# Proton-Neutron Bonding in the Deuteron Atom and its Relation to the Strong Force as Viewed from the Planck Vacuum Theory

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This paper argues that the two-particle proton-neutron bond results from the proton-proton/Planck-vacuum coupling force associated with the two particles. The neutron is assumed to be a proton with a weakly attached electron whose sole function is to eliminate the Coulomb repulsion between the two protons. Results lead to a simple model of the deuteron atom and a definition for the strong force.

## 1 Introduction

The proton core $(e_*, m_p)$ located at the radius $r = 0$ exerts the two-term coupling force [1]

$$F(r) = -\left(\frac{e_*^2}{r^2} - \frac{m_p c^2}{r}\right) = -\frac{e_*^2}{r^2}\left(1 - \frac{r}{r_p}\right) \qquad (1)$$

on the omnipresent Planck vacuum (PV) state, where $r_p$ $(= e_*^2/m_p c^2)$ is the Compton radius at which the force vanishes. The radius $r$ extends from the core to any point within the PV continuum. The massless bare charge is $e_*$ and $m_p$ is the proton rest mass. Since the Planck particles within the PV suffer a primordial zero-point agitation that is the source of the zero-point electromagnetic fields, the radius $r$ in (1) is an average over the small instantaneous random motion ($r(t) - r$ at $r \approx 0$) of the proton's bare charge $(e_*)$ [2, 3]. In part, the response of the PV to the force (1) is to create the proton mass $m_p$ from the zero-point-field driven proton charge $(e_*)$.

Figure 1 is a plot of the normalized coupling force

$$\frac{F(r)}{e_*^2/r_p^2} = \frac{F(r)}{m_p c^2/r_p} = -\frac{r_p^2}{r^2} + \frac{r_p}{r} \qquad (2)$$

where the abscissa is in units of $r_p$ (equation (5) is used in the calculation). The two fiducial points, $r = r_p$ and $r = 2r_p$, are the radii at which the force vanishes and attains its maximum respectively. The Compton radius $r_p$ has been discussed in a number of earlier papers (see www.planckvacuum.com). It is seen in what follows that the separation between the proton and neutron cores in the deuteron is related to the maximum at $2r_p$.

The coupling potential from (1) is

$$V(r) = -\int F(r)dr + V_0 \qquad (3)$$

where $V(r_p) = 0$ yields the normalized potential

$$\frac{V(r)}{m_p c^2} = -\frac{r_p}{r} + 1 + \ln\frac{r_p}{r}\,. \qquad (4)$$

The corresponding mass and Compton radius of the proton are tied to the PV state via the Compton relations

$$r_p m_p c^2 = r_* m_* c^2 = e_*^2 \qquad (= c\hbar) \qquad (5)$$

which are a manifestation of the fact that the proton possesses a Compton radius $r_p$, where $r_*$ and $m_*$ are the Compton radius and mass of the Planck particles making up the negative energy PV.

For $r \ll r_p$, (1) reduces to

$$F(r) = -\frac{e_*^2}{r^2} = \frac{(e_*)(-e_*)}{r^2} \qquad (6)$$

where $(e_*)$ belongs to the proton and $(-e_*)$ belongs to the separate Planck particles of the PV.

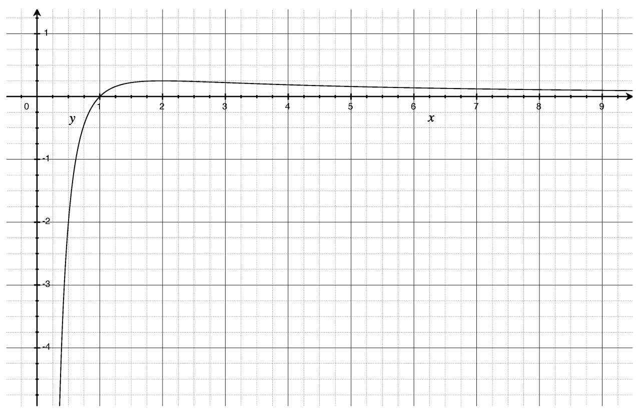


Fig. 1: The graph plots $F(r)/(e_*^2/r_p^2)$, with $r_p = 1$. The maximum of the curve is at $2r_p = 2$.

The neutron is assumed to be a proton with a negative charge weakly attached to make the neutron charge-neutral. Theoretically, it is tempting to assume that this added negative charge is the massless bare charge $(-e_*)$. However, the zero-point fields permeate both free space and any particle in that space [3]; and if that particle is the bare charge, that bare charge rapidly becomes an electron or a proton, depending upon whether the charge is negative or positive respectively. Thus the added negative charge in the neutron is assumed in the PV theory to be an electron.

## 2 Proton-proton bond

The PV is a degenerate state [5], which implies that the force in (1) does not distort the vacuum structure, except possibly

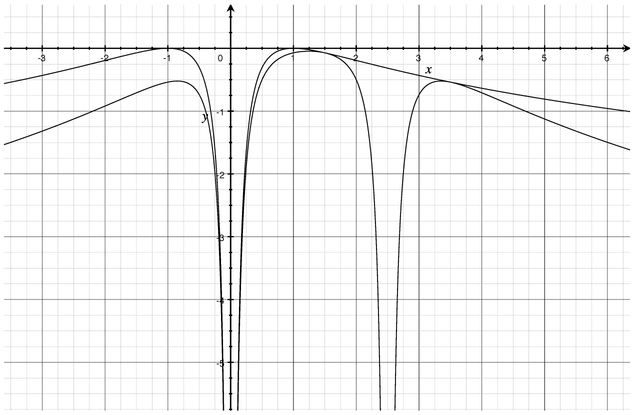


Fig. 2: The graph plots $V(t)/m_pc^2$ (the upper curve) and $V_t(r)/m_pc^2$ (the three-humped curve) with $x_0 = 2.5r_p$ and $r_p = 1$. The two intersect points are at $r = x_0 \pm r_p = 2.5 \pm 1$.

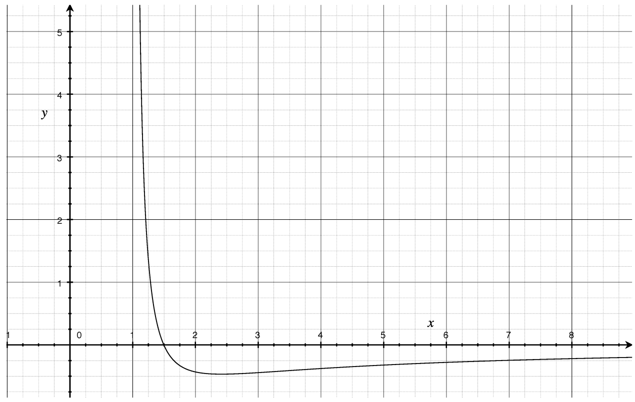


Fig. 3: The graph plots $W(x_0)$ with $r_p = 1$. The minimum of the curve is at $x_0 \approx 2.4r_p = 2.4$.

deep within the proton core. Thus the total coupling force felt by the PV due to two protons (the free proton and the proton in the neutron) is the sum of two forces similar to (1). If the two protons are separated by distance equal to $x_0$, with one of the protons at the origin, the total normalized proton-proton/PV coupling potential is simply (with $\mathbf{r} = (x, 0, 0)$)

$$\frac{V_t(r)}{m_pc^2} = -\frac{r_p}{r} + 1 + \ln\frac{r_p}{r} - \frac{r_p}{|r - x_0|} + 1 + \ln\frac{r_p}{|r - x_0|}$$

$$= -r_p\left(\frac{r + |r - x_0|}{r|r - x_0|}\right) + 2 + \ln\left(\frac{r_p^2}{r|r - x_0|}\right) \qquad (7)$$

which is plotted in Figure 2 with $x_0$ set to $2.5r_p$, where the abscissa is in units of the proton Compton radius $r_p$. The upper curve is the potential for a single proton at the coordinate origin. The three-hump two-proton curve intersects the single-proton curve at the two points (8) where the second potential in the first equation of (7) vanishes. The potential difference between the intersect points provides a means for determining the equilibrium separation $\overline{x_0}$ (the assumed separation between the proton and neutron cores in the deuterium atom). The two intersect radii in Figure 2 follow easily from

$$V_t(r) = V(r) \qquad \Longrightarrow \qquad r = x_0 \pm r_p \qquad (8)$$

and appear on either side of $x_0$.

To determine the equilibrium $\overline{x}_0$, it is convenient to define

$$W(x_0) \equiv \frac{V_t(x_0 + r_p) - V_t(x_0 - r_p)}{m_pc^2} \qquad (9)$$

$$= \frac{V(x_0 + r_p) - V(x_0 - r_p)}{m_pc^2} \qquad (10)$$

in terms of the separation distance $x_0$, which is plotted in Figure 3 with $r_p$ set to one. The equilibrium $\overline{x_0}$ is then obtained from

$$\frac{dW(x_0)}{dx_0} = \frac{2r_p(x_0^2 - r_p^2) - 4r_p^2x_0}{(x_0^2 - r_p^2)^2} = 0 \qquad (11)$$

whose solution is

$$x_0 = (1 \pm 2^{1/2})r_p \qquad (12)$$

yielding

$$\overline{x_0} = (1 + 2^{1/2})r_p \approx 2.4r_p \qquad (13)$$

for the deuteron proton-neutron core separation. A very rough experimental estimate (Appendix A) for the separation is $3.0r_p$.

## 3 Strong force

The vanishingly small magnitude ($< r_p/39000$) of the proton-core radius [4] suggests that it may be related to the so called strong force $F_s$. So identifying the Coulomb force from (6) as the strong force leads to the ratio

$$\frac{F_s(r)}{F_g(r)} = \frac{(e_*)(-e_*)/r^2}{-m_p^2G/r^2} = \frac{m_*^2}{m_p^2} = \frac{r_p^2}{r_*^2} \sim 10^{38} \qquad (14)$$

of that force to the gravitational force $F_g$ between two proton masses separated by a distance $r$ ($G = e_*^2/m_*^2$ from [1, 5], and (5) are used in the calculation).

To reiterate, the positive charge in (14) is the bare charge of the proton and the negative charge corresponds to the bare charges of the separate Planck particles in the PV. So (14) is a composite ratio involving the proton-PV coupling force for $r \ll r_p$ and the free-space gravitational force.

## 4 Summary and comments

The PV theory assumes that the proton-neutron bond results from the proton-proton/PV coupling force associated with the proton and the proton-part of the neutron. It explains the proton-neutron bond as a minimum in the proton/PV coupling potentials as characterized by equations (8)–(13) and Figure 3, with a minimum at $2.4r_p$ that is directly related to the maximum force at $2r_p$ in Figure 1. This characterization assumes that the bonding takes place suddenly when $x_0 = \overline{x_0}$ as the proton and neutron approach each other. That is, the two nucleons do not possess some type of strong *mutual* attraction for $x_0 \neq \overline{x_0}$. In summary, then, the proton-neutron bond in the PV theory is a new type of bonding that intimately involves the invisible, negative-energy vacuum state and its interaction with the proton core $(e_*, m_p)$.

The strong force, $(e_*)(-e_*)/r^2$, is seen to be a force existing between the positive proton charge and the separate negative charges of the PV. It is not a force acting between two free space particles.

## Appendix A: deuteron size

This is a rough heuristic estimate of the separation distance between the proton and neutron cores within the deuteron. It starts with the standard formula for the radius of the stable nucleus with a mass number $A$ [6, p.551]

$$R(A) = 1.2\,A^{1/3}\,[\text{fm}] = 5.71 r_p A^{1/3} \tag{A1}$$

in units of femtometers or the proton Compton radius $r_p$ (= 0.21 fm). The radii of the proton and neutron are defined by $A = 1$, and the deuteron by $A = 2$. Inserting these parameters into (A1) leads to the radii $R_1 = 5.71r_p$ and $R_2 = 7.19r_p$ for the nucleons and deuteron respectively.

Taking the cores at the origin of the two spheres defined by $R_1$ and $R_2$, it is easy to see that the separation between the nucleon cores in the deuteron is

$$2(R_2 - R_1) = 2(7.19r_p - 5.71r_p) \approx 3.0r_p\,. \tag{A2}$$

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