The Planck Vacuum

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This paper argues that there is a polarizable vacuum state (the Planck vacuum) that is the source of the quantum vacuum; the free particles; the gravitational, fine structure, and Planck constants; the gravitational field and the spacetime of General Relativity; the Maxwell equations and the Lorentz transformation; and the particle Compton relations and the quantum theory.

1 Introduction

This is an unusual paper that needs to be put into perspective to be understood because the definitions contained herein evoke preconceived ideas that get in the way of the reader. For example, the words "bare charge" mean something very specific to the quantum-field-theory specialist that evoke notions of renormalization and Feynman diagrams. The definition of these words given here, however, mean something quite different; so this preface is intended to provide a setting that will make the paper easier to understand.

About ten years ago the author derived the gravitational ($G = e_*^2/m_*^2$), Planck ($\hbar = e_*^2/c$), and also fine structure ($\alpha = e^2/e_*^2$) constants in a somewhat confused and mixed-up manner. Although their derivation at that time left something to be desired, the simple elegance and connectedness of these three fundamental equations has provided the motivation behind the search for their explanation. Thus it was the "leading" of these three constants that resulted in the paper that is about to be read. The intent at the beginning of the investigations was not some urge to discover a grand theory that unifies diverse areas of physics, although the search for the physics behind the constants appears to be doing just that.

The Planck vacuum (PV) state is envisioned as an infinite, invisible (not directly observable), omnipresent, uniform, and homogeneous negative energy state somewhat analogous to the Dirac "sea" in quantum mechanics. The quantum vacuum, on the other hand, consists of virtual particles that appear and disappear at random in free space, the space where free particles and the rest of the universe are observed. The source of this quantum vacuum is assumed to be the PV, where the fields of the quantum vacuum are analogous to non-propagating induction fields with the PV as their source. The PV is also assumed to be the source of the free particles.

The charge of the Planck particle is called the bare charge, and it is this bare charge that is the true, unscreened, charge of the electron and the rest of the charged elementary particles. The polarizability of the PV is shown to be responsible for the fact that the observed electronic charge e has a smaller magnitude than the bare charge e_*.

The PV theory is not derived from some pre-existing theory, e.g. the quantum field theory — it is assumed to be the source of these pre-existing theories. The simple calculations in the paper lead to the above constants and from there to the many suggestions, assumptions, speculations, and hand-waving that necessarily characterize the PV theory at this early stage of development. It is expected, however, that the theory will eventually lead to a "sea change" in the way we view fundamental physics. So let's begin.

The two observations: "investigations point towards a compelling idea, that all nature is ultimately controlled by the activities of a single *superforce*", and "[a living vacuum] holds the key to a full understanding of the forces of nature"; come from Paul Davies' popular 1984 book [1] entitled *Superforce: The Search for a Grand Unified Theory of Nature*. This living vacuum consists of a "seething ferment of virtual particles", and is "alive with throbbing energy and vitality". Concerning the vacuum, another reference [2] puts it this way; "we are concerned here with virtual particles which are created alone (e.g., photons) or in pairs (e^+e^-), and with the vacuum — i.e., with space in which there are no real particles". This modern vacuum state, as opposed to the classical void, is commonly referred to as the quantum vacuum (QV) [3]. The virtual particles of this vacuum are jumping in and out of existence within the constraints of the Heisenberg uncertainty principle ($\Delta E \Delta t \sim \hbar$); i.e., they appear for short periods of time (Δt) depending upon their temporal energy content (ΔE), and then disappear. The QV, then, is an ever-changing collection of virtual particles which disappear after their short lifetimes Δt, to be replaced by new virtual particles which suffer the same fate, ad infinitum.

Among other things, the following text will argue that the source of the QV is the Planck vacuum (PV) [4] which is an omnipresent degenerate gas of negative-energy Planck particles (PP) characterized by the triad (e_*, m_*, r_*), where e_*, m_*, and r_* ($\lambda_*/2\pi$) are the PP charge, mass, and Compton radius respectively. The charge e_* is the bare (true) electronic charge common to all charged elementary particles and is related to the observed electronic charge e through the fine structure constant $\alpha = e^2/e_*^2$ which is one manifestation of the PV polarizability. The PP mass and Compton radius are equal to the Planck mass and length [5] respectively. The zero-point (ZP) random motion of the PP charges e_* about their equilibrium positions within the PV, and the PV dynamics, are the source of both the QV and the free particles. The PV is held together by van der Waals forces. In addition to the fine structure constant, the PV is the source of the gravitational ($G = e_*^2/m_*^2$) and Planck ($\hbar = e_*^2/c$) constants. The non-propagating virtual fields of the QV are assumed to be real fields appearing in free space which are analogous to induction fields with the PV as their source.

A charged elementary particle is characterized by the triad (e_*, m, r_c), where m and r_c are the particle's mass and Compton radius. The field *intrinsic* to the particle is the bare Coulomb field $e_*\mathbf{r}/r^3$, where $\mathbf{r}$ is the radius vector from the particle to the field point. All other fields, classical or quantum, associated with the particle and its motion arise from this fundamental field and its interaction with the PV.

Section 2 traces the concept of the PV from the first observation of the initial paragraph after the preface to the derivation of the fine structure, gravitational, and Planck constants; to the Compton relation of the PP; and to the free-space permittivities. A rough heuristic argument shows the binding force of the vacuum to be van-der-Waals in nature.

The ultimate PV-curvature force is derived in Section 2 from Newton's gravitational equation. This ultimate force is shown in Section 3 to be tied to the Riemannian spacetime of General Relativity (GR) which, therefore, is related to the real physical curvature of the PV. As a consequence, GR describes the *spacetime* curvature of the PV.

Using the Coulomb field of the bare charge, the polarizability of the PV, and an internal feedback mechanism intrinsic to the PV; Section 4 derives the relativistic electric and magnetic fields associated with the charge, and infers the Lorentz transformation and constancy of the speed of light from the results.

The electromagnetic vacuum (EV) consists of the virtual photons mentioned in the first paragraph which lead collectively to the ZP electromagnetic field with which Section 5 argues that the EV has its origin in the PV.

A free charged particle distorts the PV in two ways. Its bare Coulomb field polarizes the vacuum, and its mass exerts a van-der-Waals attractive force on the PPs of the PV. Section 6 shows how these two vacuum-distorting forces lead to the quantum mechanics and, by inference from Section 5, to the quantum field theory (QFT).

Section 7 summarizes and comments on the ideas presented in Sections 1 through 6.

2 Planck particle and vacuum

The idea from Davies' first observation that a single superforce controls all of nature is interpreted here to mean that the ultimate strengths of nature's fundamental forces are identical, whether those forces are actually realizable or just asymptotically approachable. The static Coulomb and gravitational forces between two like, charged elementary particles are used in this section to derive the fine structure constant, the ultimate Coulomb force, the ultimate gravitational force, the gravitational constant, and the ultimate PV-curvature force. Using a new expression (4) for the gravitational force, and the results from the above; the Compton relation of the PP, and the free-space permittivities (the dielectric constant and magnetic permeability) are derived. These derivations utilize three normalization constants to isolate the ultimate forces. The three constants correspond to charge normalization (e_*), mass normalization (m_*), and length normalization (r_*). These constants start out as normalization constants, but end up defining a new fundamental particle (the PP) and a fundamental vacuum state (the PV).

The static Coulomb force between two like, charged particles can be expressed in the following two forms:

$$F_{\text{el}} = \frac{e^2}{r^2} = \alpha \left(\frac{r_*}{r}\right)^2 F'_* \,, \tag{1}$$

where r is the distance between particles, $\alpha \equiv e^2/e_*^2$, and $F'_* \equiv e_*^2/r_*^2$. If e_* is assumed to be the maximum particle charge (the electronic charge unscreened by a polarizable vacuum state), and r_* is assumed to be some minimum length ($r_* < r$ for all r); then F'_* is the ultimate Coulomb force.

The static gravitational force of Newton acting between two particles of mass m separated by a distance r can be expressed in the following forms:

$$-F_{\text{gr}} = \frac{m^2 G}{r^2} = \frac{m^2}{m_*^2} \left(\frac{r_*}{r}\right)^2 F_* \,, \tag{2}$$

where G denotes Newton's gravitational constant, and $F_* \equiv m_*^2 G/r_*^2$. If m_* is the maximum elementary particle mass, and r_* is the minimum length, then F_* is the ultimate gravitational force as m_*/r_* is the maximum mass-to-length ratio.

Adhering to the idea of a single superforce implies that the force magnitudes F'_* and F_* must be equal. This equality leads to the definition of the gravitational constant

$$G = \frac{e_*^2}{m_*^2} \tag{3}$$

in terms of the squared normalization constants e_*^2 and m_*^2.

The gravitational force in (2) can also be expressed as

$$-F_{\text{gr}} = \frac{(mc^2/r)^2}{c^4/G} \tag{4}$$

by a simple manipulation where c is the speed of light. The ratio mc^2/r has the units of force, as does the ratio c^4/G. It can be argued [6] that c^4/G is a superforce, i.e. some kind of ultimate force. The nature of the two forces, mc^2/r and c^4/G, is gravitational as they emerge from Newton's gravitational equation; but their meaning at this point in the text is unknown. As an ultimate force, c^4/G can be equated to the ultimate gravitational force F_* because of the single-superforce assumption. Equating c^4/G and F_* then leads to

$$\frac{c^4}{G} = \frac{m_*\,c^2}{r_*} \tag{5}$$

for the ultimate force c^4/G. It is noteworthy that the form m_*c^2/r_* of this force is the same as that ratio in the parenthesis of (4), which must be if c^4/G is to represent an ultimate force of the form mc^2/r. That (5) is an ultimate force is clear from the fact that m_* is the ultimate particle mass and r_* is the minimum length, roughly the nearest-neighbor distance between the PPs constituting the PV.

Invoking the single-superforce requirement for the ultimate force c^4/G from (5) and the ultimate Coulomb force F'_* leads to

$$\frac{m_*c^2}{r_*} = \frac{e_*^2}{r_*^2} \tag{6}$$

or

$$r_*m_*c = \frac{e_*^2}{c} \equiv \hbar\,, \tag{7}$$

where e_*^2/c defines the (reduced) Planck constant. Furthermore, if the reasonable assumption in made that the minimum length r_* is the Planck length [5], then m_* turns out to be the Planck mass [5]. Noting also that (7) has the classic form of a Compton relation, where r_* is the Compton radius ($\lambda_*/2\pi$), it is reasonable to assume that the triad (e_*, m_*, r_*) characterizes a new particle (the PP). Thus the Compton radius r_* of the PP is $r_* = e_*^2/m_*c^2$.

The units employed so far are Gaussian. Changing the units of the first equation in (7) from Gaussian to mks units [7] and solving for ϵ_0 leads to

$$\epsilon_0 = \frac{e_*^2}{4\pi r_*m_*c^2} \qquad \text{[mks]} \tag{8}$$

where ϵ_0 is the electric permittivity of free space in mks units. Then, utilizing $\epsilon_0\mu_0 = 1/c^2$ leads to

$$\mu_0 = 4\pi\,\frac{r_*m_*}{e_*^2} \qquad \text{[mks]} \tag{9}$$

for the magnetic permittivity. The magnitude of μ_0 is easy to remember — it is $4\pi\times10^{-7}$ in mks units. Thus r_*m_*/e_*^2 in (9) had better equal 10^{-7} in mks units, and it does (e_* in Gaussian units is obtained from (3) and G, or from (7) and $\hbar$; and then changed into mks units for the calculation).

Shifting (8) and (9) out of mks units back into Gaussian units leads to

$$\epsilon = \frac{1}{\mu} = \frac{e_*^2}{r_*m_*c^2} = 1 \tag{10}$$

for the free-space permittivities in Gaussian units. Considering the fact that the free-space permittivities are expressed exclusively in terms of the parameters defining the PP, and the speed of light, it is reasonable to assume that the free-space vacuum (the PV) is made up of PPs. Furthermore, the negative-energy solutions to the Klein-Gordon equation or the Dirac equation [3], and the old Dirac hole theory [3], suggest that a reasonable starting point for modeling the PV may be an omnipresent gas of negative-energy PPs.

The PV is a monopolar degenerate gas of charged PPs. Thus the PPs within the vacuum repel each other with strong Coulombic forces, nearest neighbors exerting a force roughly equal to

$$\frac{e_*^2}{r_*^2} = \left(\frac{5.62\times10^{-9}}{1.62\times10^{-33}}\right)^2 \sim 10^{49} \quad \text{[dyne]} \tag{11}$$

where r_* is roughly the nearest-neighbor distance. The question of what binds these particles into a degenerate gas naturally arises. The following heuristic argument provides an answer. Using the definition of the gravitational constant ($G = e_*^2/m_*^2$), the gravitational force between two *free* PPs separated by a distance r can be written in the form

$$-\frac{m_*^2 G}{r^2} = -\frac{e_*^2}{r^2} \tag{12}$$

leading to a total gravitational-plus-Coulomb force between the particles equal to

$$(-1+\alpha)\,\frac{e_*^2}{r^2} \tag{13}$$

where the Coulomb force ($\alpha e_*^2/r^2$) comes from (1). This total force is attractive since the fine structure constant $\alpha \approx 1/137 < 1$. The total force between two PPs *within* the PV must be roughly similar to (13). Thus it is reasonable to conclude that the vacuum binding force is gravitational in nature.

3 General Relativity

Newton's gravitational force acting between two particles of mass m_1 and m_2 separated by a distance r can be expressed as

$$\begin{aligned} F_{\mathrm{gr}} = -\frac{(m_1c^2/r)(m_2c^2/r)}{c^4/G} &= \\ = \frac{(-m_1c^2/r)(-m_2c^2/r)}{-m_*c^2/r_*}&\,, \end{aligned} \tag{14}$$

where (5) has been used to obtain the second expression. Although the three forces in the second expression must be gravitational by nature as they come from the gravitational equation, their meaning is unclear from (14) alone.

Their meaning can be understood by examining two equations from the GR theory [5], the Einstein metric equation

$$G_{\mu\nu} = \frac{8\pi T_{\mu\nu}}{c^4/G} = \frac{8\pi T_{\mu\nu}}{m_*c^2/r_*} \tag{15}$$

and the Schwarzschild equation

$$ds^2 = -\left[1-2n(r)\right]c^2dt^2 + \frac{dr^2}{\left[1-2n(r)\right]} + r^2\,d\Omega^2 \tag{16}$$

where the n-ratio is

$$n(r) \equiv \frac{mc^2/r}{c^4/G} = \frac{mc^2/r}{m_*c^2/r_*} \tag{17}$$

and where $G_{\mu\nu}$ is the Einstein curvature tensor, $T_{\mu\nu}$ is the energy-momentum density tensor, ds is the Schwarzschild line element, and dt and dr are the time and radius differentials. The remaining parameter in (16) is defined in [5]. The line element in (16) is associated with the curvature of spacetime outside a static spherical mass — in the particle case the equation is only valid outside the particle's Compton radius [8]. For a vanishing mass ($m = 0$), the n-ratio vanishes and the metric bracket $[1 - 2n(r)]$ reduces to unity; in which case (16) describes a flat (zero curvature or Lorentzian) spacetime.

As mc^2/r in (16) and (17) is a spacetime-curvature force, (14) implies that m_1c^2/r and m_2c^2/r are PV curvature forces. The ultimate curvature force m_*c^2/r_* appears in the denominators of (14), (15), and (17). Thus it is reasonable to conclude that the theory of GR refers to the *spacetime*-curvature aspects of the PV. The forces m_1c^2/r and m_2c^2/r are attractive forces the masses m_1 and m_2 exert on the PPs of the PV at a distance r from m_1 and m_2 respectively.

According to Newton's third law, if a free mass m exerts a force mc^2/r on a PP within the PV at a distance r from m, then that PP must exert an equal and opposite force on m. However, the PP at $-r$ exerts an opposing force on m; so the net average force the two PPs exert on the free mass is zero. By extrapolation, the entire PV exerts a vanishing average force on the mass. As the PPs are in a perpetual state of ZP agitation about their average "r" positions, however, there is a residual, random van der Waals force that the two PPs, and hence the PV as a whole, exert on the free mass.

Puthoff [9] has shown the gravitational force to be a long-range retarded van der Waals force, so forces of the form mc^2/r are essentially van der Waals forces. The ZP electromagnetic fields of the EV are the mechanism that provides the free-particle agitation necessary to produce a van der Waals effect [9]. But since the source of the EV is the PV (see Section 5), the PV is the ultimate source of the agitation responsible for the van-der-Waals-gravitational force between free particles, and the free-particle-PV force mc^2/r.

4 Maxwell and Lorentz

The previous two sections argue that curvature distortions (mass distortions) of the PV are responsible for the curvature force mc^2/r and the equations of GR. This section argues that polarization distortions of the PV by free charge are responsible for the Maxwell equations and, by inference, the Lorentz transformation. These ends are accomplished by using the bare Coulomb field of a free charge in uniform motion, a feedback mechanism intrinsic to the PV [10], and the Galilean transformation; to derive the relativistic electric and magnetic fields of a uniformly moving charge.

The bare Coulomb field $e_*\mathbf{r}/r^3$ intrinsic to a free bare charge e_* polarizes the PV, producing the Coulomb field

$$\mathbf{E}_0 = \frac{e\mathbf{r}}{r^3} = \frac{e}{e_*}\frac{e_*\mathbf{r}}{r^3} = \alpha^{1/2}\frac{e_*\mathbf{r}}{r^3} = \frac{e_*\mathbf{r}}{\epsilon' r^3} \tag{18}$$

observed in the laboratory, and creating the effective dielectric constant ϵ' $(\equiv e_*/e = 1/\sqrt{\alpha})$ viewed from the perspective of the bare charge, where α is the fine structure constant. In terms of the fixed field point (x, y, z) and a charge traveling in the positive z-direction at a uniform velocity v, the observed field can be expressed as

$$\mathbf{E}_0 = \frac{e\left[x\widehat{\mathbf{x}} + y\widehat{\mathbf{y}} + (z - vt)\widehat{\mathbf{z}}\right]}{\left[x^2 + y^2 + (z - vt)^2\right]^{3/2}}, \tag{19}$$

where the charge is at the laboratory-frame origin $(0, 0, 0)$ at time $t = 0$. This expression assumes that the space-time transformation between the charge- and laboratory-coordinate frames is Galilean.

The observed field produces an effective dipole at each field point. When the charge moves through the vacuum, the dipole rotates about the field point and creates an effective current circulating about that point. The circulating current, in turn, produces the magnetic induction field*

$$\mathbf{B}_1 = \boldsymbol{\beta} \times \mathbf{E}_0 = \frac{e\beta(z - vt)}{r^3}\boldsymbol{\phi}, \tag{20}$$

where $\beta = v/c$, $\boldsymbol{\beta} = \beta\widehat{\mathbf{z}}$, $\boldsymbol{\phi}$ is the azimuthal unit vector, and $r^2 = x^2 + y^2 + (z - vt)^2$ is the squared radius vector $\mathbf{r}\cdot\mathbf{r}$ from the charge to the field point. The field $\mathbf{B}_1$ is the first-step magnetic field caused by the bare charge distortion of the PV.

An iterative feedback process is assumed to take place within the PV that enhances the original electric field $\mathbf{E}_0$. This process is mathematically described by the following two equations [10]:

$$\nabla \times \mathbf{E}_n = -\frac{1}{c}\frac{\partial \mathbf{B}_n}{\partial t} \tag{21}$$

and

$$\mathbf{B}_{n+1} = \boldsymbol{\beta} \times \mathbf{E}_n, \tag{22}$$

where n $(= 1, 2, 3\ldots)$ indicates the successive partial electric fields $\mathbf{E}_n$ generated by the PV and added to the original field $\mathbf{E}_0$. The successive magnetic fields are given by (22). Equation (21) is recognized as the Faraday equation.

The calculation of the final electric field $\mathbf{E}$, which is the infinite sum of $\mathbf{E}_0$ and the remaining particle fields $\mathbf{E}_n$, is conducted in spherical polar coordinates and leads to [10]

$$\mathbf{E} = \frac{(1 - \lambda)\,\mathbf{E}_c}{\left(1 - \beta^2\sin^2\theta\right)^{3/2}}, \tag{23}$$

where λ is the infinite sum of integration constants that comes from the infinity of integrations of (21) to obtain the $\mathbf{E}_n$, and θ is the polar angle between the positive z-direction and the radius vector from the charge to the field point. The field $\mathbf{E}_c$ is the observed static field of the charge, i.e. equation (19) with $v = 0$. The final magnetic field is obtained from $\mathbf{B} = \boldsymbol{\beta} \times \mathbf{E}$.

*The polarization vector $\mathbf{P} = \chi_e\mathbf{E}_0 = (\epsilon' - 1)\mathbf{E}_0/4\pi$ rotating about a field point in the PV produces an effective current proportional to $\beta\sin\theta$ which leads to the magnetic induction field $\mathbf{B}_1 = \boldsymbol{\beta}\times\mathbf{E}_0$.

Finally, the constant λ can be evaluated from the conservation of electric flux [10] (the second of the following equations) which follows from Gauss' law and the conservation of bare charge e_* (the first equation):

$$\int \mathbf{D} \cdot \mathbf{dS} = 4\pi e_* \longrightarrow \int \mathbf{E} \cdot \mathbf{dS} = 4\pi e \tag{24}$$

where $\mathbf{dS}$ is taken over any closed Gaussian surface surrounding the bare charge, and where $\mathbf{D} = \epsilon' \mathbf{E} = (e_*/e)\mathbf{E}$ is used to bridge the arrow. Inserting (23) into the second equation of (24) and integrating yields

$$\lambda = \beta^2 \tag{25}$$

which, inserted back into (23), leads to the relativistic electric field of a uniformly moving charge [7]. The relativistic magnetic field is $\mathbf{B} = \boldsymbol{\beta} \times \mathbf{E}$. The conservation of electric flux expressed by the second equation of (24) is assumed as a postulate in [10]. The first equation shows that the postulate follows from Gauss' law and the conservation of bare charge.

The relativistic field equations $\mathbf{E}$ and $\mathbf{B}$ for a uniformly moving charge are derived above from the Coulomb field $e_*\mathbf{r}/r^3$ of the bare charge in (18), an assumed PV feedback dynamic given by (21) and (22), and the *Galilean* transformation. Of course, the relativistic equations can also be derived [7] from the Coulomb field $e\mathbf{r}/r^3$ (where $r^2 = x^2 + y^2 + z^2$) of the observed electronic charge e at rest in its own coordinate system, and the *Lorentz* transformation. It follows, then, that the Lorentz transformation is a mathematical shortcut for calculating the relativistic fields from the observed charge e ($= e_* \sqrt{\alpha}$) without having to account directly for the polarizable PV and its internal feedback dynamic. Furthermore, it can be argued that the constancy of the speed of light c from Lorentz frame to Lorentz frame, which can be deduced from the resulting Lorentz transformation, is due to the presence of the PV in the photon's line of travel.

If there were no polarizable vacuum, there would be no rotating dipole moments at the field points (x, y, z); and hence, there would be no magnetic field. A cursory examination of the free-space Maxwell equations [7] in the case where the magnetic field $\mathbf{B}$ vanishes shows that the equations reduce to $\nabla \cdot \mathbf{E} = 4\pi\rho_*$, and to the equation of continuity between e_* and its current density. Thus it can be argued that the Maxwell equations owe their existence to the polarizable PV.

5 Electromagnetic vacuum

The EV is the photon part of the QV mentioned at the beginning of the Introduction, i.e. the virtual photons that quickly appear and dissappear in space. This section argues that the EV has its origin in the PV.

The virtual photons of the EV lead to the ZP electric field (see [9] for detail)

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \mathrm{Re} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \widehat{\mathbf{e}}_\sigma \{A_k\} \times \times \exp\left[i\left(\mathbf{k} \cdot \mathbf{r} - \omega t + \Theta\right)\right] \tag{26}$$

the spectrum of which Sakharov [11] has argued must have an upper cutoff wavenumber k_{c*} that is related to the "heaviest particles existing in nature". In the present context, the heaviest particles existing in nature are clearly PPs. Puthoff [9, 12] has calculated the wavenumber to be $k_{c*} = \sqrt{\pi c^3/\hbar G}$, which can be expressed as $k_{c*} = \sqrt{\pi}/r_*$ by substituting the constants $\hbar = e_*^2/c$ and $G = e_*^2/m_*^2$ and using the PP Compton relation. The cutoff wave number is characteristic of the minimum length r_*, the Compton radius of the PP, associated with the PV.

The amplitude factor in (26) is [9]

$$A_k = \left(\frac{\hbar\omega}{2\pi^2}\right)^{1/2} = e_* \left(\frac{k}{2\pi^2}\right)^{1/2}, \tag{27}$$

where $\hbar = e_*^2/c$ and $k = \omega/c$ are used to obtain the second expression. This result implies that bare charges are the source of the ZP field, for if e_* were zero, the amplitude factor would vanish and there would be no field. It is reasonable to assume that these bare charges reside in the PV.

Equation (26) can be expressed in the more revealing form

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \left(\frac{\pi}{2}\right)^{1/2} \frac{e_*}{r_*^2}\, \mathbf{I}_{\mathrm{zp}}(\mathbf{r}, t)\,, \tag{28}$$

where $\mathbf{I}_{\mathrm{zp}}$ is a random variable of zero mean and unity mean square; so the factor multiplying $\mathbf{I}_{\mathrm{zp}}$ in (28) is the root-mean-square ZP field. Since $m_* c^2/r_*^3$ is roughly the energy density of the PV, the ZP field can be related to the PV energy density through the following sequence of equations:

$$\frac{m_* c^2}{r_*^3} = \frac{e_*^2/r_*}{r_*^3} = \left(\frac{e_*}{r_*^2}\right)^2 \approx \langle \mathbf{E}_{\mathrm{zp}}^2 \rangle\,, \tag{29}$$

where the PP Compton relation is used to derive the second ratio, and the final approximation comes from the mean square of (28). The energy density of the PV, then, appears to be intimately related to the ZP field. So, along with the k_{c*} and the A_k from above, it is reasonable to conclude that the PV is the source of the EV.

6 Quantum theory

A charged particle exerts two distortion forces on the collection of PPs constituting the PV, the curvature force mc^2/r and the polarization force e_*^2/r^2. Sections 2 and 3 examine the PV response to the curvature force, and Section 4 the response to the polarization force. This section examines the PV response to both forces acting *simultaneously*, and shows that the combination of forces leads to the quantum theory.

The equality of the two force magnitudes

$$\frac{mc^2}{r} = \frac{e_*^2}{r^2} \quad \Longrightarrow \quad r_c = \frac{e_*^2}{mc^2} \tag{30}$$

at the Compton radius r_c of the particle appears to be a fundamental property of the particle-PV interaction, where m is the particle mass. This derivation of the Compton radius shows the radius to be a particle-PV property, not a property solely of the particle.

The vanishing of the force difference $e_*^2/r_c^2 - mc^2/r_c = 0$ at the Compton radius can be expressed as a vanishing tensor 4-force [7] difference. In the primed rest frame ($\mathbf{k}' = \mathbf{0}$) of the particle, where these static forces apply, this force difference $\Delta F'_\mu$ is ($\mu = 1, 2, 3, 4$)

$$\Delta F'_\mu = \left[\mathbf{0},\ i\left(\frac{e_*^2}{r_c^2} - \frac{mc^2}{r_c}\right)\right] = [0,\ 0,\ 0,\ i\,0]\,, \qquad (31)$$

where $i = \sqrt{-1}$. Thus the vanishing of the 4-force component $\Delta F'_4 = 0$ in (31) is the source of the Compton radius in (30) which can be expressed in the form $mc^2 = e_*^2/r_c = (e_*^2/c)(c/r_c) = \hbar\omega_c$, where $\omega_c \equiv c/r_c = mc^2/\hbar$ is the Compton frequency associated with the Compton radius r_c. As an aside: the transformation of the force difference (31) to the laboratory frame using $\Delta F_\mu = a_{\mu\nu}\Delta F'_\nu$ leads to a $\Delta F_3 = 0$ from which the de Broglie radius ($\lambda_d/2\pi$), $r_d \equiv r_c/\beta\gamma = \hbar/m\gamma v$, can be derived.

In what follows it is convenient to define the 4-vector wavenumber tensor

$$k_\mu = (\mathbf{k}, k_4) = (\mathbf{k}, i\,\omega/c)\,, \qquad (32)$$

where $\mathbf{k}$ is the ordinary vector wavenumber, and $i\omega/c$ is the frequency component of k_μ. This tensor will be used to derive the particle-vacuum state function, known traditionally as the particle wavefunction.

The vanishing of the 4-force component $\Delta F'_4$ from (31) in the rest frame of the particle leads to the Compton frequency ω_c. Thus from (32) applied to the prime frame, and $\mathbf{k}' = \mathbf{0}$, the equivalent rest-frame wavenumber is $k'_\mu = (\mathbf{0}, i\,\omega_c/c)$.

The laboratory-frame wavenumber, where the particle is traveling uniformly along the positive z-axis, can be found from the Lorentz transformation $k_\mu = a_{\mu\nu}k'_\nu$ [7] leading to

$$k_z = \gamma k'_z - i\beta\gamma k'_4 \quad \text{and} \quad k_4 = i\beta\gamma k'_z + \gamma k'_4\,, \qquad (33)$$

where

$$a_{\mu\nu} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \gamma & -i\beta\gamma \\ 0 & 0 & i\beta\gamma & \gamma \end{pmatrix} \qquad (34)$$

is used, $\beta = v/c$ and $\gamma^2 = 1/(1-\beta^2)$, and where the x- and y-components of the wavenumbers vanish in both frames. With $k'_z = 0$ and $k'_4 = i\,\omega_c/c$, the laboratory-frame wavenumber from (32) and (33) becomes

$$k_\mu = (0,\ 0,\ \beta\gamma\omega_c/c,\ i\gamma\omega_c/c) = (0,\ 0,\ p/\hbar,\ iE/c\hbar)\,, \qquad (35)$$

where $p = m\gamma v$ and $E = m\gamma c^2$ are the relativistic momentum and energy of the particle. The second parenthesis in (35) is derived from the first parenthesis and $\omega_c = mc^2/\hbar$, from which $k_z = p/\hbar$ and $k_4 = i\,E/c\hbar = i\,\omega_z/c$ emerge.

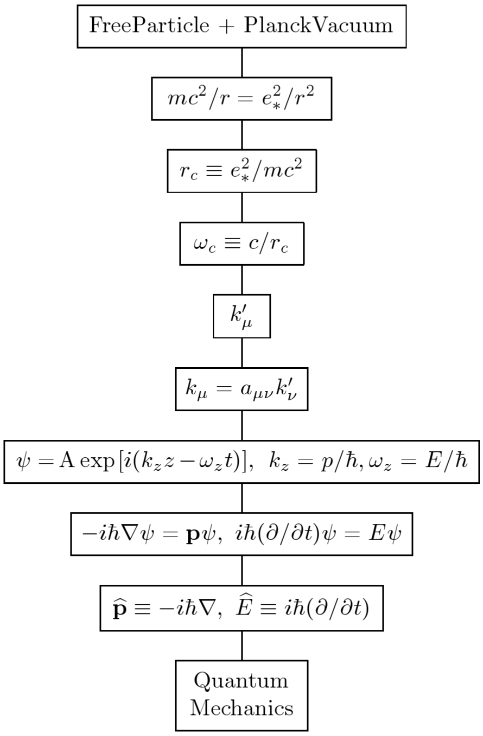

Fig. 1: The flow-diagram traces the particle-vacuum interaction to the Compton radius r_c and the Compton frequency ω_c. From there, the corresponding four-vector wavenumber k'_μ and the Lorentz transformation lead to the particle-vacuum wavefunction ψ, the gradient and time derivative of which then yield the momentum and energy operators, and the quantum mechanics.

The relativistic momentum p and energy E in $k_z = p/\hbar$ and $\omega_z = E/\hbar$ characterize the classical particle motion, and suggest the simple plane-wave

$$\psi = \mathrm{A}\exp\left[i(k_z z - \omega_z t)\right] = \mathrm{A}\exp\left[i(pz - Et)/\hbar\right] \qquad (36)$$

as a suitable state function to characterize the wave behavior of the particle-PV system. This laboratory-frame state function reduces to the state function $\psi = \mathrm{A}\exp\left(-imc^2t/\hbar\right)$ in the particle rest frame where $v = 0$. The $S(z,t) \equiv pz - Et$ in the exponent of (36) are particular solutions (for various nonvanishing m) of the free-particle, relativistic Hamiltonian-Jacobi equation [8, p.30] although this fact is not used here in deriving the state function.

Since $-i\hbar\nabla\psi = \mathbf{p}\psi$ and $i\hbar(\partial/\partial t)\psi = E\psi$ from (36), it is clear that the momentum ($\widehat{\mathbf{p}} \equiv -i\hbar\nabla$) and energy ($\widehat{E} \equiv i\hbar(\partial/\partial t)$) operators have their origin in the vacuum perturbation caused by the two forces mc^2/r and e_*^2/r^2 as these two forces are responsible for the wavefunction (36). Once the operators $\widehat{\mathbf{p}}$ and $\widehat{E}$ are defined, the quantum mechanics follows from the various classical (non-quantum) energy equations of particle dynamics. A flow-diagram of the preceding calculations is given in Figure 1.

The preceding calculations leading from the particle-PV interaction to the quantum mechanics are straightforward. Tracing the QFT [12] of the massive particles to the PV is less clearcut however. Nevertheless, as Section 5 shows the PV to be the source of the EV, it is easy to conclude that the PV must also be the source of the massive-particle-vacuum (MPV) part of the QV, and thus the QFT.

7 Summary and comments

This paper presents a new theory in its initial and speculative stage of development. Sections 2 through 6: show that the fine structure constant, the gravitational constant, and the Planck constant come from the PV; derive the free-space permittivities in terms of the PP parameters, showing that the free-space vacuum and the PV are one and the same; show that the previously unexplained force mc^2/r is a curvature force that distorts both the PV and the spacetime of GR, and that GR describes the spacetime aspects of the PV; show the PV to be the source of the Maxwell equations and the Lorentz transformation; show that the QV has its origin in the PV; show that the PV is the source of the Compton relations ($r_c mc = \hbar$) and the quantum theory.

The Compton radius r_c ($= e_*^2/mc^2$) is traditionally ascribed to the particle, but emerges from the PV theory as a particle-PV interaction parameter. Inside r_c ($r < r_c$) the polarization force dominates ($e_*^2/r^2 > mc^2/r$) the curvature force, while outside the reverse is true. Both the EV and MPV parts of the QV are omnipresent, but inside r_c the MPV is responsible for the particle *Zitterbewegung* [3, p.323] caused by "exchange scattering" taking place between the particle and the MPV, resulting in the particle losing its single-particle identity inside r_c.

The development of the PV theory thus far is fairly simple and transparent. The theory, however, is fundamentally incomplete as particle spin is not yet included in the model. Calculations beyond the scope and complexity of those here are currently underway to correct this deficiency.

Even in its presently incomplete state, the PV theory appears to offer a fundamental physical explanation for the large body of mathematical theory that is the vanguard of modern physics. The predictive ability of the QFT, or the modern breakthroughs in astrophysics made possible by GR, are nothing less than spectacular; but while the equations of these theories point toward a fundamental reality, they fall short of painting a clear picture of that reality. Most students of physics, for example, are familiar with the details of the Special Theory of Relativity, and a few with the differential tensor calculus of GR. In both cases, however, the student wonders if there is a real physical space related to these mathematically-generated spacetimes, or whether these spacetimes are just convenient schematic diagrams to help visualize the mathematical artifacts in play. The present paper argues that there is indeed a real physical space associated with spacetime, and that space is the free-space PV.

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