The Structured Proton and the Structureless Electron as Viewed in the Planck Vacuum Theory

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This paper argues that the proton possesses structure because the positive proton charge attracts the negative-energy vacuum toward the massive proton core, exposing a small spherical portion of that vacuum to free-space perturbations. Calculations indicate that the apparent charge spread of the proton is due to this structure.

1 Introduction

The proton and electron are Dirac particles in the sense that they both possess a Compton radius and they both obey the Dirac equation, but the positive and negative charge of the proton and electron make their characteristics radically different. For example, the proton is smaller and more massive than the electron because of this charge difference [1]. It is shown below that this difference also accounts for the proton structure and its apparent charge spread. The structure is the result of the perturbed Planck vacuum (PV) state [2] in the vicinity of the massive proton core.

In its rest frame the proton core (e_*, m_p) exerts the following two-term coupling force [3] [4]

$$F_p(r) = \frac{(e_*)(-e_*)}{r^2} + \frac{m_p c^2}{r} = -F_s\left(\frac{r_p^2}{r^2} - \frac{r_p}{r}\right) \tag{1}$$

on the PV negative-energy continuum, where the proton Compton radius $r_p\ (= e_*^2/m_p c^2)$ is the radius at which the force vanishes. The mass of the proton is m_p and the bare charge e_* is massless. The radius r begins at the proton core and ends on any particular Planck-particle charge $(-e_*)$ at a radius r within the PV. The strong force

$$F_s \equiv \left|\frac{(e_*)(-e_*)}{r_p^2}\right| = \frac{m_p c^2}{r_p} \tag{2}$$

is the magnitude of the two forces in the first sum of (1) where the sum vanishes. The (e_*) in (1) and (2) belongs to the free-space proton and the $(-e_*)$ to the separate Planck particles of the PV, where the first and second ratios in (1) and (2) are vacuum polarization and curvature forces respectively. It follows that the strong force is a proton/PV force (rather than a free-space/free-space force). The Planck particle mass m_* and Compton radius r_* are equal to the Planck Mass and Planck Length [5, p. 1234]. (The three Compton relations $r_e m_e c^2 = r_p m_p c^2 = r_* m_* c^2 = e_*^2$ and $c\hbar = e_*^2$ are used throughout the preceding and the following calculations.)

The massive electron core $(-e_*, m_e)$ exerts the coupling force

$$F_e(r) = \frac{(-e_*)(-e_*)}{r^2} - \frac{m_e c^2}{r} = F_w\left(\frac{r_e^2}{r^2} - \frac{r_e}{r}\right) \tag{3}$$

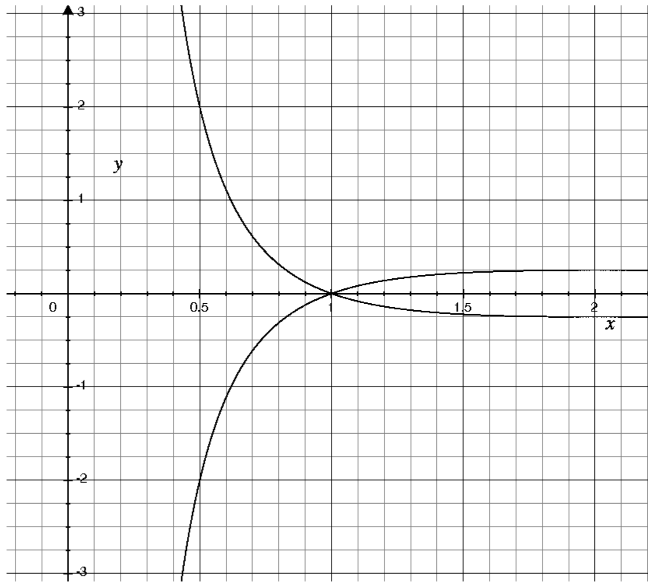

Fig. 1: Graphs of the normalized coupling forces $F_p(r)/F_s$ with $r_p = 1$ (negative to the left), and $F_e(r)/F_w$ with $r_e = 1$ (positive to the left). $(r_e/r_p = 1836)$

on the vacuum state and leads to the Compton radius $r_e\ (= e_*^2/m_e c^2)$, where the first $(-e_*)$ in (3) belongs to the electron. The weak force

$$F_w \equiv \frac{(-e_*)(-e_*)}{r_e^2} = \frac{m_e c^2}{r_e} \tag{4}$$

is the magnitude of the two forces in the first sum of (3) where the sum vanishes. Again, the first and second ratios in (3) and (4) are vacuum polarization and curvature forces respectively. Thus the weak force, like the strong force, is an electron/PV force.

It is important to note that, for $r < r_p \ll r_e$, $F_p(r)$ and $F_e(r)$ are negative and positive respectively (Figure 1). That is, the proton and electron cores attract and repel respectively the Planck particles $(-e_*, m_*)$ within the PV. This is the phenomenon that gives the proton structure, while denying structure to the electron.

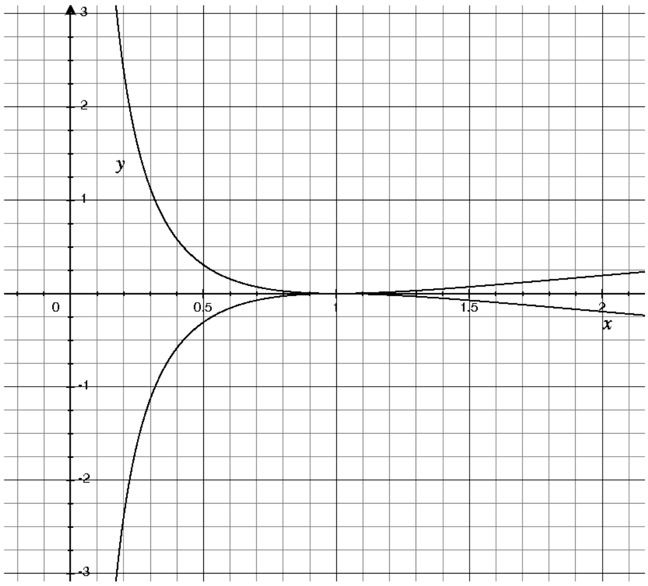

Fig. 2: Graphs of the normalized coupling potentials $V_p(r)/m_pc^2$ with $r_p = 1$ (upper curve), and $V_e(r)/m_ec^2$ with $r_e = 1$ (lower curve). $(r_e/r_p = 1836)$

2 Proton structure

The potential energy associated with the coupling forces (1) and (3) is defined as

$$V(r) = \int F(r)dr + V_0 \tag{5}$$

so that $dV/dr = F$ and $V(r_c) = 0$, where $r_c = e_*^2/mc^2$ is the force's Compton radius. For the proton and electron this definition leads to

$$\frac{V_p(r)}{m_pc^2} = \frac{r_p}{r} - 1 - \ln\left(\frac{r_p}{r}\right) \tag{6}$$

and

$$\frac{V_e(r)}{m_ec^2} = 1 - \frac{r_e}{r} + \ln\left(\frac{r_e}{r}\right) \tag{7}$$

where (6) and (7) yield $V_p(r) \geq 0$ and $V_e(r) \leq 0$ over the entire range of the radius r (Figure 2).

The spirit of the Klein Paradox discussed in Appendix A is that, if a region of free space is subjected to a sufficiently large *positive* potential, then an electron impinging on that region can extract energy from the negative-energy vacuum state. The following assumes that this paradox reflects a real physical phenomenon, implying that the positive charge of the proton core (but not the negative charge of the electron core) can expose a small region of the PV to perturbations from free-space particles. This conclusion leads to a structured proton and a structureless electron.

Equation (6) yields the quadrature formula

$$x = 1 + \frac{V_p}{m_pc^2} + \ln x \qquad \text{with} \qquad x \equiv r_p/r \tag{8}$$

from which the proton structure can be derived, where x is defined in the open interval $(0, \infty)$. The proton-proton (p-p) overlap radius (Appendix A) is determined by setting $V_p = 2m_pc^2$ in (8) and results in

$$x = 3 + \ln x \tag{9}$$

which leads to $x = 4.50$ and the p-p overlap radius r_1 ($\equiv r_p/4.50$). This is the radius where the negative-energy level $-m_pc^2$ of the vacuum state just enters the positive-energy level m_pc^2 of the free-space proton in its rest frame.

The negative energy maximum associated with the PV is $-m_ec^2$. Thus the proton electron-proton (e-p) overlap radius results from $V_p = m_pc^2 + m_ec^2$ and yields

$$\begin{aligned} x &= 1 + \frac{(m_pc^2 + m_ec^2)}{m_pc^2} + \ln x \\ &= 2 + \frac{r_p}{r_e} + \ln x \approx 2 + \ln x \end{aligned} \tag{10}$$

where $m_e/m_p = r_p/r_e = 1/1836$. Solving (10) leads to $x = 3.15$ and r_2 ($\equiv r_p/3.15$) for the e-p overlap radius. The sphere within the outer overlap radius r_2 ($> r_1$) represents the total exposed portion of the PV, and the surface of that sphere takes on a positive polarization charge due to the proton-core charge.

The size of the core $(-e_*, m_e)$ in the Dirac electron is no larger than $r_e/39,000$ [6] [7, pp. 402-403]; so it is reasonable to conclude that the proton core is similarly reduced in size below r_p. From the preceding the following picture of the proton structure emerges: the "point charge" proton core has a radius r_0 ($< r_p/39,000$); the p-p overlap radius is r_1; and the e-p overlap radius is r_2. The e-p surface at r_2 sustains a polarization charge caused by the core polarizing the exposed PV within that radius.

3 Charge spread

The core-charge polarization of the PV in the proton case leads to an apparent spread in the proton charge that can be roughly expressed in the proton electric field as

$$E(r) = \frac{e(r)}{r^2} \tag{11}$$

where the spread is

$$e(r) = \begin{cases} e_*, & r < r_0 \\ < e_*, & r_0 < r < r_2 \\ \sim e, & r_2 < r < r_p \\ e = \alpha^{1/2}e_*, & r_p < r \end{cases} \tag{12}$$

and α ($\approx 1/137$) is the fine structure constant. An important characteristic of this result is the large charge gradient

$$\frac{\Delta e}{\Delta r} = \frac{e_* - e}{r_2 - r_0} \approx \frac{e_*(1 - \sqrt{\alpha})}{r_p/3.15} \approx \frac{2.9e_*}{r_p} \tag{13}$$

between the core charge e_* and the polarization charge at r_2. This result explains a similar gradient in the QED spread depicted in Figure 11.6 of [8, p. 319].

Appendix A: Overlap radii

In the Klein Paradox [9, p. 127], a free electron propagates in the positive z-direction until it collides with the free-space region II in which the negative energy vacuum has been distorted by the *positive* step-potential

$$e\phi = \begin{cases} 0 & \text{for } z < 0 \text{ (region I)} \\ V_0 & \text{for } z > 0 \text{ (region II)} \end{cases} \tag{A1}$$

that is externally applied to the half-space $z > 0$. The Klein Paradox demonstrates that a sufficiently strong positive free-space potential can expose a portion of the vacuum state to "attack" by free-space particles.

For $V_0 = 0$, the positive energy continuum for an electron in regions I and II increases from $m_e c^2$ in the positive energy direction, while the negative-energy vacuum continuum decreases from $-m_e c^2$ in the negative-energy direction. When the positive step-potential is imposed on the $z > 0$ half-space, however, the negative energy continuum in region II is increased as a whole by V_0. The electron positive energy continuum and the vacuum negative energy continuum can then overlap in region II. The plane at $z = 0$ is referred to in the present paper as an overlap boundary, and region II as the corresponding overlap region.

Upon collision with the step, the electron excites electron-positron pairs, the electrons and positrons propagating in the negative and positive z-directions respectively. In order for there to be pair excitation, the perturbing potential V_0 must satisfy the inequality

$$V_0 > E + m_e c^2 = (m_e^2 c^4 + c^2 p^2)^{1/2} + m_e c^2 \tag{A2}$$

where E and p are the relativistic energy and momentum of the incident electron.

In the proton rest frame, the proton core (e_*, m_p) is responsible (via the coupling force (1)) for distorting the PV and for exposing the negative energy continuum to the free space around the core. The free-space spherical surfaces where the various positive and negative energy continua begin to overlap are defined in the present paper as *overlap radii*. The surface at the e-p overlap radius develops a positive polarization charge due to the polarizing effect of the positive core charge.

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6. Daywitt W. C. The source of the quantum vacuum. *Progress in Physics*, v. 5 (1), 27. There is a error in Appendix A of this paper: in the first line of the last paragraph "$p = \hbar/r_L$" should read "$m\gamma c = \hbar/r_L$".
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9. Gingrich D. M. Practical Quantum Electrodynamics. CRC, The Taylor & Francis Group, Boca Raton, London, New York, 2006. – In the Klein Paradox V_0 is assumed to be a positive electrostatic potential, whereas the nonnegative potential $V_p(r)$ includes both charge (e_*) and mass (m_p). The difference between the two potentials is of no interest to the present paper, the salient point being the positive nature of both potentials.