The Gravitational Origin of the Higgs Boson Mass

Friedwardt Winterberg

Department of Physics, College of Science, 1664 N. Virginia Street, University of Nevada, Reno, Nevada 89557-0220, USA. Office: (775) 784-6789, Fax: (775) 784-1398

Reprint requests to F. W.; E-mail: winterbe@unr.edu


Received December 10, 2013 / revised March 10, 2014 / published online May 21, 2014

The Lorentzian interpretation of the special theory of relativity explains all the relativistic effects by true deformations of rods and clocks in absolute motion against a preferred reference system, and where Lorentz invariance is a dynamic symmetry with the Galilei group the more fundamental kinematic symmetry of nature. In an exactly nonrelativistic quantum field theory the particle number operator commutes with the Hamilton operator which permits to introduce negative besides positive masses as the fundamental constituents of matter. Assuming that space is densely filled with an equal number of positive and negative locally interacting Planck mass particles, with those of equal sign repelling and those of opposite sign attracting each other, all the particles except the Planck mass particles are quasiparticles of this positive-negative-mass Planck mass plasma. Very much as the Van der Waals forces is the residual short-range electromagnetic force holding condensed matter together, and the strong nuclear force the residual short range gluon force holding together nuclear matter, it is conjectured that the Higgs field is the residual short range gravitational force holding together pre-quark matter made up from large positive and negative masses of the order $\pm 10^{13}$ GeV. This hypothesis supports a theory by Dehnen and Frommert who have shown that the Higgs field acts like a short range gravitational field, with a strength about 32 orders of magnitude larger than one would expect in the absence of the positive-negative pre-quark mass hypothesis.

Key words: Higgs Boson; Standard Model; Quantum Gravity; Hierarchy Problem.

1. Introduction

Replacing Heisenberg’s nonlinear relativistic spinor equation as a model for a unified theory of elementary particles [1, 2], with an exactly nonrelativistic Heisenberg-type equation [3] ($r_p$ and $m_p$, Planck length and mass) one has

$$i\hbar \frac{\partial \psi_\pm}{\partial t} = \mp \frac{\hbar^2}{2m_p} \nabla^2 \psi_\pm 
\pm 2\hbar c r_p^2 (\psi_\pm^\dagger \psi_\mp - \psi_\mp^\dagger \psi_\pm) \psi_\pm,$$

(1)

where the field operators $\psi^\dagger$, $\psi$ obey the canonical commutation relations

$$[\psi_\pm(x), \psi_\mp^\dagger(y')] = \delta(x - y')$$
$$[\psi_\pm(x), \psi_\pm^\dagger(y')] = \left[ \psi_\mp^\dagger(x), \psi_\mp^\dagger(y') \right] = 0,$$

(2)

where in addition to positive masses, negative masses can be introduced. But unlike Heisenberg’s relativistic spinor equation, it does not lead to a Hilbert space with an indefinite metric with negative probabilities, which has always been the main objection against Heisenberg’s theory.

With the assumption that space is densely filled with an equal number of positive and negative Planck mass particles forming a Planck mass plasma, (1) and (2) describe the quantization and many quasiparticle excitations of this plasma. An in depth study of the quantized Planck mass plasma has shown that it leads to a spectrum of quasiparticles greatly resembling the standard model.

2. The Hierarchical Structure of Matter

The structure of matter can be subdivided into two basic configurations: Those held together by the fundamental long ranges forces: the electromagnetic, the gluon, and the gravitational forces, and those held together by the short range residual forces of the fundamental forces.
The first basic configurations (Fig. 1) are:

A1. Atoms, made up from electrons and nuclei held together by the electromagnetic force, with an energy of the order of eV.

A2. Nucleons, made up from quarks and held together by the strong (color) gluon force, with an energy of the order of GeV.

A3. Quarks, made up from pre-quarks and held together by gravitational forces, with an energy of the order of 100 GeV.

The second kind of configurations (Fig. 2) are:

B1. Condensed matter held together by residual electromagnetic (Van der Waals) forces.

B2. Nuclear matter held together by residual strong (nuclear) forces.

B3. Condensed quark matter held together by residual gravitational (Higgs) forces.

New in this order is the third step because it involves gravitational forces: Pre-quarks bound by the long range gravitational forces and the short range residual (Higgs) gravitational forces.

This idea works by assuming the existence of large negative masses. According to Heisenberg [2], in the hierarchy of elementary particles the concept ‘to be composed of’ becomes problematic if the parts have a mass exceeding the mass of the composition. But this problem does not occur with the admission of negative masses. The existence of negative masses also seems to be needed to satisfy the average null energy condition of general relativity.

For a still better perspective we place in Table 1 the secondary short range forces below the primary long range forces, with the spin for both.

With the Van der Waals and the nuclear force both acting as composed particles it is quite reasonable to assume that the same is true for the Higgs force. Mak-
ing this assumption we can not only derive the Higgs mass but also give support to the conjecture by Dehnen and Frommert [4, 5].

Table 1. (a) long range and (b) short range forces.

<table>
<thead>
<tr>
<th>Force</th>
<th>Particle (fundamental)</th>
<th>Spin</th>
<th>Rest mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic</td>
<td>Photons</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Strong</td>
<td>Gluons</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Gravitational</td>
<td>Gravitons</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Force</th>
<th>Particle (composed)</th>
<th>Spin</th>
<th>Rest mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van der Waals</td>
<td>phonon (boson)</td>
<td>0</td>
<td>≠ 0</td>
</tr>
<tr>
<td>Nuclear</td>
<td>π meson (boson)</td>
<td>0</td>
<td>≠ 0</td>
</tr>
<tr>
<td>Higgs</td>
<td>Higgs (boson)</td>
<td>0</td>
<td>≠ 0</td>
</tr>
</tbody>
</table>

3. The Higgs Mass as the Gravitational Field Mass of a Mass Dipole

The gravitational interaction energy of two masses \( m_1 \) and \( m_2 \) separated by the distance \( r \) is negative and given by \((G \text{ Newton’s constant})\)

\[
E = -\frac{Gm_1m_2}{r} \tag{3}
\]

but the gravitational interaction energy of a mass dipole where \( m_1 = m^+ \) and \( m_2 = m^- = -|m^+| \), with \( m_1m_2 = -|m^\pm|^2 \), is positive and given by

\[
E = \frac{G|m^\pm|^2}{r}. \tag{4}
\]

Without this positive gravitational interaction energy a mass dipole would be self-accelerating, but because
the positive interaction energy gives it a small positive mass equal to
\[ E = \frac{m}{c^2} = \frac{G|m^+|^2}{c^2r} \]  
(5)

It makes a helical motion with the radius
\[ \rho = \frac{\hbar}{2mc} \]  
(6)
asymptotically reaching the velocity of light. This is the pole-dipole configuration extensively studied by Hönl and Papapetrou [6], as a model for Schrödinger’s ‘Zitterbewegung’ of a particle described by the Dirac equation.

Very much as one can estimate the ground state energy for the Bohr atom model with the uncertainty principle \( \Delta p \Delta q \sim \hbar \), we can do the same by combining (5) with the uncertainty principle. As in Bohr’s model we set \( \Delta q \sim r \), but for \( \Delta p \) we have to take the sum of \( |m^+| \) and \( |m^-| \), hence \( \Delta p \sim 2|m^\pm|/c \), and thus have
\[ 2|m^\pm|/c \sim \hbar \]  
(7)
The wave mechanical correctness of (7) for the pole-dipole particle was proven by Bopp [7]. By setting \( m = M_H \), where \( M_H \) is the Higgs mass, one obtains by eliminating \( r \) from (5) and (7)
\[ M_H = \frac{2G|m^\pm|^3}{\hbar c} \]  
(8)
or
\[ \frac{M_H}{m_p} = 2\left(\frac{|m^\pm|}{m_p}\right)^3 \]  
(9)
where \( m_p = \sqrt{\hbar G / c} \) is the Planck mass. Solving for \( |m^\pm| \) one has
\[ \frac{|m^\pm|}{m_p} = \left(\frac{M_H}{m_p}\right)^{1/3} \]  
(10)

With \( M_H \sim 10^2 \) GeV, \( m_p \sim 10^{19} \) GeV, one finds that \( |m^\pm| \approx 10^{13} \) GeV. The energy ratio \( m_p/|m^\pm| \sim 10^6 \) is of the same order as the nuclear–atomic energy ratio.

Because \( |m^\pm|c^2 \ll m_p c^2 \), quantum gravity can be ignored, as the quantum electrodynamical corrections to the Coulomb potential can be ignored in the Bohr atom model. The question still remains where the large energy of \( \sim 10^{15} \) GeV comes from. It is shown that the Planck mass plasma can offer a possible answer.

4. Planck Mass Plasma Model

As stated above, the Planck mass plasma hypothesis is the assumption that the vacuum is densely occupied with an equal number of positive and negative Planck mass particles, on average one Planck mass particle for each Planck length volume [3]. In its ground state the Planck mass plasma is a superfluid, which for each positive or negative mass component has a phonon-roton spectrum, in addition to a variety of quantized vortex configurations in low lying excited states [8]. For a line vortex the quantization condition is
\[ m_p \int v \cdot ds = nh, \quad n = 1, 2, \ldots \]  
(11)

For the lowest state with \( n = 1 \), one finds in setting \( v = v_\phi \)
\[ v_\phi = \frac{\hbar}{m_p r} \]  
(12)
or with \( \hbar = m_p r p c \) that
\[ \begin{cases} v_\phi = cr_p/r & \text{for } r > r_p, \\ v_\phi = 0 & \text{for } r < r_p. \end{cases} \]  
(13)

If a line vortex is deformed into a vortex ring of radius \( R \), it can undergo elliptic oscillations with the frequency [9]
\[ \omega = cr_p/R^2. \]  
(14)

If these oscillations are quantized, the ground state energy is \( \hbar \omega \). We thus put \( |m^\pm|c^2 = \hbar \omega \) or
\[ \hbar \omega = m_pc^2(r_p/R)^2. \]  
(15)

If in its ground state the Planck mass plasma is made up of a lattice of such vortex rings, then the distance of separation \( l = 2R \) in between two adjacent vortex rings determines the energy \( \hbar \omega \). For a two-dimensional vortex lattice, the distance \( l \) between two line vortices had been determined by Schlayer [10], by computing the stability of the Karman vortex street. Schlayer found the configuration to be stable for
\[ r_0 = 3.4 \times 10^{-3} l, \]  
(16)
where \( r_0 \) is the radius of the vortex core. Setting \( r_0 = r_p \) and \( l = 2R \), one obtains from (16) that
\[ R/r_p = 147. \]  
(17)
No likewise stability calculation seems to have been made for a three-dimensional lattice of vortex rings, but with Schlayer’s result a guess can be made. For line vortices, the stability apparently arises from the fluid velocity of adjacent vortices. But for a ring vortex the fluid velocity is larger by the factor \( \log(8R/r_p) \), compared to the velocity of a line vortex [11].

With \( R/r_p = 147 \) for a line vortex, a better value for a ring vortex should be obtained by solving the equation

\[
R/r_p = 147 \log \left( \frac{8R}{r_p} \right)
\]  

(18)

with the result that

\[
R/r_p = 1360.
\]  

(19)

With this value we obtain from (15) that

\[
\hbar \omega_v \approx 10^{13} \text{ GeV}
\]  

(20)

which is of the right order of magnitude to explain the Higgs mass.

There are good reasons for the Higgs field to be a residual short range gravitational field having its origin in the gravitational field of a very large positive and negative mass, as the Van der Waals force is a residual short range electromagnetic field having its origin in positive and negative electric charges, and the nuclear force a residual short range gluelike force having its origin in the color charges of the quarks.

5. Conclusion

The result obtained with this simple model supports the conjecture by Dehnen, made more than two decades ago, that the Higgs field is a kind of short range gravitational field. It is the assumption for the existence of negative masses which explains why the Higgs field appears to be ultrastrong, because it has its source in very large (\( \pm 10^{13} \) GeV) positive and negative masses. The existence of negative masses implies that the fundamental symmetry of nature is the Galilei group, where the particle numbers are conserved with the particle number operator commuting with the Hamilton operator, and where Lorentz invariance is explained dynamically by true deformations of rods and clocks, as in the pre-Einstein theory of relativity by Lorentz and Poincaré. The assumption of negative masses can make a bridge between the weak and the Planck energy scale, thereby also solving the hierarchy problem of elementary physics.

With the derivation of the Higgs mass from a resonance energy of the Planck mass plasma, Dehnen’s equation (3.5) from [5],

\[
\gamma = \frac{g^2}{2} \left( \frac{m_p}{M_{H}} \right)^2 = 2 \cdot 10^{32},
\]  

(21)

is derived without the need for any new physics.