of a local contraction embedded within the synergetic field's global equilibrium state, it is, in fact, *impossible* for the individual left-handed and right-handed VE within the synergetic field to remain *perfectly* well connected to one another. This contrasts with the synergetic field's purely *global* transformations described in Section 5.2, in which all of the left-handed and right-handed VE do remain perfectly well connected during the entire transformation.

The discrepancy in connections between adjacent VE can be made arbitrarily small by making the variations in contraction between immediately adjacent VE arbitrarily small. There will, however, always be some non-vanishing gaps between left-handed and right-handed VE, no matter how small. For example, Figure 17 shows a small region of the synergetic field in which the differences in contraction between neighboring VE are much smaller than those shown in Figure 16. This figure still illustrates much larger differences in contraction between adjacent VE than are expected to occur in nature.

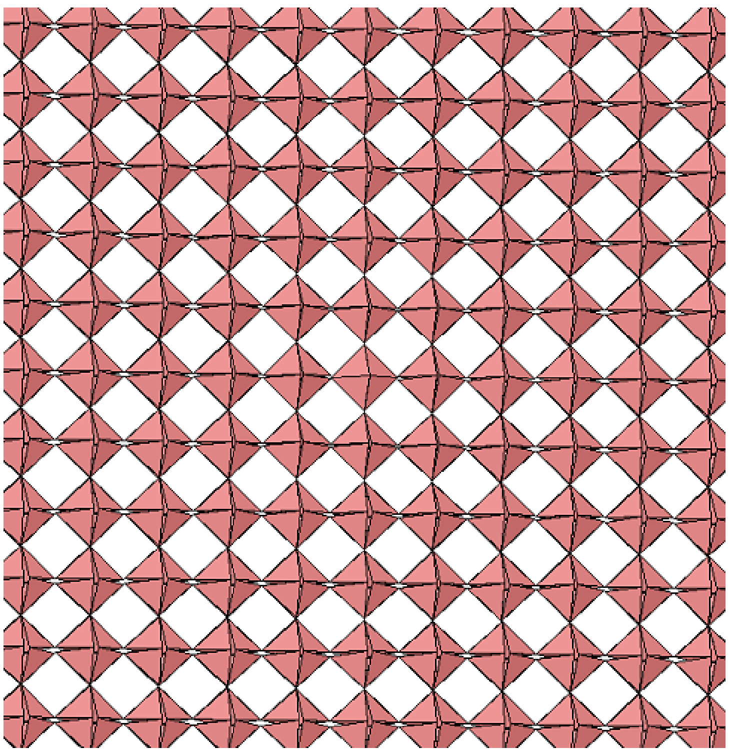


Figure 17: A local, nominally, two-dimensional cross-section through the synergetic field in a region of local contraction similar to the cross-section shown in Figure 16. The central most VE in the illustration is contracted to its octahedral configuration. In Figure 17, the rate of change in contraction between neighboring VE is much less than in Figure 16, but it is still much greater than it is expected to be in nature. The illustration shows only the left-handed, octahedrally *contracted* set of VE. The complementary right-handed, cuboctahedrally *expanded* VE are omitted for visual clarity.

The gaps between left-handed and right-handed VE in the vicinity of such localized field contractions must be reconciled with the requirement that the synergetic field's individual elements must remain physically well connected with one another. This reconciliation can be achieved through a simple hypothesis: the individual VE's triangular faces, which are the points of contact and connection between left-handed and right-handed VE, can become infinitesimally distorted (i.e., they can bow outwards towards their immediately adjacent neighbors by an infinitesimally small amount). They can thereby bridge the gaps created by the infinitesimal variations in contraction between neighboring VE. This model solves the field's connectivity problem and it also bestows elasticity on the field—through this mechanism the field becomes an elastic, deformable medium.

The local contractions described above provide a discrete, three-dimensional analogy to the previously discussed dimples in a nominally two-dimensional rubber sheet. In the case of a rubber sheet, the dimples are local deformations in one direction, downwards, perpendicular to the rubber sheet's surface. In the case of the synergetic field, the local deformations are in the form of all-directions-pulling-inwards, local contractions of the field. Figure 16 and Figure 17 illustrate this as nominally *two-dimensional, circular* patterns within slices through the synergetic field. In reality, these local contractions of the field are *three-dimensional spherical* patterns. At the center of the locally contracted area of the synergetic field that defines an elementary particle, there is an area of maximum contraction (i.e., the central VE contracted to an octahedron). This area of maximum contraction gradually decreases in intensity as one moves *spherically* outwards. As one continues to move *spherically* outwards, these areas of contraction eventually merge with surrounding areas of *nominally* zero contraction defined by the surrounding synergetic field in its (nominally) isomorphic state.

Although Fuller did make direct and explicit references to the idea of constant flux within both the vector equilibrium and the isotropic vector matrix [44], the author is not aware of any explicit descriptions by Fuller of the kinds of local deformations of the *isomorphic* isotropic vector matrix that SLFT uses to define elementary particles. The author therefore assumes that the identification of these types of local deformations of the *isomorphic* isotropic vector matrix, and their significance, are new contributions to synergetic geometry. These new elements are part and parcel of SLFT's modifications and extensions to synergetic geometry referenced in Section 1.1.

### *6.3. Neutrinos*

The formation of neutrinos within the synergetic field is very similar to the formation of electrons. The primary difference between the electron and neutrino configurations is their relative degrees of local contraction. The neutrino's overall configuration is structurally similar to the electron, but the degree of contraction relative to the synergetic field's isomorphic state is much less. In the case of the neutrino, there is a local sea of approximately symmetrical icosahedra and asymmetrical icosahedra, centered about a single, central, perfectly symmetrical icosahedron, merging into a surrounding ocean of approximately isomorphic VE (Figure 18). Visually, this configuration's geometry is rather subtle since the icosahedral configuration represents only a modest contraction of the synergetic field relative to its uncontracted isomorphic state. The formation and unique dynamics of the neutrino-icosahedron will be more fully discussed in Section 12 after some other important aspects of the synergetic field relevant to neutrinos have been discussed.

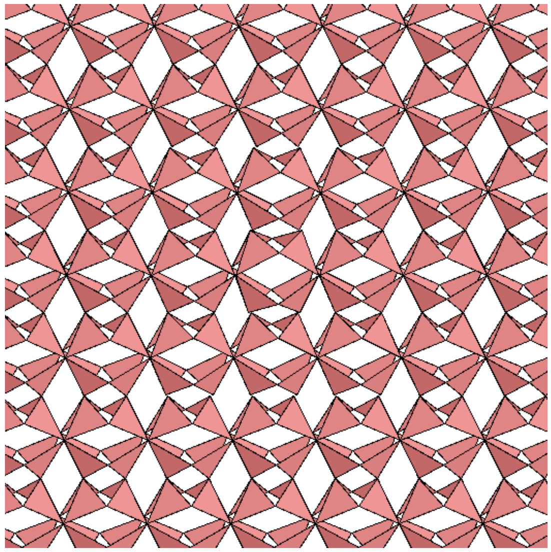


Figure 18: The formation of the neutrino is visually more subtle than the formation of the electron. The localized, icosahedral contraction of the synergetic field shown in the illustration represents only a modest contraction of the field relative to its uncontracted state. The centermost VE in the illustration is in its icosahedral configuration, while the VE around the edges of the figure are in their isomorphic configurations. If one looks closely at the illustration's centermost VE, one can see that its folded diamonds form pairs of equilateral triangles, while the folded diamonds of VE near the perimeter of the illustration form pairs of isosceles triangles.

### *6.4 Quarks*

#### *6.4.1 Global Tetrahedral Contractions in the Synergetic Field*

The formation of quarks within the synergetic field is in some ways similar to the formation of electrons, but it is also different from the formation of electrons in important ways. The quark is related to somewhat different global *and* local transformations of the synergetic field. The *global* transformation of the synergetic field associated with quarks is related to the pathway taken by *individual* VE transforming from their cuboctahedral phase to their tetrahedral phase (see Figure 6 in Section 4.6).

The first phase of this global contraction is the same as the contraction to the octahedron-cuboctahedron phase associated with the formation of electrons (see Figure 8 and Figure 10 in Section 5.2). The second phase of the quark-tetrahedral global contraction starts where the electron-octahedral-cuboctahedral global transformation stops. In the tetrahedral global transformation, the VE in the cuboctahedral phase further contract to their tetrahedral phases, as two oppositely situated square faces in each cuboctahedral phase VE pinch together in orthogonal directions, as shown in Figure 6. During this transformation, the VE in their octahedral phases remain in their octahedral phases.

It turns out that during this global transformation, half of the VE in the cuboctahedral phase pinch together in a "left-handed" sense while the other half pinch together in a "right-handed" sense. A similar convention is used for assigning left-handed and right-handed labels to the VE's tetrahedral contractions as was used in Section 5.2 for labeling octahedral contractions. The rotational sense of the upper right triangle in the VE is used as a reference point to make this distinction. As was the case in the VE's octahedral contraction, the assignment of "left-handed" and "right-handed" labels to these two versions of the tetrahedral contraction is purely a convention. The left-handed and right-handed VE are shown in Figure 19 and Figure 20 below, respectively, as lighter and darker shaded VE contracting with mirrored spatial orientations.

It is important to note that the left-handed and right-handed conventions used for the VE's tetrahedral contraction are *different* conventions than the previously described left-handed and right-handed conventions discussed in the context of the synergetic field's two sets of isomorphic VE. The tetrahedral phase VE distinguished as left-handed and right-handed contractions are themselves all formed entirely within *either* the left-handed *or* the right-handed set of isomorphic VE.

The VE in the "left-handed" and "right-handed" tetrahedral sets are arranged relative to one another in a *three-dimensional*, checker-board-like pattern. The six illustrations in Figure 19 show a small set of four cuboctahedral phase VE in a single layer undergoing this transformation. In this illustration, the darker shaded VE are contracting to left-handed tetrahedrons, and the lighter shaded VE are contracting to right-handed tetrahedrons.

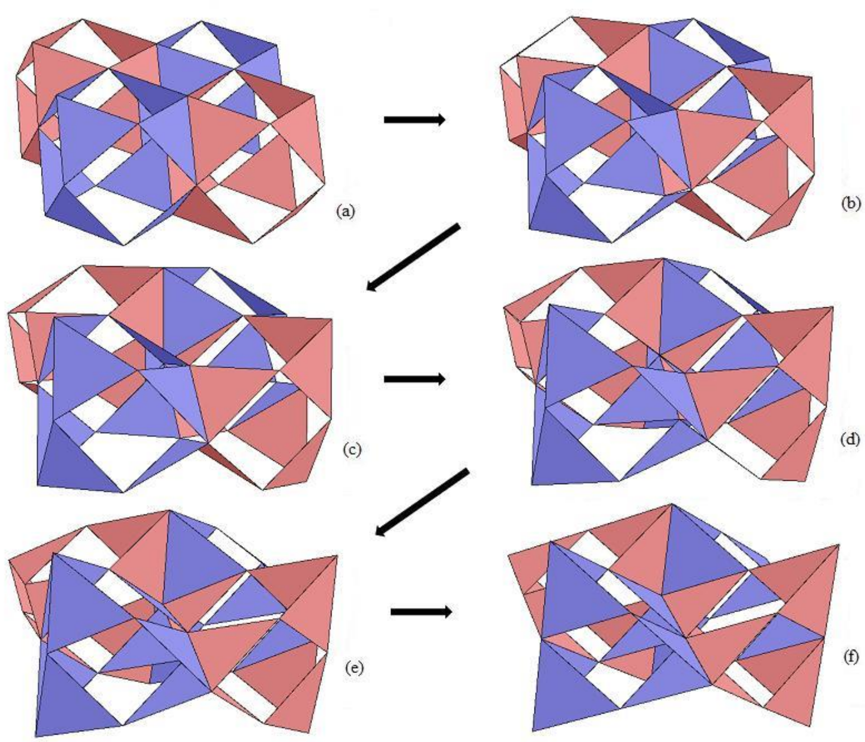



Figure 19: The six illustrations, (a) – (f), show a small set of four cuboctahedral phase VE in a single layer undergoing the IVM's tetrahedral *global* transformation. For visual simplicity, the VE in the second set of interstitial VE that are contracted to octahedrons are not shown. Proceeding sequentially from left to right and from top to bottom ((a) through (f)), the cuboctahedral phase VE contract to their tetrahedral phases.

During this transformation, the VE in the synergetic field's second set are in their octahedral phases, and they remain in their octahedral phases during the transformation. However, these octahedral phase VE undergo rotations around one of their three respective, orthogonal, vertex-aligned, symmetry axes. The six illustrations in Figure 20 show a small set of nine cuboctahedral VE with the addition of four such rotating, interstitial, octahedral phase VE. In these illustrations, the progressive *rotations* of the octahedral VE can be seen to occur in concert with the progressive *contractions* of the other set of VE to alternating left-handed and right-handed tetrahedrons. The illustrations show that one-half of the octahedrons (lighter shaded) rotate in one sense while the other half (darker shaded) rotate in the opposite sense. These two sets of oppositely rotating octahedral phase VE are arranged relative to one another in an alternating, *three-dimensional*, checker-board-like pattern, similar to the three-dimensional checker-board-like arrangement of right-handed and left-handed tetrahedral phase VE.

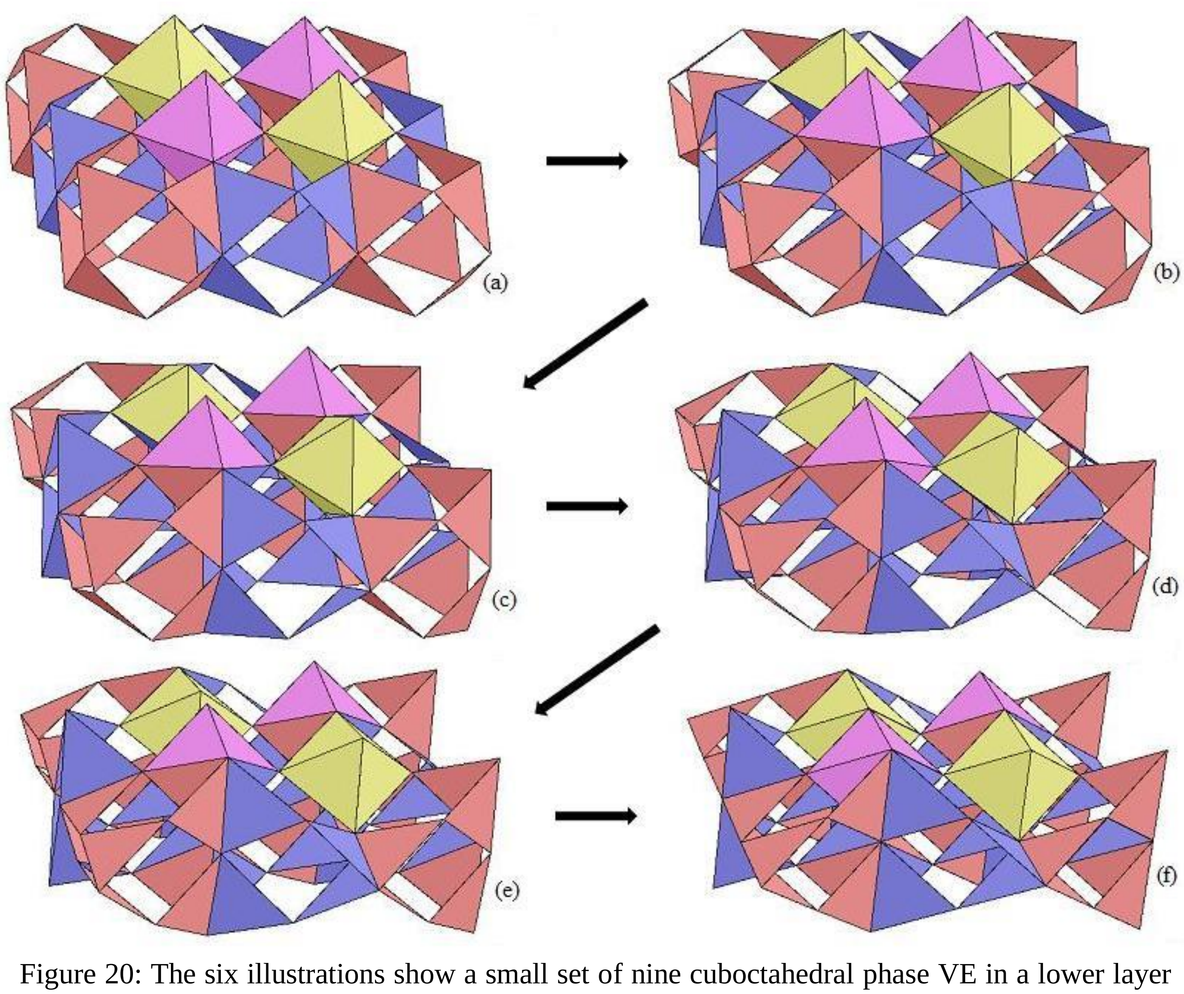



Figure 20: The six illustrations show a small set of nine cuboctahedral phase VE in a lower layer undergoing the tetrahedral global transformation illustrated in Figure 19. This illustration also shows four interstitial VE in an upper layer contracted to their octahedral phases. Proceeding sequentially from left to right and from top to bottom ((a) through (f)), the cuboctahedral phase VE contract to their tetrahedral phases, while the octahedral phase VE rotate (in two opposite senses) about one of their three orthogonal, vertex-aligned, symmetry axes.

Both the right-handed and the left-handed tetrahedral phase VE form within *either* one or the other of the synergetic field's two sets of VE—for example, the right-handed and left-handed tetrahedral VE could form as contractions of the synergetic field's right-handed isomorphic VE. In that case, all of the octahedral phase VE that accompany the tetrahedral phase VE would form as contractions of the field's left-handed isomorphic VE. Alternatively, the right-handed and left-handed tetrahedral VE could form as contractions of the synergetic field's *left-handed* isomorphic VE. In that alternative case, all of the octahedral phase VE that accompany the tetrahedral phase VE would form as contractions of the field's *right-handed* isomorphic VE.

Although Fuller did explicitly define the tetrahedral jitterbug transformations of *individual* vector equilibriums [40], the author is not aware of any explicit descriptions by Fuller of the seamless embedding of the tetrahedral jitterbug transformations of individual vector equilibriums within the isotropic vector matrix as a whole. The author therefore assumes that the identification of the global tetrahedral transformations of the isotropic vector matrix described above is a new contribution to synergetic geometry. These new elements are part of SLFT's modifications and extensions to synergetic geometry referenced in Section 1.1. They are essential for modeling quarks.

*6.4.2. Quarks as Localized Tetrahedral Contractions*

With the above understanding of the synergetic field's *global* tetrahedral transformation, it is now possible to understand how *individual* quark-tetrahedrons form *locally*, embedded within a surrounding synergetic field in its isomorphic state. The way this occurs is entirely analogous to the way that electron-octahedron-cuboctahedrons and neutrino-icosahedrons are embedded within a surrounding isomorphic synergetic field (see Figure 16, Figure 17, and Figure 18 in Sections 6.2 and 6.3).

Within the locally contracted subsection of the synergetic field that defines a quark, a central VE is contracted completely to its tetrahedral phase. The surrounding VE are only approximately in their tetrahedral configurations and approach first their cuboctahedral configurations, and then finally their isomorphic configurations, as the distance from the central VE increases. These surrounding VE define a *transition zone* between the central, tetrahedrally *contracted* VE and the surrounding synergetic field that is *nominally* in its *uncontracted*, isomorphic state. This is analogous to the transition zone that exists within the electron configuration described in Section 6.2. It is this locally extended sea of tetrahedral-octahedral contraction, including both the central tetrahedrally contracted VE, as well as the VE in the surrounding transition zone (including the octahedrally contracted VE) that SLFT identifies as a quark (Figure 26 and Figure 27).

The geometry of the tetrahedral contraction is more complicated than the contractions associated with electrons and neutrinos. Illustrations of this state of the synergetic field, such as Figure 26 and Figure 27, can therefore be visually confusing. Several clarifying figures are provided below to aid the visual comprehension of the synergetic field's quark configuration. The first figure, Figure 21, shows an exploded view of a set of tetrahedral phase VE. The second figure, Figure 22, shows how these exploded tetrahedrons come together in the horizontal direction to start to form an interconnected network. Similarly, the next figure, Figure 23, shows how the tetrahedrons come together in the vertical direction. The fourth figure, Figure 24, shows how the tetrahedrons come together in both the horizontal *and* vertical directions to form a merged, interconnected network of tetrahedral phase VE.

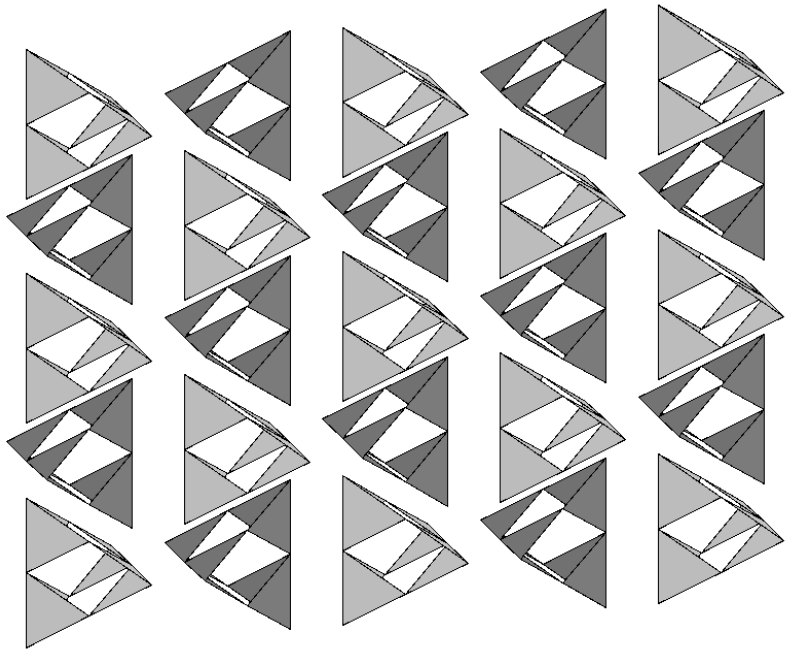


Figure 21: An exploded view of an array of 25 tetrahedral phase VE. The VE are contracted to left-handed (lighter shaded) and right-handed (darker shaded) tetrahedrons in an alternating, checkerboard-like fashion.

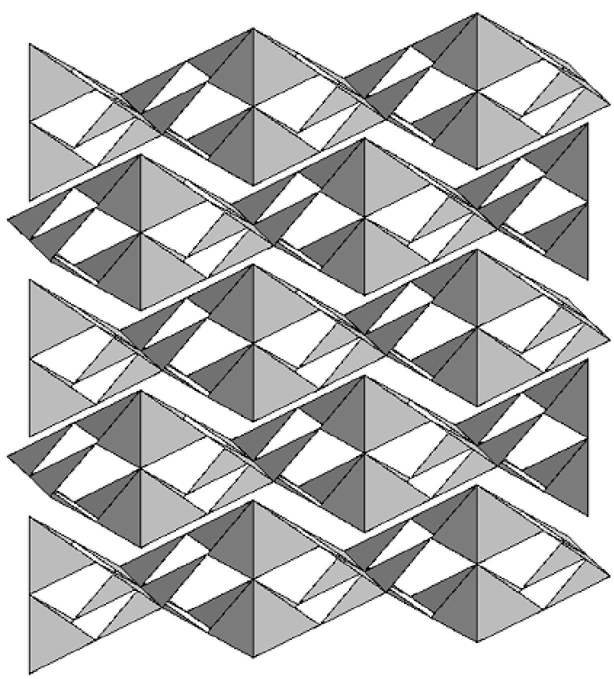


Figure 22: A partially exploded view of an array of 25 tetrahedral phase VE. The VE are contracted to left-handed and right-handed tetrahedrons in an alternating, checkerboard-like fashion. In this view, the tetrahedrons are brought together along the page's *horizontal* axis in order to visually isolate and clearly illustrate their left-to-right connections along this axis.

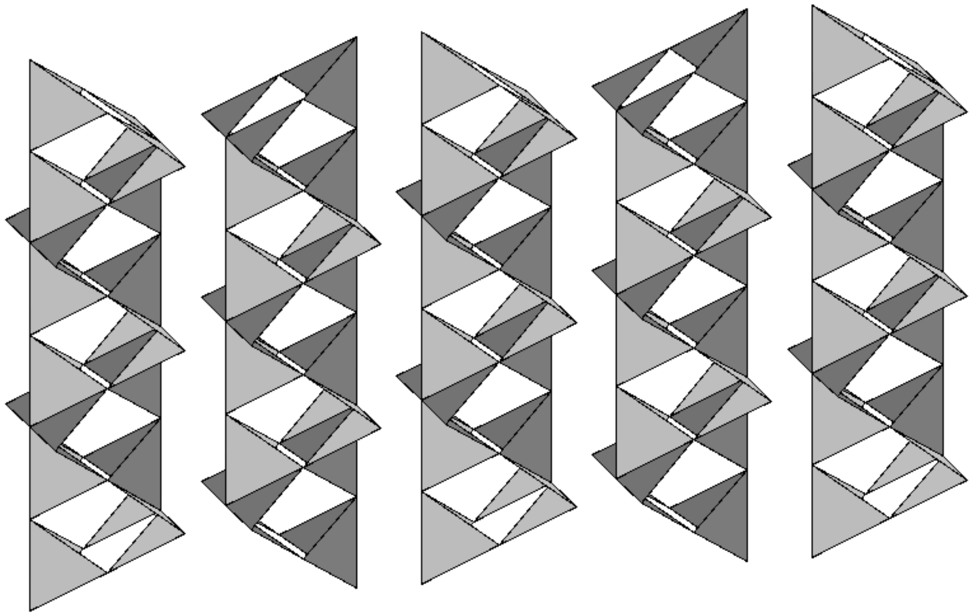


Figure 23: A partially exploded view of an array of 25 tetrahedral phase VE. The VE are contracted to left-handed and right-handed tetrahedrons in an alternating, checkerboard-like fashion. In this view, the tetrahedrons are brought together along the page's *vertical* axis in order to visually isolate and clearly illustrate their up-and-down connections along this axis.

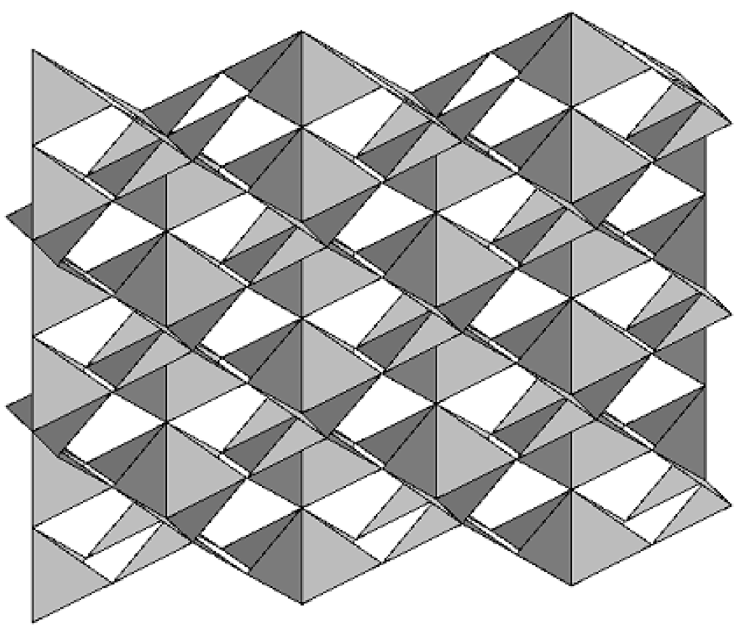


Figure 24: A merged view of an array of 25 tetrahedral phase VE. The VE are contracted to left-handed and right-handed tetrahedrons in an alternating, checkerboard-like fashion. In this view, the tetrahedrons are brought together along *both* the vertical *and* horizontal axes illustrating their full integration to form a merged, interconnected network of tetrahedral phase VE.

Figure 25 illustrates an exploded view of the synergetic field's local contraction that is identified with the center of a quark. In the previous four figures, all of the VE are fully contracted to their tetrahedral phases. In contradistinction, Figure 25 shows VE with variable degrees of tetrahedral contraction. The centermost VE is contracted completely to its tetrahedral configuration, but the degree of contraction of the surrounding VE becomes slightly less as one moves away from the central VE. The VE farther away from the central VE gradually converge first towards their cuboctahedral configurations (partially shown) and finally towards their isomorphic VE configurations (not shown).

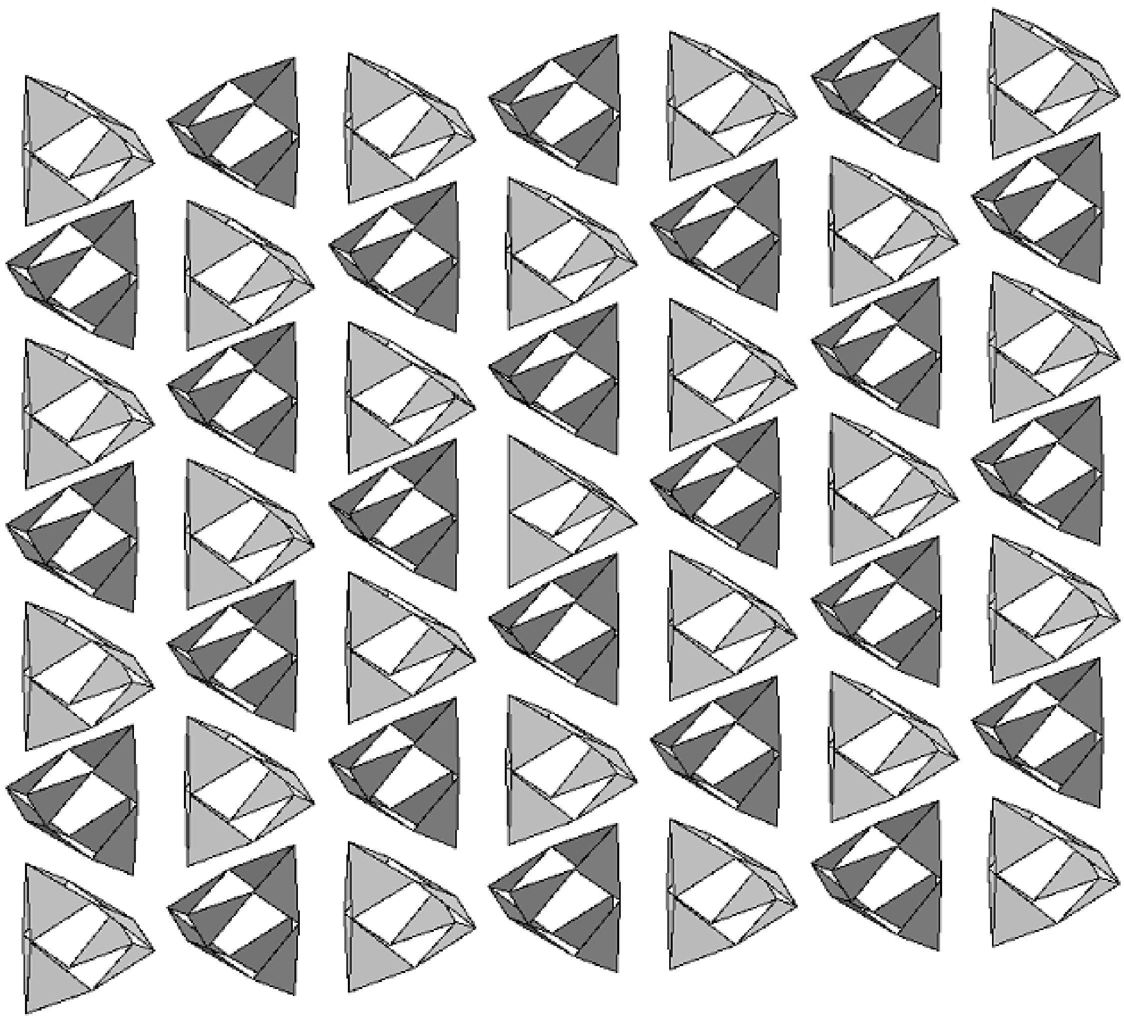


Figure 25: An exploded view of the synergetic field's local contraction identified with the central region of a quark. The centermost VE is contracted to its tetrahedral configuration. The VE farther away from the central VE gradually converge first towards their cuboctahedral configurations (partially shown in the illustration) and finally towards their isomorphic VE configurations (not shown in the illustration). This complex of tetrahedral contractions of VE is identified as a quark. For the sake of visual clarity, the rate of change in contraction between neighboring VE, as well as the associated gaps between neighboring VE, are greatly exaggerated in this illustration. For visual clarity, the VE in the synergetic field’s second set that are contracted to their octahedral phases and that are differentially rotated (see Figure 20) are not shown.

Figure 26 shows the same set of VE shown in Figure 25, but they are now merged together to form a merged, integrated, interlocking network of VE having variable degrees of tetrahedral contraction. This figure shows a two-dimensional slice through the synergetic field at the center of its quark configuration. It is analogous to Figure 16, Figure 17, and Figure 18 in Sections 6.2 and 6.3, which show two-dimensional slices through the centermost regions of electron and neutrino configurations. Although all of these figures only show two-dimensional cross-sections of elementary particles, the particles are, in fact, actually nominally *spherical*, *three-dimensional* contractions of the synergetic field.

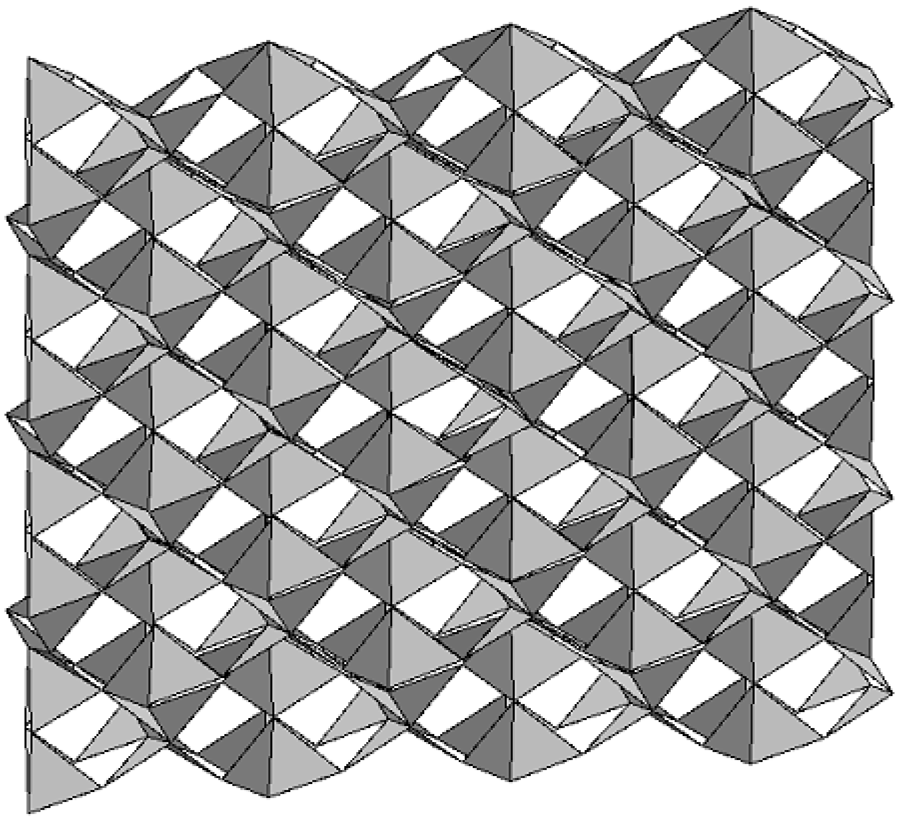


Figure 26: The local contraction of the synergetic field identified with quarks. The centermost VE is contracted to its tetrahedral configuration. The VE farther away from the central VE converge first towards their cuboctahedral configurations (partially shown) and finally to their isomorphic VE configurations (not shown). The synergetic field's second set of VE that are contracted to their octahedral phases and that are differentially rotated (see Figure 20) are not shown for visual clarity. The variation in contraction rates between neighboring VE is much greater than it is expected to be in nature.

Figure 27 is similar to Figure 26 except that the rate of change between neighboring VE is further exaggerated to more explicitly illustrate the idea of a central, tetrahedrally contracted VE gradually merging with the field of surrounding VE that are much less contracted. This figure is similar to Figure 16, in Section 6.2, which shows an exaggerated rate of change in contraction between neighboring VE inside an electron.

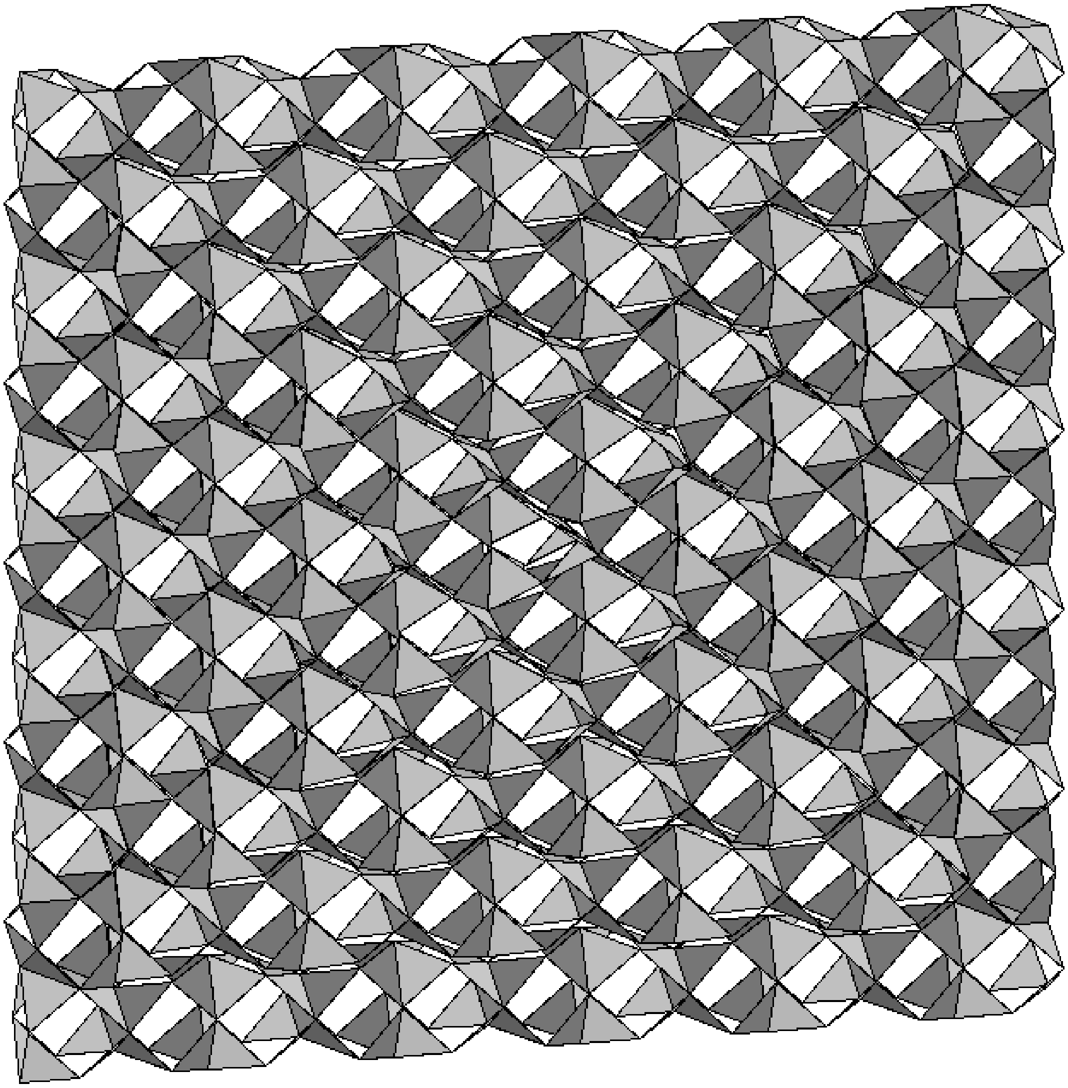


Figure 27: The local contraction of the synergetic field identified with quarks. The centermost VE is contracted to its tetrahedral configuration. The VE farther away from the central VE converge towards first their cuboctahedral configurations (partially shown), and finally to their isomorphic VE configurations (not shown). In this figure, the rate of change in contraction between neighboring VE is significantly greater than in Figure 26 in order to emphasize the transition from a central, tetrahedrally contracted VE to surrounding VE that are much closer to their cuboctahedral phases (i.e., the VE that lie along the corners and edges of the figure).

As was the case for electrons and neutrinos (see Figure 16, Figure 17, and Figure 18), there are small gaps between the individual VE within the vicinity of a quark. These VE are no longer perfectly well connected to one another. These gaps will occur even when the variation in contraction between neighboring VE is extremely small, as it is expected to be in nature. As is the case for electrons, the discrepancy in connections between adjacent VE within the quark can be made arbitrarily small by making the variations in contraction between immediately adjacent VE arbitrarily small (much smaller than is illustrated in Figure 25, Figure 26, and Figure 27).

There will, however, always be some discrepancy, no matter how small, and this discrepancy is reconciled using the same hypothesis that was used for electrons (and neutrinos). This is the hypothesis that the individual VE's triangular faces that are the points of contact and connection between tetrahedral and octahedral phase VE can become infinitesimally distorted. Specifically, they are allowed to bow outwards towards their immediately adjacent neighbors by an infinitesimally small amount. They can thereby bridge the gaps created by the infinitesimal variations in contraction between neighboring VE.

## 7. Geometric Origins of Particle Properties

### *7.1. Structural Explanations of Particle Properties*

If SLFT's discrete, three-dimensional, *geometric* model of space and elementary particles is correct, it should provide structural explanations of specific observed properties of elementary particles. These structural explanations should connect the particles' observed properties to the specific geometric characteristics of the VE's various configurations. As will be shown below, the specific structural details of the VE's tetrahedral phase provide just such explicit, detailed examples of how various observed properties of quarks can be mapped back to the internal structure of the VE and the synergetic field. These structural details provide a model that can be used to *geometrically* explain such things as the fractional electric charges of quarks (relative to the unit charges carried by electrons) and the quarks' color charges and flavors.

### *7.2. The Vector Equilibrium's Internal Structure*

In order to understand the isomorphisms between the observed properties of quarks and the geometry of the VE's tetrahedral contraction, it is first necessary to pause and take a closer look at the VE itself and at synergetic geometry's complete definition of the VE. Up to this point, we have only considered the VE's external, cuboctahedral *shell*. Fuller defined the VE, not just in terms of this external shell, but also in terms of an *internal* structure [45]. Fuller defined the VE in terms of eight tetrahedrons joined together at a common central point (Figure 28). The eight "peaks" of eight tetrahedral pyramids all join together precisely at the VE's center point. Each tetrahedron has six edges, three of which lie on the VE's external shell and three of which radiate outwards from the VE's center towards three of its 12 external vertices.

Since there are eight tetrahedrons, the VE has 24 external struts and 24 internal struts. The 24 internal struts are grouped in 12 spatially coincident pairs—each of the three internal edges of each tetrahedron is abutted to, and coincident with, an internal edge of a neighboring tetrahedron. The inclusion of these 24 internal struts makes the geometries of the VE and the synergetic field much richer.

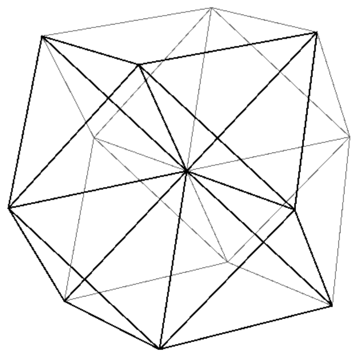


Figure 28: Internal Structure of the VE showing its construction from eight tetrahedrons situated around a common central point. Each tetrahedron contributes three internal edges or vectors and an additional three external edges, creating a total of 24 internal (radial), unit edge vectors, and 24 external (circumferential) unit edge vectors.

The joining of eight tetrahedrons around a point forms one of the fundamental, concave, regular polyhedrons, the octahemioctahedron (Figure 29). The convex hull surrounding the octahemioctahedron is the cuboctahedron. When the VE is viewed in this way, it has eight external triangular faces and twenty-four internal triangular faces. Each of the eight tetrahedrons contributes one external triangular face and three internal triangular faces to the octahemioctahedron, for a total of thirty-two triangular faces.

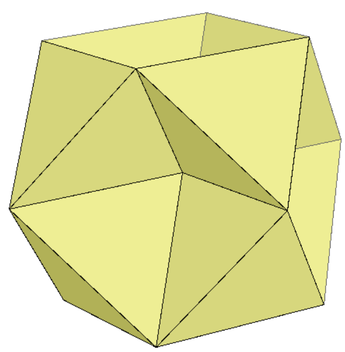


Figure 29: The octahemioctahedron, formed by joining together eight tetrahedrons so that each tetrahedron has one of its four vertex points centrally positioned, coincident with similarly centrally positioned vertex points of each of the other seven tetrahedrons. These eight centrally positioned vertices all meet at the octahemioctahedron's geometric center.

When the VE's tetrahedral contraction is viewed in the light of this richer, internal structure, an important observation can be made. As the VE transforms towards its tetrahedral configuration, its internal faces' shapes and surfaces transform. When the VE reaches its tetrahedral stage, its internal faces are divided into two subsets. The *transformed* surface areas of the faces in one subset are reduced to $\sqrt{2/3}$ of their *original* surface areas, and the surface areas of the faces in the other subset are reduced to $\sqrt{1/3}$ of their *original* surface areas (Figure 30). (The original surface areas referenced above are the surface areas of the 24 internal triangles within a VE in its fully expanded, cuboctahedral phase. These triangles are unit edge equilateral triangles as shown in Figure 29.)

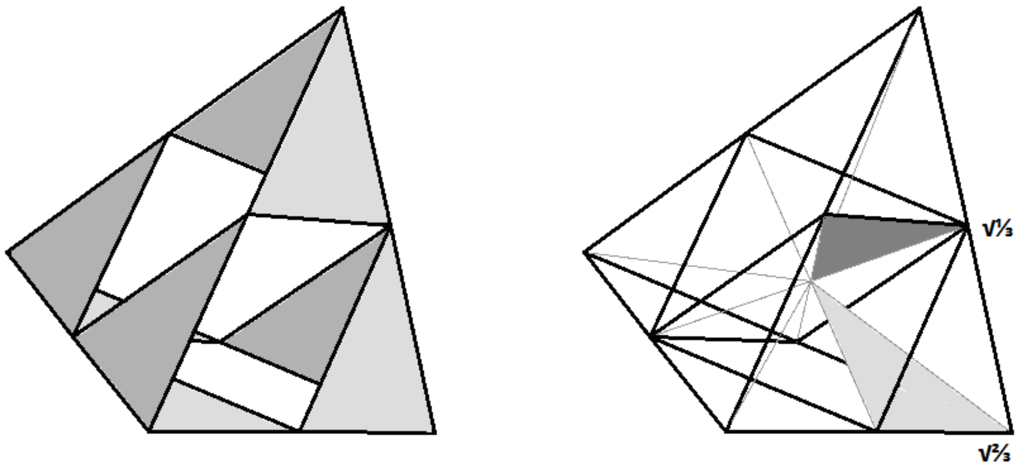



Figure 30: This figure shows the VE contracted to its tetrahedral configuration. The highlighted *internal* faces in the right-hand figure illustrate the associated contraction of the surface areas of the internal faces from unity to either $\sqrt{1/3}$ (darker triangle) or $\sqrt{2/3}$ (lighter triangle) of their original sizes, depending on their locations within the VE.

*7.3. Quark Fractional Electric Charges*

The contraction of the VE's internal faces is an important observation. Any model of elementary particles that proposes a complex, internal, three-dimensional geometry suggests the possibility that *the specific details of that geometry may be related to specific observed properties of the elementary particles*. In a very general and qualitative manner, we have already seen a relationship between particle geometries and particle properties in the *relative* masses of elementary particles. As was introduced in Section 4.3, the increasing masses of the elementary particles are *qualitatively* associated with the increasing contractions of their associated VE deformations. The change in the size of the VE's internal faces provides an even more intriguing and more specific example of the connection between the geometries of the VE and the IIVM and the specific physical properties of the elementary particles. *The values "⅔" and "⅓" define the absolute values of the quantities of electric charge carried by up-type quarks and down-type quarks, respectively, compared to the single unit of electric charge carried by electrons.* This observation leads to SLFT's *sub-particle* hypothesis.

*7.4. Sub-Particle Hypothesis*

SLFT hypothesizes that the VE's internal and external faces define a set of *two-dimensional sub-particles* that are linked in some manner to their associated, real, *three-dimensional*, particles. Specifically, SLFT proposes that elementary particles' charges are derived from the *square of the area* of their associated sub-particles. The VE's internal faces that contract to $\sqrt{2/3}$ and $\sqrt{1/3}$ of their full, original sizes during the tetrahedral contraction are therefore associated with, and the source of the ⅔ and ⅓ electric charges (i.e., *absolute values* of electric charges) carried by up and down quarks, respectively. Section 11.1 will further explain how these sub-particles both stimulate the formation of three-dimensional particles and simultaneously endow them with their respective electric charges. In a nutshell, SLFT hypothesizes that the formation of three-dimensional particle deformations are coincident with, and stimulated by, the disappearance of a sub-particle. The disappearing sub-particle is correlated with the particular elementary particle that is associated with the field's three-dimensional deformation.

The total number of different quarks further supports SLFT's sub-particle hypothesis. There are 24 known varieties of quarks when all symmetries are considered. These symmetries include positive and negative electric charge, flavor, color, and spin. Using all of these symmetries to create all possible up and down quark varieties generates the standard model's full set of 24 quarks. The number of *internal* faces of the VE and the total number of quarks are both twenty-four. This correlation, combined with the $\sqrt{2/3}$ and $\sqrt{1/3}$ relative surface area transformations of these twenty-four *internal* triangles, supports SLFT's sub-particle hypothesis.

This hypothesis is further supported by the ability to define a similar mapping of electrons and neutrinos to the VE's *external* faces. Considering charge and spin symmetries, there are four possible electrons and four possible neutrinos (assuming the existence of sterile neutrinos) for a total of eight varieties of leptons. SLFT maps these eight leptons to the eight external faces of the VE's cuboctahedral shell. This association provides an exact correspondence between 32 elementary particles (i.e., the standard model's 30 first generation elementary fermions plus two additional, *possible* sterile neutrinos) and the VE's 32 sub-particles (i.e., the VE's 32 internal and external faces). It also provides an exact correspondence to the unitary and fractional charges associated, respectively, with electrons and quarks. The charge correspondence appears to break down, however, for neutrinos. Like electron sub-particles, the neutrino sub-particles are associated with the external faces of the VE. Unlike electrons, however, neutrinos have zero electric charge. This neutrino charge discrepancy will be resolved in Section 12.

### *7.5. Quark Flavors*

In the above model, the flavor of a quark is determined by the electric charge on the two-dimensional sub-particle that disappears (see Section 11.1) in concert with the three-dimensional tetrahedral contraction of a VE. Nevertheless, there is a deeper, correlated, three-dimensional, *geometric* explanation for the existence of up and down quark flavors. As was discussed in Section 6.4.1, and as is shown in Figure 31 below, the VE's tetrahedral contraction can occur in either a left-handed or a right-handed sense. It might therefore be possible to simply associate one handedness type with up quarks and the other handedness type with down quarks. The specific handedness type that is associated with each quark flavor would be a matter of convention.

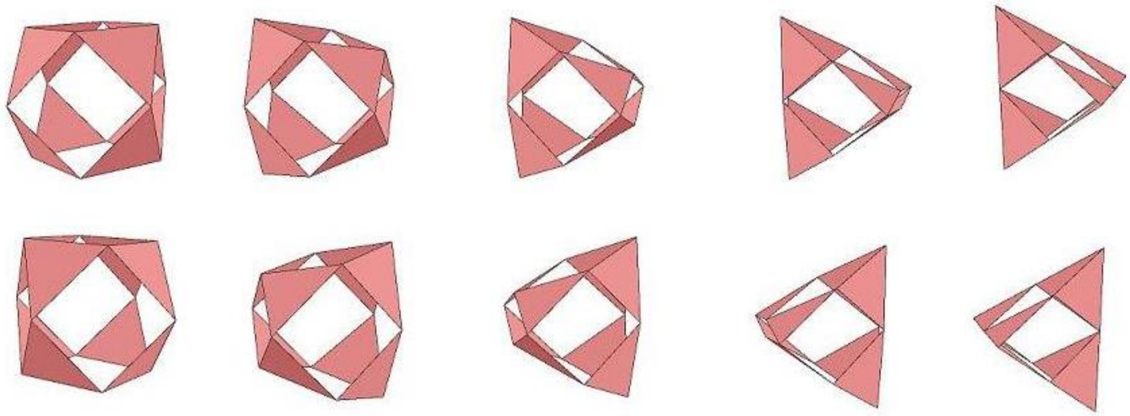


Figure 31: Left-handed (the upper set of VE) and right-handed (lower set of VE) sequential contractions of VE are shown starting from their cuboctahedral phases (left) and progressing to their tetrahedral phases (right).

With such an association, we would find that it is not just the two-dimensional sub-particles that define the identities of up and down quarks. The three-dimensional variations in their respective tetrahedral contractions could *potentially* also define their respective identities. However, the *real* situation in this case is a little more subtle and slightly more complicated than the simple idea of associating tetrahedral handedness with quark flavors. The reason for this additional complexity is the fact that *all* tetrahedral-quark contractions contain *equal* numbers of left-handed *and* right-handed tetrahedral contractions in a *checkerboard-like* layout (see Section 6.4.1 and Figure 19 and Figure 20). Nevertheless, the association of tetrahedral handedness with quark flavor *can* be successfully made, but it requires a *contextual* association with this checkerboard layout.

If we think about a checkerboard, half of its squares are black, and the other half are white. Similarly, one can say that there are “black cells” and “white cells” in the three-dimensional checkerboard layout of tetrahedral contractions associated with quarks. If the *left-handed* tetrahedral contractions lie in the field’s white cells, for example, we can say, *purely by convention*, that this style of contraction corresponds to *up* quarks. Conversely, if instead the *right-handed* tetrahedral contractions lie in the field’s white cells, we can say, *again by convention*, that this style of contraction corresponds to *down* quarks. Now we have a clear association between tetrahedral contraction handedness and quark flavor. It is important to remember, however, that this is a *contextual* association that can only be made by reference to the checkerboard layout of the left-handed and right-handed tetrahedral contractions.

It is also important to remember that up and down quarks have different rest masses. This does not seem to be explained by the right-handed and left-handed tetrahedral contraction styles described above. These appear to be completely symmetric to each other. As will be explained in Section 8.5, SLFT attributes this to the interaction between the up and down quark contractions’ different relative and *contextual* handedness and the dominant handedness of the synergetic field as a whole. This dominant handedness of the field as a whole is explained in Section 8.5

*7.6. Quark Colors*

Quarks are the only fermions that carry color charge. SLFT models the color charges carried by quarks using a spatial symmetry inherent within the VE's structure. Figure 32 illustrates a natural division of the VE's 24 internal faces (i.e., sub-particles) into six sets. Each of the six sets contains four faces. These six sets lie within the four-sided, pyramid-shaped indentations situated between the VE's eight constituent tetrahedrons. These six sets can be subdivided into three sets of oppositely oriented pairs of pyramids as shown in Figure 32: a left-and-right pair (Figure 32(a)), an up-and-down pair (Figure 32(b)), and a front-and-back pair (Figure 32(c)). Each of these three pairs of pyramids encompasses eight of the VE's 24 internal faces. SLFT associates the *threefold spatial symmetry* defined by the division of the VE's internal faces into these three, eight-faced, pyramid pair sets with the quark's *threefold color symmetry*.

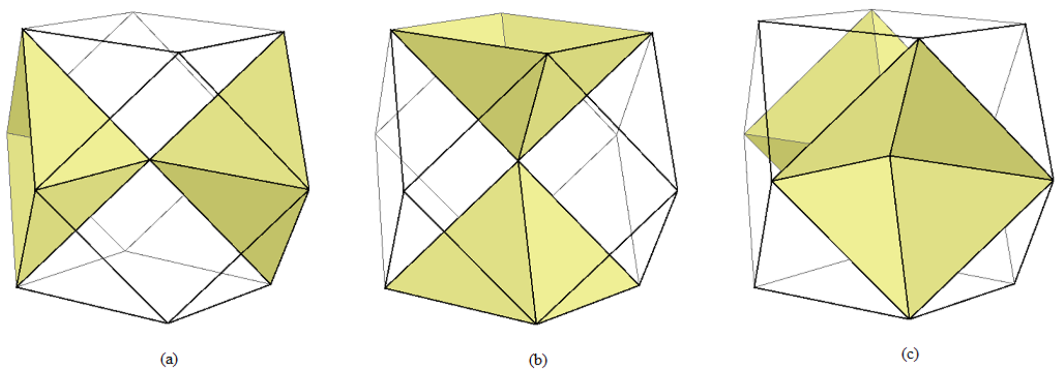



Figure 32: SLFT associates the *threefold spatial symmetry* of the VE's internal triangles with the *threefold color symmetry* of quarks. The figure illustrates six sets of four-sided, pyramid-shaped indentations situated between the VE's eight constituent tetrahedrons. These six sets can be subdivided into three sets of oppositely oriented pairs of pyramids: (a) a left-and-right pair, (b) an up-and-down pair, and (c) a front-and-back pair.

The twofold symmetries defined by the division of each of the three sets of eight internal faces into pairs of oppositely oriented, pyramid-shaped groups of four internal faces (as shown in the three illustrations in Figure 32) are associated with the twofold symmetry of color and anti-color. A quark's color charge is then defined in terms of the orientation, relative to the VE's internal structure, of the internal, sub-particle face that disappears (see Section 11.1) in concert with the formation of a particular three-dimensional, quark-tetrahedron contraction within the synergetic field.

As was the case for quark *flavors* discussed above, there is again a deeper, correlated, three-dimensional, *geometric* explanation for the existence of the quark's three *colors*. The left-handed and right-handed tetrahedral contractions shown in Figure 31 can occur relative to any one of the cuboctahedron's three orthogonal symmetry axes. These symmetry axes run through the apex points of the three pairs of internal pyramids shown in Figure 32. In these contractions, two of the VE's square faces, orthogonal to one of these three symmetry axes, pinch together in either a "left-handed" or a "right-handed" manner. In Figure 31, these contractions occur relative to the *horizontally* oriented symmetry axis.

These left-handed and right-handed tetrahedral contractions can also occur relative to the VE's other two orthogonal symmetry axes. The second axis is defined by the *vertical* symmetry axis that lies within the page (Figure 32(b)). The third axis is defined by the symmetry axis that runs perpendicularly in and out of the page (Figure 32(c)). The net result is the existence of six different possible pathways that the VE can follow to form a tetrahedron. These six different pathways can be grouped into three sets of two, in which each set of two is aligned with one of the VE's three *color-associated* and orthogonal symmetry axes. These six tetrahedral contraction pathways, grouped as three pairs, support three different colors for the up and down quarks. The up and down quarks are themselves each respectively defined by one of the two possible checkerboard-like layouts of the left-handed and right-handed tetrahedral contractions (see Section 7.5). The tetrahedral end-points of all six possible contractions are illustrated below in Figure 33.

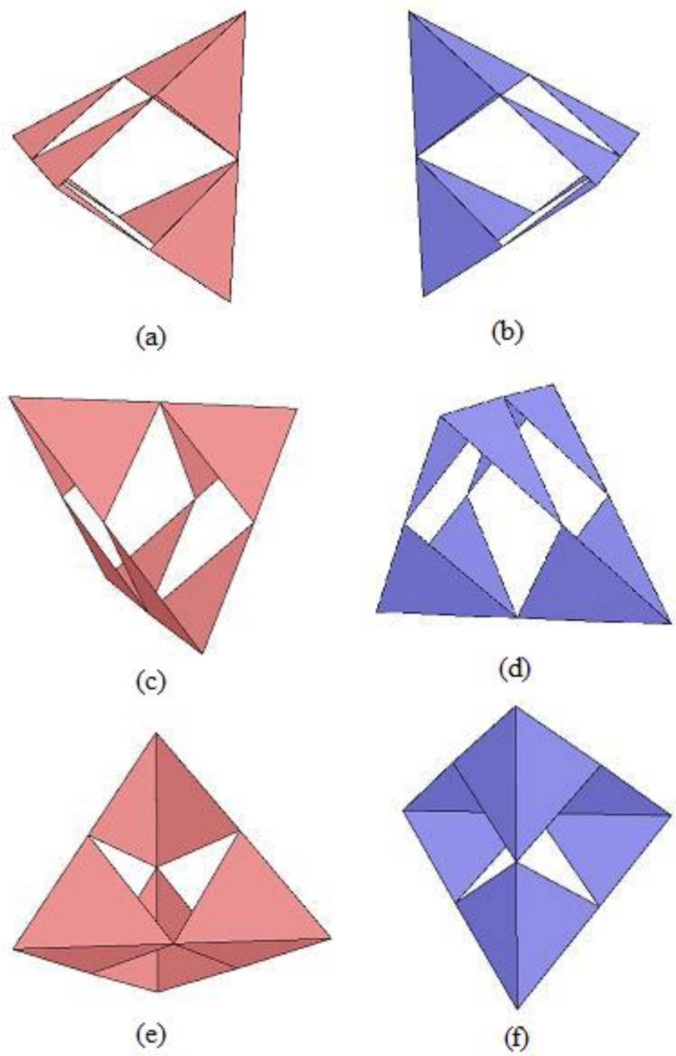



Figure 33: The end-points of the six possible VE tetrahedral contraction pathways yield three pairs of left-handed and right-handed contractions oriented along each of the cuboctahedron's three orthogonal symmetry axes. The tetrahedron pairs (a) and (b) (aligned with the page's horizontal axis), (c) and (d) (aligned with the page's vertical axis), and (e) and (f) (aligned with the axis in and out of the page) are left-handed and right-handed pairs. Each pair forms relative to one of the three color-associated, orthogonal symmetry axes referenced in Figure 32.

In addition to the static orientation of these tetrahedral contractions relative to the VE's three symmetry axes described above, there is yet another, *related*, three-dimensional, geometric feature that distinguishes the three quark colors from one another. This additional feature arises from an asymmetry in the VE's tetrahedral contraction. When the VE contracts to its tetrahedral phase, it does not contract by the same amount along each of its three orthogonal symmetry axes. Along the *primary symmetry* axis associated with a quark's color, there is no additional VE contraction relative to its cuboctahedral phase. (The above referenced *primary symmetry* axis is the one that two of the VE's square faces pinch together along to form a tetrahedron.) Along the other two axes, there is an additional net *expansion* of *individual* VE relative to their cuboctahedral phases. However, when these differential deformations of the *individual* VE are embedded within the synergetic field, *as a whole*, there is an associated additional net *contraction* of the field relative to its isomorphic phase. The reason that the individual VE exhibit differential *expansions* while the field as a whole experiences differential *contractions* is due to a geometric "nesting" effect that occurs when the tetrahedrally contracted VE are embedded within the field.

This differential *contraction* of the field as a whole becomes apparent when viewing tetrahedral phase VE woven together within the synergetic field. This can be seen, for example, in Figure 24. In that figure, the tetrahedral array's spatial extent is greater along the horizontal axis than it is along the vertical axis. This is because of the greater amount of contraction parallel to the vertical axis than to the horizontal axis. Although the third dimension of the tetrahedral array is not shown in Figure 24, the array is contracted by the same amount in this third dimension (i.e., the axis that runs in and out of the page) as it is contracted along the vertical axis of the page. This means that quark color is *physically* associated with a differential contraction of the synergetic field in two dimensions that lie in a plane perpendicular to a third dimension. Since there are three spatial dimensions, there are three ways this differential contraction can occur, and thus three colors.

The above observations present another intriguing mapping between the synergetic field's geometry and the quark's color attributes. In the discussion above, we have naively treated the color charge on quarks as simply "red", "green", or "blue". In reality, QCD's description of color charges is a bit more complicated. QCD defines each quark's color as having three color charge sub-components: R-G, G-B, and B-R [46]. For example, a red quark has the following underlying color charges: R-G; ½, G-B; 0, and B-R; -½. In general, these sub-components of the color charge can take on only one of three values: 0, -½, or ½. An important rule governs the application of these charges to quarks: one of the charges is always 0, one of the charges is always -½, and the remaining charge is always ½. Without this rule, there would be 27 possible permutations of the color charge sub-component triplets. With this rule, there are only six possible permutations, which are associated with the three quark colors and anti-colors: red, anti-red, green, anti-green, blue, and anti-blue.

This gives rise to an interesting observation. This rule can be mapped directly back to the geometric description of quark differential contractions. The differential contractions of *quarks* are correlated with the differential contractions of the *field* containing the quarks. These differential contractions are oriented parallel to the field's three orthogonal axes. If we map the ½ and -½ color sub-component charges to the two dimensions of the field that contract when a quark forms and the zero color sub-component charge to the one dimension that does not contract, then there is a direct geometric association between the six color sub-component charge triplets assigned, respectively, to red, anti-red green, anti-green, blue and anti-blue quarks by QCD, and the three possible spatial orientations of the differential contractions of the synergetic field associated with quarks. (Note: there are in fact six unique colors, when anti-colors are included, but we are pairing colors and their anti-colors together, associating these color *pairs* with the three orthogonal directions of the quark differential contractions.)

For simplicity, the model introduced in Section 4.1 initially assumed a three fermion universe. The symmetries of left-handed and right-handed tetrahedral collapses that occur in two complementary and distinct checkerboard-like patterns, and that are associated with up and down quarks, restore quark flavor symmetry. The three possible alignments of these checkerboard-like patterns of left-handed and right-handed tetrahedral collapses relative to the VE's three color-associated orthogonal axes restore quark color symmetry. The number of fermions accounted for by SLFT is thereby expanded to eight, encompassing two leptons and six quarks. This is still short of the standard model's full complement of 30 fermions. The symmetries of charge (both electric charge *and* color charge) and spin need to be restored to expand the eight fermion universe back to the standard model's full set of 30 fermions. The restorations of spin and charge symmetries will be discussed in Section 9.1 and Section 11.1, respectively.

## 8. The Origin of Particle Masses

### *8.1. Gravitational Field Sources*

The previous section discussed how specific geometric characteristics of the VE's configurations could explain certain observed properties of elementary fermions. This section will extend that idea, at least qualitatively, to the *relative* values of the fermions' rest masses—an idea that was already briefly introduced in Section 4.3. The localized contractions within the synergetic field representing the various elementary particles can occur anywhere within the field. These localized VE contractions, embedded within the field, create areas of local deformation, or tension, within the field. This tension is the ultimate source of the inertial mass of elementary particles. It is also the source of the mutual gravitational attraction between elementary particles. The underlying gravitational forces between particles are caused by the local stress and tension induced within the field by local contractions associated with the formation of elementary particles.

There is more tension within the field when the local contractions associated with two elementary particles are farther apart than when they are closer together. At the deepest and most fundamental level, the *source* of gravitational attraction between neighboring particles is nothing but the natural propensity of neighboring elementary particles to move towards one another to reduce the overall tension within the field. As will be discussed in Section 8.3, there is also a complimentary, *anti-gravitational* force in the field between positive-mass particles and negative-mass particles. In this case, there is a natural propensity for such particles to move *away* from one another to reduce the overall tension within the field.

### *8.2. The Masses of Neutrinos, Electrons, and Quarks*

The isomorphic, most expanded state of the synergetic field defined by the IIVM corresponds to the condition of space devoid of elementary particles and gravitational fields. Any local contractions of the field relative to its surrounding isomorphic state correspond to the presence of elementary particles and their associated gravitational fields—the greater the contraction, the greater the mass-energy, and the greater the associated gravitational fields. We have seen that the synergetic field's contraction is "quantized" in three well-defined ways associated with the three omni-triangulated Platonic polyhedra: the icosahedron, the octahedron, and the tetrahedron.

We can now further explain the *specific* mapping of the elementary particles in our simplified three-particle universe (see Section 4.1) to these three states of omni-triangulated contraction. The "tetrahedral-octahedral" and "symmetric-asymmetric-icosahedral" contractions respectively represent the greatest and least contractions of the synergetic field. Therefore, they are associated with the quark and the neutrino, which respectively have the greatest and the least masses of the three elementary fermions. The "octahedral-cuboctahedral" configuration defines an intermediate degree of contraction of the field. Therefore, it is associated with the electron because the electron's mass lies between the quark and the neutrino masses.

These local VE contractions occur within the lattice structure formed from the interwoven and interlocking, left-handed and right-handed isomorphic VE that constitute the synergetic field. It is important to understand that the total net contraction induced in the synergetic field by any particular VE configuration is based on the VE configurations in *both* the left-handed *and* the right-handed sets of VE, not just in one set. For example, the tetrahedral contraction viewed *in isolation* (as shown in Figure 30) forms a *two-frequency* tetrahedron that is a larger and less contracted configuration of the VE than is the single frequency octahedral configuration associated with electrons. Nevertheless, the actual *combined* tetrahedral *plus* octahedral contraction *pair* that is associated with quarks produces a modestly greater local *net* contraction of the synergetic field than does the *combined* octahedral *plus* cuboctahedral contraction *pair* associated with electrons. Both the electron-octahedral-cuboctahedral contraction and the quark-tetrahedral-octahedral contraction represent much greater contractions of the synergetic field than does the neutrino-icosahedral contraction.

The exact quantitative relationships between the synergetic field's local contractions and the amount of mass-energy associated with these contractions are nonlinear. This conclusion is inescapably reached based on a quantitative comparison of the relative spherical contractions of the synergetic field caused by the icosahedral, the octahedral-cuboctahedral, and the tetrahedral-octahedral contractions with the relative rest masses of the neutrino, electron, and quark, respectively. As will be further discussed in Section 17, the relationships between these particle-contractions and their associated rest masses are even more complicated and non-linear when all three particle generations are considered.

### *8.3. Negative Mass in the Synergetic Field*

For each of the 30 positive-mass fermions in each of the three generations of the standard model (and *potentially* also for the two *possible* sterile neutrinos in each generation), SLFT introduces a corresponding negative-mass fermion. These fermions have negative *gravitational* masses. Like positive-mass fermions, negative-mass fermions have positive *inertial* mass. This is because negative-mass particles require the same amount of positive energy in order to be created, as do their positive-mass counterparts. As will be explained below, negative-mass particles are attracted to one another gravitationally, but negative-mass particles and positive-mass particles are mutually repelled by one another. As will be further discussed in Section 14.3, this model has certain characteristics in common with bi-metric extensions to general relativity, such as the one proposed by Hossenfelder [47, 48]. The idea of negative mass, in general, has been previously proposed and explored by a number of authors in various contexts. See, for example, Hossenfelder [49], Rahman [50], and references therein. In bi-metric models, it is usually assumed that positive-mass particles and negative-mass particles only interact with each other gravitationally. As is further discussed in Section 14.3, SLFT also makes this assumption.

Such negative-mass particles arise quite naturally within the synergetic field. It will be recalled from Section 5.2 that individual VE can contract from their cuboctahedral phase to their octahedral phase in either a left-handed or a right-handed sense (Figure 9). It will also be recalled that this characteristic of the VE gives rise to left-handed and right-handed isomorphic VE (Section 5.4), and further that the synergetic field is constructed from a set of left-handed isomorphic VE interwoven with a complementary set of right-handed isomorphic VE. It will also be recalled from Section 5.3 that when the synergetic field's left-handed and right-handed VE are both in their isomorphic states, the field as a whole is in its most expanded state.

It turns out that the ability of individual VE to contract in either a left-handed or a right-handed sense carries over to the synergetic field as a whole. As is explained below, the synergetic field itself can locally contract in either a left-handed or a right-handed sense. A left-handed, localized contraction of the synergetic field occurs when a localized set of its individual, left-handed, isomorphic VE contract. This left-handed contraction is simultaneously associated with the *expansion* of a co-extensive, localized set of individual, right-handed, isomorphic VE. Conversely, a right-handed, localized contraction of the synergetic field occurs when its individual, right-handed, isomorphic VE contract and its individual, left-handed, isomorphic VE expand. In both cases, the synergetic field's localized contractions include both a curvature component and a torsion component.

The field's curvature component consists of the field's all-directions, inward-pulling contraction. For both the left-handed and right-handed cases, the degree of curvature is equivalent. The field's torsion component consists of the left-handed and right-handed rotations, or twistings, of the individual triangles (i.e., sub-particles) that make up the field's individual VE. The torsion component is also equal in magnitude for both left-handed and right-handed cases, but unlike curvature, it is oppositely signed for these two cases. Specifically, when the synergetic field contracts in a *left-handed* sense, one-half of its constituent sub-particle triangles rotate in a left-handed sense, and the other half rotate in a right-handed sense.

In contrast, when the synergetic field contracts in a *right-handed* sense, its constituent sub-particle triangles that rotate in a left-handed sense during a left-handed collapse of the field now rotate in a right-handed sense. Similarly, during such right-handed contractions of the field, the other half of the field's constituent sub-particle triangles, which rotate in a right-handed sense during a left-handed collapse of the field as a whole, now rotate in a left-handed sense. Localized left-handed and right-handed contractions of the synergetic field are illustrated in Figure 34. *By convention*, SLFT associates localized, left-handed contractions of the field with positive-mass fermions and localized, right-handed contractions with negative-mass fermions.

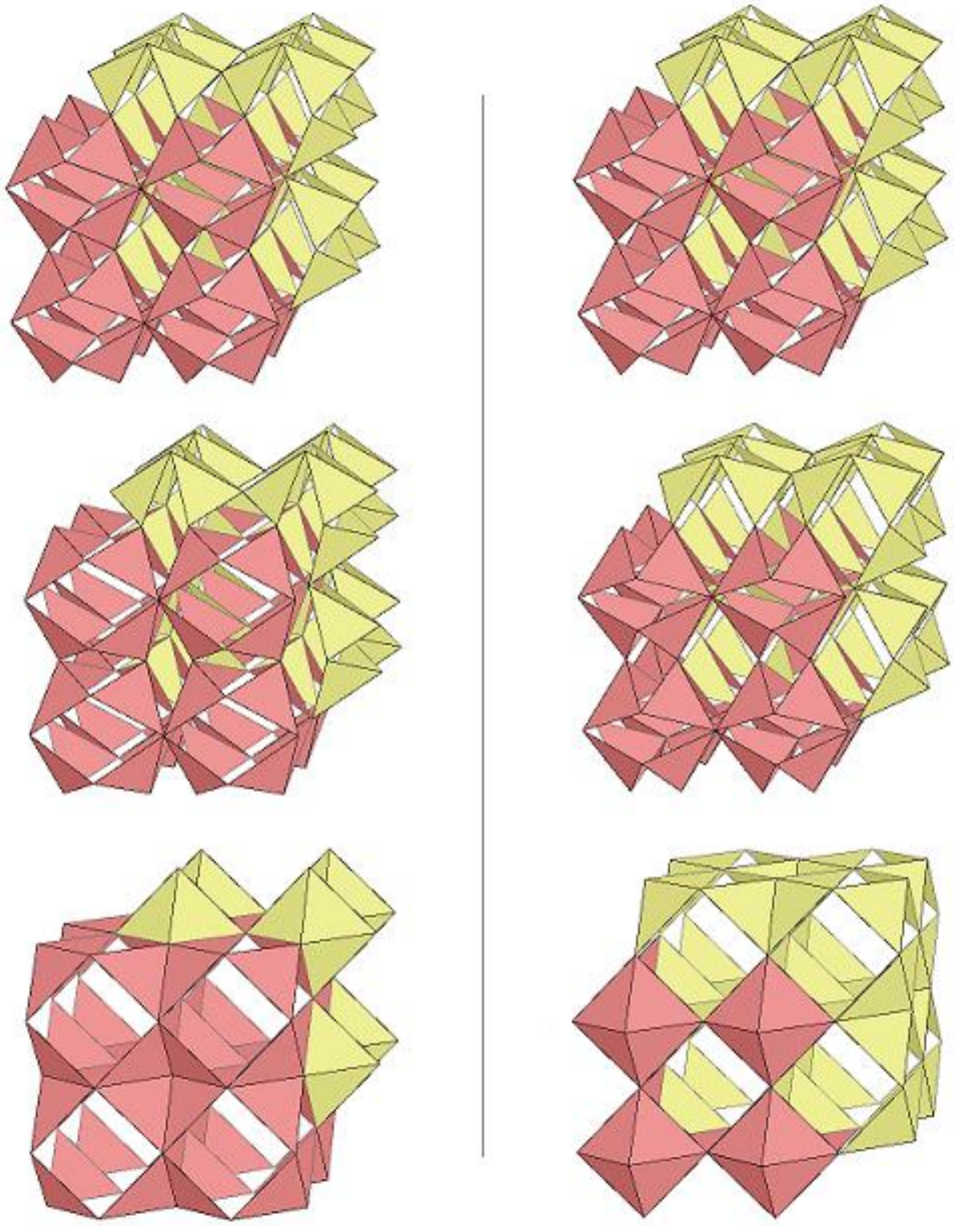


Figure 34: Two identical clusters of 16 isomorphic phase VE are shown at the top positions in the figure's left and right columns. Each cluster consists of eight left-handed VE (upper, lighter shaded VE) and eight right-handed VE (lower, darker shaded VE). In the left-hand column, this cluster is shown contracting to its octahedral-cuboctahedral phase in a left-handed sense—the left-handed VE contract to their octahedral phases while the right-handed VE expand to their cuboctahedral phases. In the right-hand column, an identical cluster is shown contracting to its octahedral-cuboctahedral phase in a right-handed sense—the right-handed VE contract to their octahedral phases while the left-handed VE expand to their cuboctahedral phases.

To get a better understanding of the dynamics of such positive-mass and negative-mass fermions, *in general*, we will first take a closer look at the *specific* formation of positive-mass and negative-mass electrons (Figure 35). SLFT identifies *positive-mass* electrons with the local *contractions* of left-handed VE towards octahedrons. The *contractions* of these left-handed VE are accompanied by corresponding local *expansions* of neighboring right-handed VE towards cuboctahedrons. Conversely, SLFT identifies *negative-mass* electrons with local contractions of right-handed VE towards octahedrons and with corresponding local expansions of neighboring left-handed VE towards cuboctahedrons.

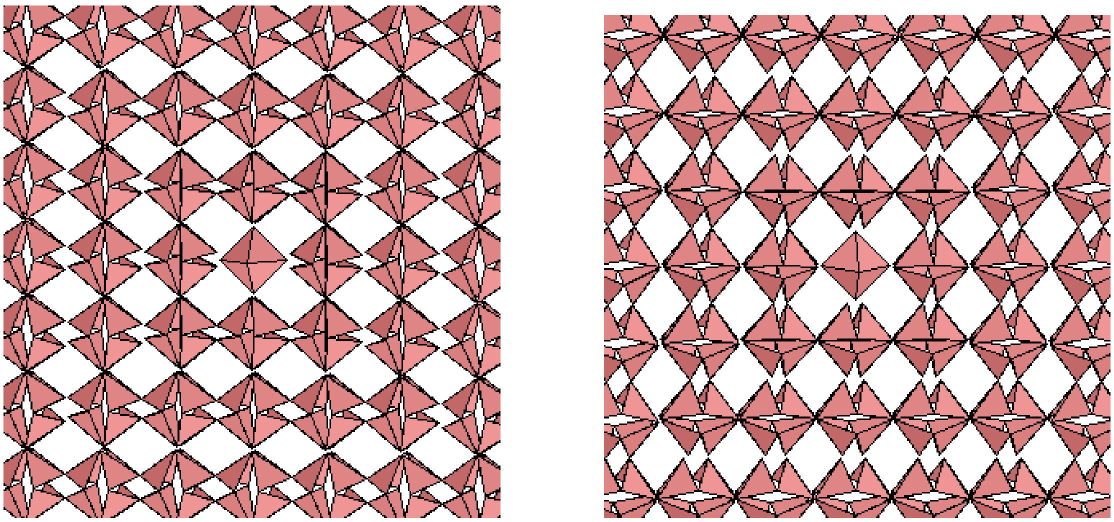


Figure 35: The positive-mass, octahedral-electron contraction in the left image is associated with a localized, left-handed contraction of the synergetic field (i.e., contractions of the field's left-handed VE). Conversely, the negative-mass, octahedral-electron contraction in the right image is associated with a localized, right-handed contraction of the synergetic field (i.e., contractions of the field's right-handed VE). In both of these contractions, half of the field's sub-particle triangles rotate in a left-handed sense and half rotate in a right-handed sense. An essential difference between the two contractions is the fact that the rotational senses of *corresponding* triangles between the two contraction cases are swapped. Therefore, left-handed and right-handed contractions of the field are associated with equal but oppositely signed degrees of field *torsion*. In both cases, the all-directions-pulling-inwards contraction of the field is the same. This contraction represents a geometric *curvature* of the field. For visual clarity, the cuboctahedrally expanded VE are not shown.

When positive-mass particles form, they cause contractions of the *left-handed* VE and expansions of the *right-handed* VE. In contradistinction, negative-mass particles cause contractions of the *right-handed* VE and expansions of the *left-handed* VE. When a positive-mass electron is close to a negative-mass electron, both particles try to *locally rotate* the field's sub-particle triangles in order to *locally contract* the field, but the respective rotations that they are trying to induce in the sub-particles have opposite senses. The formation of positive-mass and negative-mass particles, considered separately, both cause local contractions of the field, but they do so in two different ways that are inherently incompatible with each other.

As described above, when a positive-mass particle is close to a negative-mass particle, both particles try to *locally rotate* the field's sub-particles in order to *locally contract* the field, but their respective rotations of the field's sub-particles have opposite senses. The opposing senses of their rotations and the associated opposing tendencies to *simultaneously* both contract *and* expand the left-handed and right-handed VE creates increasing tension in the field as the particles approach each other. Up to a point this tension can be taken up by the local bowing of the VE's interconnected sub-particles (see Section 6.2). To minimize such tension, positive-mass particles and negative-mass particles tend to spontaneously move away from each other—positive-mass particles and negative-mass particles gravitationally repel each other.

In SLFT, non-zero *net* torsion is associated with non-zero rest mass. All particles induce positive *contractions* in the synergetic field, but only particles with non-zero rest mass induce non-zero net *torsion* in the field. Particles having net positive or net negative torsion have net positive or net negative rest masses, respectively. *This rule applies to all fermions*. As will be further discussed in Section 14, SLFT models bosons as composite particles constructed from pairwise combinations of positive-mass fermions with negative-mass anti-fermions (and vice versa). As a result of this construction, some bosons have zero *net* torsion, and therefore zero rest mass. This applies to the subset of bosons formed from pairs of positive and negative mass fermions with rest masses of *equal* magnitude but *opposite* signs (i.e., photons and gluons). Other bosons (W and Z) are formed from pairs of positive-mass and negative-mass fermions whose rest masses have different absolute values. These bosons have non-zero net torsion and therefore have non-zero rest masses.

In Section 13.4, a corresponding set of 32 new sub-particles are introduced into the VE corresponding to the new negative mass particles introduced in this section. For the time being, however, for the sake of simplicity, we will continue to use the current model that was introduced in Section 7.4, in which the VE has only 32 internal sub-particles.

### *8.4. Negative Mass Quarks and Neutrinos*

The scenarios describing positive-mass and negative-mass quarks and neutrinos are in principle similar to electrons, but in practice, are subtly different. Based on our prior association of neutrinos, electrons, and quarks with icosahedrons, octahedrons, and tetrahedrons, respectively, one might naively assume that positive-mass quarks and neutrinos are associated with the formation of tetrahedrons and icosahedrons, respectively, in the synergetic field's left-handed VE. This would be analogous to the way in which electrons are associated with the formation of octahedrons in the synergetic field's left-handed VE. This is not the case, however. The critical thing to remember is that an electron, for example, is not *just* an octahedron—it is instead the pairing of octahedral and cuboctahedral phase VE seamlessly embedded within the synergetic field as a whole. An electron is defined in terms of this pairing of these two VE configurations. Similarly, neutrinos are not *just* icosahedrons but rather pairings of symmetrical and asymmetrical icosahedrons. Likewise, quarks are pairings of tetrahedrons and octahedrons.

With this more accurate, more complete pair-based picture of particle geometries, we can now understand that positive-mass particles always have the *more contracted* VE of their respective VE pair-based configuration occurring in the field's *left-handed* VE. Conversely, these positive-mass particles always have the *less contracted* VE of their respective VE pair occurring in the field's *right-handed* VE. These handedness conventions are simply reversed for negative-mass particles. We have already seen how these rules play out for electrons. We can now look at how these rules apply to neutrinos and quarks.

In the case of neutrinos, the VE's asymmetrical icosahedral phase is more contracted than its symmetrical icosahedral phase. Therefore, the positive-mass neutrino's asymmetrical icosahedron forms within the left-handed set of VE, while its symmetrical icosahedron forms in the right-handed set. These handedness conventions are reversed for negative-mass neutrinos. In the case of quarks, the VE's octahedral phase is more contracted than its tetrahedral phase. Therefore, the positive-mass quark's octahedron forms within the left-handed set of VE while its tetrahedron forms in the right-handed set. (This is somewhat similar to the formation of electrons that also have their left-handed VE contracted to octahedrons, while their right-handed VE are expanded to cuboctahedrons.) The above handedness conventions are reversed for negative-mass quarks.

There is also another unique characteristic displayed by quark configurations. In the case of an electron, one of its associated polyhedra, the octahedron, is a contraction of the isomorphic VE, while its other associated polyhedra, the cuboctahedron, is an expansion of the isomorphic VE. Similarly, the neutrino's asymmetrical icosahedron is a slight contraction of the isomorphic VE, while its symmetrical icosahedron is a slight expansion of the isomorphic VE. In contradistinction, the quark's associated polyhedra—the tetrahedron and the octahedron—are *both* contractions of the isomorphic VE. Nevertheless, the dynamics of positive mass and negative mass for quarks are essentially the same as they are for electrons and neutrinos. The critical point that unifies the three fermions' mass dynamics is that for positive-mass particles, the left-handed VE contract *relatively* more than the right-handed VE (and vice versa for negative-mass particles). It does not matter what the specific contractions of left-handed and right-handed VE are relative to the isomorphic VE, per se, but rather to each other.

In any universe such as ours, in which it appears that all matter attracts all other matter gravitationally, all matter will be associated with *relatively* greater contractions of *either* the right-handed *or* the left-handed set of VE. By convention, SLFT associates the bulk of our Universe's matter with relatively greater contractions in the left-handed set of VE. By this same convention, elementary particles associated with relatively greater contractions in the right-handed set of VE have negative mass.

### *8.5. Negative Mass and Quark Mass Splitting*

Section 7.5 discussed SLFT's mapping of the VE's left-handed and right-handed tetrahedral contractions to up and down quarks (within the context of their checkerboard-like layout in the field). Section 7.5 noted the mass "splitting" observed between up and down quarks but did not explain it. Since the only apparent geometric difference between the VE's up and down quark configurations is the handedness of their associated tetrahedral contractions, it would seem reasonable to assume that up and down quarks should have the *same* mass. The understanding of negative-mass particles gained in the last section may provide a possible geometrically based explanation of quark mass splitting.

The concept of negative-mass fermions is tightly coupled with the synergetic field's interwoven left-handed and right-handed isomorphic VE. When a localized VE contracts in the left-handed set, a positive-mass fermion is created. This is associated with the contraction of the immediately surrounding VE in the left-handed set and with the expansion of the immediately surrounding VE in the right-handed set. If the handedness of the above process is reversed, a negative-mass fermion is created.

The fact that the Universe appears to be almost exclusively populated by positive-mass particles means that particle-induced contractions in one of the synergetic field's two sets of VE dominate over particle-induced contractions in the other set of VE. One set of VE tends to preferentially contract during the formation of elementary particles versus the other set. This is a sort of broken symmetry of the synergetic field. It must occur to form a universe like ours populated predominantly by particles with like-signed masses, which all attract one another gravitationally. It *is* possible that a universe could alternatively be formed in which contraction dominates in *the other* set of VE. However, it does have to be one set of VE or the other in which contractions dominate. This is required to create a universe like ours that is constituted of *like-signed* matter and governed primarily by attractive gravitational forces.

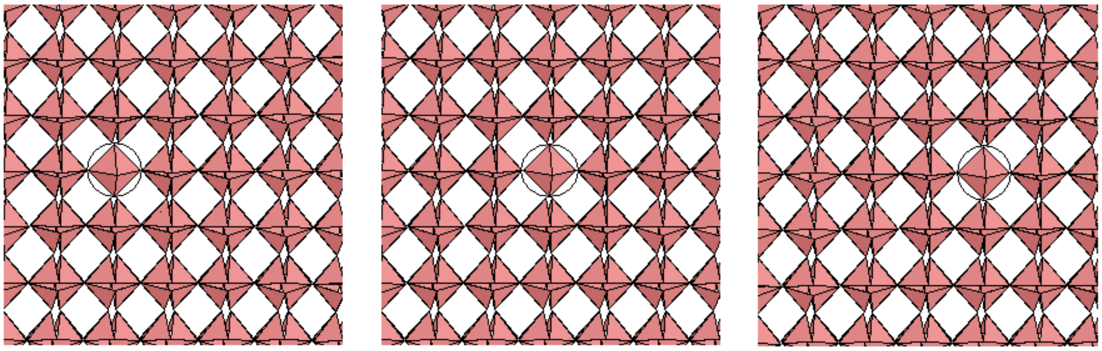
The interaction of the localized, right-handed and left-handed, quark-tetrahedral contractions with the synergetic field's larger global broken symmetry discussed above may at least partially account for the mass splitting observed between up quarks and down quarks. The idea is essentially that one type of tetrahedral handedness contracts "with the grain" of the synergetic field's residual *global* torsion, while the other type of tetrahedral handedness contracts "against the grain" of the field's *global* torsion. The handedness type that contracts "with the grain" produces less overall tension, and therefore less mass-energy than the handedness type that contracts "against the grain".

When the second and third generations are considered, the phenomenon of quark mass splitting is even more complicated. As will be discussed in Section 13.3, the quark mass splitting observed in second and third generation quarks occurs in the opposite direction of the quark mass splitting in the first generation. Section 13.3 discusses how the differential electric charges carried by different flavored quarks may also play a separate, contributing role to mass splitting. Section 13.3 also discusses how the existence of two independent sources of mass splitting may help explain, at least conceptually, the *different directions* of quark mass splitting seen in the second and third generations relative to the first generation.

## 9. The Motion of Elementary Particles in the Synergetic Field

### *9.1. Moving Wave-Pulses*

The previously described local contractions of the synergetic field's VE associated with electrons, neutrinos, and quarks, provide pictures of single, isolated particles at fixed locations within the synergetic field. In reality, elementary particles are never found resting at single fixed locations, but they are instead in constant motion. Figure 36 shows how the pattern of contraction defining an electron, for example, *moves* through the synergetic field. As is shown in Figure 16 and Figure 17 in Section 6.2, Figure 36 shows the local contraction of a central VE to its octahedral phase, but Figure 36 also shows this contraction in three temporally sequential steps. When these steps are viewed together *as a time sequence*, they provide a model of electron motion. (The figures show radially symmetric, two-dimensional cross-sections of an electron that are, in fact, actually spherically symmetric, three-dimensional contractions of the synergetic field.)



(a) t = t1 (b) t = t2 (c) t = t3

Figure 36: The motion of an octahedral wave pulse (i.e., electron) through a local slice of the synergetic field. The circles in these figures highlight which VE in each of the three sequential "snapshots" of the synergetic field are contracted completely to their octahedral phases. These circled VE that are contracted completely to their octahedral phases define the center of the electron as it moves through the field.

Starting at an initial time "t1", Figure 36(a) shows an octahedral phase, fully contracted VE, just to the left of the center position in a two-dimensional slice of the synergetic field. At an immediately subsequent time "t2", Figure 36(b) shows that the left of center VE has slightly expanded, and its adjacent neighbor, immediately to its right (i.e., the centermost VE) has contracted completely to its octahedral phase. At a third time, "t3", Figure 36(c) shows a similar transfer of octahedral contraction pattern from the center position to the immediately adjacent, right of center position. In each of the illustrations (a), (b), and (c) in Figure 36, the VE that is fully contracted to its octahedral phase is highlighted by a small circle.

*This model provides a picture of a wave of contraction moving through the synergetic field*. The motion of the electron through the synergetic field is nothing other than the motion of such an octahedral "wave pulse". The individual components of the underlying field, its constituent VE, are not themselves moving from one place to another in the field. Instead, a well-defined and stable *pattern* of localized contraction, formed within and from the synergetic field itself, moves through the field. Borrowing from Einstein, one can think of the contraction as a moving area of local "field intensity" [13]. Fuller would likely have referred to this as the motion of a "pattern integrity" [51].

As will be discussed at greater length in the next section, such localized wave pulses that maintain well-defined shapes and spatial localizations as they move through a medium, such as the electron pattern discussed above, are examples of *solitons*. Before moving forward to a discussion of solitons, two other important details regarding the motions of these localized particle wave-pulses through the synergetic field need to be explained. The first detail is related to a core principle of quantum mechanics and elementary particle theory. All elementary fermions carry one-half unit of intrinsic spin. A particle's intrinsic spin is loosely analogous to a toy top's spinning about its axis, but it comes in only well-defined, quantized units. Within the context of SLFT's *realist* model of elementary particles, this spin implies that particles must always follow spiraling, helical pathways through the field instead of following simple straight-line pathways. The central axis of each such helical pathway defines the path of the particle's general forward motion, while the actual spiral path that the particle follows around this central axis is associated with the quantized angular momentum, or spin, of the particle. This is the only way to associate an intrinsic angular momentum with elementary particles in SLFT. Since the particles are embedded within, and inextricably connected to, the surrounding synergetic field, there is no possible way for the particles themselves to rotate about axes through their respective centers.

The second detail regarding the motion of particle wave-pulses through the synergetic field is related to the discrete nature of the synergetic field. An elementary particle's motion was described above as having at least one centrally located and fully contracted VE. *If this is true*, this implies that the electron can only move along orthogonal, rectilinear tracks in a three-dimensional, cubic “jungle gym”. This cubic jungle gym is defined by the layout of the neighboring members of each of the synergetic field’s two sets of VE. (The left-handed and right-handed VE are respectively centered at the grid points of two interwoven cubic lattices that are each other’s duals.) Given the large-scale, helical motion of elementary particles, such a point-to-point, locally rectilinear, discrete mode of motion *might* be tenable. On the larger scale of elementary particles' helical motions, these small-scale, local, rectilinear motions could be seen as just local noise on the particles’ otherwise smooth helical pathways.

Nevertheless, it is also possible to assume a more general model of particle motion. This more general model allows particles to move along arbitrarily oriented paths through the synergetic field. Therefore the *centermost* VE in an electron, for example, may not always be *completely* contracted to its octahedral phase. Instead, it will be contracted to some linear interpolation of the contraction *implied* by the particle’s *actual* path through the field. This path will sometimes *coincidentally* intersect with VE centers, in which case a particle’s centermost VE will be *momentarily* completely contracted to its octahedral phase. Currently, SLFT favors the latter model, however, it ultimately leaves the issue of locally smooth particle motions versus jungle gym constrained, locally rectilinear particle motions as an open question.

Sections 7.5 and 7.6 used symmetry considerations grounded in the VE’s geometry to restore flavor and color symmetries to quarks. This expanded the three-particle universe to a total of eight particles: the electron, the neutrino, three colors of up quarks, and three colors of down quarks. The symmetries of left-handed and right-handed spin further expand the eight particle universe to a sixteen particle universe. As discussed immediately above, elementary fermions all have equal magnitudes of quantized intrinsic angular momentum or spin. In SLFT, this spin arises from the helical motion of elementary particles through the field. These helical motions through the field can occur with either left-handed or right-handed senses. The left-handed and right-handed senses of the particles’ helical motions through the field restore left-handed and right-handed spin symmetries.

### *9.2. Elementary Particles as Solitons*

SLFT’s electron-octahedron-cuboctahedron pattern defines a localized wave-pulse that maintains a well-defined shape and spatial localization over time. Such wave-pulses are described by a particular type of non-linear wave called a soliton. *SLFT models all* *elementary fermions as such soliton-like wave-pulses.* Solitons can be described by a number of different mathematical equations. One of the most widely studied and applied soliton equation is the sine-Gordon equation [52, 53]. The British physicist, Cyril Isenberg, invented a soliton wave "machine" in the form of a nominally one-dimensional apparatus that elegantly demonstrates the essential characteristics of solitons and the sine-Gordon equation [54].

Isenberg's one-dimensional soliton wave machine defines a medium that is resistant to longitudinal compression but that allows rotational displacements. The machine consists of equally spaced, torsionally coupled rods, each of which is free to rotate about a central horizontal axis. Each rod's mass is distributed asymmetrically about this central axis so that one end of each rod has a greater moment of inertia than the other (Figure 37). This asymmetrical distribution of the rods' weights is essential to the machine's ability to support solitons. A wave machine constructed without this asymmetry will produce only linear waves of some model-specific, constant velocity, c.

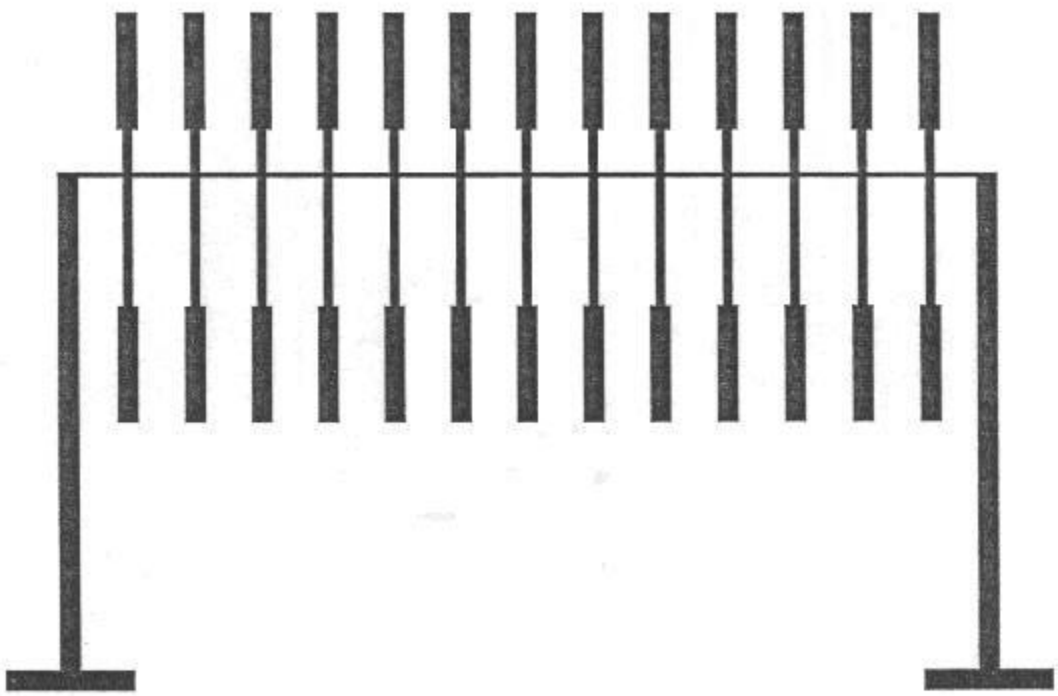


Figure 37: A schematic diagram of Isenberg's soliton wave machine illustrating a set of asymmetrically weighted rods hanging from a taut cable. They can twist around the cable, in a sense, in and out of the page.

The actual wave velocities supported by Isenberg's machine are defined by specific physical parameters and characteristics of the machine's construction. For small rod displacement angles, the machine produces waves that travel at a constant, model-specific, maximum limiting velocity, c. If the angle of rod displacement is larger, however, solitons are produced. The solitons have velocities ranging from zero to the model-specific, limiting velocity. For a given velocity v (where v is less than c), the lengths of the soliton-based, moving wave-forms contract (i.e., as defined by a localized group of displaced rods). They contract by an amount specified by Lorentz's relativistic length contraction equation, $L = L_o \sqrt{(1-v^2/c^2)}$.

Since the elementary fermions described by SLFT are all solitons, they all naturally undergo Lorentz-type contractions when moving through the synergetic field. It can also be shown that soliton-like dimples in elastic media undergo relativistic type increases in mass-energy when in motion relative to the media [55]. As will be discussed in greater detail in Section 20, these relativistic length contractions and mass-energy increases associated with moving solitons, in general, and with SLFT's elementary fermions, in particular, form the foundation of reconciling SLFT with special relativity.

## 10. The Charge Structure of the Synergetic Field

### *10.1. Sub-Particle Field Components*

Section 7.4 introduced SLFT's "sub-particle" hypothesis—the idea that two-dimensional triangles (i.e., "sub-particles") defined by the internal and external faces of the VE are somehow associated with their three-dimensional elementary particle counterparts in a one-to-one mapping. SLFT posits that these sub-particles are associated with the electric charges of elementary particles based on three observations from Section 7.4: 1) the fractional ratios between the respective squares of the surface areas of the up quark and down quark sub-particles compared to the squares of the surface areas of the electron sub-particles, 2) the correspondence between the number of the VE's *internal* quark sub-particles and the number of observed quarks, and 3) the correspondence between the number of the VE's *external* lepton sub-particles with the *theoretically* possible number of leptons (assuming the existence of two sterile neutrinos in each generation). *The sub-particle hypothesis leads to the further hypothesis that the entirety of space, as modeled by the synergetic field, has an inherent, underlying charge structure.* This structure is modeled by associating alternating positive and negative charges with the triangular faces of each VE within the synergetic field.

This charge structure associates one unit of positive or negative electric charge with each of the VE's eight external faces and with each of its twenty-four internal faces (i.e., when the VE is fully expanded to its octahedral phase). These charges are associated with the VE's faces in a manner that maintains a zero net charge on the VE has a whole and in a manner that is symmetrical and homogenous. These constraints are met for the VE's eight external faces by associating opposite charges to diametrically opposite faces. Within this configuration, each face is associated with a charge that is the opposite sign of the charge associated with its three nearest neighbor faces (Figure 38). Given this charge configuration, all of the individual, isomorphic phase VE can be joined together to form the synergetic field in such a manner that all pairs of adjacent, abutting faces have opposite charges relative to each other.

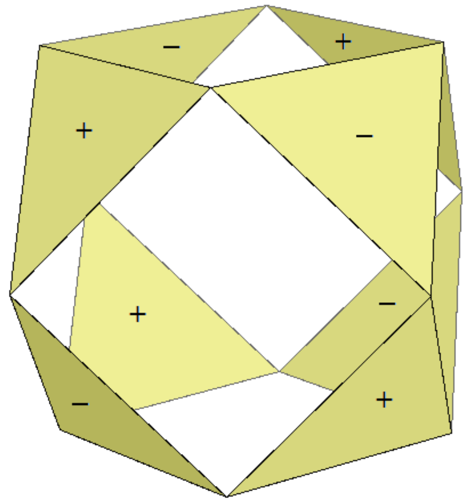


Figure 38: The alternating positive and negative charge structure of the VE’s external faces.

Similar constraints apply to the VE’s twenty-four internal faces—opposite charges are associated with faces positioned symmetrically opposite each other, and each face is associated with a charge having the opposite sign of its immediately adjacent neighbors (Figure 39).

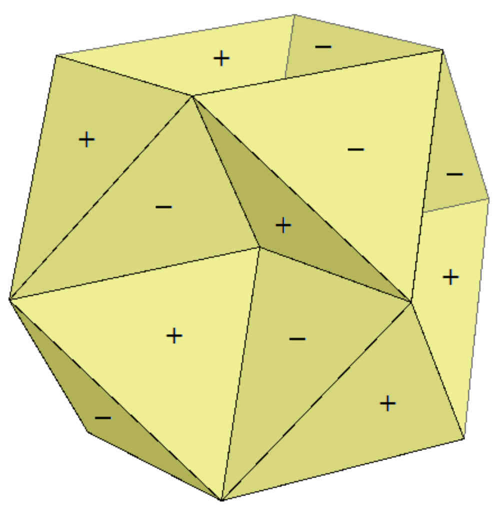


Figure 39: The alternating positive and negative charge structure of the VE’s external *and* internal faces.

*10.2. Binding Forces within the Synergetic Field*

The internal charge structure of the synergetic field has fundamentally important consequences. First and foremost, it provides a mechanism that holds the synergetic field’s constituent VE together—it is the mutual attraction of the VE’s external, oppositely charged, adjacent faces that holds the synergetic field’s component VE together. This mechanism of attraction between the external, abutting, charged faces of the VE requires introducing a fundamentally new type of force. This mechanism assumes that an *inherent* attractive force exists between the charged faces of the VE. The nature of this force is not currently understood or explained by SLFT. Nevertheless, it is *fundamentally* different from the attractive force between electrically charged elementary particles mediated by the exchange of gauge bosons.

### *10.3. Dynamic Equilibrium within the Synergetic Field*

The mechanism that maintains the synergetic field in its maximally expanded state (i.e., "isomorphic" state) is based on the assumption that the field's VE have an inherent resistance to contraction. This resistance to contractions would tend to maintain individual, isolated VE in their most expanded, cuboctahedral phase. To better understand this, one can imagine a scenario in which the synergetic field is initially *globally* contracted to its octahedral-cuboctahedral configuration. As is explained below, the resistance to contraction of the synergetic field's VE would, of necessity, drive the field from this initial state towards its isomorphic configuration.

In the above scenario, both of the synergetic field's sets of VE (i.e., the set initially in the octahedral phase and the set initially in the cuboctahedral phase) equally *resist* being in their contracted, octahedral phases. The VE in their octahedral phases are maximally *contracted*, while the VE in their cuboctahedral phases are maximally *expanded*. The maximally contracted, octahedral phase VE will push back against their contracted states with greater force than the cuboctahedral phase VE will resist undergoing some relatively small contraction relative to their maximally expanded state.

Therefore, if the synergetic field starts in a *globally* contracted, octahedral-cuboctahedral state, it will spontaneously move towards its isomorphic phase. It will do so to rebalance the opposing, out-of-balance forces between the octahedral and cuboctahedral phase VE. In the synergetic field's isomorphic phase, both its left-handed and right-handed sets of isomorphic VE are *equally* contracted relative to their respective, maximally expanded, cuboctahedral phases. In its isomorphic phase, the synergetic field as a whole attains a state of dynamic equilibrium that is also its maximally expanded state. The synergetic field's maximally expanded state is a state of balance between the shared resistance to contraction of the individual VE within the synergetic field's left-handed and right-handed sets of VE.

The synergetic field tends to stay in this globally most expanded configuration because any deviation from this configuration would create an imbalance between the mutually opposing resistances to contraction of the synergetic field's two interpenetrating sets of VE. Any such deviation would also result in a net contraction of the field as a whole. Thus, when many contraction-resistant VE are joined together to form the synergetic field, the entire field will spontaneously seek a point of balance in which all of its VE are equally contracted, i.e., the isomorphic, equilibrium, *globally most expanded state of the synergetic field*.

The VE's eight external faces' electric charges cannot give rise to this resistance of individual VE to contraction. The exact abutment of oppositely charged faces of immediately adjacent VE implies a zero *net* charge on these adjoining pairs. Furthermore, the fact that the VE's symmetrically opposing faces are oppositely charged means that they would cause, if anything, a tendency of the VE to contract—not a tendency to resist contraction. However, the VE's 24 internal faces can provide a possible explanation for the VE's resistance to contraction. The internal sub-particle faces must contract when the

VE contracts. Therefore, a first-order understanding of the VE's resistance to contraction can be gained by hypothesizing a resistance of these internal sub-particle faces to contraction.

## 11. The Synergetic Field's Charge Structure and Particle Formation

### *11.1. Localized Charge Imbalances*

We will now investigate what causes elementary particles to form within the synergetic field in the first place. Why do local contractions of the field occur? Why doesn't the field simply remain in its global state of equilibrium? In order to explain local particle formation within the field, SLFT introduces an additional hypothesis related to the field's sub-particle charge structure. SLFT hypothesizes that the creation of *localized* imbalances in the synergetic field's otherwise *globally* neutral and balanced charge structure causes elementary particles to form as localized contractions. This idea can be realized by allowing one of the charged sub-particle faces within one of the synergetic field's VE to either temporarily disappear, or alternatively, to temporarily lose its charge. The result will be a local imbalance in the internal charge structure of the field.

For example, suppose that one of the VE's eight external faces loses its charge. If the charge on that face is positive, its disappearance will leave behind a bear, negative charge on the face of one of the adjacent VE. This bare negative charge will polarize neighboring *pairs* of oppositely charged faces. These pairs of oppositely charged faces consist of abutting faces of immediately adjacent left-handed and right-handed VE. These polarized face pairs will be attracted toward the bare positive charge and cause the VE to contract. This central VE's contraction will pull on the surrounding VE connected to it, thereby causing them to contract. As was described in the prior discussions on the formation of various elementary particles, the degree of contraction of the VE surrounding a particle's center gradually decreases as the distance from the central VE increases. This is because the contraction of these central VE will be fighting the global tendency of the surrounding synergetic field to remain in its isomorphic state.

This mechanism explains two crucial aspects of particle formation within the synergetic field. It creates a local contractive force within the synergetic field that drives the creation of localized VE deformations that in turn define localized particles. It also creates a charge imbalance within the VE associated with these particle deformations. Such charge imbalances give effective *external* charges to the created particles. As a particle moves through the field, the missing charge also moves with the particle. A localized, *co-moving*, "missing" sub-particle (i.e., a sort of "hole" in the sub-particle field) is always associated with the central most VE within a particle, whether the particle is moving or at rest relative to the field.

Sections 7.5 and 7.6 used symmetry considerations grounded in the VE's geometry to restore flavor and color symmetries to quarks. This expanded the three-particle universe to a total of eight particles: the electron, the neutrino, three colors of up quarks, and three colors of down quarks. Section 9.1 further expanded the eight particle universe to a sixteen particle universe through the introduction of left-handed and right-handed spin symmetry. As a final step in restoring the full complement of the standard model's 30 particles, the symmetry of positive and negative electric charge can now be addressed through the VE's 32 sub-particles. As discussed immediately above, elementary particles form when the charge of one of the VE’s sub-particles temporarily disappears. There are 32 sub-particles, half of which carry positive electric charge and half of which carry negative electric charge. Therefore, in the case of electrons, if a sub-particle with one unit of negative charge disappears, there is one unit of net positive charge that is left behind. This one unit of positive electric charge is associated with the three-dimensional particle deformation induced by the negatively charged sub-particle's disappearance. The ability for either sub-particles or anti-sub-particles to disappear supports the formation of both electrons and positrons (i.e., anti-electrons). The charge symmetry between electrons and anti-electrons is thereby restored.

Similarly, the ability for either sub-particles or anti-sub-particles to disappear during the formation of quarks restores the electric charge symmetry between quarks and anti-quarks. In the case of quarks, the VE’s twenty-four *internal* sub-particles are themselves associated with positive or negative electric charges *and* correlated color or anti-color charges, depending on their position within the VE (Figure 32). Quarks’ color and anti-color charges are correlated with the signs of the quarks’ positive and negative electric charges—quarks and anti-quarks always have opposite color charges *and* electric charges relative to each other. The signs of electric and color charges on the VE’s quark and anti-quark *sub-particles* are also correlated in the same manner.

It might seem that the above picture implies a total of 32 particles instead of just 30. Since spin symmetries doubled the particle count from 8 to 16 it seems to follow that the introduction of charge symmetry should similarly double the number of particles from 16 to 32. This would be the case if sterile neutrinos exist. As is further discussed in Section 12.3, SLFT’s neutrino model seems to argue against sterile neutrinos and in favor of 30 (versus 32) particles, as is assumed by the standard model.

### *11.2. Pair Production—Populating the Synergetic Field*

In order to maintain a global charge balance across the synergetic field as a whole, the particle formation process described above always occurs simultaneously to *pairs* of VE. This means that when particles are created in the synergetic field, they must always be created in *pairs* centered on two spatially separated VE that are nevertheless close to each other. These two VE will each simultaneously lose the charge on one of their sub-particles faces. The two lost sub-particles’ charges will have equal but opposite charge values. The synergetic field’s global charge equilibrium is therefore maintained. Starting with an empty synergetic field containing no localized elementary particles, the process of pair production described above can continue indefinitely until the local force of contraction required to form new particles becomes less than the countermanding force generated by the synergetic field’s global tendency to remain in its isomorphic state.

In this way, an initially empty synergetic field, in its globally most expanded, isomorphic state, can spontaneously give rise to a cascading process of particle-antiparticle pair production. The equal and opposite charges associated with the sub-particles faces of pairs of neighboring VE disappear, causing pairs of VE to contract to particle configurations with equal and opposite charges. As this process continues, and the number of particles populating the synergetic field increases, the synergetic field's net induced global contraction continues to increase. The *field's global contraction* increases with each new particle pair's formation until a new equilibrium is reached.

This new equilibrium is reached when the local tendency of pairs of VE to contract (induced by the disappearance of pairs of charged faces) is no longer strong enough to overcome the global resistance to further contraction of the synergetic field as a whole. This global resistance to further contraction becomes greater with each additional, particle-pair induced, local contraction. This is because each particle in the synergetic field is pulling radially inwards on the entire synergetic field, inducing within it a tendency to contract relative to its most expanded, isomorphic state. The creation of each new particle pair cumulatively adds to the global elastic tension within the synergetic field. Eventually, this elastic tension becomes large enough to prevent the creation of any additional localized contractions of the field, i.e., the tension becomes large enough to prevent the creation of any additional elementary particles.

### *11.3. Virtual Particle Fluctuations in the Vacuum State*

Once the synergetic field's above global equilibrium state is reached, further random *local* fluctuations can occur within the synergetic field. The charges on random members of the field's constituent sub-particles, "blinking" in and out of existence in charge-balanced pairs, can induce further random, localized states of contraction (i.e., elementary particle, anti-particle pairs). Through this process, further pair production can occur even after dynamic equilibrium has been reached between the synergetic field's *global* elastic tension and the *local* tendency towards further pair production.

Within the context of this global dynamic equilibrium, any additional particle pairs that form are constrained from escaping the locales of their creation by the synergetic field's *global* resistance to further contraction. In combination with the oppositely charged particles' mutual attraction, this resistance causes them to quickly move back towards each other and ultimately annihilate each other. This gives rise to a continual process of "virtual" particle-antiparticle pair creation and destruction throughout the synergetic field. SLFT identifies these as the *virtual fluctuations* of quantum field theory's vacuum state. This model applies to all of the fermions—neutrinos, electrons, and quarks—as well as to all of the gauge bosons.

The above discussion presents a *hypothetical* "story" of the synergetic field's sequential population with elementary particles until global equilibrium is reached. This "story" is not meant to be taken literally—it is not proposing an actual sequence of events that occurred at some point in the distant past, but rather it is provided as a purely conceptual model to facilitate a better understanding of the internal structure and dynamics of the synergetic field. The above story implies that the Universe should contain equal amounts of matter and anti-matter. This is out of sync with the observation that the universe is constituted almost entirely of matter, versus anti-matter. We will revisit this question in Section 22.2, which examines some of the possible implications that SLFT has for modern cosmology. We will consider one possible alternative "story" in Section 22.2, that incorporates negative-mass particles, which might be more compatible with actual observations regarding the balance of matter and anti-matter in the universe.

## 12. Neutrinos Revisited

### *12.1. The Neutrino's Charge Discrepancy*

As was discussed in the immediately preceding sections, SLFT posits that a sub-particle face "disappears" within one of the synergetic field's VE during particle formation. This creates a charge imbalance in the field and consequently induces a local contraction of the field, resulting in the formation of a particle. The disappearance of the positive or negative charge associated with one of a VE's internal or external faces (i.e., sub-particles) is also associated with the endowment of a "real" net charge, of opposite sign, to the elementary particle: +/- 1 unit of charge in the case of electrons, and +/- 1/3 or +/- 2/3 units of charge in the case of quarks.

Since the neutrino has zero electric charge, it does not seem to fit with the above model. The neutrino's lack of electric charge implies that the synergetic field's underlying charge structure remains undisturbed during neutrino formation. However, if this is the case, then there can be no charge imbalance in the synergetic field to induce the local contraction of the field required to form a particle. The resolution of this charge discrepancy is related to SLFT's previously discussed description of elementary particles as soliton-like wave pulses.

### *12.2. Resolution of the Neutrino's Charge Discrepancy*

Section 9.2 discussed Isenberg's one-dimensional, discrete soliton wave machine. It will be recalled that the solitons in Isenberg's machine associated with minimal amounts of rotational displacement of the machine's rods travel as linear waves with a constant speed characteristic of the wave machine's specific construction. It is only when the machine's rod rotations are larger than a certain threshold that solitons arise. These *non-linear* soliton waves travel at various speeds, up to the machine's limiting velocity, and they experience relativistic-like length contractions of their waveforms based on their speeds relative to this limiting velocity.

SLFT's IIVM can be thought of as a *three-dimensional* analogue to Isenberg's *one-dimensional* soliton wave machine. In this three-dimensional soliton wave machine, neutrinos form with the minimal rotational displacements associated with the VE's icosahedral phase. They thus *may* fall within the *linear* wave domain of the sine-Gordon equation. Therefore, they may be associated with constant, maximal velocity waves, just as small rotational displacements in Isenberg's physical model of the sine-Gordon equation are associated with constant, maximal velocity waves.

Within SLFT, such disturbances of the medium that fall below the rotational displacement threshold required for solitons may represent a second type of fermionic matter distinct from electrons and quarks. Electrons and quarks form above the rotational displacement threshold for solitons and hence behave as massive relativistic particles. In contrast, neutrinos *may* display a dual behavior lying somewhere between massive fermions and massless bosons (e.g., photons). Experimental evidence to date indicates that neutrinos *always* travel at the speed of light [56, 57, 58, 59, 60] as they would be *required* to do if they had zero rest mass. Equally strong experimental evidence [61, 62] (i.e., neutrino oscillations) indicates that neutrinos do have some tiny amount of rest mass, in which case they should be able to travel at speeds less than light. It is certainly *possible* that low energy neutrinos may someday be observed traveling at speeds less than the speed of light, but this has not yet been experimentally observed.

SLFT's soliton model of elementary particles provides a possible resolution for these issues. It does so by allowing neutrinos to form as localized contractions of the synergetic field similarly to electrons. This allows them to be endowed with vanishingly small rest masses—they are allowed to have non-zero rest masses, albeit tiny, because the field's local asymmetrical-symmetrical icosahedral contractions (i.e., neutrinos) induce a non-zero but vanishingly small degree of torsion in the field. Nevertheless, the magnitude of the associated contractions *may* lie within the linear domain of the sine-Gordon equation. Therefore, neutrinos carrying tiny rest masses *may* yet travel at the speed of light as is predicted for cases that fall below the rotational displacement threshold required for the formation of nonlinear waves (i.e., solitons).

The relatively small amount of localized contraction of the field required to form a neutrino explains the neutrino's lack of electric charge. The perturbations of the field associated with the formation of neutrinos are linear and are very small. Therefore, they do not require a sub-particle's disappearance (or alternatively, the loss of charge on a sub-particle) to stimulate their formation and support their on-going existence. They can therefore form freely as very low magnitude, linear-like waves of the field. This neutrino model does not require a neutrino's central VE to be contracted exactly to a perfectly symmetrical icosahedron. It can be contracted to an asymmetrical icosahedron configuration close to a symmetrical icosahedron as long as it is slightly different from the asymmetrical icosahedron that defines the isomorphic VE.

### *12.3. Sterile Neutrinos*

The restoration of spin symmetry in Section 9.1 increased the number of neutrino types from one to two. It does not seem to make sense to consider a corresponding restoration of charge symmetry, however, since neutrinos do not carry any electric charge. More specifically, as described in the previous section, no sub-particles disappear during the formation of a neutrino, so there does not seem to be any additional geometric distinction that would support the identification of more than two neutrinos per generation, in contradistinction to the four unique types of electrons per generation. It may be that there is some subtle, yet to be defined, geometric differentiation of neutrinos associated with their sub-particles, but at this time, it seems most logical to assume that there is not. So even though there are four neutrino sub-particles, including distinct neutrino sub-particles and neutrino anti-sub-particles, SLFT currently assumes that these fail to manifest as corresponding, "real", three-dimensional particles. This is because, unlike electrons and quarks, the neutrinos' associated sub-particles do not disappear during the process of neutrino formation. Nevertheless, SLFT holds open the possibility that sterile neutrinos *might* exist based on some as-yet-to-be identified geometric distinction.

## 13. The Three Generations of Elementary Particles

### *13.1. Three IIVMs*

SLFT's explanation of the three generations of elementary particles arises naturally from spatial symmetry considerations. SLFT proposes a model in which each generation of elementary particles is associated with its own separate IIVM lattice. This model assumes the existence of three interpenetrating and partially interacting IIVMs. This model is conceptually simple on the surface, but it gives rise to complex interactions and interrelationships between the three generations.

This model accounts for the mass differences between corresponding particles in different generations, at least qualitatively. It assumes that particles in the first generation represent contractions within one IIVM. It further assumes that particles in the second generation represent a local coupling of two IIVMs, so that second generation particles involve simultaneous contractions within two IIVMs. It assumes that particles in the third generation are associated with simultaneous contractions within all three IIVMs. This model assumes that it requires greater energy to form particles in the second generation than in the first generation because second generation particles involve distortions of two IIVMs instead of just one. Likewise, it requires even greater energy to form third generation particles that involve the distortion of all three IIVMs. Although such a model qualitatively agrees with greater particle masses in the second and third generations, it does not attempt to explain these particles' actual observed mass values, which increase in a highly non-linear manner in the higher generations.

There are a few important potential issues with the above model that need to be addressed. The hypothetical "story" of how the IIVM became populated with particles, which was initially presented in Section 11.2 (and that will be further revised in Section 22.2), would seem to imply that the process of particle and anti-particle pair production should have occurred simultaneously in all three generations. In reality, the vast bulk of the universe's matter exists only in the first generation. SLFT must therefore propose a rule forbidding this from happening. The reason for this rule could be that under normal circumstances the energy required to create *second* and *third* generation particles is too large to be overcome by charge imbalances produced by disappearing IIVM sub-particle faces (i.e., in contradistinction to the formation of first generation particles described in Section 11.1 ).

The second issue that needs to be addressed is maintaining global spatial alignment between the three IIVMs. If particles form primarily in the first generation, this will create some small global contraction of the first generation's IIVM relative to the IIVMs of the second and third generations. In order to address this issue, SLFT assumes that there is some charge-based connectivity between the sub-particles that make up the three IIVMs. This connectivity keeps the three IIVMs co-aligned globally. The assumption is that the second and third generation's IIVMs are pulled into alignment with the small global contraction of the first generation's IIVM that is induced by its population of elementary particles. The IIVMs may become locally less than perfectly aligned only near the central regions of elementary particles, and in this case, any misalignment is mostly of only a small degree and is mostly taken up by the elasticity of the IIVM.

The third issue that needs to be addressed is related to the actual nature of the struts and faces (sub-particles) that make up each IIVM. These are not some naïve, mechanical, physical elements. Their true nature is unknown, but we can infer some requirements regarding their nature and behavior. They can possibly best be thought of as some kind of primordial, trans-physical energy flows. They must be able to freely move past and through the corresponding struts and faces of second and third generation VE to accommodate the contraction and folding of local VE in the center regions of first generation particles. When first generation particles form, the local struts and faces of individual VE in the first generation, in the vicinity of the particles' centers, *must* pass through the struts and faces of the associated VE in the second and third generation, since those VE remain nominally in their isomorphic configurations.

*13.2. Cross-Generational Interactions*

The fact that particles in each successive generation include contractions of the preceding generation's IIVM ensures that all particles can "talk" to one another. For example, a second generation particle can interact with a first generation particle because they both incorporate contractions of the first generation's IIVM. Similarly, all second and third generation particles include elements of the first and second generation IIVMs. More generally, *all* particles in *all* generations incorporate contractions of the first generation. This provides the physical basis for *all* particles being able to interact with one another. If the particles in the first, second, and third generations lived completely independently within their own completely separate IIVMs, there would be no basis or mechanism for these particles to interact with one another. There would be no mechanism for them to transform into one another or to transfer energy and momentum between one another.

This model is qualitatively consistent with the laws governing inter-generational transformations and the experimentally observed *propensity* for particles to remain primarily "locked" within their own generations. Important conservation laws largely restrict particle transformations between generations—electromagnetic and color force interactions always leave a particle's flavor (and therefore generation) unchanged. Except for weak force mediated interactions and the special case of inter-generational neutrino oscillations, elementary particles tend to remain locked within their own generations.

Even in the case of the weak force, particle transformations allowed *between* generations are slower and less likely to occur than are transformations *within* the same generation as is described by the relative probabilities of quark transformations in the CKM matrix. The weak force can facilitate transformations between the two flavors of quarks within each generation. It can also, in general, facilitate transformations between up-type and down-type quarks *across* different generations. These latter transformations have lower probabilities of occurring and hence occur at significantly lower average rates. All of the above particle behaviors indicate some sort of dominant but imperfect segregation between particles in different generations. These behaviors are conceptually in line with SLFT's hypothesis of three distinct but co-extensive and interacting IIVMs corresponding to the three distinct particle generations.

*13.3. Quark Mass Splitting Revisited*

Section 8.5 discussed quark mass splitting between the first generation's up and down quarks. That section explored a possible explanation for this mass splitting. When the second and third generations are considered, the questions related to quark mass splitting become more complicated. In the second and third generations, up quarks' and down quarks' masses split *much* more strongly. In addition, they split in the opposite direction than they split in the first generation. In the first generation, up quarks are *less* massive than down quarks, but in the second and third generations, the counterparts of the first generation up quarks (charm and top quarks, respectively) are *more* massive than the second and third generation counterparts of the first generation down quarks (strange and bottom quarks, respectively). In order to explain the different directions of quark mass splitting between the first generation and the second and third generations, SLFT hypothesizes that two *opposing* forces drive quark mass splitting.

As was discussed in Section 8.5, the first proposed source of quark mass splitting is the differential interaction of the left-handed and right-handed tetrahedral contractions with the synergetic field's broken *global* symmetry. The second proposed source is the difference in electric charge carried by up-type quarks and down-type quarks. SLFT proposes that one of these quark mass splitting sources dominates in the first generation while the other dominates in the second and third generations. The change in dominance changes the direction of the mass splitting in the first generation relative to the mass splitting direction in the second and third generations.

### *13.4. IIVM Symmetries and the Three Generations*

SLFT's model of three separate IIVMs corresponding to the three generations of fermions sheds some potential new light on the questions of why there are multiple generations of elementary particles and, more specifically, why there are exactly three generations. SLFT hypotheses the existence of exactly three generations based on the restoration of certain spatial symmetries broken at the level of the IIVM associated with any *single* generation. SLFT's introduction of 32 (or 30) new negative-mass particles in each generation (Sections 8.3 and 8.4) creates a geometric asymmetry in the layout of the sub-particles within each VE. If the *full* complement of 32 new negative-mass *particles* is introduced, it is necessary to introduce 32 new, corresponding *sub-particles* within the VE. In order to accomplish this, SLFT introduces a *lateral* division of the VE's sub-particle faces. With this lateral division, each face contains two sub-particles, one corresponding to a positive-mass particle and one corresponding to a negative-mass particle. This is done to preserve the one-to-one correspondence between two-dimensional sub-particles and three-dimensional "real" particles. This division defines a unique direction within each VE and within an IIVM formed from these individual VE (Figure 40).

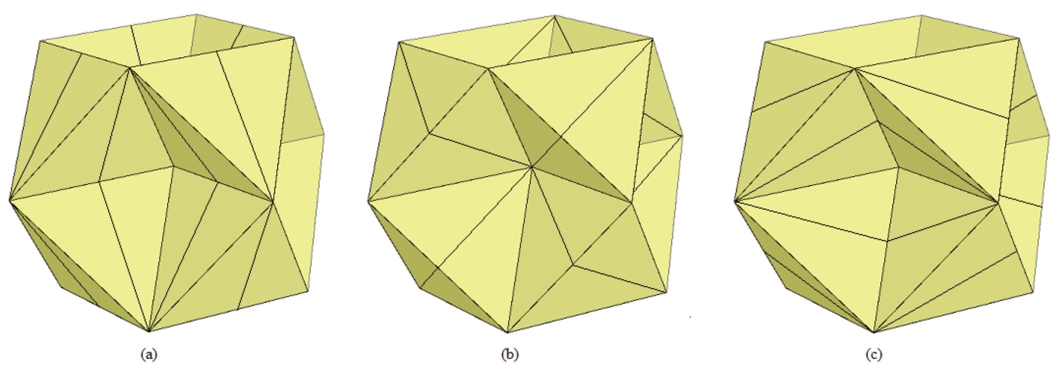



Figure 40: The introduction of negative-mass sub-particles introduces a lateral division in the VE's internal and external faces. This lateral division defines a preferred direction within an individual VE and within an IIVM formed from such VE.

This unique direction is parallel to a symmetry axis defined by the midpoints of a pair of diametrically opposite square faces on the exterior shell of the VE's cuboctahedral phase. There are three such symmetry axes, and therefore there are three possible unique directions defined by the lateral divisions of the VE's faces (Figure 40(a-c)). There is no reason to choose any one of these directions preferentially over the other two, and in order to maintain maximum symmetry, SLFT proposes that nature chooses all three. The three IIVMs hypothesized by SLFT are aligned such that each of their constituent sub-particles' lines of left-right symmetry each lie along one of these three orthogonal axes. In this manner, the asymmetry in the layout of the VE's sub-particles caused by introducing 32 additional sub-particles associated with negative-mass fermions is addressed—symmetry is restored on a global basis when *three* co-extensive IIVMs are considered together.

The resolution of lower-level asymmetries by introducing higher-level meta-symmetries is a recurring theme in SLFT. As will be explained in Section 14.3, the left-right asymmetry in the weak force is "resolved" by the new symmetry between positive and negative masses previously introduced in Section 8.3. As was discussed immediately above, the introduction of this new mass symmetry, in turn, created a new asymmetry in the underlying fabric of the IIVM (i.e., the asymmetrical layout of the VE's 64 sub-particles shown in Figure 40). This asymmetry is in turn resolved by the introduction of three separate but co-extensive IIVMs. The respective sub-particle fields of these three IIVMs are oriented in three different, orthogonal directions relative to one another. Taken together, they globally restore a higher level of spatial symmetry. The existence of the three generations ultimately resolves these cascading layers of asymmetries and related symmetries. From this perspective, within the context of SLFT, the existence of three generations is both natural and necessary. It is tied directly to the symmetry of the three orthogonal directions of three-dimensional space.

## 14. Gauge Bosons

### *14.1. Gauge Bosons as Composite Particles*

SLFT's model of the Universe includes the standard model's fermions incorporated into the synergetic field as localized contractions of the field. It also includes a new set of matching negative-mass fermions. For this model to be complete, the gauge bosons that mediate the fermions' interactions must also be incorporated. In order to accomplish this, there must either be an entirely new set of structural deformations within the synergetic field that can be used to model the gauge bosons, or else there must be a way to construct the gauge bosons from the already defined fermions. SLFT chooses the latter approach because the icosahedral, octahedral, and tetrahedral contractions of the VE, which are already used to describe the fermions, are the only symmetrical, omni-triangulated, structurally stable configurations available within the synergetic field.

### *14.2. Negative-mass Fermions and Composite Bosons*

SLFT proposes that gauge bosons are composite particles constructed from pairs of positive-mass and negative-mass fermions. Without negative-mass fermions, there would be a significant challenge facing SLFT's proposed composite model of gauge bosons. This challenge arises from the fact that all existing fermions have nonzero rest masses while some of the bosons do not (e.g., photons and gluons). The existence of both positive-mass and negative-mass fermions provides the raw materials from which such zero rest mass bosons can be constructed.

It will be recalled from Sections 5.4, 8.3, and 8.4 that one set of the synergetic field's isomorphic VE is contracted in a left-handed sense and that the other set is contracted in a right-handed sense relative to the VE's cuboctahedral phase. Suppose we start with the synergetic field in its fully expanded, most relaxed, isomorphic state, consisting solely of these interwoven left-handed and right-handed isomorphic VE, and then suppose that we allow a group of VE in the left-handed set to contract. This will induce contraction in the surrounding left-handed set of VE and, depending on the specific particle being considered, either an expansion or a lesser degree of contraction in the right-handed set (i.e., a lesser degree of contraction in the case of quarks—see Section 8.4). The resulting deformations of the surrounding VE decrease exponentially as one proceeds away from the central, most contracted VE. Similarly, the contraction of a local group of VE in the right-handed set induces a contraction throughout the right-handed set and either an expansion or a lesser degree of contraction (i.e., in the case of quarks) throughout the left-handed set. In both cases, there is a net global, albeit infinitesimal, contraction of the synergetic field as a whole.

If we again start with the synergetic field in its most relaxed, most expanded state, and allow a group of VE in a localized region to contract in the left-handed set, and then *simultaneously* allow another group VE in the same general vicinity to contract *by the same amount* in the right-handed set, the *net* radial distortion (torsion) of the synergetic field will be zero. This is because, from a far enough distance, the equal and opposite, left-handed and right-handed torsion that these two contractions respectively induce within the two sets of VE have equal and opposite rotational senses, and thus, on a global scale, the associated radial distortions that they induce in the field cancel each other out. However, the individual contractions (i.e., curvature) that they induce in the field do not cancel out. An example of such a scenario would be a positive-mass electron forming in the left-handed set of VE and a negative-mass positron forming in the right-handed set.

If we add some mechanism to the above scenario that bound these two particles with oppositely signed masses together into a single effective entity, then we would have a way to construct zero rest mass gauge bosons from pairs of positive-mass and negative-mass fermions. In order to realize such a mechanism, SLFT proposes a fundamentally new type of force. This force is fundamentally different from the forces that arise from the exchange of gauge bosons since it is these very gauge bosons that are being defined. This new binding force is based on an analogy to Cooper pairs in superconducting lattices and is more fully discussed in Section 16.

As was noted in Section 8.3, SLFT associates nonzero rest mass with a *net* positive or *net* negative *radial* distortion, or torsion, of the field. Such instances of nonzero torsion and associated nonzero rest mass *always* occur for isolated fermions. They also occur for composite bosons whose constituent positive-mass and negative-mass fermions have rest masses with unequal *magnitudes*. In contradistinction, composite bosons whose constituent fermions have equal magnitude but oppositely signed rest masses will have zero *net* radial distortion and therefore zero net torsion. Such particles, therefore, have zero rest mass even though they do have positive energy values. The mass associated with these positive energy values has its source in the non-vanishing, non-radial *contraction* (i.e., curvature) of the synergetic field associated with the *contractions* of the boson's constituent fermions.

There is a structural detail of such composite bosons that is worth mentioning. There is a special region of the IIVM situated directly between a composite boson's positive-mass fermion and its negative-mass fermion. This region is nominally encompassed by a circular disk-like area located at the midpoint between the two fermions and that is oriented perpendicularly to the axis joining the two fermions. In this disk-like area, the synergetic field is in its isomorphic (i.e., IIVM) configuration. This is the geometric "join point" between the left-handed and right-handed contractions of the field induced by the positive-mass fermion and the negative-mass fermion, respectively. Thus, the boson has a morphological structure that encompasses a left-handed "bubble" of contraction on the positive-mass side of the central disk and a right-handed "bubble" of contraction on the negative mass side. At a large distance, the boson is enclosed in a spherical region of the field that is nominally in its isomorphic state. The central disk-like area merges into this surrounding spherical region at its periphery.

### *14.3. Zero Rest Mass Bosons – Photons and Gluons*

SLFT's addition of negative-mass fermions to the currently accepted spectrum of positive-mass fermions provides one of the essential elements required to solve the problem of constructing zero-rest-mass, composite bosons from pairs of fermions. Merely introducing a set of negative-mass fermions, however, is not sufficient to *completely* solve this problem.

The introduction of negative-mass fermions allows the correct modeling of the zero rest masses of photons and gluons, but by itself, it does not support the correct modeling of the charges carried by these bosons. Specifically, if we simply assign all of the same charge values of the positive-mass fermions to their negative-mass counterparts and only reverse the signs of their masses, we cannot use pairs of such positive-mass and negative-mass fermions to make the required constructions.

For example, if we try to construct a left-handed photon from the bound state of a left-handed, positive-mass electron and a left-handed, negative-mass positron, the resulting composite particle will not have properties that correctly match the properties of a photon. As shown in Table 1, this combination will, like a photon, have zero rest mass and zero electric charge, but it will have nonzero weak charge. No such particle has ever been observed. (The tilde symbol placed in front of a particle's symbol will be used to indicate negative-mass particles. For example, a negative-mass electron will be represented as "~e".)

Table 1: The correct charge characteristics of photons cannot be met by merely combining a positive-mass electron with a negative-mass positron (i.e., anti-electron) if only the sign of the positron's mass is reversed.

| | Electric Charge | Weak Charge |
|---|---|---|
| $e_L$ | -1 | -0.5 |
| $\sim\bar{e}_L$ | 1 | 0 |
| Charge Sums | 0 | -0.5 |

In order to solve this problem, *a connection must be made between a fermion's weak charge and the sign of its gravitational rest mass.* In our Universe, we observe an asymmetry in the weak force: left-handed fermions and right-handed anti-fermions are subject to the weak force, while right-handed fermions and left-handed anti-fermions are not. In order to construct bosons with all of the correct charge values, we must assume that negative-mass fermions have a different relationship to the weak force than positive-mass fermions. *For negative-mass fermions, SLFT reverses the weak force's basic rules: right-handed fermions and left-handed anti-fermions are subject to the weak force, while left-handed fermions and right-handed anti-fermions are not.* With the introduction of this new meta-symmetry encompassing gravitational mass polarity and the weak force, zero rest mass bosons (photons and gluons) can be successfully constructed as composite pairings of positive-mass fermions and negative-mass anti-fermions (or alternatively from composite pairings of positive-mass *anti-fermions* and negative-mass *fermions*).

Such particles with parity reversed weak charges, albeit with positive gravitational masses, have been previously proposed in the literature dating back to Lee and Yang [63], and have been extensively investigated by Foot [64] among others. See Okun [65] for a comprehensive list of references. Such particles are usually referred to as mirror matter, and they are often assumed to constitute a complete copy of the standard model's particles, but with a conjugated weak force. Mirror matter theories forbid most interactions between the standard model's bosons and fermions and their mirror matter counterparts, with the primary exception of gravitational interactions. Some versions of bi-metric general relativity, such as those proposed by Hossenfelder [47, 48], and separately by Petit [66, 67, 68], have a similar characteristic—the only interactions allowed between positive-mass particles and negative-mass particles are gravitational interactions. Henry-Couannier [69] has entertained the possibility of bringing together the characteristics of both mirror matter and bi-metric theories. He has considered the possibility of a negative mass copy of the standard model's particles, which also has a conjugated weak force. This is similar to SLFT's proposal.

Using such pair-wise constructions consisting of positive-mass and negative-mass fermions yields gauge bosons whose properties are all correct. The zero rest masses of photons and gluons, for example, can be correctly modeled, as well as all of their correct charges and spins. If this assumption is *not* made, an attempt to construct zero rest mass bosons from positive-mass and negative-mass fermion pairs will, in general, not succeed. With the application of this new meta-symmetry, it is possible, for example, to successfully construct a left-handed photon from a left-handed, positive-mass electron and a left-handed, negative-mass positron. As shown in Table 2, the resulting particle has all of the correct attributes of a photon. We can similarly successfully construct a left-handed gluon from a left-handed, positive-mass up quark and a left-handed, negative-mass anti-up quark. The resulting particle has all of the correct properties of a gluon.

Table 2: The correct charge characteristics of photons can be realized by combining a positive-mass electron with a negative-mass positron (i.e., anti-electron) if the weak charge is parity-reversed between positive-mass and negative-mass particles (left table). A similar correct construction can be made for gluons by combining a positive-mass up quark with a negative-mass anti-up quark (right table).

| | Electric Charge | Weak Charge |
|---|---|---|
| $e_L$ | -1 | -0.5 |
| $\sim\bar{e}_L$ | 1 | 0.5 |
| $\gamma$ | 0 | 0 |

| | Electric Charge | Weak Charge | R-G | G-B | B-R |
|---|---|---|---|---|---|
| $u_L$ (Red) | 0.67 | 0.5 | 0.5 | 0 | -0.5 |
| $\sim\bar{u}_L$ (Anti-Blue) | -0.67 | -0.5 | 0 | 0.5 | -0.5 |
| g (R-B) | 0 | 0 | 0.5 | 0.5 | -1 |

The fact that these gauge bosons are composite particles constructed from pairs of fermions allows SLFT to geometrically model another important characteristic of zero rest mass gauge bosons—they always travel at the speed of light, yet they can have various energies. The variable energies of these zero rest mass, constant velocity gauge bosons can potentially be modeled as an effect of their constituent fermions' internal dynamics, including different relative distances and different relative motions between constituent fermions.

SLFT defines two additional rules required to make its composite boson model work correctly. The first rule is that positive-mass particles and negative-mass particles only interact with each other via the gravitational force—there are no weak, electromagnetic, or color force interactions between such particles. As was discussed above, this characteristic is shared with the bi-metric versions of general relativity proposed by Hossenfelder [47, 48] and separately by Petit [66, 67, 68]. This rule is required to prevent an infinitely nested, iterative cascade of exchange bosons between said bosons' fermionic components.

The second rule is related to the positive-mass fermions and negative-mass anti-fermions that are bound together to form bosons. *The positive-mass and negative-mass constituents of these fermion-pairs are not allowed to interact externally with any other fermions outside of their bound states.* This rule applies regardless of the specific mass polarities of such external fermions. Gravitational interactions are excluded from this second rule. This rule suppresses similarly complicated and infinitely regressing, nested processes between the internal, fermionic components of bosons with external particles, including other bosons' internal components. SLFT does not currently provide any explanation or model regarding the mechanisms behind these rules. It simply requires that these rules exist in order for SLFT's composite boson model to agree with observed particle behaviors.

*14.4. Massive Gauge Bosons - W and Z Bosons*

This model accommodates the zero rest masses of photons and gluons formed from fermion pairs that have exactly opposite gravitational rest masses. It can also accommodate the nonzero rest masses of W and Z bosons. These bosons are formed from particles whose masses have unequal *magnitudes* but have oppositely signed gravitational rest masses. However, the W and Z bosons' masses cannot be the simple sums of the masses of their component fermions. The W and Z bosons' observed masses are approximately 80 GeV/$c^2$ and 91 GeV/$c^2$, respectively. The only fermion in this general mass range is the top quark at approximately 173 GeV/$c^2$ (approximately twice either the W or Z masses). Therefore, the top quark is too massive to account for the W and Z masses, and all of the other fermions are not nearly massive enough. It thus appears that regardless of which pairs of positive and negative-mass fermions combine to create W and Z bosons, a large part of their masses must come from some as-yet-to-be defined *dynamical* effect(s).

Most of the mass of electro-weak bosons is derived from more complicated interactions of their subcomponent fermions with each other and with the underlying synergetic field. This idea is *conceptually* similar to the way that the masses of protons (and other mesons and baryons) are generated in QCD. The proton's sub-components (i.e., two up quarks and one down quark) only *directly* contribute on the order of 1% of the proton's mass. The remainder is generated dynamically from quantum mechanical and relativistic effects of virtual particles within the protons.

The fact that SLFT rules out strong, weak and electromagnetic interactions between positive-mass and negative-mass fermions *may* preclude quantum mechanical effects from being the source of such "dynamical" mass. Relativistic effects and other, *new*, synergetic-field-based effects may account for the masses of these composite gauge bosons. Such effects may include possible highly non-linear effects arising from the close proximity of a positive-mass particle and a negative-mass anti-particle within a bound state.

The large masses of the W and Z bosons may also be a side-effect of constructing W and Z bosons from *cross-generational* combinations of fermions. Combining fermions across generations may introduce additional, new, nonlinear components to the masses of the resulting composite bosons. Indeed, the "calculus" of combining positive-mass fermions with negative-mass anti-fermions to generate bosons *demands* that the Z boson, *at least*, must be constructed from a cross-generational, pair-wise combination of fermions.

Z bosons must be cross-generational because, like photons, they carry zero charge, but they *also* have nonzero rest mass. The only fermion pairs that create charge-free bosons are positive-mass fermions combined with negative-mass anti-fermions of the *same* type (or vice versa). For example, a positive-mass electron combined with a negative-mass positron creates a photon. If the particles forming such a combination are from the same generation, as in the above example, then their rest masses will cancel out, and the resulting composite particle will have zero rest mass, yielding either a photon or a gluon. To bestow mass on such a pairing, the pair's members must be *corresponding* particle *types* residing within two *different* generations.

An example of this would be a third generation, positive-mass tau paired with a second generation, negative-mass anti-muon. The summed rest mass of these two particles is on the order of 1.8% of the Z boson's rest mass. In this example, the ratio of the masses of the proposed constituent fermions making up the Z boson to the Z boson itself is similar to the ratio of the masses of the up and down quark triplets that make up a proton to the proton itself. Other possible pairings that could be associated with the Z boson include a third generation, positive-mass tau paired with a first generation, negative-mass positron, or a second generation positive-mass muon paired with a first generation negative-mass positron. In the latter case, this might represent a new, yet-to-be detected, light-weight variant of the Z boson.

It might also be possible to form a Z boson from colorless, cross-generational, same-flavor combinations of positive-mass and negative-mass quarks. Possible combinations include bottom and strange quarks, bottom and down quarks, strange and down quarks, and charm and up quarks. If such combinations exist, they would be yet-to-be detected Z-like bosons with various rest masses. If these Z-like bosons exist, they would include some light-weight Z bosons. For example, the Z-like boson formed from the combination of strange and down quarks would likely be much lighter than the standard model's Z boson.

Since W bosons are involved in the transformation of particles *across* different generations as well as within the same generations, it makes some sense that they, like Z bosons, might also be cross-generational. Such a construction of W bosons seems to be more consistent with their observed mass. For example, a possible W particle pair-wise combination might be a positive-mass bottom quark paired with a negative-mass anti-charm quark (in which the two quarks carry each other's anti-color charges). (Section 15.6 discusses additional details regarding the formation of W bosons from pairs of up-*type* and down-*type* quarks.) The summed rest mass of these two particles is on the order of 3.6% of the rest mass of the W boson. The ratio of the masses of these possible constituent fermions of the W boson to the W boson itself is nominally similar to the ratio of the masses of some of the above described possible constituents of the Z boson to the Z boson itself. It is also similar to the ratio of the masses of the up and down quark triplets that make up the proton to the mass of the proton itself.

By similar arguments, other possible candidates for the pair-wise components of the W boson include a positive-mass bottom quark and negative-mass anti-up quark, a positive-mass charm quark and a negative-mass anti-strange quark, and a positive-mass charm quark and a negative-mass anti-down quark. It is possible that all of these potential combinations can occur, but with different probabilities. In that case, the combination most likely to occur would be associated with the standard model's W boson. The other possibilities might be new, rare, as-yet undetected, exotic bosons, similar to the standard model's W boson, but with different masses.

## 15. Composite Boson Matrices

### *15.1. Composite Boson Combinatorial Rules*

The above discussion explored how the standard model's currently observed gauge bosons might be generated from pair-wise combinations of positive-mass fermions and negative-mass anti-fermions (and vice versa). In order to complete the discussion of SFLT's composite model of bosons, it is necessary to not only consider "what is" (i.e., the currently observed spectrum of gauge bosons) but also "what could be." Considering all possible pair-wise combinations of positive-mass fermions and negative-mass fermions yields *the possibility* of new types of as yet unobserved gauge bosons. At this stage, SLFT does not explicitly predict that any such new, exotic gauge bosons actually exist. The following sections will explore what exotic new bosons *might* exist *in principle* and will *conversely* consider a set of prohibitive combinatorial rules that would disallow the existence of *most* such bosons.

Each generation contains 30 positive-mass fermions and 30 negative-mass fermions. A simple combinatorial matrix of positive-mass and negative-mass pairs implies the possibility of as many as 900 total combinations of positive-mass and negative-mass fermions within *each* generation. If cross-generational combinations are considered, there are another 2700 possible combinations. To simplify the initial discussion, we will at first consider only the 900 such particle combinations within the first generation, and we will explicitly ignore cross-generational combinations such as those discussed above for W and Z bosons. Some of the sub-groupings within these 900 possible pairings are degenerate cases. The members of such degenerate pairing cases all have the charge characteristics of the same underlying boson. Therefore, there are not truly 900 possible *unique* composite bosons in each generation. Notwithstanding the degenerate cases, there would definitely be some fundamentally new bosons if all 900 possible combinations were allowed. Some of these new bosons would have zero rest masses like photons and gluons, but many would have nonzero rest masses, including both positive and negative rest masses.

For example, the X and Y bosons proposed by Georgi and Glashow [70] would be included in the set of 900 possible combinations. These bosons are hypothetical massive bosons that, if they existed, would mediate transformations of leptons (electrons and neutrinos) into quarks and vice versa. Their existence would imply the possibility that protons could spontaneously decay into other particles over very, very long time periods. Since no experimental evidence has yet been found supporting the existence of X and Y bosons, we can assume that they probably do not exist.

Within the context of SLFT, the non-existence of X and Y bosons would result from one or more restrictive rules governing the allowed pair-wise combinations of positive-mass fermions and negative-mass fermions. It is useful to explore all such restrictive rules that might exist, *in general*, to minimize the number of potential exotic new bosons beyond the standard model implied by SLFT's composite boson model. This can be accomplished by exploring the rules governing the types of combinations that *must* be disallowed to suppress the existence of combinatorially *possible* but currently unobserved bosons.

The first proposed rule is that positive-mass fermions can only pair with negative-mass *anti-fermions*, and vice versa. We have already been using this rule implicitly in the preceding discussions, but we state it explicitly here. If positive-mass fermions were allowed to pair with negative-mass fermions (as opposed to negative-mass *anti-fermions*), or if positive-mass anti-fermions were allowed to pair with negative-mass anti-fermions (as opposed to negative-mass *fermions*), then, in either case, exotic particles would result. For example, zero rest mass bosons with two units of electric charge would be generated from a positive-mass positron paired with a negative-mass positron. If such exotic particles existed, they would have already been detected. More importantly, their existence would substantially change currently known physics. It is, therefore, reasonable to rule out such combinations.

*The second proposed rule is that only fermions of the same handedness can combine.* Combined with the first rule, this means that only left-handed, positive-mass fermions and left-handed negative-mass anti-fermions (or alternatively, their conjugates) can be combined. Similar combinations can occur between right-handed, positive-mass fermions and right-handed, negative-mass anti-fermions and their conjugates (i.e., right-handed, positive-mass anti-fermions and right-handed, negative-mass fermions). This rule means that only bosons with one unit of spin can be formed. This rule disallows the formation of scalar bosons with zero spin. This rule is in accord with current experimental observations to date that have not detected any fundamental scalar bosons (with the exception of the recently discovered Higgs boson). The Higgs boson will be further discussed in Section 15.11.

*The third proposed rule is that neutrinos never participate in the formation of bosons, except possibly with other neutrinos.* This rule is motivated by dynamical considerations. It will be recalled that although neutrinos are fermions, in SLFT, they *may* also inhabit a unique niche lying somewhere between fermions and bosons. Because they are low amplitude contractions of the field, they *may* have some important characteristics of linear waves versus non-linear, soliton waves. For example, it is *possible* that they *may* only travel at the speed of light. If this is true, then the only fermions they could reasonably combine with would be themselves because all of the other fermions have nonzero rest masses, and therefore always travel at speeds less than light.

*The fourth proposed rule is that quarks and electrons cannot be combined to form composite bosons.* This rule is in accord with the lack of experimental evidence supporting the existence of X and Y bosons. Within the context of SLFT, this seems to be a reasonable, *structurally* based constraint. The formation of electrons is associated with the VE's octahedral-cuboctahedral contraction. The formation of quarks is associated with a somewhat different morphological transformation (i.e., VE's tetrahedral-octahedral contraction). Disallowing the co-existence of these two types of morphological transformations within the same bound state seems to provide a good motivation for this restriction.

*15.2. Composite Boson Combinatorial Matrices*

The above rules disallow the formation of a number of unobserved, exotic gauge bosons. With the exclusion of these exotic particles, it is now possible to look at what pair-wise particle combinations remain. Since these rules dictate that neutrinos can only combine with themselves and that quarks and electrons cannot combine with one another, it follows immediately that only particles of the *same type* can combine with each other. Neutrinos can (possibly) combine with neutrinos, electrons can combine with electrons, and quarks can combine with quarks. The quark combinations include the possibility for combinations of quarks that have different *flavors*. For example, a positive-mass up quark can combine with a negative-mass anti-down quark. The next sections systematically examine the possible pairings within each of these three pair-type sub-groupings. We will first examine pairings of positive-mass electrons with negative-mass anti-electrons (and vice versa).

*15.3. Electron Based Composite Bosons*

There are four varieties of positive-mass electrons and four varieties of negative-mass electrons, as shown in Table 3.

Table 3: This table shows the electric and weak force charges carried by the four positive-mass and the four negative-mass electrons.

| Particle | $e_L$ | $e_R$ | $\sim\bar{e}_L$ | $\sim\bar{e}_R$ | $\sim e_L$ | $\sim e_R$ | $\bar{e}_L$ | $\bar{e}_R$ |
|---|---|---|---|---|---|---|---|---|
| Electric Charge | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 |
| Weak Charge | -0.5 | 0 | 0.5 | 0 | 0 | -0.5 | 0 | 0.5 |

Without considering the four exclusionary combinatorial rules defined above, there would be 16 possible electron-type, pairwise combinations between positive-mass electrons and negative-mass electrons. When the four combinatorial rules are taken into consideration, the number of possible combinations is significantly reduced. The remaining possible combinations are included in Table 4 below, which arranges these eight particles into two, 2 X 2 matrices to show *potential*, allowed ways that the four positive-mass electrons can combine with the four negative-mass anti-electrons (i.e., negative-mass positrons).

The eight cells of the two matrices shown in Table 4 are labeled with either the symbol for a photon or the number "2". Photons populate the matrices' diagonal elements, and various disallowed exotic particles populate the matrices' off-diagonal elements. The number "2" indicates that the second, previously defined combinatorial rule disallows the pairings that would otherwise be found along the off-diagonal matrix elements. The specific charges carried by each of these exotic particles, if they were allowed to exist, can be calculated directly by summing the charges shown in Table 3. We will not go into any further details regarding these or any other disallowed exotic particles' specific characteristics.

Table 4: The left and right matrices, below, show combinatorial possibilities between (a) positive-mass electrons and negative-mass anti-electrons (i.e., positrons) and between (b) negative-mass electrons and positive-mass anti-electrons, respectively. The diagonal elements contain photons. The off-diagonal elements contain combinations defining unknown exotic bosons disallowed by the second exclusionary rule (indicated by "[2]"), which disallows particles with oppositely oriented spins to combine.

| | $\sim\bar{e}_L$ | $\sim\bar{e}_R$ |
|---|---|---|
| $e_L$ | $\gamma$ | [2] |
| $e_R$ | [2] | $\gamma$ |

(a)

| | $\bar{e}_L$ | $\bar{e}_R$ |
|---|---|---|
| $\sim e_L$ | $\gamma$ | [2] |
| $\sim e_R$ | [2] | $\gamma$ |

(b)

*15.4. Neutrino Based Composite Bosons:*

Assuming that neutrinos combine to form composite bosons in a manner similar to electrons, a similar set of results are obtained. Table 5 shows the electric and weak charges of the four positive-mass neutrinos and the four negative-mass neutrinos. (For the sake of completeness, the table includes sterile neutrinos, which may or may not exist.)

Table 5: This table shows the weak force charges carried by the four positive-mass and the four negative-mass neutrinos. The grayed out columns indicate sterile neutrinos, which may or may not exist.

| **Particle** | $\nu_L$ | $\nu_R$ | $\sim\bar{\nu}_L$ | $\sim\bar{\nu}_R$ | $\sim\nu_L$ | $\sim\nu_R$ | $\bar{\nu}_L$ | $\bar{\nu}_R$ |
|---|---|---|---|---|---|---|---|---|
| **Electric Charge** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Weak Charge** | 0.5 | 0 | -0.5 | 0 | 0 | 0.5 | 0 | -0.5 |

Table 6, below, shows the two, 2 X 2 matrices of *potential* pair-wise combinations of the four positive-mass neutrinos with the four negative-mass neutrinos. As was the case for the electron combinatorial matrices shown in Table 4, the neutrino matrices' diagonal elements contain photons. The off-diagonal elements contain exotic bosons that have never been observed and that are disallowed by the previously defined second combinatorial rule. The neutrino matrices have one additional important characteristic. They include two positive-mass sterile neutrinos and two negative-mass sterile neutrinos. It is not known whether such sterile neutrinos exist. SLFT seems to imply that they probably *do not* exist (Section 12.3). If they do *not* exist, then the two, 2 X 2 neutrino matrices would be reduced to two, 1 X 1 matrices, but with similar results.

Table 6: The left and right matrices, below, show combinatorial possibilities between (a) positive-mass neutrinos and negative-mass anti-neutrinos and between (b) negative-mass neutrinos and positive-mass anti-neutrinos, respectively. The diagonal elements contain photons. The off-diagonal elements contain combinations defining unknown exotic bosons disallowed by the second exclusionary rule indicated by "[2]". The lower right photon in matrix (a) and the upper left photon in matrix (b) will not exist if sterile neutrinos do not exist.

| | $\sim\bar{\nu}_L$ | $\sim\bar{\nu}_R$ |
|---|---|---|
| $\nu_L$ | $\gamma$ | [2] |
| $\nu_R$ | [2] | $\gamma$ |

(a)

| | $\bar{\nu}_L$ | $\bar{\nu}_R$ |
|---|---|---|
| $\sim\nu_L$ | $\gamma$ | [2] |
| $\sim\nu_R$ | [2] | $\gamma$ |

(b)

The above discussion of the electron and neutrino combinatorial matrices indicates that the diagonal elements of the matrices associated with both electrons *and* neutrinos contain bosons with the characteristics of photons. This raises the question of whether photons are exclusively associated with either one or the other of these sets of matrices, or possibly with *both*. SLFT currently offers no guidance on this choice and currently holds open the possibility that any one of these three choices may be correct.

*15.5. Same-Flavor, Quark Based Composite Bosons*

The matrices associated with same-flavor, quark-based composite bosons display patterns similar to those seen in the electron and neutrino combinatorial matrices. The electric and weak charges for the eight up quarks and the eight down quarks are shown in Table 7 and Table 8, respectively, below.

Table 7: This table shows the electric and weak force charges carried by the four positive-mass and the four negative-mass up quarks.

| **Particle** | $u_L$ | $u_R$ | $\sim\bar{u}_L$ | $\sim\bar{u}_R$ | $\sim u_L$ | $\sim u_R$ | $\bar{u}_L$ | $\bar{u}_R$ |
|---|---|---|---|---|---|---|---|---|
| **Electric Charge** | 0.67 | 0.67 | -0.67 | -0.67 | 0.67 | 0.67 | -0.67 | -0.67 |
| **Weak Charge** | 0.5 | 0 | -0.5 | 0 | 0 | 0.5 | 0 | -0.5 |

Table 8: This table shows the electric and weak force charges carried by the four positive-mass and the four negative-mass down quarks.

| **Particle** | $d_L$ | $d_R$ | $\sim\bar{d}_L$ | $\sim\bar{d}_R$ | $\sim d_L$ | $\sim d_R$ | $\bar{d}_L$ | $\bar{d}_R$ |
|---|---|---|---|---|---|---|---|---|
| **Electric Charge** | -0.33 | -0.33 | 0.33 | 0.33 | -0.33 | -0.33 | 0.33 | 0.33 |
| **Weak Charge** | -0.5 | 0 | 0.5 | 0 | 0 | -0.5 | 0 | 0.5 |

The gauge bosons *potentially* created from the possible pairings of the up quarks shown in Table 7 and from the possible pairings of the down quarks shown in Table 8 are shown in Table 9 and Table 10, respectively. Gluons populate the diagonal elements of all four of the 2 X 2 up and down combinatorial matrices shown in Table 9 and Table 10. The off-diagonal elements are populated by currently unobserved exotic particles excluded by the previously defined, second combinatorial rule.

Table 9: The left and right matrices, below, show the combinatorial possibilities between (a) positive-mass up quarks and negative-mass anti-up quarks and between (b) negative-mass up quarks and positive-mass anti-up quarks, respectively. The diagonal elements contain gluons. The off-diagonal elements contain combinations defining unknown exotic bosons disallowed by the second exclusionary rule indicated by “[2]”.

| | $\sim\bar{u}_L$ | $\sim\bar{u}_R$ |
|---|---|---|
| $u_L$ | g | [2] |
| $u_R$ | [2] | g |

(a)

| | $\bar{u}_L$ | $\bar{u}_R$ |
|---|---|---|
| $\sim u_L$ | g | [2] |
| $\sim u_R$ | [2] | g |

(b)

Table 10: The left and right matrices, below, show the combinatorial possibilities between (a) positive-mass down quarks and negative-mass anti-down quarks, and between (b) negative-mass down quarks and positive-mass anti-down quarks, respectively. The diagonal elements contain gluons. The off-diagonal elements contain combinations defining unknown exotic bosons disallowed by the second exclusionary rule indicated by “[2]”.

| | $\sim\bar{d}_L$ | $\sim\bar{d}_R$ |
|---|---|---|
| $d_L$ | g | [2] |
| $d_R$ | [2] | g |

(a)

| | $\bar{d}_L$ | $\bar{d}_R$ |
|---|---|---|
| $\sim d_L$ | g | [2] |
| $\sim d_R$ | [2] | g |

(b)

There is an additional important characteristic of these up and down quark matrices. Quarks can carry three different color charges or three different anti-color charges. Therefore there are actually *multiple* 2 X 2 matrices associated with the various color charge combinations for both the up quark based and *separately* for the down quark based bosons. Specifically, there are nine such matrices for each of the two up quark combinatorial matrices (Table 9) and for each of the two down quark combinatorial matrices (Table 10).

These nine possible versions of the four matrices in Table 9 and Table 10 are associated with the nine possible combinations of red, green, and blue color charges with anti-red, anti-green, and anti-blue color charges. The associated gluons in all of the resulting color variants of Table 9 and Table 10 define *theoretical* elements that *underlie* the eight gluon basis vectors of QCD’s SU(3) model. From a dynamical, quantum theoretical perspective, only these eight basis vectors and their linear combinations exist. Nevertheless, at a new and deeper level, SLFT defines a model of nine color variants of gluons that are the sub-components of the eight basis vectors defined by QCD. With the above caveats in mind, SLFT associates *three* matrices from each set of nine matrices with colorless gluons. These three matrices represent the red-to-anti-red, green-to-anti-green, and blue-to-anti-blue color combinations. The other six matrices in each set of nine matrices map to the six gluons that carry nonzero color charge.

### *15.6. Mixed-Flavor, Quark Based Composite Bosons*

The combinatorial matrices for *mixed-flavor,* quark based composite bosons mirror the matrices for *same-flavor* composite bosons shown in Table 9 and Table 10. The mixed-flavor combinatorial matrices are shown in Table 11 and Table 12. They follow the same patterns for charge, spin, and mass polarities as Tables 9 and 10, except that the quarks in the matrices' rows and columns have different flavors.

Since up and down quarks have nonzero rest masses with different absolute values, none of the possible combinations of negative-mass and positive-mass, up and down quarks, can have zero rest mass. Instead, all possible gauge bosons formed from mixed-flavor quark pairs have nonzero rest masses. Some of them have positive rest masses, and some of them have negative rest masses. In the first generation, the positive-mass combinations are constructed from pairs of positive-mass down quarks, and negative-mass up quarks as shown in Table 11(b) and Table 12(a), and the negative-mass combinations are constructed from pairs of positive-mass up quarks and negative-mass down quarks as shown in Table 11(a) and Table 12(b). This is because, in the first generation of elementary particles, down-type quarks have larger rest masses than up-type quarks. This situation is reversed in the second and third generations. Therefore, the mass polarities described above for mixed-flavor quark combinations are reversed in the second and third generations.

Table 11: The left and right matrices, below, show the combinatorial possibilities between (a) positive-mass up quarks and negative-mass anti-down quarks and between (b) negative-mass up quarks and positive-mass anti-down quarks, respectively. The upper right and lower left diagonal elements in (a) and (b), respectively, contain bosons *with the charge characteristics* of W+ bosons. The W+ boson in (a) has negative mass, as indicated by the tilde symbol. The grayed-out elements contain combinations defining unknown exotic bosons disallowed by the second and fifth exclusionary rules indicated by “[2]” and “[5]”. (The fifth exclusionary rule is defined below.)

| | $\sim\bar{d}_L$ | $\sim\bar{d}_R$ |
|---|---|---|
| $u_L$ | ~W+ | [2] |
| $u_R$ | [2] | [5] |

(a)

| | $\bar{d}_L$ | $\bar{d}_R$ |
|---|---|---|
| $\sim u_L$ | [5] | [2] |
| $\sim u_R$ | [2] | W+ |

(b)

Table 12: The left and right matrices, below, show the combinatorial possibilities between (a) positive-mass down quarks and negative-mass anti-up quarks and between (b) negative-mass down quarks and positive-mass anti-up quarks, respectively. The upper right and lower left diagonal elements in (a) and (b), respectively, contain bosons *with the charge characteristics* of W- bosons. The W- boson in (b) has negative mass, as indicated by the preceding tilde symbol. The grayed-out elements contain combinations defining unknown exotic bosons disallowed by the second and fifth exclusionary rules “[2]” and “[5]”. (The fifth exclusionary rule is defined below.)

| | $\sim\bar{u}_L$ | $\sim\bar{u}_R$ |
|---|---|---|
| $d_L$ | W- | [2] |
| $d_R$ | [2] | [5] |

(a)

| | $\bar{u}_L$ | $\bar{u}_R$ |
|---|---|---|
| $\sim d_L$ | [5] | [2] |
| $\sim d_R$ | [2] | ~W- |

(b)

We will now take a closer look at the up and down quark combinations in Table 11 and Table 12. We will first look at the particular case in which the up and down quarks carry each other’s anti-color charge. In this case, the resulting bosons have zero color charge. Although the core patterns displayed by such pairs of color-free, mixed-flavor, quark combinatorial matrices are similar to the combinatorial matrices for electrons, neutrinos, and same-flavor quarks (Tables 4, 6, 9, and 10), there are nevertheless significant differences. Like these other matrices, the off-diagonal elements contain disallowed exotic particles. Unlike these other matrices, only *one* of the on-diagonal elements in each matrix contains a particle *with the charge characteristics* of a standard model gauge boson, while the other on-diagonal elements contain unobserved exotic bosons.

Specifically, one of the diagonal elements in each of the four matrices contains a boson with *the charge characteristics* of a weak force gauge boson (W+ or W-). Although these *might* correspond to W bosons, it is unlikely. As discussed in Section 14.4, it is more likely that *W-like* particles shown in Table 11 and Table 12, which are generated *solely* from first generation quarks, are *possibly* new, exotic "light-weight" versions of W bosons. This is because the masses of the first generation's up and down quarks are a tiny fraction of the W boson's mass. Because of this, it is difficult to see how the standard model's W bosons could be constructed from combinations of the first generation's up and down quarks. As was previously discussed in Section 14.4, it is more likely that the standard model's W bosons are constructed from cross-generational quark combinations.

One of the *on-diagonal* elements in each of the mixed-flavor quark matrices corresponds to currently unobserved exotic particles. Specifically, one on-diagonal element in each of the four matrices contains an exotic, massive vector boson with either one unit of positive or negative electric charge and zero weak charge. Such particles have never been observed. Therefore, we need to consider what additional exclusionary rules are required to suppress the formation of these exotic, *on-diagonal* bosons. In order to suppress the formation of such particles, SLFT proposes a *fifth* exclusionary rule. This *fifth* rule is more case-specific than the previous rules. It simply states that *quarks of different flavors can only combine to form composite bosons if they have nonzero weak charges*. This fifth rule applies to the four mixed-flavor combinatorial matrices shown in Table 11 and Table 12.

Like the *same-flavored* quark combinatorial matrices discussed above (Table 9 and Table 10), each of the four up-to-down, *mixed-flavored*, quark combinatorial matrices shown in Table 11 and Table 12 comes in nine color charge variants, three of which are color-free and were discussed above, and six of which carry color charges. The off-diagonal elements of six of these nine matrices that carry color charge are exotic particles excluded by the preceding rules, just as they are excluded in the color-free matrices. Like the color-free matrices, the nonzero color matrices' diagonal elements contain one particle *similar* to a W+ or W- particle and one exotic particle disallowed by the fifth exclusionary rule defined above. The *W-like* particles in these color charged matrices are, themselves, *possible*, new, exotic particles. This is because these particles have all of the characteristics of a W boson but also carry nonzero color charges. No such particles have ever been observed.

In order to exclude these color-charged, *W-like* particles, SLFT proposes a *sixth* exclusionary rule. This sixth rule states that *mixed-flavor quark pairs can only form if the color charges that they carry are each other's anti-color*. This means that the only combinatorial matrices allowed for mixed-flavor quark combinations are those associated with color-to-anti-color charge combinations.

### *15.7. Categories of Exotic Bosons*

Six rules were proposed above to suppress the formation of various *potential*, new, exotic bosons. Nevertheless, some exotic bosons could potentially form even within the context of these rules. Such exotic bosons are discussed below. They fall into three major categories: *inter-generational* bosons within the second and third generations, *cross-generational* bosons, and *negative-mass* bosons. Some of these were mentioned in passing in the previous sections. In the following sections, we will further discuss these possible exotic bosons. (Section 15.6 considered a fourth category of possible exotic bosons in the form of light-weight W bosons formed from first generation quark pairs.)

### *15.8. Inter-Generational Bosons in the Second and Third Generations*

Having reviewed the possible gauge bosons that can be formed from pair-wise combinations of positive and negative-mass, first generation bosons, we can now consider the possibility of such combinations occurring purely within the second generation, and separately, purely within the third generation. That is, we can now consider the possibility of "higher generation" gauge bosons. If such higher generation bosons exist, they are likely rare and short-lived because of the short-lived nature of their second and third generation component fermions. Although SLFT leaves open the *possibility* of such second and third generation based bosons, it does not explicitly require or predict their existence.

### *15.9. Cross-Generational Bosons*

As was discussed in Section 14.4, Z bosons can *only* be constructed by using fermions drawn from *different* generations. The large masses of the W bosons suggest the *likelihood* that they, like the Z bosons, are also composed of pair-wise combinations of fermions from different generations. The fact that they are involved in important cross-generational interactions and transformations further supports this idea's likelihood.

These observations give rise to some important questions regarding the formation of bosons within SLFT's triple IIVM model of the three generations. Are cross-generational (and therefore massive) versions of the zero rest mass gauge bosons possible (i.e., massive photon-like and gluon-like particles)? The Z boson appears to be just such a massive, cross-generational photon-like particle, and there might be similar, massive, cross-generational, gluon-like particles as well. If such particles generally exist, are they extremely rare, exotic particles, or do they exist more commonly, and if so, under what circumstances? Are the massive W bosons cross-generational, as seems likely? If so, which specific cross-generational combination corresponds to the standard model's W boson? Are multiple, different, cross-generational combinations possible that would give rise to new, exotic particles with the same charge properties of W or Z bosons but with different masses?

### *15.10. Negative-mass Gauge Bosons*

SLFT's model of composite bosons implies the existence of negative-mass bosons corresponding to each of the positive-mass bosons. This is true for massive bosons formed purely within the first, second, or third generations and for cross-generational massive bosons. Examples of such negative-mass bosons are the negative mass counterparts of the positive-mass W and Z bosons. If they exist, such particles might not be directly detectable, in principle, since SLFT does not allow any interactions between positive-mass particles and negative-mass particles, except for gravitational interactions.

*15.11. The Higgs Boson*

The recently discovered Higgs boson does not seem to fit in with SLFT's composite model of gauge bosons. The Higgs mechanism does not seem relevant within SLFT because the seed masses of elementary particles are generated from localized contractions of the synergetic field itself. There is no need for a separate Higgs mechanism to bestow masses on particles. Regardless of its theoretical role, the Higgs boson itself does not seem to fit in with SLFT's rules governing the formation of gauge bosons. These rules preclude the existence of scalar bosons.

A Higgs-like particle *could* be generated within SLFT's combinatorial model for bosons if some violations of the previously outlined combinatorial rules were allowed. Specifically, if particles and anti-particles of the same particle type, and with the same mass polarity, but with opposite spins could combine, it might be possible to construct a particle with the Higgs' general characteristics. This approach would, of course, allow the creation of both positive-mass and negative-mass Higgs bosons. It would also allow the creation of Higgs-like particles with *many* different masses, both cross-generationally, and inter-generationally. Because of the large number of candidate combinations that would be allowed, and because of the violation of some of SLFT's primary and most important, previously defined rules for combining fermions to form bosons, this approach seems flawed and unlikely to be correct.

Given the above considerations, another possible way to understand the observed Higgs boson within the context of SLFT is to assume that it is some sort of short-lived bound state of two vector bosons with oppositely oriented spins—for example, a short-lived bound state of two Z bosons. In this case, it might be either a bound state of the Standard model's Z boson, with one of the potential new, as-yet-to-be detected, light-weight Z bosons introduced in Section 14.4, or alternatively a combination of two of these new, light-weight Z bosons.

*15.12. Gravitons*

Gravitons are hypothetical gauge bosons required by proposed quantum field theories of the gravitational force [71]. Gravitons have never been detected, and they may be in principle undetectable [72, 73]. Regardless of gravitons' current experimental and theoretical status, they do not play any role in SLFT. SLFT explains the origins of both mass and gravity in terms of the curvature (i.e., local contractions) and torsion of the field. Although the curvature and torsion of the three-dimensional synergetic field are different entities than general relativity's curvature of four-dimensional spacetime (and torsion in certain extensions of general relativity), they are nevertheless conceptually similar.

## 16. Gauge Boson Bound States

SLFT borrows the mechanism underlying superconductivity in order to model the force that binds fermion pairs together to form composite gauge bosons. In a superconductor, all normal resistance to the flow of electric current drops to zero. An electric current can flow essentially forever in a loop of superconducting wire without ever dissipating or losing any energy. Electrons accomplish this feat of moving through a superconductor with zero resistance by pairing up with their siblings. Each electron in a superconductor becomes coupled and loosely bound to another electron in the population of electrons moving through the superconductor. When electrons pair up in this manner, the particle pairs behave as single entities even though the two electrons that constitute each pair are spatially separated.

The new entities that these pairs of electrons jointly create are called "Cooper pairs" [74]. Cooper pair bosons typically have zero spin (versus the half-integer spin of their component electrons). They have, however, been observed to have one unit of spin under certain circumstances [75]. The zero spin of Cooper pair bosons is the sum of the oppositely signed, half-integer spins of their electron pair constituents. By virtue of their combinations as Cooper pairs, to effectively form bosons, the electrons become endowed with zero electrical resistance. The mechanism that binds electrons together to form Cooper pairs consists of their exchange of vibrations of the atomic lattice through which they are traveling. These exchanged lattice vibrations create a loose coupling between spatially separated pairs of electrons.

SLFT proposes a different but analogous mechanism to explain the force that binds positive-mass fermions to negative-mass anti-fermions to form gauge bosons. In this model, the lattice structure of the synergetic field replaces the atomic lattice of a superconductor. The synergetic field's "Cooper pairs" are not composed of electrons coupled to other electrons, but instead of positive-mass fermions paired with their negative-mass, anti-fermion counterparts (or alternatively positive-mass anti-fermions paired with negative-mass fermions). In contradistinction to electron-electron Cooper pairs, these pairings are of like oriented spins, but oppositely signed masses, instead of oppositely oriented spins and like signed masses. Suzuki's model forming composite gauge bosons from fermions [76] may also be relevant in this context, including his conclusion that the emergence of composite gauge bosons is inevitable "when a gauge-invariant local field theory is written in terms of matter fields alone" [77].

## 17. Mass Revisited

Previous sections discussed mass in various contexts. With the benefit of a more complete picture of the various elements of SLFT, it is now possible to provide a more complete summary and review of SLFT's concept of mass. SLFT treats mass in a fundamentally different way than the standard model. The standard model's concept of mass depends on the Higgs mechanism, which is not relevant in SLFT. In SLFT, mass is derived from the synergetic field's local contractions that define and are one and the same with the elementary fermions. At this point, SLFT does not have a way to calculate the precise masses of the elementary fermions quantitatively but can only conceptually and qualitatively consider their approximate *relative* masses.

For example, the neutrino, which is associated with a relatively small, local, icosahedral contraction of the field, has almost zero rest mass. The electron, which is associated with the next most contracted state of the field, the octahedral-cuboctahedral contraction, has the next greatest rest mass. Finally, the first generation's up and down quarks, which have roughly similar, but *moderately* higher rest masses than the electron, are respectively associated with tetrahedral-octahedral contractions of the field. These tetrahedral-octahedral contractions represent roughly similar but *moderately* higher local contractions of the field than electron-octahedral-cuboctahedral contractions.

The above associations of neutrinos, electrons, and quarks with their respective local icosahedral, octahedral, and tetrahedral contractions of the synergetic field were made *solely* based on associating sequentially increasing, localized contractions of the synergetic field with the sequentially increasing rest masses of the elementary fermions. *No consideration* was made regarding these contractions' structural characteristics—*only* their relative degrees of contraction were considered. An important success of SLFT's model is the happy coincidence of specific particle characteristics of neutrinos, electrons, and quarks with the specific structural characteristics of their *purely mass-assigned*, local contractions of the field.

For example, the neutrino's unique characteristics of very small rest mass, light-speed velocities, and zero electric charge all map back to specific details of the neutrino's icosahedral contraction. Similarly, the quark's two flavor variants (including the 2/3 and 1/3 electric charges carried by up-type and down-type quarks, respectively) and its three color variants both correspond with specific structural elements of the quark's tetrahedral contraction. These "fortuitous coincidences" between the particles' relative masses, their specific observed properties, and the structural characteristics of their associated VE geometric configurations could not have been predicted in advance.

Beyond the first generation, the masses of the elementary fermions increase rapidly in a non-linear manner. SLFT gives a purely qualitative, conceptual explanation of these mass increases as non-linear effects of the interactions between the three co-extensive IIVMs, respectively associated with the first, second, and third generations.

SLFT models the masses of the gauge bosons that have nonzero rest masses (i.e., W and Z bosons) in terms of complicated, yet-to-be-fully-defined interactions between their composite fermions. It is assumed that this model is analogous to but different from, for example, the complicated interactions between quark triplets in protons and neutrons and similar effects in the other mesons and baryons. The analogous dynamics contributing to the masses of W and Z bosons likely arise from some different mechanisms since SLFT rules out all of the standard model's forces between the fermionic components of these bosons.

Finally, SLFT introduces negative mass as a fundamental new property of elementary particles. Negative mass arises naturally in the synergetic field due to local positive and negative "twistings" (torsion) associated with the formation of particles in the synergetic field. Negative mass also plays a fundamental role in SLFT's model of composite gauge bosons constructed from positive-mass particles and negative-mass anti-particles (and vice versa).

SLFT does not supply any precise *quantitative* derivation of particle masses. It *does* present a picture of mass as a complicated, highly "relational" entity. In SLFT, mass at all levels of consideration is essentially an *emergent* property associated with the *net* degree of local contraction and torsion of the field. We have seen that the degree and complexity of the synergetic field's local contractions can vary widely. In the future, it may be possible to develop a more quantitative model of mass within the context of SLFT when the details of the IIVM and its dynamics are better characterized and understood.

## 18. SLFT and the Core Tenants of Modern Physics

SLFT describes a realist model of elementary particles embedded within a universal, all-pervading, ether-like substratum. Realist models of elementary particles are generally out of vogue mainly due to the widespread acceptance of positivist interpretations of quantum mechanics. Nevertheless, quantum mechanics can, at least in theory, be cast within a realist, albeit nonlocal and contextual framework [78, 79]. Realist models of elementary particles are tenable if not generally accepted.

Ether type models are also generally out of vogue. The advent of Einstein's special theory of relativity convinced most physicists to discard all ether type models. As will be further discussed below, ether type models are, in fact, tenable within the context of both special relativity and general relativity. Einstein himself believed that general relativity described a sort of ether model of space, albeit a greatly expanded model relative to the original luminiferous ether.

At first glance, SLFT also seems to be at odds with some of the most widely accepted concepts of modern cosmology. For example, how can ideas like the expansion of space be understood within the framework of SLFT? SLFT posits the existence of an essentially non-changing, eternal, discrete geometric field lying at the foundations of the Universe. It does not seem to easily support the idea of an expanding universe.

A discussion is certainly in order regarding the compatibility of SLFT with these core tenants of modern physics, including special and general relativity, quantum theory, and modern cosmology. SLFT cannot be a reasonable candidate for a correct model of physical reality if it cannot be reconciled, for now at least conceptually, with these well-established pillars of modern physics. Previous sections have almost completely ignored the question of compatibility between SLFT and modern physics. The following sections will briefly discuss various alternative interpretations of relativity theory, quantum theory, and modern cosmology, with which SLFT *may* be at least *conceptually* compatible.

## 19. SLFT and Quantum Theory

*19.1. Realist Interpretations of Quantum Mechanics*

Since its inception, quantum theory has been the subject of many different interpretations. There is still no universal consensus among physicists regarding its correct interpretation. Since SLFT defines a concrete, realist model of the Universe, it is expected that an understanding of its compatibility with quantum theory should perforce be related to one or more realist interpretations of quantum theory. *Local* realism has been essentially disqualified as a possible approach to quantum theory by Bell's theorem [80], including related confirming experiments [81, 82]. *Nonlocal* realism, on the other hand, has been considered as a possible framework for quantum theory, despite various theoretical (i.e. Leggett inequalities [83]) and experimental results [84] narrowing the definition of the realism component of such nonlocal frameworks. Notwithstanding these results, *nonlocal* realism has not been completely excluded as a possible approach to quantum theory, as long as it includes certain important characteristics—specifically *contextuality* (see Gleason [85], Bell [86], and Kochen and Sprecker [87]).

*19.1.1. Bell-type Experiments*

SLFT naturally embraces *both* nonlocality *and* contextuality. To understand how it does so, it will be instructive to describe how SLFT describes the measurement process for correlated photon pairs in Bell-type experiments. From the instant that two photons are created in such experiments to the time of the *first* measurement (i.e. to the time that the first particle reaches its detector in the *preferred* reference frame defined by the synergetic field), the two particles are described as a single, spatially extended entity. The two photons are "connected" by some form of "communication" as they fly apart towards their respective detectors. The connection between the two photons is modeled as superluminal lattice vibrations of the synergetic field exchanged between the two photons. These superluminal vibrations define the nonlocal component of SLFT's model. In this model the two photons each still have their own independent but correlated and well-defined polarization states.

The first photon to reach its detector undergoes a "measurement" process in which it either passes or does not pass a polarizer. This measurement is a *random* but statistically bounded process that changes the pre-existing polarization state of the photon so that it either passes or does not pass the orientation of the detector. Since the two photons are a single, superluminally connected entity, this measurement process also affects the polarization of the second distant photon in a manner that is correlated with the first measured photon. The polarization state of the distant photon is also changed at the same *nominal* instant that the measured value of the first photon's polarization state is *created* by the measurement process. In this scenario, the measurement process is not performed on *just* the "first" photon, but rather on the entangled photon pair, as a single, effectively indivisible whole. Notwithstanding the indivisible nature of the photon pair there is yet some *nominal* time delay for the transmission of influences from the first photon to the second photon. This is due to the superluminal but finite velocity of the connecting lattice vibrations.

*19.1.2. Quantum Nonlocality*

Per the above model, SLFT embraces nonlocality, but a very specific type of nonlocality. In principle there can be two different types of nonlocal correlations. One type is based on instantaneous influences and the other type is based on superluminal influences that nevertheless have finite speed. SLFT assumes the second type of nonlocality. Popper, and separately Eberhard, gave early expressions to this type of model. Popper considered EPR experiments not *primarily* as a locality question for quantum mechanics, but *more importantly* as a discriminator between two possible interpretations of special relativity [88]. Eberhard in turn considered in detail what a nonlocal model of quantum mechanics would look like in the context of a preferred reference frame [89]. SLFT makes this interpretation of quantum nonlocality possible by the very nature of the physical medium that it defines. This medium can support more than one propagation velocity. The limiting speed of light governs the motion of the soliton-like elementary particles, but higher wave speeds are possible for vibrations of the linear struts and sub-particles that make up the fabric of the synergetic field.

As was discussed in Section 16, it is the exchange of these vibrations of the *fabric* of the synergetic field itself that accounts for the binding of positive-mass particles and negative-mass anti-particles to form gauge bosons. This binding mechanism is analogous to the mechanism underlying the formation of Cooper pairs in a superconducting lattice. In the context of quantum theory, SLFT extends this mechanism to also account for non-local quantum correlations. In this model, composite gauge bosons and entangled particle pairs are, in a sense, “first cousins” since somewhat similar mechanisms underlie their respective dynamics.

One criticism of superluminal yet finite velocity models is that such models open the way for violations of the no signaling condition [90]. This is true, but the no signaling condition does not give rise to any fundamental conceptual paradoxes when it is couched in terms of a preferred reference frame, such as is defined by SLFT. Conceptual paradoxes only arise when special relativity is interpreted in terms of a fundamentally and existentially symmetric equivalence between co-moving reference frames. Such paradoxes do not arise in any *relativistic* ether in which such symmetries are only *observational* realities instead of fundamental realities (see Section 20).

### *19.1.3. Quantum Contextuality*

Per the above model, SLFT also embraces contextuality. Specifically it embraces *causal* contextuality [91]. Noncontextual models assume *value definiteness*—they assume that particles and their properties, such as position, momentum, spin, etc., exist and have definite values at all times, independent of observers and measurement processes. Such models also assume *faithful measurement*—they assume that any measurement of any particle property reveals the value of that property that existed immediately before the measurement process began. SLFT does assume value definiteness. However, the value definiteness assumed by SLFT is not always instrumentally meaningful because it does not require faithful measurement in all instances. Specifically, per contextuality, the value of an observed property may be *created* by the interaction between the particle and the measuring apparatus during the measurement process. This does not mean that the particle did not exist before the measurement, nor that the particle’s measured property did not have some specific and definite (but possibly different) value before measurement—it just means that any value that existed prior to measurement may not be knowable, in principle. The value that becomes known through measurement is a value that may be different than the value that existed prior to measurement. In such cases the value is created by the specific context of the measurement process itself.

SLFT assumes that notwithstanding the reality of any pre-existing state(s) of a particle’s observable(s), the measured values of these states can be created by the measurement process—that is they can be created by the interaction of the particle with the measuring device. So whatever the pre-existing value of an observable might be, it may not be the value revealed by measurement because of the active role that the measuring device has in creating the measured value. Depending on the experimental context, the measured value of an observable may be different from that observable’s value prior to the measurement, because in some instances the measurement process actively changes it.

SLFT’s model of the measurement process for a pair of spatially separated entangled particles explicitly embraces contextuality. Even though some polarization state exists for both particles *after* emission and *prior* to measurement, these states are inherently unknowable. The *observed* polarization states are created by the interactions with detectors. It is only these observed, post-measurement states that can ever be known and that have objective meaning. In a more general sense, it can be said that SLFT is *inherently* contextual because it explicitly excludes the concept of separability at a fundamental level. Every particle is inseparable from every other particle because they are all just local deformations of one and the same field. They are inherently physically connected, and in a sense unified, by the underlying field that all particles arise within. Because of this, every particle cannot, in principle, be separated from *any* measuring device.

### *19.1.4. Leggett-type Experiments*

To wrap up the discussion of realism and quantum mechanics we will briefly consider the recent experiment by Groblacher et. al. [84] demonstrating violation of Leggett's inequality [83] for certain types of nonlocal realism models. We will specifically consider why this experiment's no-go result does not apply to SLFT. One of the important assumptions behind this experiment is that all measurement outcomes are determined by *"pre-existing"* properties of the particles independent of the measurement process. This assumption essentially assumes both value definiteness and fair measurement—and is essentially a statement of noncontextuality. The authors further elaborate on the specific types of models being tested by stating that an individual binary measurement is *"predetermined"* by a combination of hidden variables, pre-existing polarization states, and other nonlocal parameters including measurement settings. The key word here is "predetermined". This implies that the authors are assuming a fully deterministic model. This assumption is confirmed in their discussion of results which makes reference to certain elements that are "implicit" in their approach. They explicitly include determinism in this list of implicit elements.

Based on the above considerations, we conclude that SLFT lies outside the framework of the nonlocal realist models excluded by this experiment. In contradistinction to the operative framework of this experiment, SLFT is contextual since it abandons fair measurement and embraces a causal contextual model in which the measured values of observations can be created by the measurement process itself. Further, SLFT assumes a non-deterministic framework. For example, the contextual change in polarization that is produced by the measurement process is assumed to be random for any single particle, notwithstanding having well-defined statistics for an ensemble of particles that are in the same state prior to measurement.

### *19.1.5. Nonlocal Realist Models*

We will now further explore the potential compatibility of SLFT with quantum theory. To do so, we will consider various alternative approaches to quantum theory which may shed some light on this potential compatibility. SLFT implicitly includes a well-defined set of constraints that can act as guidelines in the search for the most compatible of such alternative and interpretation(s) of quantum theory.

The first of these constraints is defined by the superluminal vibrations of the synergetic field discussed above, which define nonlocal influences in SLFT. The second of these constraints is the idea that elementary particles are *at all times* precisely defined, localized contractions of the synergetic field. In this sense, they exist as particle-like entities at all times. However, these particle-like entities are not point-particles since they have, by definition, spatial extents. They are also not classical particles in the purest sense since they are soliton-like waves *embedded* within the discrete medium defined by the synergetic field. Within the context of various interpretations of quantum theory, the synergetic field's localized contractions do, however, definitely fall on the side of particle-based interpretations of quantum mechanics versus wave-based interpretations.

For example, in interference experiments such as the double-slit experiment, SLFT's elementary particles always follow specific, well-defined paths through the field. There is no sense that they ever transition from a particle-like configuration to some extended wave-like configuration and then back again. Their centers of mass always traverse single, well-defined trajectories. For example, these center-of-mass trajectories always pass through one and only one slit in a double-slit apparatus.

A third constraint is SLFT's requirement that the intrinsic spin of elementary particles arises from the particles' traversal of helical pathways through space. As was discussed in Section 9.1, as particles move along a linear or curvilinear trajectory through space, they also always have an orbital motion about the center of their trajectory's path. The synergetic field's elementary particles, defined by localized field contractions, are embedded within, and tightly connected to, the surrounding field. Therefore, the only way that these elementary particles can obtain an intrinsic angular momentum is via an orbital motion centered on the paths of their respective average net trajectories. When such an orbital motion is combined with a particle's linear motion through space, a helical pathway is naturally traced. Elementary particles, therefore, have both *linear* momentum associated with their net forward motion and intrinsic *angular* momentum associated with their helical pathways through space.

Given the above constraints, we will now consider several different but related, realist interpretations of quantum theory with which they may be compatible. We will examine how these interpretations paint a picture that might point toward a yet-to-be-realized realist interpretation with which SLFT *might* be compatible. Our present goal is not to definitively solve this problem, but rather to simply point the way towards a possible future model that potentially could solve it. The theoretical and experimental findings that we will discuss below present interesting possibilities in this direction.

### *19.2. Quantum Mechanics on a Lattice*

We will first consider the third constraint related to the intrinsic spin of elementary particles. Mecklenburg and Regan demonstrated that quantized angular momentum can be modeled as an emergent property of graphene's hexagonal lattice [92]. The relationship of quantized angular momentum, and the relationship of Dirac's equation, to graphene has been previously investigated [93, 94, 95, 96, 97, 98]. In the Mecklenburg and Regan paper, it was determined that the spin that *emerges* from a graphene lattice can be interpreted as an exact analog to the intrinsic spin of elementary particles. In the paper's conclusion, the authors offer explicit speculations about their findings' potential implications for our understanding of three-dimensional space. *Specifically, they speculate that space might be some sort of discrete lattice, ostensibly with some kind of hexagonal symmetry.*

Graphene defines an essentially two-dimensional, discrete, hexagonal lattice. It might be possible to generalize the above findings regarding emergent spin in graphene to three-dimensions. For example, it would be natural to consider the extension of such a two-dimensional, hexagonal lattice into three-dimensions. It turns out that the most straightforward such extension is none other than synergetic geometry's isotropic vector matrix. The IVM is made up of tetrahedrons and octahedrons, and it thereby defines a set of symmetric arrays of equilateral triangles within three-dimensional space. More explicitly, the IVM can be seen as four sets of equally spaced, triangulated planes parallel to the four faces of some arbitrary reference tetrahedron. These planes intersect and interlock with one another to define a spatially extensive packing of tetrahedrons and octahedrons. The equilateral triangles within each plane can be grouped to form sets of hexagons that tile each plane. *In this sense, the IVM can be seen as four sets of hexagonally tiled planes symmetrically arranged to fill three-dimensional space.*

It turns out that all of the important configurations of the synergetic field *implicitly* share these same hexagonal symmetries *explicitly* present in the IVM. As was discussed in Section 5.4, the isomorphic VE that defines the atomic unit of the IIVM is a particular truncation of the truncated octahedron. The truncated octahedron is constructed of eight hexagonal faces and six square faces. Be reference, hexagonal symmetry is therefore *implicitly* built into the IIVM at its most fundamental level. The contracted states associated with the electron (cuboctahedrons and octahedrons) and the quark (tetrahedrons and octahedrons) also implicitly embrace hexagonal symmetries. Just as the IVM can be viewed as a latticework of tetrahedrons and octahedrons, so can these contracted states. These contracted states can all be broken down into collections of tetrahedrons and octahedrons. So whether it is in its most expanded state (i.e., the IIVM) or its locally contracted states, the synergetic field implicitly and explicitly contains hexagonal symmetries.

These observations are intriguing. They beg the question of whether the three-dimensional IVM lattice and the synergetic field, more generally, in its IIVM configuration, can be used to model the Dirac equation and emergent spin in full three-dimensional space, just as graphene's hexagonal lattice can be used for such purposes in two-dimensional space. This seems like a promising avenue of investigation. It could potentially yield a representation of quantum mechanics with which SLFT *might* be compatible.

### *19.3. Quantum Mechanics and Spin*

David Hestenes' work supports the idea that the spin of elementary particles can be associated with the actual helical motions of localized, *real* particles. Hestenes proposes a realist interpretation of the Dirac equation (as well as of the Pauli and Schrodinger equations) as a description of a well-defined, point-like particle following a helical, corkscrew-like path through space [99, 100, 101]. Hestenes recasts the Dirac equation in the mathematical formalism of spacetime algebra [102] in order to be able to better understand the geometric content of Dirac's equation [103]. The upshot of his work is the ability to associate the Schrödinger equation's $i\hbar$ term with particles traveling along helical pathways through space. Others have also explored related ideas along various lines of thought [104, 105, 106].

Hestenes speculates that the electron's *zitterbewegung* motion implied by Dirac's equation is generated by the electron's orbital motion about the central axis of its helical path. He proposes that this orbital-*zitterbewegung* also sets up a high frequency oscillating electromagnetic field around the electron that he speculates might be directly related to the quantum potential of de Broglie-Bohm type models of quantum mechanics [107]. Preliminary experimental results seem to possibly support Hestenes's idea [108, 109].

The idea of associating high-frequency oscillations of the electromagnetic field with Bohm's quantum potential does, however, raise a question regarding the *nonlocal* nature of that potential. It seems that an electromagnetic model, which by definition is *local*, cannot serve as the source of the quantum potential, which by definition is *nonlocal*. Within the context of SLFT, however, there may be a new effect that could add nonlocality to Hestenes's model. It would be reasonable to conjecture that the orbital motion of the electron transverse to the centerline of its helical path might set up subtle, infinitesimal vibrations in the struts and sub-particles that make up the synergetic field. As has been previously discussed, such vibrations are superluminal, and therefore nonlocal. The idea of such superluminal vibrations of the field has been previously discussed in the context of the Cooper-like pairing of positive-mass fermions and negative-mass anti-fermions to form gauge bosons. This idea was also used to account for the nonlocal quantum correlations between spatially separated particles.

Hestenes's research points towards a way in which elementary particles can be modeled as well-defined, physically *real*, point-like particles. In this model, the intrinsic spin of elementary particles arises from the helical pathways that they trace out as they travel through space. When Hestenes's ideas are combined with the idea of graphene as a model of the Dirac equation and emergent spin, we are led to some interesting speculations. It might be possible to combine graphene's emergent spin and Hestenes's *zitterbewegung* model in such a manner that they form two complementary aspects of a single, underlying, realist model of quantum mechanics.

### *19.4. The Two Slit Experiment*

For the sake of argument, let us imagine that the above speculations someday bear fruit. Imagine that a realist, albeit *nonlocal*, model of elementary particles and quantum mechanics can be realized by using the synergetic field as a three-dimensional realization of graphene's two-dimensional hexagonal lattice. Questions would still remain regarding some of the more conceptually perplexing quantum phenomenon, such as the interference patterns seen in the well-known two-slit experiment. SLFT's description of this experiment must embrace a picture in which particles always traverse one and only one of the two slits. In such a picture, elementary particles always remain tightly localized and always travel along well-defined trajectories. They nevertheless land on the detector screen at locations consistent with an interference pattern.

Well-known alternative interpretations of quantum mechanics that closely match this sort of model include Lande's interpretation [110, 111, 112, 113] and the de Broglie-Bohm "pilot wave" interpretation [114, 78, 79]. Lande's interpretation can itself be traced back to earlier proposals of Duane [115], Compton [116], and Epstein and Ehrenfest [117, 118]. In this model, it is assumed that particles exchange momentum with the screen and that further, the screen is only capable of exchanging momentum with particles in the specific discrete spectrum required to produce, over time, the interference pattern observed at the detecting screen.

The spectrum of allowed momentum exchanges can be correctly calculated from the geometry of the two-slit barrier, and more generally, from the geometry of a crystal lattice for the case of an electron beam diffracting off of a crystal. However, this model contains an implicit and unexplained *nonlocal* element—each particle must interact with the two-slit barrier or crystal lattice simultaneously as a *single, indivisible* unit [107]. Nevertheless, the idea does provide a *starting point* for a nonlocal, realist, particle-based model of quantum interference effects.

A modern treatment of the two-slit experiment may shed more light on this situation. O'Hara purports to explain quantum interference based on the quantum entanglement of spin between the particles passing through the double-slit barrier and the barrier itself [119]. In this picture, particle spin and quantum entanglement (i.e., the non-local quantum correlations between particles and the double-slit barrier) are explicitly part of the model. In this picture, the particles can be modeled as *always* being localized and *always* following well-defined, helical trajectories. The interference patterns are explained as a direct result of spin correlations between the elementary particles and the double-slit barrier.

This model is very similar to Lande's interpretation, with the positive addition that it explicitly includes non-local connections, and it provides a more direct explanation of what may be actually occurring. If this approach is correct, then it implies that a deeper understanding of quantum interference effects may be grounded in the concepts of physically "real" particle spins combined with quantum entanglement (i.e., *physically real*, nonlocal, superluminal connections between particles). If this is the case, then quantum mechanics could be seen as an *emergent* property of the synergetic field. As previously discussed, SLFT considers both intrinsic spin and non-local (i.e., super-luminal) connections between particles to be *emergent* properties.

Although these approaches seem somewhat different from one another (i.e., the work of Mecklenburg and Regan, Hestenes, and O'Hara), it might nevertheless be possible to weave together threads from all of these approaches to create a viable realist model of quantum mechanics. Such a realist model could *potentially* be one with which SLFT is compatible.

## 20. SLFT and Special Relativity

It is a widely held assumption that special relativity precludes the existence of a universal, ether-like substratum. It is well documented that this is not, in fact, the case [120, 121, 122, 123, 124, 125, 126]. As long as an ether-like substratum does not establish an experimentally detectable, privileged reference frame, it can be entirely consistent with the principle of relativity. The essential characteristic of any relativistic ether is that all objects that move through the ether experience Lorentz contractions. In conjunction with the limiting velocity of energy transfer within the ether and with relativistic mass increases, these contractions ensure that the rates of all processes will be slowed down by the same Lorentz factor relative to their rates when at rest in the ether [127]. That such an ether is consistent with relativistic dynamics has been well demonstrated in the literature.

The first relativity theory based on a real contraction of objects in motion relative to the ether was developed by Lorentz. He developed this theory principally to account for the null results of the Michelson-Morley experiment [128]. He argued that the contraction was natural if intermolecular forces behaved in the same manner as electromagnetic forces [129]. Lorentz then used this assumption to show that objects whose structure is based on forces that behave *like* the electromagnetic force (e.g., atoms and groups of atoms) must undergo a contraction along their direction of motion to keep their constituent binding fields in a state of equilibrium. This assumption, and the length contraction it requires for electromagnetically structured objects, guarantees that any attempt to detect the ether will fail.

One weakness in Lorentz's theory lay in its need to continually introduce new hypotheses to account for each new type of ether drift experiment's null results. For example, to account for the results of the Rayleigh-Brace [130, 131] and Trouton-Nobel [132] experiments, Lorentz needed the added hypothesis that individual electrons themselves were subject to contraction (Lorentz viewed electrons not as point-like objects, but rather as spatially extended objects [133].) This removed the electromagnetic explanation for the contraction of matter: hypothetical non-electromagnetic forces maintained the form of Lorentz's electrons. Thus, it was necessary to generalize the effects that motion through the ether had on electromagnetic forces to all forces. These added hypotheses gave an ad hoc appearance to Lorentz's theory. They also weakened the essential philosophical foundation of the theory, which was to provide an *explanatory* theory of natural phenomenon as opposed to a theory of *stated principles*. These additional hypotheses, in effect, transformed it into just such a theory of stated principles.

All of the early ether theories, such as Lorentz’s, shared the further drawback that they only encompassed electromagnetic vibrations. Matter was completely excluded. This presented a major problem. Any universal, all-pervading medium capable of transmitting waves at light’s extremely high speeds would have to be extremely rigid. This begged the question of how matter could travel through such an extremely rigid, all-pervading medium. Given these multiple, seemingly insurmountable problems, it was natural that Einstein's special theory of relativity, and its associated “ether free” interpretation, prevailed. However, while it is true that the restricted form of Lorentz's theory (i.e., the theory of a *luminiferous* ether coextensive with, but independent from, space, time, and matter) is indeed untenable and ad hoc, an expanded, universal application of his length contraction, time dilation, ether theory to all forms of matter and energy is, in fact, tenable and natural.

In order to understand the viability of such an expanded version of Lorentz's theory, it is useful to look back to the ether concept's foundations. It was originally postulated as a medium for transmitting light waves when it became incontrovertibly evident that light traveled as waves. Within the context of quantum theory, it has since been discovered that *all* corpuscles of matter-energy are associated with waves, not just light. This fact was discovered after the demise of the luminiferous ether and Lorentz’s length-contraction interpretation. If quantum mechanical “matter waves” had been discovered while the ether was still under serious consideration, it might have naturally led to the conclusion that matter, as well as light, is associated with waves within the ether [134]. This could then have possibly removed the serious objection to the ether discussed above, i.e., that an ether rigid enough to carry waves at the velocity of light and that yet allows matter to pass freely through it is unrealistic.

In the context of an expanded, universal ether concept in which all manifestations of matter and energy are deformations of the ether and are transported through it as wave patterns, the above objection does not arise. This is precisely the type of model described by SLFT. The model proposed by SLFT also eliminates the problem Lorentz encountered in explaining the contraction of elementary particles themselves. SLFT describes a model in which elementary particles are spatially extended, soliton-like waves within the IIVM. Therefore, as solitons, they naturally contract by exactly the Lorentz factor (at least up to some extremely high-energy cutoff). Prokhovnik pointed out that such relativistic-type contractions are a very general and natural phenomenon—they are a direct consequence of the limiting velocity of energy transmission within a medium and the asymmetry of such transmission within a system in motion relative to the medium [135].

One striking difference between ether and ether-free interpretations of special relativity is the mathematical asymmetry of the former in comparison with the mathematical symmetry of the latter. In the ether-free theory, the relative length contractions and time dilations seen by co-moving observers are completely reciprocal and stand on inherently equal footings. This is not the case in ether theories: reciprocity applies only to *observations*, not to the actual state of the underlying medium.

In ether-based interpretations of special relativity, if an observer happens to be at rest relative to the medium, then by this coincidence, the length contractions and time dilations that the observer sees in other inertial systems moving relative to self and to the medium are in fact real. They reflect actual changes in the form of the ether objects in these other frames. The length contractions and time dilations observed by observers in all other moving reference frames are fictitious in the sense that they are, in the general case, only observational realities. For example, an observer moving relative to the ether at a velocity, v, will observe length contractions and time dilations of objects and events at rest relative to the ether, but these *observed* contractions are in fact due to the real contractions and time dilations of the moving observer's own instruments [121, 122, 136, 137, 138]. Therefore, in the general case, in ether-based models, the symmetrical mathematical structure describing special relativity's spacetime represents only an *observational* reality, not an absolute, underlying *physical* reality.

In the case of a discrete model of space, such as SLFT's IIVM, this illusion of a symmetric, relativistic spacetime structure, even in the special case of an observer at rest in the ether, does not reflect an actual change in the abstract of space *itself*, but only in the lengths of *patterns* existing within the ether. Per Prokhovnick [135], these patterns *must* contract due to their motion through the ether. These patterns are embedded in an ether structure that is absolute—that has an absolute length scale. It is not that space is relative for different observers, but instead, that space is absolute, and the objects moving through it change length relative to the ether's absolute length scale. Isenberg's model, which was introduced in Section 9.2, provides a concrete example of these ideas. In Isenberg's model, the rod spacing represents the absolute length scale of the medium. This length scale does not change. However, the lengths of spatially extended, soliton wave patterns traveling through Isenberg's machine do change when traveling at velocities greater than zero.

Einstein himself recognized the experimental equivalence of the ether and non-ether interpretations of relativity theory [139]. What disturbed Einstein about the ether interpretation was that it postulated the above-referenced asymmetry in the theoretical description of phenomena that was not reflected in the observational data associated with the phenomenon [140]. It was this line of reasoning that initially led Einstein to conclude that the ether was *"superfluous"* [141] and to the statement that *"the ether does not exist* *at all"* [140]. However, he provided no physically based, theoretical *requirement* for an ether-free interpretation. The crux of his argument reveals a theoretical *preference* rather than a theoretical *necessity*. He felt that assuming the existence of an ether frame uniquely at rest, despite the observational equivalence of all reference frames, to be *"not indeed downright incorrect, but nevertheless inacceptable"* [140].

## 21. SLFT and General Relativity

### *21.1. General Relativity and Ether Concepts*

With the development of general relativity, Einstein's original attitudes toward the ether changed from *"superfluous," "intolerable,"* and *"inacceptable"* to *"space without ether is unthinkable"* [142]. In light of general relativity's implications, he reconsidered his original positions on the ether, and he explicitly concluded that the ether concept was not in conflict with special relativity [143]. Einstein initially felt that the ether concept, within the context of the special relativity, was *"superfluous."* In contradistinction, he later concluded that within the context of general relativity, it was actually a theoretical necessity [144].

The ether considered by Lorentz was purely electromagnetic and did not directly include matter. As discussed above, the ether makes much more sense when its definition is expanded to include inherent connections with all matter (and energy), i.e., when it is assumed that all corpuscles of matter and energy are nothing other than localized deformations of the ether. Einstein attempted to use such a picture of a gravitationally based, spacetime ether as the foundation for extending general relativity towards a unified field theory. He expressed such ideas in *The Evolution of Physics*, co-authored with Leopold Infeld [13]. In such a picture, all that remains is a universal field, and the spacetime curvature always associated with corpuscles of matter and energy is related to these corpuscles in a manner *loosely* analogous to the way in which the distortion of a rubber membrane containing a kink, is related to the kink.

Einstein was hindered in fulfilling his vision of such a unified field by a number of problems, not the least of which was that all the different types of field excitations (i.e., the elementary particles) were not known at the time. A well-defined set of solutions to his hoped-for field equations should have corresponded to the set of elementary particles, but unfortunately, the standard model's full set of elementary particles, and hence all the solutions to the field equations, were not yet known.

From the above discussion, we can see that general relativity and its possible extensions are *conceptually* compatible with the idea of a universal ether, and, at least in Einstein's opinion, they actually demand such an ether. This provides a conceptual basis for explaining the possible compatibility of SLFT with general relativity. As discussed above, SLFT interprets special relativity's spacetime as a mathematical formalism—a conceptual construct riding on top of the underlying physical reality of the relativistic ether defined by the synergetic field. As a relativistic ether model, SLFT supports the relativistic transformation laws between reference frames, but it does not take the covariance of inertial reference frames as a fundamental reality. As previously discussed, within relativistic ether models, such as the synergetic field, this covariance is an observational but illusory reality. The synergetic field defines an underlying fixed space, with a fixed metric, underlying the relativistic *observations*.

SLFT views general relativity in a similar manner. General relativity starts with flat spacetime and uses the equivalence principle to infer how flat spacetime becomes curved in the presence of matter. The mathematical framework of general relativity is constructed from the curvature of special relativity's flat spacetime, which is itself an observational, conceptual reality that is once removed from the synergetic field. Therefore, we can similarly view general relativity as at least once or even twice removed from the synergetic field. One can think of general relativity's *mathematical model* of the gravitational field as lying on top of the *physical* synergetic field as an abstraction. Although the synergetic field's local contraction is loosely *analogous* to general relativity's spacetime curvature, and although it physically underlies spacetime curvature, it is in no sense mathematically *equivalent* to it. In addition to not being equivalent to general relativity's gravitational field, the synergetic field is inherently different from it in several other important ways. SLFT introduces fundamentally new concepts that go beyond standard general relativity. The most important of these new concepts are discrete space, negative-mass, and the anti-gravitational force associated with negative mass.

Despite the fundamental differences between SLFT and general relativity, there are several proposed extensions of general relativity that could potentially incorporate SLFT's new concepts. SLFT is certainly not one hundred percent compatible with any of these extensions of general relativity in their current forms. However, they *do* point in the direction of potential, new, mathematical frameworks with which SLFT *might* be compatible. In the following sections, we will consider the new ideas introduced by SLFT within the context of some possible extensions and modifications of general relativity.

### *21.2. General Relativity and Negative Mass*

As was previously discussed in Section 8.3 and Section 14.3, Hossenfelder [47, 48] has developed a bi-metric version of general relativity that incorporates the ideas of negative mass and anti-gravitational forces. In Hossenfelder's model, negative mass is introduced based on particles having negative gravitational rest masses but always having positive kinetic energies. This is in agreement with SLFT's model of negative mass in which like-signed masses attract one another and oppositely signed masses repel one another**.**

There is at least one important difference between Hossenfelder's definition of negative mass versus SLFT's definition of negative mass (Section 8.3). Hossenfelder's model includes photons that come in both positive-mass and negative-mass versions. In this model, positive-mass photons are gravitationally attracted to positive-mass bodies and are gravitationally repelled by negative-mass bodies, and vice-versa for negative-mass photons. In contradistinction, SLFT assumes that photons are *always* gravitationally attracted to *both* positive-mass and negative-mass bodies—in other words, SLFT has no concept of positive-mass and negative-mass photons, *at least within the context of the gravitational field*. This is because the mass of energy associated with *all* photons, regardless of their component fermions, is *always* associated with only *positive* curvature and zero *net* torsion. They are therefore always gravitationally attracted to both positive-mass *and* negative-mass bodies. Because of this difference, SLFT in its current form does not predict the potential for the divergent gravitational lensing that both Hossenfelder [48] and Petit [67] have considered.

Hossenfelder's model assumes that the *only* interaction between positive-mass and negative-mass fermions is gravitational. As was discussed in Section 14.3, this is an essential element of SLFT's model of composite bosons. It is required in order to avoid infinite regression problems. SLFT's composite bosons can be constructed either as a *first type*, from combinations of positive-mass particles and negative-mass anti-particles, or as a *second type*, from combinations of positive-mass anti-particles and negative-mass particles. Internally, these bosons have different component fermions, but for those with zero rest mass, their external properties represent degenerate instances of the same bosons. As referenced above, Section 14.3 introduced a rule requiring that positive-mass fermions and negative-mass fermions can only interact gravitationally. This rule can potentially be further augmented by an additional rule requiring that positive-mass fermions can only exchange bosons of the *first type* and that negative-mass fermions can only exchange bosons of the *second type*. Like Hossenfelder's model, this rule would preclude any interactions between positive-mass and negative-mass fermions other than gravitational interactions.

### *21.3. Alternative Formulations of General Relativity*

Hossenfelder's proposal provides some promise for the ability to construct modified versions of general relativity incorporating negative mass with which SLFT *might* be compatible. There are, however, other modifications of general relativity that are perhaps deeper and more natural candidates for such a construction. These other models include Einstein-Cartan theory and some of its offshoots. These approaches to gravity introduce the concept of torsion. Torsion is a concept that arises naturally in SLFT. It is tightly coupled with SLFT's representations of positive-mass and negative-mass particles, respectively, as localized contractions of the field's left-handed and right-handed isomorphic VE. It will be recalled from Section 5.2 that the VE's component triangles rotate in opposite senses between left-handed and right-handed VE contractions. It is these opposing rotations, which occur in concert with the VE's contractions, that generate positive and negative torsion in the field.

### *21.4. Einstein-Cartan Theory*

Einstein-Cartan theory was first proposed by Elie Cartan [145] and was later revisited by Dennis Sciama [146] and Tom Kibble [147], and is therefore also referred to as ECSK theory. Standard general relativity only includes spacetime deformations in the form of *curvature* and assumes that spacetime *torsion* is always zero. Cartan's extension preserves standard general relativity's curvature but adds torsion as an additional degree of freedom. Modern researchers have generally assigned the physical source of torsion in ECSK theory to the intrinsic spin of elementary particles [148, 149, 150], although other physical sources of torsion are theoretically possible [151].

It is likely that a model like ECSK theory that has some hybrid combination of curvature and torsion would yield a model with which SLFT might be compatible. It is reasonable to expect that the curvature (i.e., contraction) and torsion of the synergetic field could be *indirectly* linked to the curvature and torsion components of such a modified version of general relativity. This is because SLFT's model of elementary particle masses contains elements of both curvature *and* torsion.

The idea proposed by SLFT is to couple a signed torsion term with the internal torsion of the synergetic field associated with the formation of elementary particles. The positive and negative torsions associated with positive-mass and negative-mass particles, respectively, would then be associated with positive and negative torsions in an ECSK-like theory.

*21.5. Curvature and Torsion in the Synergetic Field*

When VE contract to form elementary particles, their deformations include both curvature *and* torsion components. The all-directions, inward pulling, contraction of the IIVM centered on an elementary particle is associated with the field's *curvature*, while the associated left-handed or right-handed twisting of the field's elements (i.e., the individual sub-particle triangles making up the field's constituent VE) is associated with the field's *torsion*. Further, SLFT posits that zero rest mass bosons, such as photons, have zero *net* torsion and yet are still gravitationally attracted to both positive and negative masses. To model gravitational forces between particles that have curvature and net torsion (e.g., fermions and massive bosons) *and* particles that only have curvature (e.g., zero rest mass bosons), it would seem reasonable to use a modified form of general relativity that, like ECSK, includes both curvature *and* torsion.

It is important to remember that even if a modified version of general relativity that SLFT is compatible with could be realized, it would still not be *equivalent* to a theory of the dynamics of the synergetic field itself. General relativity and its extensions describe curvature and torsion relative to a 3+1 dimensional *spacetime,* while SLFT describes just three *spatial* dimensions within the context of a single universal time that exists across the entire field.

*21.6. Regge Calculus and Discrete Space*

Assuming that such a modified version of general relativity could be realized, it would not necessarily have to be a discrete theory, even though the synergetic field itself is discrete. Instead, it could be cast as a continuum-based *approximation* of the gravitational dynamics that ride on top of the discrete synergetic field. It might nevertheless prove useful to further extend such a modified version of general relativity to fully and explicitly embrace a discrete model of space.

One candidate for such discretization of general relativity's spacetime continuum is Regge calculus [152]. Regge calculus has often been used as a convenient calculating tool. This is similar to how lattices are used in quantum chromodynamic simulations. Like lattice QCD, the usual assumption is that Regge calculus is merely a mathematical tool and not a reflection of space's true nature. Nevertheless, one can consider the idea that it reflects an underlying reality of a true, physically discrete spacetime. Regge calculus has been successfully applied to standard general relativity and ECSK theory [153]. Therefore it *may* be possible to apply it to other potential curvature-torsion hybrid extensions of general relativity.

*21.7. General Relativity and World Crystal Models*

Kleinert's world crystal approach and similar lattice models provide other possible formulations of general relativity [154, 155]. In Kleinert's model, a universal lattice defines the substratum of space. The spacing of this lattice is on the order of the Planck length. Kleinert assumes that matter is the source of lattice defects in the form of dislocations and disclinations of the lattice. Based on these assumptions, he derives the equations of general relativity based on the close mathematical analogy between such lattice defects and spacetime curvature [156, 157, 158]. Other researchers have proposed different variations of world crystal type models. For example, Schmidt and Kohler explored ties between lattice defects and a proposed discrete version of Einstein-Cartan gravity [153]. Petti's related work discusses Einstein-Cartan gravity as a theory of discrete affine defects [159]. The regular, discrete lattices that underlie all of these models are *conceptually* similar to SLFT's IIVM lattice.

World crystal type models have certain significant similarities to, and significant differences from, SLFT. Both approaches assume a regular lattice as the underlying model of space, and both assume that local distortions of the lattice are sources of gravitational fields. SLFT goes a bit further by defining matter as more extreme local distortions of the lattice *itself*. The world crystal model defines the lattice deformations as generic crystallographic defects—dislocations and disclinations—while SLFT describes them more specifically as precisely defined geometric deformations of the field's constituent VE. Despite the differences between SLFT and the world crystal model, the significant similarities between the two hold out hope that SLFT could go beyond a theory of just the *structure and form* of space and elementary particles and also become compatible with theories describing the *dynamical behavior* of matter, such as general relativity.

It may be possible to model not only general relativity but also quantum mechanics and elementary particles as emergent properties within a world crystal type of model. For example, Musienko explores a discrete spacetime framework that models not only gravity but also the Dirac equation and elementary particles [160]. In this framework, elementary particles are modeled as topological solitons in discrete spacetime—a model that has clear parallels to the model of elementary particles proposed by SLFT. Ross and separately Unzicker have considered similar models of elementary particles as defects in spacetime [161, 162]. It would not be unreasonable to speculate that quantum field theory *and* general relativity might *both* be emergent properties of SLFT's discrete lattice—general relativity based on Kleinert's world crystal and related approaches, and quantum field theory based on the inherent hexagonal symmetries of the synergetic field referencing the work of Mecklenburg and Regan [92] on emergent spin in graphene lattices discussed in Section 19.2.

The various models discussed above aspire to cast gravitational fields, and in some cases also quantum fields and elementary particles, as emergent phenomenon of a world crystal type model. However, they do not account for the specific spectrum and characteristics of the elementary fermions and related force fields observed in nature. Some sort of yet-to-be-defined amalgamation of SLFT's model with one or more of the world crystal type models might prove enriching and fruitful for both lines of inquiry, joining the very general *dynamical* aspects of world crystal models with the very case-specific *geometric and structural* aspects of the synergetic field model. It seems that such an amalgamation might most naturally start with a mapping of the local deformations and contractions of the VE within the synergetic field to the mathematical formalisms of dislocations and disclinations of the lattice in the world crystal model. Such an amalgamation could provide a possible framework for expanding SLFT beyond a purely *structural* theory to a *dynamical* one.

## 22. SLFT and Modern Cosmology

SLFT is, by definition, primarily a theory of Planck scale physics. At this stage in its development, SLFT does not attempt to make any definite statements regarding, or connections with, modern cosmology. Neither does it try to seriously answer any of modern cosmology's essential questions. Nevertheless, because it simultaneously defines the nature of *both* elementary particles *and* space, it implicitly begs questions about the macroscopic nature of the universe at the scale of the cosmos. This is because the second element that SLFT addresses, i.e., space, is, by definition, both microscopic *and* macroscopic. Therefore, it will be interesting to briefly touch on a few speculative ideas regarding possible relationships between SLFT and modern cosmology without trying to draw any definite conclusions.

### *22.1. Negative Mass and Cosmology*

One central element of SLFT that *may* imply significant consequences for modern cosmology is the idea of negative mass and associated anti-gravitational forces. The fact that negative-mass particles only interact with positive-mass particles gravitationally make them possible candidates for dark matter. This idea has been explored by different authors, including Petit [66, 67, 68], Henry-Couannier [69], and Hossenfelder [163], among others. In a similar manner and for similar reasons, *mirror matter* has been extensively investigated as a dark matter candidate by Foot [164]. SLFT embraces both the negative-mass particles of bi-metric theories together with the conjugated weak force particles of mirror matter theories. The above-referenced conjectures about dark matter *may* therefore similarly be implied by SLFT.

Research and simulations conducted by various authors [66, 67, 68, 50], using the assumption that negative-mass particles only interact with positive-mass particles gravitationally, appear to provide explanations for at least some of the observed effects of dark matter and the large scale, bubble-like structures of galaxies surrounding cosmic voids [66, 67, 68, 69, 165, 166]. These simulations reveal the formation of negative-mass, dark matter halos surrounding galaxies. In such models, it seems natural to consider that a dynamic equilibrium might be reached in which the halo's constituent, negative-mass particles would attract one another gravitationally, laterally, and circumferentially, while those same particles would be gravitationally repelled radially away from the positive-mass galaxy center. This would be roughly analogous to a balloon's skin in which the molecules of the balloon hold together circumferentially in a dynamic balance against the air pressure pushing the balloon's skin outwards.

This is, of course, a very limited analogy. It is only meant to illustrate the idea of a dynamic balance between circumferential, "binding" forces (e.g., gravitationally attractive forces between negative-mass particles in a dark matter halo) and outwardly expansive forces (i.e., gravitationally repulsive forces between the negative-mass particles of the dark matter halo and a galaxy's positive-mass particles). Such a model echoes ideas developed by Fuller [167] and Kenneth Snelson [168] regarding "tensegrity" structures. Fuller regarded such structures as fundamental design elements of the Universe. Negative-mass particles have also been considered as possible explanations for other not fully explained cosmological observations, including the cosmological constant problem [48, 169] and dark energy [47, 170, 171].

### *22.2. Matter and Anti-Matter*

One of the more important unanswered questions in modern cosmology is why there is an overwhelming predominance of matter versus anti-matter in the observed universe. Section 11.2 told a purely hypothetical "story" regarding the initial, cascading, and sequential population of the synergetic field with matter and anti-matter. Because of the observed predominance of matter in the universe, this story, as told in Section 11.2, cannot be actually true. An alternative version of this story *might* be true, however. In the alternative version, it is positive-mass particles and *negative-mass* anti-particles that form together in pairs. The implication here is that the cosmological voids discussed in the previous section, which are hypothetically populated with negative-mass *particles*, are in fact populated with negative-mass *anti-particles*. Since these negative-mass particles are *dark*, they would take the form of *unobservable* anti-matter. In this scenario, the Universe could have a closer balance between matter and anti-matter in the universe. However, this balance would be hidden due to the dark nature of the negative-mass, mirror matter, anti-particles.

### *22.3. SLFT in Four Spatial Dimensions*

Because SLFT models space as a discrete entity built up of innumerable, identical atomic units of space, it begs the question of whether the synergetic field is infinitely spatially extended, or if it is finite—and if it is finite, does it define an open or a closed universe. Perhaps primarily based on aesthetics, one could argue that it should be both finite and closed. Such a model could be achieved by assuming that the synergetic field that defines our universe is a curved three-dimensional volume draped over the surface of a vast four-dimensional surface, for example, a four-dimensional hypersphere. The rate of curvature of such a hypersphere would have to be vanishingly small from the perspective of humans on Earth. This is because such curvature has never been detected. This would be a curiously attractive model since it would bring in another aspect of Fuller's synergetic geometry—the geodesic sphere. A geodesic sphere is a discrete, omni-triangulated model of a sphere. It is a closed, discrete, *two-dimensional*, curved surface draped over a *three-dimensional* sphere. By analogy, the model proposed above is a closed, discrete, *three-dimensional*, curved *volume* draped over the surface of a *four-dimensional* hypersphere.

Such a picture would be conceptually compatible with a *steady-state model* of the Universe in which space itself is not expanding. The current preponderance of evidence indicates, however, that our Universe *is* expanding. It seems difficult to reconcile such universal expansion of space with SLFT's discrete model of space because there does not seem to be any reasonable mechanism or method to insert new atomic units of space (i.e., VE) into the synergetic field to drive its expansion.

### *22.4. SLFT in Five Spatial Dimensions*

One purely speculative approach to solving the problem of an expanding, *discrete* universe is to extend the four-dimensional model discussed above to a model encompassing *five* large-scale *spatial* dimensions. Such a five-dimensional model can be understood by referencing an analogous system spanning one, two, and three spatial dimensions. By inference, a similar schema that is instead based on three, four, and five spatial dimensions can be used as a model of the Universe.

For example, one can consider a "circle universe" defined as a curved one-dimensional universe that is closed and finite. One can then imagine this circle universe as a circle of latitude on a three-dimensional, discrete sphere, such as a geodesic sphere. Thus, this circle universe can be seen as spatially discrete versus continuous since it intersects the line segments defining the geodesic sphere. If the circle universe starts as a small circle of latitude near the bottom of the geodesic sphere and then starts to move up the sphere toward its equator, it will encounter more and more discrete breaks around its circumference, reaching a maximum number of breaks when the circle reaches the geodesic sphere's equator. In this way, the number of discrete units making up the circle universe's space will increase as the circle moves up the sphere. It thus models a curved and closed, one-dimensional, expanding, discrete-space universe.

Such a model of a curved, discrete, one-dimensional universe can expand without requiring any mechanism to dynamically or mechanically add in additional atomic units of space. The circle is expanding because it is not merely a single one-dimensional circle universe. Instead, it is a series of temporally sequential and progressively larger, circular slices through a closed, curved, two-dimensional, discrete surface draped over a three-dimensional (geodesic) sphere.

We can use this circle-universe model to conceptually understand, by analogy, an expanding, curved, *discrete*, three-dimensional universe—we can imagine the three-dimensional, spatial elements of the synergetic field, i.e., its constituent VE, tessellating a curved four-dimensional hypersphere that is, in turn, draped over a five-dimensional hypersphere.

In this model, our three-dimensional Universe expands as it moves up the tessellated, curved, four-dimensional volume draped over a five-dimensional hypersphere (i.e., a five-dimensional geodesic-like hypersphere). In this sense, all future *extents* and *locations* of our expanding three-dimensional Universe already and always exist as higher-dimensional circle-of-latitude slices of the five-dimensional, "geodesic" hypersphere. They are just waiting for our three-dimensional Universe to traverse them. The expansion of the Universe is just this traversal of our Universe over subsequent, higher dimensional circles-of-latitude of the five-dimensional, geodesic hypersphere. This does *not* imply that the future *internal* states and configurations of matter within our Universe are somehow pre-determined or already exist. It is just *the future locations and extents* of our Universe, as a whole, that already exist, but *not* the *specific* time evolution of its internal elements.

For simplicity, the preceding discussions have assumed the simple case in which the higher dimensional surfaces are hyperspheres. This is not a requirement. The higher dimensional surfaces could, in theory, be based on virtually any shape. Variations in the specific shapes of these higher dimensional surfaces would directly affect the rate of perceived expansion of the three-dimensional universe that rides on top of them. As a result of the specific shapes of the higher dimensional surfaces, the rates of expansion (or contraction) of the three-dimensional universe have the potential to vary with time.

This model opens the door to a possible variant of the multiverse concept. It is possible that the five-dimensional background space that contains the tessellated five-dimensional geodesic hypersphere may hold any number of other, similarly structured, synergetic-field-carrying, five-dimensional hypersphere universes like our own. Each such universe would be assumed to be wholly independent and physically separate from all the others. While possibly interesting, this is an entirely speculative and likely completely un-testable hypothesis, assuming that there are no interactions between such hypothetical universes.

*22.5. Evolving Models of the Universe*

It is worth noting that SLFT considers the above ideas regarding hypothetical four-dimensional and five-dimensional models of space to be *purely speculative*. They are not meant to be taken as part of the core model proposed by SLFT. Instead, these are speculations regarding how SLFT's essentially three-dimensional model of space *might* be integrated into larger cosmological models.

It is fair to say that there are so many fundamental questions that remain open regarding the large-scale structure and evolution of the Universe that it is premature to assume that the current widely accepted models of the universe will not undergo further radical revisions and evolution in the future. Therefore, the above discussions should be taken for no more or less than what they are—speculative ideas regarding how SLFT *might* be integrated with our *current* best guesses regarding the nature of the Universe in the large.

## 23. Predictions

Any new theory should make specific new predictions about the world. It should predict new phenomena and possibly also preclude certain other phenomena. SLFT does make a number of predictions of various new phenomena. A number of these predictions are somewhat general and could be properties of other theories as well. Because of this, the validation of any single one of these *general* predictions would not offer strong evidence in favor of SLFT. However, the validation of one or more *clusters* of these general predictions would support the theory.

SLFT's more *general* predictions explicitly related *to elementary particles* include the existence of negative-mass fermions, the "conjugation" of the weak force for these negative-mass fermions, the existence of anti-gravitational forces between positive and negative-mass particles, the composite nature of gauge bosons as pairwise combinations of positive-mass fermions and negative-mass anti-fermions, and the *possible*, but not required, existence of new, exotic composite gauge bosons and associated new forces. There is also another related, general prediction implied by SLFT's combinatorial model of bosons. This prediction requires that all *fundamental* bosons can only have charges consistent with summing the charges of positive-mass fermions with negative-mass anti-fermions (and vice versa).

SLFT's more *general* predictions, explicitly related *to space*, encompass several broad areas: (i) the existence of a universal ether in the form of a discrete lattice (i.e., the IIVM), (ii) the existence of three co-extensive and interacting discrete lattices each associated with one of the three generations of elementary particles, (iii) the existence of elementary particles as localized contractions of one or more of these lattices, and (iv) the existence of vibrations within the lattice that have superluminal but finite velocities, and that are the sources of nonlocal, quantum correlations.

The predictions made by SLFT, more specific to the theory itself, are related to the very specific geometric structures that it defines for space and elementary particles. These more specific predictions related *to elementary particles* include the association of neutrinos with icosahedral contractions of the field, electrons with octahedral-cuboctahedral contractions, and quarks with tetrahedral-octahedral contractions. SLFT's more specific prediction related *to space* itself is the identification of the left-handed and right-handed isomorphic VE as the atomic units of space.

New types of experiments will be required to uncover evidence supporting the above predictions regarding the specific geometries of elementary particles and space. It might be possible to design novel experiments based on potential resonances between macroscopic-scale structures that are morphologically similar to the elementary particles' Planck-scale structures. For example, a macroscopic structure with the same symmetries as the Planck-scale structure of a specific elementary particle could potentially alter the production, transformation, or other dynamics for that particle type. These effects might be induced by some forces applied to the macroscopic structure, such as strong electric or magnetic fields, possibly including high-frequency oscillations of those fields. For such experiments to be successful, it would be necessary to repeat the experiments many times, canvassing the entire space of the instrument's angular orientation relative to the fixed stars. This would be necessary since any resonance effects would be expected to be strongest when the macroscopic structure's symmetry axes are aligned with the synergetic field's symmetry axes.

Another possibility, again involving the interaction between macroscopic fields and the Planck-scale structure of the synergetic field, involves a possible "drag" effect. In this case, a strong and rapidly rotating electromagnetic field might potentially cause either a local increase or decrease in the field's torsion. This rotating field's effect might manifest itself as an increase or decrease in the measured weights of objects in the experimental device's vicinity. As in the prior experiment, this experiment would also require canvassing the entire space of the instrument's angular orientation relative to the fixed stars. This would be necessary since any coupling effects between the rotating electromagnetic field and the synergetic field would be strongest when the field's rotational symmetry axis is aligned with one of the synergetic field's symmetry axes.

Both the "resonance effect" experiment and the "rotating field" experiment would require macroscopic-to-microscopic coupling between external electromagnetic fields and the synergetic field. SLFT does not predict any such coupling. SLFT assumes that the synergetic field is always a perfect superconductor for local wave-pulses (i.e., elementary particles) traveling through it. The types of experiments described above would require a violation of this rule, albeit subtle, in the case of very strong fields or very high field velocities.

## 24. The Origin of the Synergetic Field

The origin and existence of the synergetic field is itself an a priori mystery. The how and why of its existence are not questions currently addressed by SLFT. SLFT proposes that all of what we call "physics" lies within the structure and dynamics of the synergetic field. However, the questions of how and why the field came into existence (if these are indeed meaningful questions) are not addressed.

A closely related question is, “How did the *somethingness* of the synergetic field arise out of the *nothingness* of empty space, or further out of the *nothingness* of pure existence itself?” Perhaps the notion of “arise” is inappropriate in this context. Perhaps a more accurate question is, "What is it in the nature of existence that causes it to structure itself in the form of the synergetic field?"

## 25. Conclusions

These investigations have had two primary goals. The first goal has been to determine the possible validity of Fuller’s conjecture that his synergetic geometry describes the actual “coordinate system of nature.” The second closely related goal has been to determine synergetic geometry's possible applicability to core problems in modern physics. In order to realize these goals, the paper has used Fuller’s synergetic geometry, with some natural modifications and extensions, to construct a candidate model of physical reality. It has then explored the possible mapping of known elements of physical reality onto this model. Based on these results, we feel that it has been successfully demonstrated that Fuller’s vision can be accepted as *at least* a plausible *possibility*.

In the course of these explorations, we have expanded the scope of the original investigations beyond the confines of simply considering the possible validity of Fuller’s conjectures. We have essentially recast these investigations more broadly into an exploration of the *specific* nature of physical space, assuming that physical space is, in fact, a regular, discrete lattice. In this broader context, we feel that the model described herein is at least a reasonable candidate for a unified model of physical reality. *If* physical space does indeed take the form of *some* regular, discrete lattice, then the *specific* form of that lattice described by SLFT seems to be a reasonable candidate for consideration.

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