

The Planck Particle Higgs Condensate Model Revisited: Limits on the Net Vacuum Pressure = Net Vacuum Energy Density for Higgs Binding

Christopher Pilot 

Maine Maritime Academy (Retired), Castine, ME, USA

Email: chris.pilot43@gmail.com

How to cite this paper: Pilot, C. (2026)

The Planck Particle Higgs Condensate Model Revisited: Limits on the Net Vacuum Pressure = Net Vacuum Energy Density for Higgs Binding. *Journal of High Energy Physics, Gravitation and Cosmology*, 12, 2339-2352.

<https://doi.org/10.4236/jhepgc.2026.124119>

Received: July 6, 2026

Accepted: October 20, 2026

Published: October 23, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative

Commons Attribution International

License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

We revisit our model of a Higgs field as a $\langle \psi_+ \psi_- \rangle$ condensate, where ψ_+ and ψ_- are the Planck Particle wave functions of Winterberg. Winterberg's version of space deals with a two-component superfluid model, made up of material particles, which have positive and negative Planck mass,

$m_p = \pm \sqrt{hc/2\pi G} = \pm 2.176 \text{E} - 8 \text{ kg}$. According to Winterberg, 3-D space is literally made up of a vast assembly (sea) of such particles. 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 Higgs condensate can only exist if the (net vacuum Planck Particle pressure) = (net vacuum Planck Particle energy density) lies within certain bounds, not too high, nor too low. Outside of these bounds, the BEC structure collapses, and no Higgs condensate state can exist. We'll establish those bounds for a cubic cell construction.

Keywords

Higgs Condensate, Planck Particles, Winterberg Model, Vacuum Pressure, Vacuum Energy Density, Discrete Space, BEC Stability

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 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. 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 3-D sea, or ocean, 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 Schroedingers' 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 (General 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, and the attractive force between particles of the opposite species. So, a positive Planck Particle is really a quantum field, having (mass, charge) equal to $(+m, +q)$. A negative Planck Par-

ticle 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 $L^{-3} = 3.93\text{E}54$, 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 size or “reach” of the Higgs field. This relation holds for an unperturbed vacuum, *i.e.*, a vacuum with no net energy density or pressure. The coherence length for the Higgs is defined by the relation, $\xi \equiv \hbar / (m_\phi c)$, where m_ϕ equals the mass of the Higgs, $m_\phi = 125.35 \text{ GeV}/c^2$ [17] [18].

The calculation for L is independent of the mass of the Higgs. Hence, there should be no connection between ξ and L . And yet, they are close in value. 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 be a $\langle \psi_+ \psi_- \rangle$ condensate, in the first place. Hence, we took a leap of faith, played with this concept, and made the 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, $L = 5.028\text{E} - 19$ meters, is, by contrast, much larger. It was derived in reference [16]. Our " L " value depends on the CBR (Cosmic Background Radiation) temperature, T_{CBR} , of the universe. 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. See reference [19] for two similar models for a specific cosmic evolution of " L ". Winterberg's value for a fundamental length for space does not scale as the universe expands.

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).

In this paper, in section II, we review our Higgs condensate model. We also establish the upper and lower bounds, pressure-wise, within which the Higgs field can exist as a Planck Particle condensate. Outside of these limits, the Higgs boson, or 3-D space, for that matter, cannot exist if this model for space is valid. In section III, we generalize the concepts of Higgs force and Higgs binding energy within the vacuum, when the vacuum, *i.e.*, 3-D space, is under net pressure or net energy density.

We will also establish limits for the binding force and binding energy. If the quantum vacuum has too much negative pressure, or equivalently, negative net energy density, then the Higgs condensate cannot exist. The converse is also true. If too much positive vacuum pressure, or too much positive vacuum energy density, exists, then the Higgs bond gets broken. We'll establish these limits for one of the simplest examples of a tessellated cell, a cubic cell.

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

According to Winterberg [14], the potential energy operators, $U_{\pm}$, acting on the positive and 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 is 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 $U_-(\psi_-)$. See reference [1] for details and a more rigorous treatment, including the transition from relativistic fields to non-relativistic fields. The Higgs boson is normally considered a field in 4-D space-time.

We next substitute Equation (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 $z + dz$

Then, Equation (2-3) 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. The length scale introduced by Winterberg does not scale with the universe.

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. We may be on the verge of soon observing the graininess of space, directly.

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

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

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

$$M \equiv \hbar / (L c) \quad (2-9a)$$

$$n_0 \equiv L^{-3} \quad (2-9b)$$

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 discrete energy levels 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 collective energy states can differ. Not all are in the ground state, and the excited states within a volume, V , can differ in their respective populations. This leads to $\langle n_+ \rangle \neq \langle n_- \rangle$, in general. 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 boxes, a positive and a negative, to define a net vacuum pressure, or energy density.

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

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

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 Planck Particle equation of state, $p = \rho c^2$. Therefore, by Equation (2-10), we may also write

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

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.

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,

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

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

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

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 have replaced the Planck mass, $m_p = \hbar/(l_p c)$, by the vacuum mass, $M \equiv \hbar/(Lc)$, which is 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], and we found that L equals $L = 5.028\text{E} - 19$ meters. Substituting this into Equation (2-9a), we find

$$M = 6.994\text{E} - 25 \text{ kg} = 392.5 \text{ GeV}/c^2\tag{2-14}$$

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

$$M/m_\phi = 3.13\tag{2-15}$$

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

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

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. In fact, we can explain this number geometrically, which will be done in a follow-up paper. 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 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 $p(\bar{x}) = \Delta p(\bar{x})$. We have also employed Equations (2-9a) and (2-9b). For an unperturbed vacuum, the second terms on the right-hand side of Equation (2-18) vanish. In Equation (3-18), m'_ϕ is the adjusted or modified Higgs mass to take into account any net pressure, or equivalently, any net energy density, within the vacuum. The m_ϕ , on the other hand, is the unperturbed mass of the Higgs boson when the vacuum has no net pressure, or, equivalently, net energy density. In other words, if $\Delta p = \Delta u = 0$, within a region of space, then, $m'_\phi = m_\phi = 125.35 \text{ GeV}/c^2$.

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 ψ_+ Planck Particle cell, and the other to the adjacent 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) now 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 mass of the Higgs field within a volume, V . A net positive vacuum

pressure (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.

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 or, more generally, $2\xi'$, when dealing with a perturbed vacuum. Twice the coherence length is defined from outer end to outer end, and it encompasses two volumes, one for ψ_+ and one for ψ_- . Moreover, remember that $\xi = 3.13L$, holds only for an undisturbed vacuum. 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 $m_\phi c^2 = 125.35 \text{ GeV} = 2.008\text{E}-8 \text{ Joules}$. The V in this equation is, of course, the volume. The volume could be $2L^3$, for two adjacent cubic cells. If $m'_\phi = 0$, then, obviously, $\xi' = \infty$, by Equation (2-22). We have broken the Higgs bond between ψ_+ and ψ_- at this vacuum pressure. The Higgs condensate is no longer a BEC. The pressure required for that is given by Equation (2-23), using the appropriate Higgs volume, $2L^3$. We are assuming that we are decreasing the pressure within the original volume. This dissociation vacuum pressure, or dissociation vacuum energy density, will be important when we construct vortex models for elementary particles (being worked on).

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 cell normally occupies a volume, L^3 . Since ψ_+ , cannot be sitting on top of ψ_- , the smallest value for $2\xi'$ is $2\xi' = L$. Normally, in the unperturbed vacuum state, one with no net pressure or energy density, $2\xi' = 2L$, for a ψ_+ and ψ_- condensate, taken together. If $2\xi' = L$, then $m'_\phi = 2M$, by Equation (2-22). Moreover, Equation (2-21) now reads,

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

Solving for Δp , we find

$$\begin{aligned}\Delta p &= (6.263 - 1)m_\phi c^2 / V \\ &= (5.263)(2.008E - 8) / V\end{aligned}\quad (2-25)$$

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, if 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 $\Delta p = \Delta u$, where Δu is the difference in vacuum energy density.

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 pressure limits. 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 = net energy density. And the $\Delta p = \Delta u$, is the independent variable, 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

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

We have employed our estimated value for L , which is, $L = 5.028E - 19$ meters, in this equation. 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 = net energy density (the independent variable) are constrained. For cubic cells, Equation (2-23) is the lower limit, and Equation (2-25) is the upper limit. When we evaluate those limits numerically, using our volume, Equation (2-26), we find,

$$\Delta p = \Delta u = -7.90E46 \text{ (lower limit, cubic cell)} \quad (2-27a)$$

$$\Delta p = \Delta u = +4.16E47 \text{ (upper limit, cubic cell)} \quad (2-27b)$$

Outside of these limits, the Higgs field cannot exist if we accept the notion that it is a Planck Particle condensate, $\langle \psi_+ \psi_- \rangle$.

3. The Higgs Binding Force, and Binding Energy

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.

$$F_p = \hbar c / l_p^2 = 1.21E44 \text{ Newtons} \quad (3-1)$$

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

$U_p = -F_p l_p = -1.956E9$ Joules. 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 (3-1), we prefer

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

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,

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

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

Actually, a better result is

$$F_{pp} = \hbar c / \xi^2 = 1.28\text{E}10 \text{ Newtons} \quad (3-4)$$

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

$$U_{pp} = -\hbar c / \xi = -m_\phi c^2 = -2.01\text{E} - 8 \text{ Joules} \quad (3-5)$$

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 results will become clearer as we progress further.

We also note in passing that

$$Gm^2 = kq^2 = \hbar c \quad (3-6)$$

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 (3-1) and (3-2), and their modifications, Equations (3-4) and (3-5), therefore, make sense from an electrostatic and gravistatic 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. In fact, in that work, we also tried to make a case for why the gravitational force is, effectively, an electric force.

The numerical value of M , in Equation (3-6), is relatively close to the Higgs mass. See Equations (2-14) through to (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 seemingly accidental 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 (equivalently to net vacuum energy density), before the Higgs condensate bond gets broken apart. See, for example, Equations (2-27a) and (2-27b), which hold for simple cubic 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

$$F_{PP} = \hbar c / \xi'^2 = m_\phi'^2 c^3 / \hbar \quad (3-7)$$

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

$$U_{PP} = -\hbar c / \xi' = -m_\phi' c^2 \quad (3-8)$$

The m'_ϕ is the adjusted 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 . And $2\xi'$ is the size of the Higgs cell, outer cell end to outer cell end. 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 (3-7) and (3-8), it is obvious that a greater Higgs mass means a stronger binding force and binding energy. A weaker Higgs mass, due to negative vacuum pressure, means the opposite. It must lead to a weaker binding force and a weaker binding energy. See Equations (3-7) and (3-8).

4. Summary

We revisited our Higgs condensate model, based on Planck Particles. We were able to establish bounds, upper and lower limits, for vacuum pressure and, equivalently, energy density. Outside of these limits, the Higgs field ceases to exist. This was done for a cubic tessellated cell construction, which was used to model our 3-D space. Other discrete tessellated structures are possible, but a cubic cell is one of the simplest to understand and appreciate. Space is discrete because it has a graininess associated with it. This graininess lies in the realm of the Higgs boson,

energy-wise, if our thinking is correct.

Our fundamental equation for the Higgs field is given by Equation (2-21). From this equation, we see that the Higgs mass is variable and depends critically on the net vacuum pressure = net vacuum energy density. By raising the pressure within a volume, V , we increase the Higgs mass. This implies shrinking its size, or lowering its coherence length, ξ' . By lowering the pressure, the reverse happens. The value of the Higgs mass decreases, and its size, ξ' , increases. See Equations (2-16), (2-22), and (2-21). When the vacuum is undisturbed, with no net pressure or energy density, its mass is simply $m_\phi = 125.35 \text{ GeV}/c^2$. And interestingly enough, if $\Delta p = \Delta u = 0$, then its size, $\xi' = \xi = 3.13L$. See Equations (2-16) and (2-17).

Finally, we talked about binding force and binding energy for a Higgs condensate. These are also variable and are given by Equations (3-7) and (3-8), respectively. The independent variable is the net vacuum pressure= net vacuum energy density, within a volume, V . This determines the Higgs mass and, consequently, the Higgs size, represented by its coherence length, ξ' . If there is no net vacuum pressure, the mass equals $m_\phi = 125.35 \text{ GeV}/c^2$. And the size reduces to $\xi' = \xi = 3.13L$. In a follow-up paper, we will offer a geometrical explanation for why this last relation holds.

Conflicts of Interest

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

References

- [1] Pilot, C. (2021) Is the Higgs Field a Positive and Negative Mass Planckion Condensate, and Does the LHC Produce Extreme Dark Energy? *Journal of High Energy Physics, Gravitation and Cosmology*, **8**, 432-456. <https://doi.org/10.4236/jhepgc.2022.82033>
- [2] Pilot, C. (2023) A New Interpretation of the Higgs Vacuum Potential Energy Based on a Planckion Composite Model for the Higgs. *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 666-683. <https://doi.org/10.4236/jhepgc.2023.93054>
- [3] Winterberg, F. (1988) Substratum Approach to a Unified Theory of Elementary Particles. *Zeitschrift für Naturforschung A*, **43**, 1131-1150. <https://doi.org/10.1515/zna-1988-1219>
- [4] Winterberg, F. (1990) Maxwell's Equations and Einstein-Gravity in the Planck Aether Model of a Unified Field Theory. *Zeitschrift für Naturforschung A*, **45**, 1102-1116. <https://doi.org/10.1515/zna-1990-9-1008>
- [5] Winterberg, F. (1991) Wave Function Collapse as a Real Physical Phenomenon Caused by Vacuum Fluctuations near the Planck Scale. *Zeitschrift für Naturforschung A*, **46**, 746-758. <https://doi.org/10.1515/zna-1991-0903>
- [6] Winterberg, F. (1992) Cosmological Implications of the Planck Aether Model for a Unified Field Theory. *Zeitschrift für Naturforschung A*, **47**, 1217-1226. <https://doi.org/10.1515/zna-1992-1207>
- [7] Winterberg, F. (1993) Physical Continuum and the Problem of a Finitistic Quantum Field Theory. *International Journal of Theoretical Physics*, **32**, 261-277. <https://doi.org/10.1007/bf00673716>

- [8] Winterberg, F. (1994) The Planck Aether Model for a Unified Theory of Elementary Particles. *International Journal of Theoretical Physics*, **33**, 1275-1314. <https://doi.org/10.1007/bf00670794>
- [9] Winterberg, F. (1995) Equivalence and Gauge in the Planck-Scale Aether Model. *International Journal of Theoretical Physics*, **34**, 265-285. <https://doi.org/10.1007/bf00672806>
- [10] Winterberg, F. (1995) Planck Scale Plasma Vacuum and the Fine Structure Constant. *International Journal of Theoretical Physics*, **34**, 399.
- [11] Winterberg, F. (1995) Derivation of Quantum Mechanics from the Boltzmann Equation for the Planck Aether. *International Journal of Theoretical Physics*, **34**, 2145-2164. <https://doi.org/10.1007/bf00673076>
- [12] Winterberg, F. (1997) Planck Scale Physics and Newton's Ultimate Object Conjecture. *Zeitschrift für Naturforschung A*, **52**, 183-209. <https://doi.org/10.1515/zna-1997-1-246>
- [13] Winterberg, F. (2003) Planck Mass Plasma Vacuum Conjecture. *Zeitschrift für Naturforschung A*, **58**, 231-267. <https://doi.org/10.1515/zna-2003-0410>
- [14] Winterberg, F. (2002) The Planck Ether Hypothesis. C.F. Gauss Academy of Science Press.
- [15] Pilot, C. (2021) Does Space Have a Gravitational Susceptibility? A Model for the Density Parameters in the Friedmann Equation. *Journal of High Energy Physics, Gravitation and Cosmology*, **7**, 478-507. <https://doi.org/10.4236/jhepgc.2021.72028>
- [16] Pilot, C. (2021) Q-Theory: A Connection between Newton's Law and Coulomb's Law? *Journal of High Energy Physics, Gravitation and Cosmology*, **7**, 632-660. <https://doi.org/10.4236/jhepgc.2021.72037>
- [17] <https://cms.cern/cms-precisely-measures-mass-higgs-boson>
- [18] <https://atlas.cern/Updates/Briefing/Run2-Higgs-Mass>
- [19] Pilot, C. (2023) On the Cosmic Evolution of the Quantum Vacuum Using Two Variable G Models and Winterberg's Thesis. *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 1134-1160. <https://doi.org/10.4236/jhepgc.2023.94081>