

Does 3-D Space Have the Structure of a Kelvin Cell?

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Abstract

If we accept the interpretation of a Higgs field as a $\langle \psi_+ \psi_- \rangle$ condensate, where ψ_+ and ψ_- are the Planck Particle wave functions of Winterberg, we will prove that 3-D space has a unique 3-D cellular structure. It was a structure already discovered in 1887 by Lord Kelvin (aka Sir William Thomson) in his attempts to come up with a “luminiferous ether” for space. He thought in terms of a foam-like structure for space, one that could be vibrated or set oscillating for the propagation of electromagnetic waves. Winterberg’s version of space deals within a totally different context, a two-component superfluid model, made up of material particles, which have positive and negative, the Planck mass, $m_p = \pm \sqrt{\hbar c / G} = \pm 2.176 \text{E} - 8 \text{ kg}$. According to Winterberg, 3-D space is literally made up of a vast assembly (sea) of such particles. It turns out that space also has a cellular structure because the superfluid forces keeping these particles in place, are very strong, and thus anchor the particles spatially in position. The particles are effectively bound, and box quantization conditions apply. We believe that space is discrete and has a graininess of the order, $L = 5.028 \text{E} - 19 \text{ meters}$, as shown in previous work. If we accept the notion that space is made up of discrete, tessellated cells, consisting of ψ_+ and ψ_- particles, each occupying a fixed volume, and if the Higgs condensate is, indeed, a bound $\langle \psi_+ \psi_- \rangle$ structure, then we can prove that the quantum vacuum has the characteristic structure of a so-called Kelvin cell, otherwise formally known as a truncated octahedron. This is the only cellular structure, among many, which satisfies the requirements of being discrete, having the property of being tessellated, and which satisfies the additional requirement that the Higgs condensate in the unperturbed vacuum (one with no net vacuum pressure or energy density) has a size equal to $\xi = 3.13L$. This 14-sided polygon also has the unique distinction of enclosing the maximum volume for a given surface area.

Keywords

Quantum Vacuum, Planck Particles, Winterberg's Vacuum Model, Tessellated 3-D Space, Planck Particle Condensate, Higgs BEC (Bose-Einstein Condensate), Granular Geometrical Structure for Space

1. Introduction

Recently [1] [2], we proposed that the Higgs boson is really a composite particle, *i.e.*, a bound state, or BEC (Bose-Einstein Condensate), made up of a positive-mass Planck particle and a negative-mass Planck particle. In order to explain features of the quantum vacuum, Winterberg, in a series of papers [3]-[13] and in a book (monograph) [14], introduced and promoted the novel idea that space is, in fact, made up of a vast assembly (ocean) of positive and negative massive particles, quantum fields, which he called Planck particles, or Planckions, for short. They form a two-component superfluid (we prefer super-solid), where they repel one another within their own species, but attract particles of the opposite species.

These Planck Particles interact very strongly with other Planck particles. In fact, when displaced from their equilibrium positions, this author has shown [15] [16] that there are very strong restoring forces wanting to bring them back. Hence, we believe that a two-component super-solid, versus superfluid, is the more appropriate term for describing these particles. Each species forms a cellular 3-D grid of sorts, and both grids, one for each species, cannot overlap. Each cell occupies a fixed volume, which can be tessellated, *i.e.*, partitioned with no gaps or overlaps, to fill all of space. Each cell occupies a volume of order L^3 , where length L is the fundamental length scale to be associated with 3-D space. This graininess associated with space is estimated to equal $L = 5.028 \times 10^{-19}$ meters, as calculated in previous work by this author [16]. Unless otherwise stated, all units not written out within this paper will be in the MKS system.

Space, therefore, *i.e.*, the quantum vacuum, has a material structure, one which can be deformed, bent and twisted due to external influences. The general theory of Relativity arises naturally from such a construction. Space also has a quantum mechanical nature, or component, given that elastic collisions with CBR (cosmic background radiation) black body photons will cause vibrations and random chaotic motions within this space [15] [16]. These photons will collide with the positive and negative mass Planck Particles, which occupy the same space. An elementary particle, such as an electron, when placed in this sea of Planck Particles, will feel these vibrations and exhibit random, chaotic motions, much like a ship when placed upon the surface of an open ocean. That electron will be tossed to and fro, which helps explain the statistical nature of quantum mechanics. In fact, both the Heisenberg uncertainty principle, as well as Schrodinger's equation, have been derived by Winterberg [11] using this very concept. Winterberg's theory is an alternative model to string theory, in that it seeks to unify (reconcile) the GTR (Gen-

eral Theory of Relativity) with QM (Quantum Mechanics). Within Winterberg's framework, both theories are special cases of a more fundamental underlying concept, a two-component superfluid vacuum.

In the Winterberg model, there exists for every positive-mass Planck Particle, a corresponding negative-mass Planck Particle. We generalized the concept to include charge, q , where q is the Planck charge [16]. The charge explains the repulsive force between Planck Particles of one species, as well as the attractive force between Planck particles of opposite species. So, a positive Planck Particle is really a quantum field, having (mass, charge) equal to $(+m, +q)$. A negative Planck Particle is really a quantum field characterized by (mass, charge) equal to $(-m, -q)$. Due to the equal numbers of positive and negative Planck Particles, there is an inherent mass/charge neutrality to the vacuum. When unperturbed, *i.e.*, when the vacuum has no net pressure, or equivalently, no net energy density, then the vacuum appears massless, chargeless, and without entropy. According to Winterberg, when dealing with a Planck Particle vacuum, there is no difference between energy density and vacuum pressure. Both are one and the same. We are dealing with a vast assembly (ocean) of such particles. In empty space, we expect, order-of-magnitude-wise, that there are, $L^{-3} = 3.93\text{E}54$, particles per cubic meter, half positive, and the other half, negative Planck Particles.

Winterberg originally developed his idea of a two-component, $+/-$ mass, superfluid for space, in order to explain the cosmological constant problem, the vast discrepancy between the QM value, which is ridiculously large, and the GTR, or Lambda-CDM, value, which is extremely low, of the order, $\Lambda \sim 10^{-52} \text{ m}^{-2}$. This has often been referred to as the “worst fine-tuning problem in physics”, an order of magnitude discrepancy in the neighborhood of 10^{122} . Winterberg's solution was simple. Allow for two types of quantum mechanical oscillators, one positive and the other negative, throughout space. The positive Planck Particle oscillator counteracts the negative, effectively neutralizing it, and we are left with a residual, the Lambda-CDM value. There are many reasons to appreciate his model. It is unfortunate, in the view of this author, that it never received the recognition or attention it deserved. We pursue it here further, nonetheless.

One of the intriguing consequences of this model is our identification of the Higgs field as a Bose-Einstein Condensate (BEC). We put forward the notion that the Higgs field is, in essence, a positive and a negative Planck Particle pair, $\langle \psi_+ \psi_- \rangle$. It is a bound system. See references [1] [2]. The brackets denote a vacuum expectation value. The ψ_+ is the positive mass/charge Planck particle wave function. The ψ_- is the negative mass/charge Planck Particle wave function. When trapped, or anchored spatially in position, in a box having volume, of order, L^3 , the particle has a discrete energy level, one per box. Associated with a specific energy level is a corresponding wave function. The vacuum, *i.e.*, 3-D space, is, in our view, partitioned, or tessellated into such boxes. When we identified the Higgs boson as a $\langle \psi_+ \psi_- \rangle$ condensate, we kept running into an intriguing and mysterious relation, namely, that the coherence length, ξ , associated with the Higgs field, ϕ , is equal

to $\xi = 3.13L$, where L is the fundamental length scale to be associated with space. The coherence length may be regarded as a measure of the size or “reach” of the Higgs field. This relation holds for an unperturbed vacuum, *i.e.*, a vacuum with no net energy density or net pressure. The coherence length for the Higgs is defined by the relation, $\xi \equiv \hbar/(m_\phi c)$, where m_ϕ equals the unperturbed mass of the Higgs boson. The observed value [17] [18] is $m_\phi = 125.35 \text{ GeV}/c^2$.

Our calculation, for L , was independent of the mass of the Higgs. Hence, there should be no connection between ξ and L . And yet, they are close in value. But why this factor of 3.13? Is this a coincidence, or does it have a deeper meaning? We believe the connection is not accidental, and it is a profound one. The factor of 3.13 may help us identify the very nature of space itself! Incidentally, the fact that our fundamental length scale for space, L , is relatively close to the mass of the Higgs field led us to suspect that the Higgs field might, very well, be a $\langle \psi_+ \psi_- \rangle$ condensate, in the first place. Hence, we played with the concept, and made that identification.

We emphasize that our value for the fundamental length scale for space (its graininess, so to speak) does not match that of Winterberg. Winterberg’s fundamental length scale for space is the Planck length, $l_p \equiv \sqrt{\hbar G/c^3} = 1.616\text{E} - 35$ meters. Our fundamental length scale equals, $L = 5.028\text{E} - 19$ meters, which, by contrast, is a much, much larger value. It was derived in reference [16]. Our L value depends on the CBR (Cosmic Background Radiation) temperature, T_{CBR} , of the universe, and the Planck oscillator model. In the present epoch, $T_{\text{CBR}} = 2.73 \text{ K}$. As such, our L value expands with the expansion of the universe, and, as T_{CBR} cools, our L value becomes larger. Winterberg’s value for a fundamental length for space does not scale, and therefore, does not expand, as the universe expands. In reference [19], we presented two specific, but similar, models for how L scales, *i.e.*, becomes larger as the universe cools.

A further reason why we believe our “ L ” value is preferable over his “ l_p ” value, is that our “ L ” value puts us squarely within the realm of the Higgs boson. This, we believe, is also no coincidence. This was one of our motivations for treating the Higgs field as a BEC (Bose-Einstein Condensate).

It is the purpose (goal) of this paper to explain the value of $\xi = 3.13L$. We can explain this factor of 3.13 geometrically, but only if we assume a very specific 3-D cellular structure for 3-D space itself.

In section II, we review our Higgs condensate model. In section III, we explain the factor of 3.13. We assume that space is discrete, *i.e.*, has a granular structure, and has a fundamental length scale, L , associated with it. Space is also tessellated and populated by Planck Particle cells having a definitive volume. Another way of saying this is that space is properly partitioned. We also claim that space is made up of Higgs condensates, $\langle \psi_+ \psi_- \rangle$. And finally, we demand that $\xi = 3.13L$, or close to it. There is only one 3-D cellular structure, which satisfies all four requirements. And here is where we make our surprising discovery. That 3-D structure was already discovered in 1887 by Lord Kelvin (otherwise known as Sir William

Thomson). It is now known as the Kelvin cell [20]. More formally, it is also known as a truncated octahedron.

Interestingly, Lord Kelvin also proposed this as the cellular structure for 3-D space [20]-[22]. His idea was to provide for a medium for the propagation of light or, more generally, electromagnetic waves. He contributed to the theory of sound waves, and ultimately proved that these were pressure waves within a medium. He attempted to do the same for light. His framework was that space is made up of a kind of foam, which could be set in vibration and oscillate as light passes through it. Our notion of space, based on Winterberg's model, is totally at odds with his version. Lord Kelvin didn't know about quantum mechanics, nor the general theory of relativity, nor the expansion of the universe. However, when light passes through space, it could very well be that the Planck particles are set vibrating or oscillating in some fashion, within their respective cells, and it may be in this way, that light is able to carry energy and momentum. We are literally dealing with pressure waves, as will become apparent with this work. See, in this regard, also reference [23], where we tried to make a case for Planck pressure waves within the vacuum.

Even in his day, Lord Kelvin had many detractors when he proposed his "luminiferous ether" hypothesis. His contemporaries criticized his model, claiming it was "utterly frothy", and a "pure waste of time". See reference [21], and references therein, for some very interesting history regarding this matter. Lord Kelvin always insisted, however, that his model was a "real thing". We intend to prove him right with this paper, although within a totally different context and framework. Our summary and conclusions are presented in section IV, our final section.

2. The Higgs Boson as a Positive and Negative Planck Particle Condensate

According to Winterberg [14], the potential energy operators, $U_{\pm}$, acting on the positive and the negative Planck Particle wave functions, ψ_{+} and ψ_{-} , respectively, are given by the following expressions,

$$U_{\pm}\psi_{\pm} = \pm\hbar c l_p^2 (\psi_{\pm}^{\dagger}\psi_{\pm} - \psi_{\mp}^{\dagger}\psi_{\mp})\psi_{\pm} \quad (2-1)$$

In Equation (2-1), $\hbar$ is the reduced Planck constant, c is the speed of light, and l_p is the fundamental length, to be associated with 3-D space. Winterberg assumes that this equals the Planck length, $l_p \equiv \sqrt{\hbar G/c^3} = 1.616\text{E}-35$ meters. The G is Newton's constant, $G = 6.674\text{E}-11$, in MKS units. MKS units are the assumed units in this paper, unless otherwise stated. When a quantity has no units written out, we can assume that it is MKS.

To obtain the fundamental equation relating the Higgs field, ϕ , to the Planckion wave functions, ψ_{+} with ψ_{-} , we assume that the potential energy of the ϕ field equals the potential energy of the Planckion wave functions, ψ_{+} with ψ_{-} , when added together. Mathematically, let

$$U(\phi) = U_{+}(\psi_{+}) + U_{-}(\psi_{-}) \quad (2-2)$$

The operator, $U(\phi)$, acts on the non-relativistic ϕ , whereas the operators,

$U_+(\psi_+)$, and, $U_-(\psi_-)$, act on the non-relativistic ψ_+ and ψ_- fields, respectively. However, if ϕ is assumed to be a composite of the ψ_+ and ψ_- wave functions, then the potential energy of ϕ , should equal the sum of $U_+(\psi_+)$, with $U_-(\psi_-)$. Refer to reference [1] for details and a more rigorous treatment, including the transition from relativistic to non-relativistic fields. The Higgs particle is usually treated as a field in 4-D space-time.

We next substitute Equations (2-1) into Equation (2-2), and find that

$$U(\phi) = \hbar c l_p^2 (\psi_+^\dagger \psi_+ - \psi_-^\dagger \psi_-) * (\psi_+ + \psi_-) \quad (2-3)$$

With the identification of (ϕ) , with $(\psi_+ + \psi_-)$, this is the potential energy equation for the Higgs field.

Let us next define the following quantities,

$$\langle n_+ \rangle \equiv \langle \psi_+^\dagger \psi_+ \rangle = \text{the number density probability of finding } \psi_+, \quad (2-4)$$

at a point $\vec{x}$, within a cellular volume

In other words,

$$\langle n_+ \rangle dx dy dz = \text{the probability of finding } \psi_+, \text{ between } x \text{ and } x + dx,$$

between y and $y + dy$, and between z and $z + dz$

Also, let

$$\langle n_- \rangle \equiv \langle \psi_-^\dagger \psi_- \rangle = \text{the number density probability of finding } \psi_-, \quad (2-5)$$

at a point $\vec{x}$, within a cellular volume

And, correspondingly,

$$\langle n_- \rangle dx dy dz = \text{the probability of finding } \psi_-, \text{ between } x \text{ and } x + dx,$$

between y and $y + dy$, and between z and $z + dz$

With these definitions, Equation (2-13) can alternatively be written as

$$U(\phi)\phi = \hbar c l_p^2 (\langle n_+ \rangle - \langle n_- \rangle) * (\psi_+ + \psi_-) \quad (2-6)$$

Our modification to Equations (2-3) and (2-6) is to replace l_p by L , which we believe is a better length scale to be associated with space. We now have, in place of Equation (2-6),

$$U(\phi)\phi = \hbar c L^2 (\langle n_+ \rangle - \langle n_- \rangle) * (\psi_+ + \psi_-) \quad (2-7)$$

Numerically, L has been calculated by this author, in reference [16], and its value is $L = 5.028 \times 10^{-19}$ meters. Our “ L ” value increases as the universe expands, as it is T_{CBR} dependent, where T_{CBR} is the cosmic background temperature of the universe. In the current epoch, $T_{\text{CBR}} = 2.73$ Kelvin. As mentioned, the length scale introduced by Winterberg does not scale.

The reader will also notice that our length scale, besides being significantly larger than the one introduced by Winterberg, is within reach of what is achievable in modern-day accelerators. If this theory is correct, we may be on the verge of soon observing the graininess of space itself, directly.

With the replacement of l_p by L , Equation (2-7) can be rewritten as follows

$$\begin{aligned}
U(\varphi)\varphi &= \hbar c L^2 (\langle n_+ \rangle - \langle n_- \rangle) * (\psi_+ + \psi_-) \\
&= (\hbar c / L) L^3 (\langle n_+ \rangle - \langle n_- \rangle) * (\psi_+ + \psi_-) \\
&= M c^2 (\langle n_+ \rangle - \langle n_- \rangle) / n_0 * (\psi_+ + \psi_-)
\end{aligned} \tag{2-8}$$

In Equation (2-8), we have defined and made use of the following quantities,

$$M \equiv \hbar / (Lc) \tag{2-9a}$$

$$n_0 \equiv L^{-3} \tag{2-9b}$$

The $\langle n_+ \rangle$ and $\langle n_- \rangle$, in Equation (2-8), are defined at a certain point in space within a cell. The, n_0 , by contrast, is simply the inverse volume of that cell. The mass, M , in Equation (2-9a), is the mass associated with the graininess of space, or, vacuum mass, to give it a name.

In a quantum box or cell, we have a discrete energy level due to the Planck Particles being effectively anchored in position, one per box. However, given a collection of such boxes, half occupied by positive Planck Particles, and the other half by negative Planck Particles, the energy states can differ. Not all are in the ground state, and the excited states can differ in their populations within a volume. This leads to $\langle n_+ \rangle \neq \langle n_- \rangle$, in general, within a region of space. For each unique energy level, we have a specific wave function for either a positive or negative Planck Particle wave function. Thus, in a region of space, where we have a volume of such cells, we can, in general, have a net pressure or net energy density associated with the vacuum. It takes at least two cells, a positive and a negative, to define a net pressure, or a net energy density, within the vacuum.

According to Winterberg, the total Planck vacuum pressure, p , due to both positive and negative Planck particles, in a region of space, $\vec{x}$, equals

$$\begin{aligned}
p(\vec{x}) &= p_+ + p_- \\
&= m_p c^2 (n_+ - n_-) \\
&= 0 \text{ (undisturbed fluid)} \\
&\neq 0 \text{ (disturbed fluid)}
\end{aligned} \tag{2-10}$$

The undisturbed fluid is the ground state of the vacuum. Here, the positive and negative mass number densities exactly balance, *i.e.*, $n_+(\vec{x}) = n_-(\vec{x})$, and the net vacuum pressure vanishes.

The Planck vacuum pressure is related to the net Planck particle mass density, ρ , by the equation of state, $p = \rho c^2$. Therefore, by Equation (2-10), we may also write,

$$\begin{aligned}
\rho(\vec{x}) &= \rho_+ + \rho_- \\
&= m_p (n_+ - n_-) \\
&= 0 \text{ (undisturbed fluid)} \\
&\neq 0 \text{ (disturbed fluid)}
\end{aligned} \tag{2-11}$$

If $n_+(\vec{x}) > n_-(\vec{x})$ or $n_+(\vec{x}) < n_-(\vec{x})$, the two-component superfluid will no longer be undisturbed. Then, we will have a net Planck vacuum pressure, and a

net Planck vacuum mass (energy) density. A net Planck vacuum mass/energy density, and net pressure for the vacuum, positive or negative, is a prediction of Winterberg's theory.

There is a second kind of disturbed vacuum Planck fluid possible, one for which, $n_+(\vec{x}) = n_-(\vec{x})$. We can have vortex rotation within a region of space. Here, the positive and negative Planck number densities of the rotating particles can match. Winterberg believes that these quasiparticle excitations due to rotating positive and negative Planck particles, either with or counter to one another, can produce elementary particles, and the characteristics associated with them, such as spin, mass, charge, and magnetic moment. The mass, specifically, would be a consequence of their rotational kinetic energy. There has to be a localized pressure difference, which is responsible for such vortex rotations. We can think of elementary particles as mini eddy currents arising within such a superfluid, which can decay or remain stable with time. Both are possible in a superfluid. This is an intriguing notion, but further discussion of this would take us too far afield. Vortex rotation will be discussed in a follow-up paper.

We will not work with Equations (2-10) and (2-11). These will have to be modified to take into account our new length scale, since it differs from that of Winterberg. Instead of using l_p , we use L . Then,

$$\begin{aligned} p(\vec{x}) &= p_+ + p_- \\ &= Mc^2(n_+ - n_-) \end{aligned} \quad (2-12)$$

where M is defined by Equation (2-9a). Similarly, Equation (2-11) gets replaced by

$$\begin{aligned} \rho(\vec{x}) &= \rho_+ + \rho_- \\ &= M(n_+ - n_-) \end{aligned} \quad (2-13)$$

We call M , our vacuum mass. The vacuum energy density is obtained by multiplying Equation (2-13) by c^2 . Thus, $u(\vec{x}) = \rho(\vec{x})c^2 = p(\vec{x})$. This will sometimes be written as $\Delta u(\vec{x}) = \Delta \rho(\vec{x})c^2 = \Delta p(\vec{x})$, as we are really talking about a net energy density difference between positive versus negative Planck Particle wave functions. The same holds for the pressure, $p(\vec{x})$. It is really a net vacuum pressure difference between positive and negative mass Planck particle wave functions. And thus, $p(\vec{x}) = \Delta p(\vec{x})$.

The reader will notice that we replaced the Planck mass, $m_p = \hbar/(l_p c)$, by the vacuum mass, $M \equiv \hbar/(Lc)$, which is defined by Equation (2-9a), in going from Equations (2-10) and (2-11) to Equations (2-12) and (2-13). We calculated the value of " L " in a previous work [16]. Its value equals $L = 5.028 \times 10^{-19}$ meters. Substituting this into Equation (2-9a), we find

$$M = 6.994 \times 10^{-25} \text{ kg} = 392.5 \text{ GeV}/c^2 \quad (2-14)$$

This is numerically close to the Higgs mass, $m_\phi = 125.35 \text{ GeV}/c^2$ [17] [18]. Evaluating the ratio, we see that

$$M/m_\phi = 3.13 \quad (2-15)$$

We can define a coherence length for the Higgs field by the relation,

$$\text{coherence length, } \xi \equiv \hbar / (m_\phi c) \quad (2-16)$$

Then, using our definitions, one can prove that

$$\xi / L = 3.13 \quad (2-17)$$

The coherence length is sometimes called the correlation length, and it is a measure of the size or “reach” of the Higgs boson. This factor of 3.13 is no accident, if our thinking is correct. In fact, it is the goal of this paper to explain this number, geometrically. Both Equations (2-15) and (2-17) hold only if the vacuum is unperturbed. In other words, we are assuming that there is no net pressure, or no net energy density associated with the vacuum.

The Higgs field permeates all of space. Thus, any added net vacuum pressure, or, equivalently, any net vacuum energy density, must be an add-on to the rest mass potential energy of the Higgs. Therefore, we are justified in writing a generalized version for the Higgs mass equation,

$$\begin{aligned} m'_\phi c^2 &= m_\phi c^2 + Mc^2 (\langle n_+ \rangle - \langle n_- \rangle) / n_0 \\ &= m_\phi c^2 + \Delta p L^3 \end{aligned} \quad (2-18)$$

The second term on the right-hand side, in the first line, is just the vacuum potential energy associated with a perturbed vacuum. See Equation (2-8). For the second line, we made use of Equation (2-12), remembering that $p(\vec{x}) = \Delta p(\vec{x})$. We have also employed Equations (2-9a) and (2-9b). For an unperturbed vacuum, the second terms on the right-hand side of Equations (2-18) vanish. In Equation (3-18), m'_ϕ is the adjusted Higgs mass to take into account any net vacuum pressure, or equivalently, any net vacuum energy density, within the vacuum. The m_ϕ , on the other hand, is the unperturbed, or undisturbed, mass of the Higgs boson, when the vacuum has no net pressure, nor net energy density. In this case, $\Delta p = \Delta u = 0$, within a region of space. The undisturbed mass of the Higgs equals $m_\phi = 125.35 \text{ GeV}/c^2$.

Actually, in Equation (2-18), the L^3 should be replaced by $2L^3$ in the second line. This is because two cells are in play for a Higgs particle. One cell is due to the positive ψ_+ Planck Particle cell, and the other to the adjacent negative ψ_- Planck Particle cell. Each has a volume L^3 .

Equation (2-18) can be generalized for a larger volume, V . The generalization to volume V is to make the replacement in Equation (2-18),

$$L^3 \Delta p \rightarrow 2L^3 \Delta p \rightarrow (V) \Delta p \quad (2-19)$$

In volume V , we have $N_+ = N_- = N$ number of cells where, N_+ are the number of cells occupied by ψ_+ , and N_- are the number of cells populated by ψ_- . Since $N_+ = N_-$, within an arbitrary volume, V , the total number of cells equals

$$2N = V/L^3 \quad (2-20)$$

The number of Higgs fields within volume V is simply N . For an arbitrary volume, V , Equation (2-18) reads,

$$m'_\phi c^2 = m_\phi c^2 + \Delta p V \quad (2-21)$$

The second term on the right-hand side of this equation can either increase or decrease the undisturbed mass of the Higgs field within a volume, V . A net positive vacuum pressure (vacuum energy density) increases the mass, whereas a net negative vacuum pressure (energy density) decreases it. For a fluid, $\Delta p V$ is the standard expression for potential energy; in fact, $\Delta p V$ is often referred to as fluid potential energy, or, what is the same, pressure potential energy.

Up to this point, we have considered cubic cells, for which the volume of an individual cell is L^3 . For a Kelvin cell, however, the cellular volume is much larger, namely, $11.314L^3$, where L designates the length of an edge. In a truncated octahedron, there are 36 such edges, separating the 14 flat surfaces: 6 square and 8 hexagonal. This is what is assumed to scale as the universe expands. So, for a Higgs condensate, comprised of two such adjacent Kelvin cells, one for ψ_+ , and another for ψ_- , the combined volume is equal to $2 * (11.314L^3)$.

Equation (2-21) has its limits. In other words, the Higgs boson can only exist within certain prescribed bounds. We will describe these next. To this end, let us define a new coherence length, ξ' , as follows

$$\text{modified coherence length, } \xi' \equiv \hbar / (m'_\phi c) \quad (2-22)$$

In this equation, m'_ϕ is the modified Higgs mass, which is on the left-hand side of Equation (2-21). This mass takes into account any net pressure, or net energy density, within the quantum vacuum. Contrast this with Equation (2-16), which holds for an unperturbed vacuum, where there is no net vacuum pressure, or equivalently, no net vacuum energy density. The actual size of a Higgs condensate is 2ξ , measured outer edge to outer edge, or more generally, $2\xi'$, when dealing with a perturbed vacuum. Remember that the undisturbed coherence length is $\xi = 3.13L$. See Equation (2-17).

We next consider two extremes. The first is to decrease the net vacuum pressure from zero (unperturbed vacuum state) to some negative value. Let us decrease Δp , in the negative sense, until, at some point, the left-hand side of Equation (2-21) reaches zero. Then, by Equation (2-21), the vacuum pressure difference, Δp , must equal

$$\Delta p = -m_\phi c^2 / V = -2.008\text{E}-8 \text{ Joules}/V \quad (2-23)$$

For the second expression, we have made use of the fact that $m_\phi c^2 = 125.35 \text{ GeV} = 2.008\text{E}-8 \text{ Joules}$. The V is, of course, the volume. The volume could be $2L^3$, for two adjacent cubic cells. Or, alternatively, it could equal $2(11.314L^3)$, for two adjacent Kelvin cells. If $m'_\phi = 0$, then, obviously, $\xi' = \infty$, by Equation (2-22). We have broken the Higgs bond between ψ_+ and ψ_- . The Higgs condensate is no longer a BEC. The pressure required for that is given by Equation (2-23), using the appropriate Higgs volume, which is $2L^3$ for two adjacent cubic cells, or $2(11.314L^3)$ for two adjacent Kelvin cells. This separation vacuum pressure, or separation vacuum energy density, imposed on the original

(unperturbed) volume, will be important when we construct vortex models for elementary particles. This will be seen in another paper, to come out shortly.

The other extreme is to increase the pressure, Δp , in Equation (2-21) in the positive sense. This also has its limits. Consider the distance of closest approach between ψ_+ and ψ_- . For cubic cells, each occupies a volume, L^3 . Since ψ_+ cannot be sitting on top of ψ_- , the smallest value of ξ' is $2\xi' = L$. Remember that the outer-edge-to-outer-edge distance of the combined 2-cell unit is $2\xi'$. Normally, in the unperturbed vacuum state, one with no net pressure or energy density, $\xi' = 2L$, for a ψ_+ and ψ_- condensate, taken together. If $2\xi' = L$, then one Planck Particle is sitting on top of the other. We also have $m'_\phi = 2M$ by Equation (2-22).

Moreover, Equation (2-21) now reads,

$$(m'_\phi - m_\phi)c^2 = \Delta p V \quad (2-24)$$

Solving for Δp , we find,

$$\begin{aligned} \Delta p &= (6.263 - 1)m_\phi c^2 / V \\ &= (6.263 - 1)(2.008\text{E} - 8)/V \end{aligned} \quad (2-25)$$

We have used Equations (2-15) and (2-24) to obtain this expression. This is the maximum positive pressure limit. A Higgs condensate cannot be compressed, or squeezed any further. Otherwise, the ψ_+ cell would be sitting on top of the ψ_- cell.

The Higgs field as a BEC can only exist within these vacuum pressure limits, assuming we accept the notion that the Higgs field is a Planck Particle, $\langle\psi_+\psi_-\rangle$ condensate. Equivalently, Equations (2-23) and (2-25) are also the vacuum energy density limits, since $\Delta p = \Delta u$.

Before we close this section, we note that our fundamental equation for the Higgs field, Equation (2-21), is the equation of a straight line, but with bounds. The perturbed Higgs mass $m'_\phi c^2$ is the dependent variable, the “y” variable, so to speak. The unperturbed mass, $m_\phi c^2$, is the “y-intercept”. This value holds if the vacuum is not under any net pressure, or, equivalently, net energy density. And the, $\Delta p = \Delta u$, is the independent variable, or the “x” value. The volume, V , determines the slope. For two cubic cells, each having volume $V = L^3$, the Volume to be used in Equation (2-21) is

$$V = 2L^3 = 2.542\text{E} - 55 \text{ m}^3 \quad (2 \text{ cubic cells}) \quad (2-26)$$

For two Kelvin cells, each having volume $V = 11.314L^3$, the volume to be used in Equation (2-21) is

$$V = 2(11.314)L^3 = 2.876\text{E} - 54 \text{ m}^3 \quad (2 \text{ Kelvin cells}) \quad (2-27)$$

We have employed our estimated value for L , which is $L = 5.028\text{E} - 19$ meters, in these last two equations. The factor of two is necessary in both equations because a Higgs field consists of two cells, one for ψ_+ , and the other for ψ_- . However, the values for net pressure, or net energy density (the in-

dependent variable), are constrained. For cubic cells, Equation (2-23) is the lower limit, and Equation (2-25) is the upper limit. When evaluated, the limits are

$$\Delta p = \Delta u = -7.90\text{E}46 \quad (\text{lower limit, cubic cells}) \quad (2-28a)$$

$$\Delta p = \Delta u = +4.16\text{E}47 \quad (\text{upper limit, cubic cells}) \quad (2-28b)$$

Outside of these limits, the Higgs field ceases to exist. This is assuming we accept the notion that a Higgs particle is a Planck Particle condensate, $\langle \psi_+ \psi_- \rangle$.

For a Kelvin cell, the corresponding vacuum pressure limits are

$$\Delta p = \Delta u = -6.98\text{E}45 \quad (\text{lower limit, Kelvin cells}) \quad (2-29a)$$

$$\Delta p = \Delta u = +5.96\text{E}45 \quad (\text{upper limit, Kelvin cells}) \quad (2-29b)$$

For a Kelvin cell, the distance of closest approach will turn out to equal $2\xi' = 1.689L$, to be seen in the next section. For this ξ' value, $m'_\varphi = 4.142\text{E} - 25$. And Equation (2-24) renders Equation (2-29b).

3. Geometrical Proof That $\xi = 3.13L$ Leads to a Kelvin Cellular Structure for the Quantum Vacuum

We start by considering a much simpler cellular structure, a cubic cell. Once we understand the process there, we proceed to the Kelvin cell.

Consider two cells, A and B . Cell A is occupied by a positive Planck Particle wave function, ψ_+ , whereas cell B is populated by the negative mass Planck Particle wave function, ψ_- . They are adjacent to one another, and one square surface, L^2 , is shared between them. Within an arbitrary volume, V , there are $2N = V/L^3$ such cells, where $N_+ = N_- = N$. The N_+ refers to the number of cells populated by a positive Planck Particle wave function, ψ_+ , and the N_- designates the number of negative mass Planck Particle cells, populated by ψ_- , within volume V . Since both ψ_+ and ψ_- occupy the same L^3 volume, we also recognize that the total number of Higgs condensates $\langle \psi_+ \psi_- \rangle$ is simply N within an arbitrary volume V .

There is a famous theorem, the Cauchy theorem, which allows us to find the mean chord length for any three-dimensional structure, which has volume, V , and total surface area, S . Let $\langle l \rangle$ equal the mean or average chord length. Then, the Cauchy theorem states that

$$\langle l \rangle = 4V/S \quad (3-1)$$

Think of $\langle l \rangle$ as the average distance traveled by a random line through a body before it encounters a surface. The theorem works for any discrete 3-D cell, a polygon, but also for a smooth, curved 3-D cell. For a sphere, the volume is $V = 4\pi R^3/3$, and the surface area is $S = 4\pi R^2$. Thus, using Equation (3-1), we see that $\langle l \rangle = 4R/3$. For cubic cells A and B , having volume L^3 , we have

$$\langle l_A \rangle = \langle l_B \rangle = 4L^3/(6L^2) = 2L/3 \quad (3-2)$$

The 6 in the denominator is due to the 6 sides of a cube, each having surface area, L^2 .

For two such cells, with one square face being shared by both cells, the average

chord length is not simply $2\langle l_A \rangle$. Let us consider $\langle l_{A+B} \rangle$, where $\langle l_{A+B} \rangle$ is the combined chord length for two cells, side by side. The total volume increases to $V = 2L^3$. The total surface area now equals $S = 2(6L^2) - 2L^2 = 10L^2$. We have subtracted $2L^2$ from the total surface area of cells A and B , because they are no longer exposed to the outside world, being a shared surface. Even though we have double the volume, only 5 sides for cell A and 5 sides for cell B are exposed. Thus, by Equation (3-1), we find that

$$\langle l_{A+B} \rangle = 4(2L^3)/(10L^2) = 4L/5 \quad (3-3)$$

The mean intercept length has now increased to $0.8L$, when compared to Equation (3-2), because lines passing lengthwise through the shared wall travel a larger total distance inside the combined space before exiting.

According to Winterberg, the Planck Particle force, which exists between a positive and a negative Planck Particle, when the vacuum has no net vacuum pressure, or, equivalently, no net vacuum energy density, is attractive and has magnitude.

$$F_p = \hbar c / l_p^2 = 1.21\text{E}44 \text{ Newtons} \quad (3-4)$$

Here, l_p is the Planck length, $l_p = 1.616\text{E}-35$ meters. This is the distance between the midpoint of the two cells. The potential energy is simply

$$U_p = -F_p l_p = -1.956\text{E}9 \text{ Joules}. \text{ It is negative because the force is attractive.}$$

However, we don't believe that l_p is the fundamental length scale to be associated with 3-D space. We prefer $L = 5.028\text{E}-19$ meters, based on previous work [16]. Our length scale expands with the expansion of the universe as it is dependent on the cosmic background radiation temperature. Winterberg's l_p does not scale. Our L value also places us within the Higgs sector, which we believe is not accidental. There are other compelling reasons for preferring L versus l_p , which we cannot discuss here, as it would take us too far afield. With this in mind, we present a different force equation. Instead of Equation (3-4), we prefer

$$F_{pp} = \hbar c / L^2 = 1.25\text{E}11 \text{ Newtons} \quad (3-5)$$

This is still an extremely large force, but nowhere near the Winterberg result. The corresponding binding energy is also much less. If we multiply F_{pp} by L , we obtain the potential energy,

$$U_{pp} = -\hbar c / L = -Mc^2 = -6.29\text{E}-8 \text{ Joules} \quad (3-6)$$

The negative sign indicates a binding energy. We have made use of Equation (2-9a) in Equation (3-6).

Actually, a better result is

$$F_{pp} = \hbar c / \xi^2 = 1.28\text{E}10 \text{ Newtons} \quad (3-7)$$

where $\xi = 3.13L$. See Equation (2-17). And the corresponding potential energy is

$$U_{pp} = -\hbar c / \xi = -m_\phi c^2 = -2.01\text{E}-8 \text{ Joules} \quad (3-8)$$

The m_ϕ is the mass of the Higgs field, $m_\phi = 125.35 \text{ GeV}/c^2$. The ξ is now the new distance between the midpoints of the adjacent cells, A and B . These re-

sults will become clearer as we progress further.

We also note in passing that

$$Gm^2 = kq^2 = \hbar c \quad (3-9)$$

In this expression, m is the Planck mass, and q is the Planck charge. G is Newton's gravitational constant. And k is the electrostatic constant, $k = 1/(4\pi\epsilon_0)$, where ϵ_0 is the permittivity of free space. Equations (3-4) and (3-5), and their modifications, Equations (3-7) and (3-8), therefore, also make sense from an electrostatic and gravitastic point of view, except that on this level, it is assumed that Planck masses of a different species attract, whereas those of the same species repel. In reference [16], we went to great lengths to show the equivalence of gravity and electrostatics at this level. Moreover, in that work, we tried to make a case for why the gravitational force may, in effect, be a disguised electric force.

The numerical value of M , in Equation (3-6), is relatively close to the Higgs mass. See Equations (2-14) through (2-17). As mentioned, we believe this is no accident. We emphasize that L and, consequently, M , were both calculated independently from the value of the Higgs mass. In fact, it was precisely that close proximity between these two masses that led us to suspect that the Higgs field could indeed be a condensate particle, specifically, a Planck Particle, $\langle\psi_+\psi_-\rangle$ condensate.

What would happen if we tried to bring cell A, occupied by ψ_+ , closer together to cell B, populated by ψ_- ? When the vacuum is unperturbed, or undisturbed, there is no net pressure or net energy density. Then, the normal distance of separation between the midpoints of these two adjacent cells is $\xi = 3.13L$. Refer to Equation (2-17). The cells, A and B, are assumed to lie adjacent to one another. Equations (3-7) and (3-8) also apply. However, if we bring the two cells, A and B, closer together, $\xi = 3.13L$ gets replaced by $\xi' < \xi$. Thus, $m'_\phi > m_\phi$, by our definitions for ξ' and ξ . And by Equation (2-21), we must have an increase in, (net vacuum pressure = net vacuum energy density), within volume, V .

If we started separating the distance between the adjacent cells, A and B, the opposite would happen. The ξ' would increase over ξ , i.e., $\xi' > \xi$. Thus, $m'_\phi < m_\phi$. And by Equation (2-21), we must have a decrease in (net vacuum pressure = net vacuum energy density), within volume, V . There are limits, of course, as to how much we can increase or decrease the net vacuum pressure, or equivalently, the net vacuum energy density, before the Higgs condensate bond gets broken apart. See, for example, Equations (2-28a) and (2-28b), which hold for two cubic cells. Or, alternatively, Equations (2-29a) and (2-29b), for two Kelvin cells.

If there is a net vacuum pressure, or equivalently, a net vacuum energy density, then Equations (3-7) and (3-8) get replaced by

$$F'_{PP} = \hbar c / \xi'^2 = m'^2_\phi c^3 / \hbar \quad (3-10)$$

See Equation (2-17), the corresponding potential energy, or binding energy, is

$$U'_{PP} = -\hbar c / \xi' = -m'^2_\phi c^2 \quad (3-11)$$

The m'_ϕ is the adjusted, or modified, mass of the Higgs field, given by the left-

hand side of Equation (2-21), which takes into account any net pressure or net energy density within the vacuum. The ξ' is now the modified distance between the midpoints of the adjacent cells, A, and B. Again, the net vacuum pressure can either increase the mass of the Higgs, $m'_\phi > m_\phi$, or decrease the mass of the Higgs, $m'_\phi < m_\phi$. From Equations (3-10) and (3-11), it is obvious that a greater Higgs mass means a stronger binding force and binding energy. A weaker Higgs mass means the opposite: a weaker binding force and weaker binding energy.

We now consider the Kelvin cell. It has 14 sides: 6 square and 8 hexagonal [24] [25]. Being a polygon, it has flat surfaces and 24 vertices. We have 36 edges of length L , separating these 14 flat surfaces. This is what we believe will scale upon expansion of the universe. As the CBR temperature, T_{CBR} , decreases, our " L " value will increase. In a Kelvin foam, it is precisely the length of the edges, L , which expand and contract when the temperature increases or decreases. The permeability of space will also influence the value of " L ". This L is assumed to have the same value as the length scale associated with 3-D space, namely, $L = 5.028\text{E} - 19$ meters. This value, which we evaluated in reference [16], holds only in the present cosmological epoch.

Formally, the Kelvin cell is known as a truncated octahedron. Think of it as two pyramids, where the base is shared. Then truncate the 6 sharp, outward protruding edges to form squares. It looks much like a sphere from a distance, and hence, it encloses the largest volume of all the polygons for a given surface area. Images of the truncated octahedron are given in **Figure 1** and **Figure 2**. This type of cell can be tessellated, or partitioned, to fill all of 3-D space with no gaps or overlaps. Although known to the ancient Greeks, this type of cell was put forward by Lord Kelvin as representing a model for 3-D space as a foam, in 1887.

There is actually another cellular structure, which encloses slightly more volume for a given surface area, the Weaire-Phelan cell (The Phelan-Weaire structure really consists of two different types of cells). However, this entity really consists of two separate types of cells, and will not be considered here.

Some specifics relating to the Kelvin cell are its volume, V , and surface area, S . For a truncated octahedron,

$$V = 8\sqrt{2}L^3 \cong 11.314L^3 \quad (3-12)$$

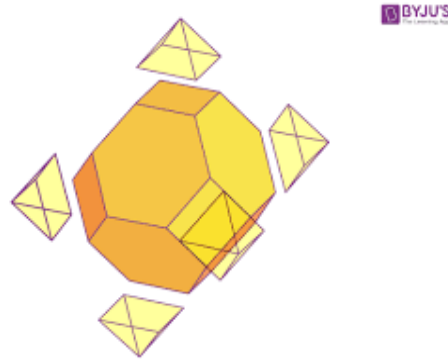


Figure 1. Geometric model of the Kelvin cell represents a truncated octahedron, showing its central polyhedron with associated pyramidal elements.

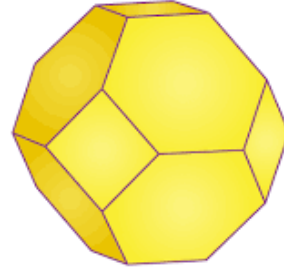


Figure 2. Isolated view of the Kelvin cell modeled as a complete truncated octahedron.

$$S = \left[6L^2 + 8\left(3\sqrt{3}/2\right)L^2 \right] \cong 26.785L^2 \quad (3-13)$$

The surface area of a hexagon is, $\left(3\sqrt{3}/2\right)L^2$. Using Cauchy's theorem, Equation (3-1), we find the mean chord length,

$$\langle l \rangle = 4V/S \cong 1.689L \quad (3-14)$$

This is the average distance traveled by a random line passing through the body. This is also the limiting distance of closest approach for two adjoining cells, outer end to outer end. Otherwise, the two cells would be sitting on top of each other. This established the upper bound for the vacuum pressure in Equation (2-29b).

We next put two such Kelvin cells together. We have two possibilities for a shared face. The first is to match two square faces, *i.e.*, a square face of cell *A*, with that of cell *B*. The probability of that happening is the square surface area divided by the total surface area. The total surface area is given by Equation (3-13). Thus, the probability of this happening is

$$P_{SS} = 6L^2 / (26.785L^2) = .244 \quad (3-15)$$

See Equation (3-13), where we take the first term on the right-hand side and divide it by the total surface area.

The probability of a random line crossing a hexagonal surface in passing from cell *A* to cell *B* is the second term on the right-hand side of Equation (3-13), divided by the total. We find

$$P_{HH} = 8\left(3\sqrt{3}/2\right)L^2 / (26.785L^2) = 0.776 \quad (3-16)$$

The sum of these two probabilities must add up to unity, as these are our only options.

The total surface area of the combined cells, *A* and *B*, equals the specific surface areas multiplied by their respective probabilities. Thus,

$$S_{A+B} = P_{SS} (10L^2) + P_{HH} (21\sqrt{3}L^2) \quad (3-17)$$

We have 5 exposed squares for each cell, *A* and *B*, if they share a square face. This gives us the first term on the right-hand side.

$(2 \text{ cells}) * (5 \text{ exposed surfaces}) * L^2 = 10L^2$. And if a hexagonal face is shared be-

tween cells A and B , then we have 7 exposed faces per cell. This gives us the second term on the right-hand side, because
 $(2 \text{ cells}) * (7 \text{ exposed surfaces}) * \left(3\sqrt{3}/2\right)L^2 = 21\sqrt{3}L^2$. The 8th hexagonal surface, which is shared between cells A and B , is not exposed to the outside world, and therefore doesn't count.

Let us next substitute the values of Equations (3-15) and (3-16) into Equation (3-17). We find for the exposed, combined, surface area,

$$S_{A+B} = 30.465L^2 \quad (3-18)$$

The total volume for cells A and B is just twice Equation (3-12), or

$$V_{A+B} = 16\sqrt{2}L^3 \quad (3-19)$$

Employing Cauchy's theorem now gives,

$$\langle l_{A+B} \rangle = 4V_{A+B}/S_{A+B} = 4(16\sqrt{2})L/30.465 \cong 2.97L \quad (3-20)$$

We can improve upon this result. The distance between two square faces in a Kelvin cell is

$$d_{SS} = 2\sqrt{2}L = 2.83L \quad (3-21)$$

The distance between two hexagonal faces in a Kelvin cell is

$$d_{HH} = \sqrt{6}L = 2.45L \quad (3-22)$$

Their average is, $\bar{d} = 2.64L$. If a random line crosses a square interface, it has a greater distance to travel before it exits, versus if it were to cross a hexagonal surface. Let us scale the first term on the right-hand side of Equation (3-20) to reflect this fact. We multiply the first term on the right-hand side of Equation (3-20) by $d_{SS}/\bar{d} = 2.83/2.64 = 1.07$. Let us scale the 2nd term on the right-hand side of Equation (3-20) as well. We multiply this term by $d_{HH}/\bar{d} = 2.45/2.64 = 0.93$. This reduced factor is due to the smaller distance traveled if a random line crosses a hexagonal interface. Then, Equation (3-17) gets modified to

$$S'_{A+B} = 1.07(P_{SS})(10L^2) + 0.93(P_{HH})(21\sqrt{3}L^2) \cong 28.593L^2 \quad (3-23)$$

We apply Cauchy's theorem once more, but now, using our modified, combined $A+B$, surface area, Equation (3-23). The new result is

$$\langle l'_{A+B} \rangle = 4V_{A+B}/S'_{A+B} = 90.509L/28.593 \cong 3.168L \quad (3-24)$$

This value is close to the average distance a random line would travel if it passed through two adjacent Kelvin cells. If two adjacent Kelvin cells made up a Higgs condensate, then this distance would represent the average size of a Higgs condensate in the unperturbed vacuum. In other words, it could be a proxy for $\xi = 3.13L$.

For a proper treatment, which involves complex integration, we refer the reader to two textbooks on the subject [26] [27]. The method for finding the mean chord length for two adjacent Kelvin cells is technically known as the "random intercept method". It involves evaluating the following integral,

$$\begin{aligned}\langle l_{A+B} \rangle &= (4\pi)^{-1} \int_0^{2\pi} \int_0^\pi D(\theta, \varphi) \sin(\theta) d\theta d\varphi \\ &= 48/(4\pi) \int_0^{\pi/4} \int_{\arccos 0}^{\pi/2} D(\theta, \varphi) \sin(\theta) d\theta d\varphi\end{aligned}\quad (3-25)$$

In this equation, we define the following terms,

$D(\theta, \varphi) \equiv$ the distance between parallel faces of the cell in the direction (θ, φ)

$\theta \equiv$ polar angle (from the z axis) (3-26)

$\varphi \equiv$ azimuthal angle : 0 to $\pi/4$ in the x - y plane

The bounds in the second line of Equation (3-25) cover 1/48 of the sphere, which is one fundamental domain of the octahedral domain.

Upon evaluating Equation (3-25), the exact result is

$$\langle l_{A+B} \rangle = 3.13L \quad (3-27)$$

Compare this to $\xi = 3.13L$, which holds for an unperturbed vacuum with no net pressure, nor net vacuum energy density. The agreement couldn't be more perfect! That this value can be replicated to this degree comes as a complete surprise to us, as we would have never suspected it. We had hoped to come close, but this result defies expectation. Of all the polyhedra out there that can be tessellated, none come close to this value, except for the Kelvin cell.

Could this interpretation be correct? This result brings so many disparate ideas together that it would have seemed impossible to confirm. Is this a coincidence? Or does it incredulously validate and support all of our very many assumptions? We list a few of our underlying assumptions here. Does it confirm and support all of the following?

1) Our independent calculation for the fundamental length scale for 3-D space, namely, $L = 5.028E - 19$ meters ?

2) Our notion that the quantum vacuum is made up of positive and negative mass Planck Particles, each occupying a fixed volume in space? Together, they form a two-component super-solid, and tessellate all of space.

3) Our conjecture that the Higgs field is really a Bose-Einstein condensate, consisting of two Planck Particles, positive and negative. In other words, is a Higgs boson a $\langle \psi_+ \psi_- \rangle$ condensate?

4) Our assumption that the binding force and the binding energy for the Higgs field are given by the expressions in Equations (3-7) and (3-8), respectively?

5) The very idea that 3-D space is not smooth and continuous? Rather, it is discrete and has an inherent graininess associated with it. This graininess can scale with the expansion of the universe, as it is inherently dependent on the cosmic background temperature of the universe.

We admit that these are unconventional ideas. Nevertheless, they are compelling. And what's more, they seem to validate much previous work by both Winterberg and this author.

4. Summary and Conclusions

With this work, we sought to make a case for identifying the Higgs field as a $\langle \psi_+ \psi_- \rangle$

Bose-Einstein condensate. We believe that the Higgs boson may well turn out to be a bound state, where the constituents are the positive and negative wave functions of Winterberg. These fermions can bind to form a Higgs field. The binding force and the binding energy are given by Equations (3-7) and (3-8), respectively. The underlying potential energy of the Higgs field is that of the quantum vacuum. If our thinking is correct, it is given by Equation (2-21), which is our fundamental equation for the Higgs field. This equation takes into account any net pressure, or equivalently, any net energy density associated with the vacuum. If the vacuum is unperturbed, with no net pressure or net energy density, then the mass of the Higgs field is simply $m_\phi = 125.35 \text{ GeV}/c^2$, and its size, or correlation length, is given by $\xi = 3.13L$. If the vacuum is under net pressure, or, equivalently, has a net energy density, within a region of space, then the second term on the right-hand side of Equation (2-21) will alter the original mass, which is the first term on the right-hand side. The Higgs mass will now assume a new value, m'_ϕ , which is found using this equation. This new mass may be greater than, or less than, the original, unperturbed mass, m_ϕ , depending on whether the vacuum pressure is positive or negative, within volume, V . Associated with the modified Higgs mass, m'_ϕ is a new correlation length, ξ' . The ξ' is less than ξ , if $m'_\phi > m_\phi$, and greater than ξ , if $m'_\phi < m_\phi$. Both ξ and ξ' , refer to the size, or “reach” of the Higgs boson. The binding force, and binding energy, depend critically on their values. See, Equations (3-10) and (3-11).

A further goal of this paper was to come up with a natural explanation for why, $\xi = 3.13L$, when the vacuum is in the unperturbed state. The L is the fundamental length scale, to be associated with 3-D space. It has been calculated in previous work by this author, and we derived the value, $L = 5.028\text{E} - 19$ meters. Our quest was to understand why $\xi = 3.13L$. This led us to the realization that its explanation may be geometrical, and has to do with the very nature of space itself. We can explain this relation if we assume that space is discrete, is tessellated, and is made up of cells occupied by, and populated with, Planck Particles, positive and negative. The specific factor of 3.13 can only be explained if its cellular structure is that of a Kelvin cell, or truncated octahedron. See Equation (3-27). No other polyhedron can satisfy these requirements, or come close to it. This result is remarkable, given that there were so many underlying assumptions behind it. A partial listing of the assumptions made was given at the end of section III. That the fit is dead-on is compelling.

The Higgs condensate model that we have presented may indeed turn out to be correct. This rests, however, on many other supporting arguments and assumptions. Much work remains to be done before these ideas can be accepted. We list, for example, the Planck Particle wave functions inside a Kelvin cell. What do they look like? And what are the permissible energy levels? We assumed that many of the ideas which hold for 3-D box quantization in a cubic cell can be directly carried over to a Kelvin cell. This, however, remains to be worked out.

Another line of reasoning which could be pursued is how those wavefunctions

and energy levels react, as light, or more generally, electromagnetic radiation, passes through these cells. Is a medium needed for the propagation of light, as Lord Kelvin suspected? We believe that this may well turn out to be the case, in spite of the negative results of the Michelson-Morley experiment, and the axioms of the special theory of relativity. What could be set oscillating or vibrating? We believe that it is not a foam-like structure as envisaged by Lord Kelvin. Rather, it may have something to do with the properties of the Planck Particles within their particular cells. Pressure waves might indeed exist within a superfluid. See, for example, in this regard, previous work by this author, reference [23].

We have also developed models [19] for how the fundamental length scale for 3-D space, L , scales upon expansion of the universe. It depends critically on the Planck oscillator model, and is driven by the cosmic background temperature of the universe. Could these models be correct? And what are some of the ramifications for cosmic evolution if these models are valid? Can other models for the cosmic evolution of “ L ” be constructed?

Finally, it was theorized by Winterberg that Planck Particles may hold the key to the formation of elementary particles, such as the electron. The mass and spin, for example, for the electron, may be a consequence of the rotation of Planck Particles, once the Higgs bond has been broken. Mass, specifically, may be due to the rotational kinetic energy of these positive and negative Planck particles. Winterberg developed a model, along these lines, for the electron and the neutrino. While his model is probably not the final story, it is an intriguing notion. This is a further line of inquiry, which may hold some promising revelations. Clearly, we have only scratched the surface with the Winterberg Planck Particle superfluid model.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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