A Model for Davies' Universal Superforce

W. C. Daywitt[1]

Abstract

This paper pursues the idea that nature is controlled by one universal superforce and suggests a unification of the Newton and Coulomb forces under this universal force. Calculations yield a super-particle (SP) whose parameters define the gravitational, Planck, and fine-structure constants, plus the permittivity and permeability of free space. The superforce is seen to be the source of the zero-point (ZP) electromagnetic fields.

Keywords: Compton wavelength, fine-structure constant, free-space vacuum, gravitational constant, Planck constant, superforce, unification, zero-point fields.

1 Introduction

Davies' observations that "...investigations point towards a compelling idea, that all nature is ultimately controlled by the activities of single *superforce*.", and that an energetic vacuum "...holds the key to a full understanding of the forces of nature." [1] are inspired in part by the negative energy states and anti-particles accompanying the second quantization of all single particle fields, and in part by the ubiquitous and unavoidable presence of the ZP vacuum fields [2]. That the vacuum states may be polarizable is generally accepted and some calculations [3] suggest that this polarizability may lead to an explanation for the curvature of space.

The Einstein tensor-field equation for gravity [4]

$$R_{\mu\nu} - (1/2)g_{\mu\nu}R + g_{\mu\nu}\Lambda = (8\pi G/c^4)T_{\mu\nu} \tag{1}$$

the quintessential expression for this space curvature, contains the ratio c^4/G where c is the speed of light and G is Newton's gravitational constant. This ratio has the units of force and it can be argued [5] that c^4/G is the magnitude of the universal superforce of Davies' first observation.

The modern vacuum is closely related to the ZP field energy which persists even at the absolute zero of temperature where classically all motion ceases [2] and where the vacuum energy density spectrum is generally assumed to cover all frequencies from zero to infinity. However, Sakharov [6,4] argues from a relativistic vacuum-fluctuation model for gravity that Newton's gravitational constant G should be determined by the equation

$$G = \frac{2Ac^5}{\hbar\omega_c^2} \qquad \text{or} \qquad \omega_c = \left(\frac{2Ac^5}{\hbar G}\right)^{1/2} \tag{2}$$

where ω_c is an effective Planck cutoff frequency for the ZP-fluctuation spectrum of the vacuum and where the constant A is of unity order. In effect, the frequency range of the energy density spectrum is truncated at the upper frequency

[1] *Galilean Electrodynamics*, Sept./Oct., 83(2006).

ω_c. Furthermore, the inverse relationship between G and ω_c, and the weakness of the gravitational force imply that this effective cutoff frequency must be very large (but not infinite as $G \neq 0$), a result that prompted Sakharov to note that ω_c must be related to "the heaviest particles existing in nature".

In a stochastic-electrodynamic (SED) calculation, Puthoff [7] realizes Sakharov's hypothesis of the last paragraph in a fully self-consistent way from a point-particle, ZP-fluctuation model for gravity. In the process he calculates the cutoff frequency to be $\omega_c = \sqrt{\pi}\omega_*$ ($\omega_* = m_* c^2/\hbar$ is the Planck frequency for the Planck mass m_* [4]), yielding the constant $A = \pi/2 \sim 1$ for (2). Although the static SP vacuum calculations to follow cannot determine this cutoff frequency, the results of the calculations will agree in every other aspect with both the Sakharov and Puthoff calculations, thereby lending significant support to the new vacuum model.

If it is assumed that nature is controlled by a single superforce, then this force must certainly be responsible for the two well-known static forces of Newton and Coulomb. This conclusion suggests that the vacuum force which is derived from the superforce and its associated SP vacuum state must in some way reflect the $1/r^2$ nature of these static forces, and provides a starting point for the theoretical calculations of the next section. Emerging from that section will be a SP theory that defines the gravitational, Planck, and fine-structure constants and the free-space permittivities; that unifies both the Newton and Coulomb forces under a superforce with the Heaston magnitude c^4/G [5]; and that shows the superforce to be the source of the well-established ZP electromagnetic fields.

A 'Summary and Discussion' section that takes a closer look at the vacuum force; that briefly relates the present theory to classical electron theory and the quantum mechanics of the free particle ends the paper.

2 A Super-Particle Vacuum

The section begins by assuming the static Newton and Coulomb forces to be proportional to the same universal force F_* and develops equivalent equations for these forces. Three normalization constants, e_*^2, m_*^2, and r_*^2, are generated in addition to the two ratios $G = e_*^2/m_*^2$ and $\alpha = e^2/e_*^2$. The first ratio provides a fundamental definition for Newton's gravitational constant in terms of two of the normalization constants. Here the constant α is merely a convenient way of writing the ratio e^2/e_*^2. At this point, the equations are nothing more than a mathematical curiosity awaiting further development to give them meaning.

In the next step the universal force F_* is set equal in *magnitude* to the superforce c^4/G of the Einstein equation (1), leading to two more ratios $e_*^2/r_*^2 = c^4/G$ and $m_*^2/r_*^2 = c^4/G^2$. Eliminating G between these two ratios leads to the equation $r_* m_* c = e_*^2/c$ between only the normalization constants. Now, if a value for r_* were given, then both e_* and m_* could be determined and the results checked to see if the first ratio in the preceding paragraph does indeed numerically yield the gravitational constant. If that numerical value is correct, then the value chosen for r_* is also correct, leading to the values that both e_*

and m_* must assume. The gravitational constant calculation provides the first check on the self-consistency of the development.

Having determined the magnitudes of all the normalization constants, the constant α and both sides of the equation $r_* m_* c = e_*^2/c$ can now be evaluated. The calculation will show α to be the fine-structure constant. Also, both sides of the equation will agree numerically, providing another self-consistency check on the development. Furthermore, the calculations will show e_*^2/c to be the (reduced) Planck constant and the corresponding equation to be the definition of the Compton wavelength relationship in terms of the normalization constants. This last result shows the normalization constants to be the viable parameters (e_*,m_*,r_*) of an elementary particle.

With the definition for the Planck constant established, the relationship between it and the gravitational constant shows the particle (e_*,m_*,r_*) defined above to be the SP cutting off the vacuum-fluctuation spectrum. The second quantization of the corresponding single-particle field would then lead to the SP vacuum state. This result is followed immediately by the results of a SED calculation showing F_* to be the origin of the well-established ZP electromagnetic fields, thus independently re-affirming the concept of F_* as a universal force.

Finally, the calculations end by showing the SP vacuum to be polarizable. Another self-consistency check is provided here with regard to the mks value of the free-space magnetic permittivity (permeability). So, let the calculations begin.

The static gravitational and electrical forces acting between two charged elementary particles are given by the Newton and Coulomb equations

$$F_{\rm gr}(r) = -\frac{m_1 m_2 G}{r^2} \qquad \text{and} \qquad F_{\rm el}(r) = \pm\frac{e^2}{r^2} \tag{3}$$

where m_1 and m_2 are the particle masses and e is the observed electronic charge. These are classical equations so r must be larger than the larger of the two Compton radii (reduced Compton wavelengths) associated with the masses m_1 and m_2. Since both forces are assumed to be proportional to a single universal force F_*, it will be necessary to 'normalize out' the units of the mass product $m_1 m_2$, the radius squared r^2, and the charge product e^2 in order to effect this assumption. Choosing the corresponding normalization constants to be m_*^2, r_*^2 and e_*^2 respectively, leads from the equations in (3) to the equations

$$F_{\rm gr}(r) = -\left(\frac{r_*}{r}\right)^2 \frac{m_1 m_2}{m_*^2} F_* \qquad \text{and} \qquad F_{\rm el}(r) = \pm\left(\frac{r_*}{r}\right)^2 \left(\frac{e}{e_*}\right)^2 F_* \tag{4}$$

where now both $F_{\rm gr}$ and $F_{\rm el}$ are proportional to F_* as desired. It is clear that for these equations to reduce to the initial two, the three equations in

$$F_* = \frac{m_*^2 G}{r_*^2} = \frac{e_*^2}{r_*^2} \tag{5}$$

must be satisfied simultaneously. Finally, inserting the second expression for F_* into the equations of (4) leads to (inserting the first expression for F_* is unproductive)

$$F_{\rm gr}(r) = -\frac{m_1 m_2}{m_*^2}\frac{e_*^2}{r^2} \qquad \text{and} \qquad F_{\rm el}(r) = \pm\alpha\frac{e_*^2}{r^2} \tag{6}$$

where $\alpha \equiv e^2/e_*^2$. At this point the equations in (6) are just a mathematical curiosity, although the definition $G = e_*^2/m_*^2$ (from the second equation in (5)) for the gravitational constant in terms of two of the normalization constants has been generated. For lack of a better name, the force e_*^2/r^2 in (6) will be referred to as the 'vacuum force'.

Setting the magnitude of the force F_* equal to the superforce c^4/G of the Einstein equation (1) allows the first equation in (5) to be solved for G ($= r_* c^2/m_*$) which can be substituted back into (5) to reexpress F_* in terms of only the normalization constants:

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

The second equation in (7) yields

$$r_* m_* c = \frac{e_*^2}{c}\ (\equiv \hbar) \tag{8}$$

where the parenthesis will be discussed later. Note that both (7) and (8) required setting $F_* = c^4/G$. Alternatively, setting F_* to c^4/G in (5) also yields the ratios $e_*^2/r_*^2 = c^4/G$ and $m_*^2/r_*^2 = c^4/G^2$ which will be useful below to determine the magnitudes of e_* and m_* from r_*.

The formal development from (3) to (8) becomes more compelling when the magnitudes of the normalization constants are identified. Assigning a value to the normalization constant r_* will allow the values of e_* and m_* to be determined from the two equations at the end of the previous paragraph. A reasonable choice for r_* is the Planck length L^* [4] as the superforce F_* can be reasonably assumed to apply to the Planck level of forces. Making this choice ($r_* = 1.616 \times 10^{-33}$ [cm]) sets the value of m_* to the Planck mass (2.177×10^{-5} [gm]) and the value of e_* to 5.623×10^{-9} [esu]. With these values for m_* and e_*, the ratio $G = e_*^2/m_*^2$ does indeed lead to the correct value (6.673×10^{-8} [dyn cm^2/gm^2]) for the gravitational constant — so the results thus far are self-consistent. Also, the unknown ratio $\alpha = e^2/e_*^2 = 7.297 \times 10^{-3}$ when the value of the observed electronic charge $e = 4.803 \times 10^{-10}$ [esu] is inserted. Since the value calculated for α is the fine-structure constant, the ratio e^2/e_*^2 is the fundamental definition for that constant.

Calculating the ratio e_*^2/c gives the same value (1.054×10^{-27} [erg sec]) as the (reduced) Planck constant $\hbar$. Therefor, the ratio e_*^2/c defines the Planck constant, showing the nature of that constant to be a ratio of squared charge and velocity rather than a product of energy and time. The fact that the lhs of (8) equals the rhs numerically provides another self-consistency check. The Compton relation (8) qualifies the constants (e_*,m_*,r_*) as the parameters of an elementary particle.

The particle (e_*,m_*,r_*) defined above and the definition of Planck's constant allow the gravitational constant to be expressed as

$$G = \frac{e_*^2}{m_*^2} = \frac{c\hbar}{(\hbar\omega_*/c^2)^2} = \frac{c^5}{\hbar\omega_*^2} = \frac{2(\pi/2)c^5}{\hbar\omega_c^2} \tag{9}$$

where $\omega_c = \sqrt{\pi}\omega_*$ (see the Introduction) was used to obtain the final expression. This result agrees precisely with the Sakharov[6]-Puthoff[7] results from the discussion of equation (2). In the spirit of those results, then, e_* and m_* must be the charge and mass of that 'heaviest particle' envisioned by Sakharov to cut off the ZP-fluctuation spectrum of the vacuum.

Second quantization of the SP wavefunction (not pursued in the present text) would lead to the *SP vacuum* consisting of negative energy states and the collection of anti-SPs [2]. The ZP electromagnetic fields from these multi-particle states should manifest themselves in the ZP vacuum fields of both QED and SED. Evidence that this is so is obtained from the truncated SED representation of the ZP electric field [7,8] given by

$$\mathbf{E}_{\rm zp} = {\rm R}e \sum_{\sigma=1}^{2} \int_0^{k_c} d^3k\, \widehat{\mathbf{e}}\, A_k \exp[i(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta(\mathbf{k},\sigma))] \tag{10}$$

where $k_c = \omega_c/c$ is the cutoff wavenumber and 'Re' stands for 'real part of'. The amplitude spectral density in (10) is given by

$$A_k = \left(\frac{\hbar\omega}{2\pi^2}\right)^{1/2} = e_* \left(\frac{k}{2\pi^2}\right)^{1/2} \tag{11}$$

where $\hbar = e_*^2/c$ and $k = \omega/c$ have been used to obtain the final expression. The field in (10) can be more recognizably expressed as

$$\mathbf{E}_{\rm zp} = \left(\frac{\pi}{2}\right)^{1/2} \frac{F_*}{e_*} \mathbf{I}_{\rm zp} \tag{12}$$

where the expectation value $< \mathbf{I}_{zp}^2 >= 1$ is calculated over the random phase $\Theta(\mathbf{k},\sigma)$ in (10), and leads to the rms value of the electric field equal to the factors multiplying $\mathbf{I}_{zp}$ in (12). This result shows the well-established ZP electromagnetic fields, $\mathbf{E}_{\rm zp}$ and $\mathbf{H}_{\rm zp}$, to be proportional to the superforce field F_*/e_*, suggesting that F_* is the source of those ZP fields.

Viewed in terms of the bare charge, the SP vacuum is highly polarizable: comparing the second equations in (3) and (6) leads to the conclusion that the electronic charge e is the screened version of the bare charge e_*, so the SP vacuum polarizability could be characterized by

$$\epsilon = \frac{e_*}{e} = \frac{1}{\sqrt{\alpha}} \doteq 12 \qquad \text{and} \qquad \chi_{\rm e} = \frac{e_* - e}{4\pi e} \tag{13}$$

which are an effective dielectric constant and electric susceptibility respectively. These constants are, of course, unobserved because the bare charge is always screened. Nevertheless, this high vacuum polarizability is real — indeed, the fine-structure constant owes its existence to this effect. Calculations in the next paragraph illustrate other hidden and important facets of the vacuum-SP connection.

Shifting into mks units for the duration of the present paragraph, the free-space electric and magnetic permittivities can be expressed in terms of the SP parameters by changing the Gaussian units of (8) to mks units and solving for ϵ_0:

$$\epsilon_0 = \frac{e_*^2}{4\pi r_* m_* c^2} \qquad \text{and} \qquad \mu_0 = \frac{4\pi r_* m_*}{e_*^2} \qquad [\text{mks}] \tag{14}$$

where the magnetic permittivity μ_0 comes from $\mu_0\epsilon_0 = 1/c^2$. It is noteworthy that the ratio $r_* m_*/e_*^2$ in mks units (with $e_* = 1.876 \times 10^{-18}$ [Coulomb] from the earlier esu units) is numerically equal to 10^{-7} as it must since $\mu_0 = 4\pi \times 10^{-7}$ in those units. A dimensional check on the equations in (14) shows them to have the proper mks dimensions also. These agreements in magnitude and dimensionality represent another check on the self-consistency of the development and provide further evidence that the SP (e_*,m_*,r_*) is a "creature" of the vacuum state. The ratio of electric-to-magnetic plane-wave field amplitudes becomes

$$\frac{E}{H} = \left(\frac{\mu_0}{\epsilon_0}\right)^{1/2} = \frac{4\pi r_* m_* c}{e_*^2} \doteq 377\,[\text{ohms}] \qquad [\text{mks}] \tag{15}$$

where again the magnitude and dimensions are correct.

The results of the previous paragraph become

$$\epsilon = \frac{e_*^2}{r_* m_* c^2} = 1 \qquad \text{and} \qquad \mu = \frac{r_* m_* c^2}{e_*^2} = 1 \tag{16}$$

and

$$\frac{E}{H} = \left(\frac{\mu}{\epsilon}\right)^{1/2} = \frac{r_* m_* c^2}{e_*^2} = 1 \tag{17}$$

in Gaussian units.

3 Summary and Discussion

What started out as a set of normalization constants (e_*^2,m_*^2,r_*^2) ended up as the parameters (e_*,m_*,r_*) of an elementary super-particle. To metamorphose from normalization constants to particle parameters, these parameters had to numerically satisfy a remarkable number of conditions and equations simultaneously: the three equations in (5) in addition to $F_* = c^4/G$; the values for G, $\hbar$, and α; the Compton relation (8); the Sakharov condition (2); equation (12) for the ZP electric field; and the vacuum equations from (14) to (17). The Compton relation (8) shows that these parameters define an elementary particle (e_*,m_*,r_*) and, through the superforce in (7), the SP vacuum. This vacuum state is, as witnessed by equations (14) through (17), intimately connected to the free-space vacuum of electromagnetic theory and appears to be the source of the ZP vacuum fields.

The SP calculations and the Puthoff calculations in [7] are radically different in their respective approaches, yet the two produce remarkably similar results in those areas where they intersect. This kind of agreement between two theories significantly strengthens both. The calculations in [7] derive the gravitational constant $G = \pi c^5/\hbar\omega_c^2 = c\hbar/m_*^2$ which is the same as the SP result if the substitution $\hbar = e_*^2/c$ is made. For like particles, then, both theories lead to

$$F_{\rm gr}(r) = -\frac{m^2 G}{r^2} = -\frac{m^2(e_*^2/m_*^2)}{r^2} = -\left(\frac{r_*}{r_c}\right)^2 \frac{e_*^2}{r^2} \qquad (18)$$

where the ratio $(r_*/r_c)^2$ comes from $r_* m_* = r_c m$ which originates in the Compton relations. This ratio converts the so-called vacuum force e_*^2/r^2 into the gravitational force although the static SP theory presented here is incapable of explaining that ratio's electromagnetic origin. Puthoff, however, has shown the gravitational force to be a long range van der Waals force, so this ratio is a mathematical construct that accounts for the ZP averaging process germane to that force [7]. It could also be argued that the vacuum force is a mathematical construct, but at this early stage of the SP development it doesn't seem so — two pieces of information argue for that conclusion. The first is that the Coulomb force in (6) is also proportional to the vacuum force even though the Coulomb force is significantly different from the gravitational force. The second indication comes from the calculations immediately below.

The quantum field (QED) expression [9,2] for the effective Coulomb potential $V_{\rm ef}(r)$ of two identical point charges of mass m separated by a distance r ($\gg r_c$) is

$$V_{\rm ef}(r) = \frac{e^2}{r}\left[1 + \frac{\alpha}{2\sqrt{\pi}}\left(\frac{r_c}{r}\right)^{3/2} \exp(-2r/r_c)\right] \qquad (19)$$

where r_c ($= e_*^2/mc^2$) is the Compton radius associated with the particles. The second term in (19) represents the local screening of the observed e-charges due to their interaction with the electron-positron field from the Dirac 'sea'. Using $\alpha = e^2/e_*^2$ changes (19) to

$$V_{\rm ef}(r) = \frac{e_*^2}{r}\left[\alpha + \frac{\alpha^2}{2\sqrt{\pi}}\left(\frac{r_c}{r}\right)^{3/2} \exp(-2r/r_c)\right] \qquad (20)$$

where the global screening of the bare e_*-charges represented by the first term in (20) is, of course, due to the basic $1/r^2$ nature of the vacuum force. Again, the second term represents the local screening. The form of (20) suggests an intimate connection between the SP vacuum (first term) and the Dirac 'sea' (second term), the Dirac 'sea' appearing perhaps as an offspring of the parent SP vacuum. Heuristically, equation (20) can be taken a step further by expanding it to include the gravitational potential:

$$V_{\rm ef}(r) = \frac{e_*^2}{r}\left[-\left(\frac{r_*}{r_c}\right)^2 + \alpha + \frac{\alpha^2}{2\sqrt{\pi}}\left(\frac{r_c}{r}\right)^{3/2} \exp(-2r/r_c)\right] \qquad (21)$$

where the first and second terms represent the Newton and Coulomb potentials corresponding to (6). Dynamically speaking, the two bare charges responsible for (21) are separated by an average distance r and perform a small random dance around their average positions due to agitation from the ZP vacuum fields. The point of this calculation, however, is that the universal nature of the vacuum force multiplying the bracket in (21) survives even to the QED third term.

The Compton radius r_* is related to those of the proton and electron through the coupling e_*^2 in the string of Compton relations (the subscripts p and e refer to the proton and electron respectively)

$$r_* m_* c^2 = r_p m_p c^2 = r_e m_e c^2 = e_*^2. \tag{22}$$

The premature breakdown in classical electron theory is eliminated by assigning this bare charge e_* to the electron rather than the screened version e. For then the Compton electron radius r_e $(= e_*^2/m_e c^2)$ is that distance at which classical breakdown is expected as the electron is approached rather than the much smaller and quantum mechanically troublesome [2] classical radius r_0 $(= e^2/m_e c^2)$.

Finally, the free particle Schrödinger, Klein-Gordon, and Dirac equations share similar plane-wave solutions of the form

$$\Psi = A \exp(iS/\hbar) \tag{23}$$

where the dynamic phase function $S = \mathbf{P} \cdot \mathbf{r} - Et$ is a solution of the appropriate Hamilton-Jacobi equation [10]. Rewriting (23) in the form

$$icS = c\hbar \log(\Psi/A) = e_*^2 \log(\Psi/A) \tag{24}$$

reveals the bare-charge coupling $c\hbar = e_*^2$ connecting the particle and its classical Lagrangian $L = dS/dt$ to the particle's quantum mechanical phase $\log(\Psi/A)/i$ and the SP vacuum.

References

[1] P. Davies, *Superforce: The Search for a Grand Unified Theory of Nature*, (Simon and Schuster, New York, 1984).

[2] P.W. Milonni, *The Quantum Vacuum: An Introduction to Quantum Electrodynamics*, (Academic Press, New York, 1994).

[3] H.E. Puthoff, "Polarizable-Vacuum (PV) Approach to General Relativity," *Foundations of Physics*, Vol. 32, No. 6, pp. 927-943, June 2002.

[4] C.W. Misner, K.S. Throne, J.A.Wheeler, *Gravitation*, (W.H. Freeman and Co., San Francisco, 1973).

[5] R.J. Heaston, "Identification of a Superforce in the Einstein Field Equations," Journal of the Washington Academy of Sciences, Vol. 80, No. 1, pp. 23-27, March 1990.

[6] A.D. Sakharov, "Vacuum Quantum Fluctuations in Curved Space and the Theory of Gravitation," Dokl. Akad. Nauk SSSR [Sov. Phys. – Dokl. **12**, pp. 1040-1041, 1968].
[7] H.E. Puthoff, "Gravity as a Zero-Point-Fluctuation Force," Phys. Rev. **A**, Vol. 39, No. 5, pp. 2333-2344, 1989..
[8] L. de la Peña, A.M. Cetto, *The Quantum Dice: An Introduction to Stochastic Electrodynamics* (Kluwer Academic Publishers, Boston 1996).
[9] R. Serber, "Linear Modifications in the Maxwell Field Equations," Phys. Rev. **48**, pp. 49-54, 1935. E.A. Uehling, "Polarization Effects in the Positron Theory," Phys. Rev. **48**, pp. 55-60, 1935.
[10] H. Goldstein, *Classical Mechanics*, second edition, (Addison-Wesley Publishing Co., Massachusetts, 1980).