Preprint: Exploration

Neutronium or Neutron?

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Abstract

In the reading Nyambuya (2015), we proposed a *hypothetical* state of the Hydrogen atom whose name we coined '*Neutronium*'. That is to say, in the typical Hydrogen atom, the Electron is assumed to orbit the Proton, while in the Neutronium, the converse is assumed, *i.e.*, the Proton orbits the Electron. In the present reading, we present some seductive argument which lead us to think that this Neutronium may actually be the usual Neutron that we are used to know. That is to say, we show that under certain assumed conditions, a free Neutronium may be unstable while a non-free Neutronium is stable in its confinement. Given that a free Neutron is stable in it confinement of the nucleus and unstable where free with a lifetime of $\sim 15\,min$, one wonders whether or not this Neutronium might be the Neutron if we are to match the lifetime of a free Neutronium to that of a free Neutron.

Keywords: Pre-Main Sequence Stars: power source – Star formation.

1 Introduction

In the reading Nyambuya (2015) [hereafter Paper (I)], we proposed a *hypothetical* state of the Hydrogen atom whose name we coined '*Neutronium*'. In the present reading, we ask whether or not this Neutronium is actually the usual Neutron that we are used to know. If indeed the Neutronium is the Neutron, then, its properties must match that of the Neutron. We argue here-in that the Neutronium may be an unstable state. If the lifetime of the Neutronium is set equal to the lifetime of the free Neutron, then, one can safely entertain the idea of the Neutronium being the Neutron. The instability of a free Neutron is a hallmark of the Neutron that until this day has not been satisfactory explained. In our feeble view, we are of the opinion that by demonstrating this instability of the Neutronium, we might have moved a step closer to understanding not only the Neutronium state, but the Neutron itself.

In the Hydrogen atom, the Electron is assumed to orbit the Proton while in the Neutronium, the converse is assumed – *i.e.*, the Proton orbits the Electron. The Neutronium atom was conceived after the following series or steps of careful logical reasoning:

1. The orbit of the Electron around the Proton in the Hydrogen atom are quantized according to the relation: ($r_n = a_B n^2$), where a_B is the usual Bohr radius, ($n = 1, 2, 3, \dots, etc$) and r_n is the n^{th} radius of orbit of the Electron around the Proton in the Hydrogen. The radius of the Hydrogen atom in the ground state ($n = 1$) can thus be assumed to be equal to the Bohr radius, a_B.

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2. From the above, assuming a spherically Hydrogen atom with a radius equal to the Bohr radius and located in this sphere are the Proton and Electron, it follows from this that the density (ϱ_H) of a single Hydrogen atom in the ground state is thus [$\varrho_H = 3(m_p + m_e)/4\pi a_B^3$] where ($m_p, m_e$) are the masses of the Proton and Electron respectively. Evaluating this, one obtains [$\varrho_H = 2.70 \times 10^3\,\mathrm{kg/m^3}$].

3. Since the minimum possible orbit of the Electron in the Hydrogen atom is a_B, we began to wonder what would happen to this Electron the minute the Hydrogen atom is compressed to densities greater than the (ϱ_H)? We know the Hydrogen burning core of stars should have densities ($\gtrsim 5.00 \times 10^3\,\mathrm{kg/m^3}$) much greater than this. It is at this point that we conceived of the Neutronim.

4. We realised that in the Hydrogen atom, the Electron is considered to be in the Coulomb electrical potential of the Proton and this literally and technically translates to the Electron orbiting the Proton. We felt that – from a logical and physics point of view, there really is nothing wrong or sinister in considering a Proton in the Coulomb electrical potential of the Electron and this – likewise, literally and technically translates to the Proton orbiting the Electron.

After the conception of the Neutronium state, we did the maths (Nyambuya 2015) and realised that indeed, the Electron and Proton's centre of mass can come together and be much closer than permitted by the quantum mechanical constraints on the Hydrogen atom, *i.e.* instead of one Bohr radius, they came closer to about 1836^{th} of the Bohr radius and in the process, emit about 0.02 MeV of energy (radiation). Our initial thoughts (Nyambuya 2015) on the possible use of this energy output from the Neutronium by *Nature*, where that this energy might power Pre-Main-Sequence (PMS) Low Mass Stars (LMS). We no longer hold this view and the reason for this new position being that, our insight into what this Neutronium might are getting deeper and better.

We have now began to think of – and to see – this Neutronim state as most likely the Neutron that we are used to know. This Neutronium might be present in all Hydrogen burning stars helping or taking part in the fusion of Hydrogen to Helium. We shall not venture – yet – into these – potentially polemical – ideas now, but – rather – concentrate first on putting some logically credible and acceptable arguments pointing to the possibility of this Neutronium being a Neutron.

To that end, in §(2), we shall give an exposition of the extension of Maxwellian Electrodynamics (MED) where in this extension, MED is not described by just one electrical potential – the Coulomb electrical potential, but has two other potentials, one of which is the Yukawa (1935) potential that we are used to know and the other a new sinusoidal potential [Paper (II)]. It is this sinusoidal potential that is key to our likening the Neutronium to the Neutron. Thereafter, in §(4), we apply the sinusoidal potential to the Neutronium and there-in, make our comparison of the resulting atom with the Neutron.

2 Extended Maxwellian Electrodynamics

We here give an exposition of theory given in the reading Nyambuya (2016) [herefater Paper (II)] where Maxwellian Electrodynamics (MED) has been extended so that it is described by not just by one electrical potential – the Coulomb electrical potential, but two other potentials, one of which is the Yukawa (1935) potential that we are used to know and the other is a new sinusoidal potential. As is well known, Maxwell (1865)'s Electromagnetic theory is usually understood to constitute two forces *i.e.*, the Coloumb electrical force and the magnetic force. In this theory of Maxwell (1865), the electrical and magnetic forces interact interchangeably as a unified force field that submits to a description by a four vector potential A_μ. This potential A_μ, is known as the electromagnetic four vector potential. The other two forces present at the nuclear scale *i.e.*, the *Strong* and *Weak* force fields, these forces are generally assumed to be separate phenomenon from Maxwell (1865)'s theory. The extent to which these forces – the Strong and Weak nuclear forces; are thought to be separate from Maxwell (1865)'s Electromagnetic theory is that, physicists, have had to find a unified description of Maxwell (1865)'s Electromagnetic theory and the Strong and Weak nuclear forces (*e.g.*, Weinberg 1967, Glashow 1959, Salam & Ward 1959).

Maxwell (1865)'s celebrated and embellished classical theory of electrodynamics can be summed up in two beautiful and simple looking tensor equations, namely:

$$\partial^\mu F_{\mu\nu} = \mu_0 J_\nu, \tag{2.1}$$

which is the source-coupled set of field equations, and:

$$F_{\mu\nu,\lambda} + F_{\lambda\mu,\nu} + F_{\nu\lambda,\mu} = 0, \tag{2.2}$$

which is the source free set of field equations, where μ_0 is the permeability of free space and:

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu, \tag{2.3}$$

is the electromagnetic field tensor $(J_\mu = \varrho_\mathrm{e} v_\mu)$, is the four current and the Greek indices (μ, ν, λ) are such that $[(\mu, \nu, \lambda) = 0, 1, 2, 3]$. In the four current $(J_\mu = \varrho_\mathrm{e} v_\mu)$, ϱ_e is the electronic charge density and $[v_\mu = (c, \boldsymbol{v})]$ is the four velocity with c being the speed of Light in *vacuo* and $\boldsymbol{v}$ the velocity of the charges, and the object $[A_\mu = (\Phi_\mathrm{e}, \boldsymbol{A})]$, is the electromagnetic four vector potential with Φ_e being the electric potential and $\boldsymbol{A}$ the magnetic vector potential. The electromagnetic four vector potential A_μ satisfies the Lorenz (1867) gauge, namely:

$$\partial^\mu A_\mu = 0. \tag{2.4}$$

In showing or demonstrating that Maxwell's theory submits to a description of three electrical potentials, one will not need equation (2.2). With the Lorenz (1867) gauge (2.4) taken into account, equation (2.1) yields the well known four Poisson-Laplace equation for electrodynamics, namely:

$$\Box A_\nu = \mu_0 J_\nu, \tag{2.5}$$

where $\Box$ is the four Laplacian or the D'Alembert operator defined as:

$$\Box = \boldsymbol{\nabla}^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}. \tag{2.6}$$

Now, taking the component $(\nu = 0)$ of equation (2.5), we will have:

$$\boldsymbol{\nabla}^2 \Phi_\mathrm{e} - \frac{1}{c^2}\frac{\partial^2 \Phi_\mathrm{e}}{\partial t^2} = \frac{\varrho_\mathrm{e}}{\varepsilon_0}. \tag{2.7}$$

where ε_0 is the permittivity of free space.

We will consider the natural time-dependent radial solutions of (2.7) for a point charge. By natural solutions we mean those solutions which are separable when expressed in spherical coordinates *i.e.* $[\Phi_e(r,\theta,\varphi,t) = \Phi_e(r)\Phi_e(\theta)\Phi_e(\varphi)\phi_e(t)]$. Since we are considering only the time-dependent radial solutions, this means we are considering the solutions $[\Phi_e(r,t) = \Phi_e(r)\phi_e(t)]$. For simplicity, we will consider the vacuum solutions ($\varrho_e \equiv 0$) of equation (2.7).

Substituting $[\Phi_e(r,t) = \Phi_e(r)\phi_e(t)]$ into equation (2.7) and separating the time and space variables, we will have:

$$\nabla^2\Phi_e(r) - \frac{1}{c^2}\left[\frac{1}{\phi_e(t)}\frac{\partial^2\phi_e(t)}{\partial t^2}\right]\Phi_e(r) = \frac{\varrho_e}{\varepsilon_0\phi_e(t)}. \tag{2.8}$$

For the time-dependent component, the solutions that we obtain for the vacuum ($\varrho_e \equiv 0$) solutions are the same as those for the non-vacuum ($\varrho_e \neq 0$) solutions; so there really is no need to find the complicated solution for the general case of the non-vacuum. We shall assume:

$$\frac{1}{\phi_e(t)}\frac{\partial^2\phi_e(t)}{\partial t^2} = \mu^2 c^2, \tag{2.9}$$

where μ is a 'constant' and:

$$\varepsilon(t) = \varepsilon_0\phi_e(t). \tag{2.10}$$

Substituting (2.9) and (2.10) into (2.8), we will have:

$$\nabla^2\Phi_e(r) - \mu^2\Phi_e(r) = \frac{\varrho_e}{\varepsilon(t)}. \tag{2.11}$$

Setting ($\varrho_e \equiv 0$), one finds that there are three natural cases to be considered and these are ($\mu^2 = 0$), ($\mu^2 > 0$) and ($\mu^2 < 0$). This implies that there will be three solutions for $\Phi_e(r,t)$ and these will correspond to three solutions for $\Phi_e(r)$ and $\phi_e(t)$. Let us – for a particle with electrical charge q, write these three solutions with a superscript label as $[\Phi_{ej}(r,t) = \Phi_{ej}(r)\phi_{ej}(t)]$ where "j" takes three values *i.e.*, ($j = 0$) corresponding to ($\mu^2 = 0$); ($j = 1$) corresponding to ($\mu^2 > 0$); and ($j = 2$) corresponding to ($\mu^2 < 0$). For $\Phi_{e0}(r,t)$, which corresponds to the case for ($\mu^2 = 0$), we have the Coulomb potential:

$$\Phi_{e0}(r,t) = \frac{1}{4\pi\varepsilon_0(t)}\frac{q}{r}, \quad \text{where} \quad \frac{1}{\varepsilon_0(t)} = \frac{(\omega_0 t \pm 1)}{\varepsilon_0(0)}. \tag{2.12}$$

For $\Phi_{e1}(r,t)$, which corresponds to the case for ($\mu^2 > 0$), we have the Yukawa (1935) potential:

$$\Phi_{e1}(r,t) = \frac{1}{4\pi\varepsilon_1(t)}\frac{qe^{-\mu_1 r}}{r}, \quad \text{where} \quad \frac{1}{\varepsilon_1(t)} = \frac{e^{-\omega_1 t}}{\varepsilon_1(0)}. \tag{2.13}$$

Lastly, for $\Phi_{e2}(r,t)$, which corresponds to the case for ($\mu^2 < 0$), we have a new sinusoidal potential:

$$\Phi_{e2}(r,t) = \frac{1}{4\pi\varepsilon_2(t)}\frac{q\cos(\mu_2 r + \theta)}{r}, \quad \text{where} \quad \frac{1}{\varepsilon_2(t)} = \frac{\cos(\omega_2 t + \phi)}{\varepsilon_2(0)}. \tag{2.14}$$

With three potentials, one may wonder which of the three acts on a given particle and if so, what are the reasons for that potential acting on that potential. The hypothesis that we here make is that all these three potentials are present simultaneously in any fundamental particle system that carries electronic charge such as Proton, Electron *etc.* The resultant or effective electrical potential $\Phi_{\text{eff}}(r,t)$, should therefore – be given by the sum total of the three potentials, *i.e.*:

$$\Phi_{\text{eff}}(r,t)=\sum_{j=1}^{2}\Phi_{\text{e}j}(r,t). \tag{2.15}$$

The 'constants' ε_j and μ_j are assumed to be such that:

$$c=\frac{1}{\sqrt{\varepsilon_j(t)\mu_j(t)}}. \tag{2.16}$$

It is important to note that, for every potential Φ_{ej}, there is a corresponding 'magnetic vector' potential $\boldsymbol{A}_j$, so that we have a complete four vector: $[A_{\mu j}=(\Phi_{ej},\boldsymbol{A}_j)]$.

3 Neutronium

The Schrödinger (1926) equation for the Electron [mass m_e and electronic charge $(q=e)$] orbiting inside the Proton's Coloumb potential $(V=-e^2/4\pi\varepsilon_0 r)$, is given by:

$$-\frac{\hbar^2}{2m_e}\boldsymbol{\nabla}^2\Psi_e+V\Psi_e=i\hbar\frac{\partial\Psi_e}{\partial t}, \tag{3.1}$$

where Ψ_e is the Schrödinger (1926) wavefunction of the Electron in the Proton's Coulomb potential, $\hbar$ is Planck's normalized constant and t is the time coordinate. With the help of Professor Hermann Klaus Hugo Weyl (1885 – 1955), Schrödinger (1926) was able to solve equation (3.1) and demonstrate that the energy $E_n(H)$ of the Electron orbiting the Proton is quantized and is given by:

$$E_n(H)=-\left(\frac{m_e e^4}{8\pi^2\varepsilon_0^2\hbar^2}\right)\frac{1}{n^2},\quad\text{where}\quad(n=1,2,3,etc). \tag{3.2}$$

The theory of the Hydrogen atom assumes that the Electron orbits the Proton and these orbits are quantized *i.e.* from the center of mass of the Proton, these orbits have a well ordered placement given by $[r_n(H)=n^2a_B]$.

Now, in the case of the Proton orbiting the Electron *i.e.*, the Proton under the direct influence of the Electron's Coulomb potential, the corresponding Schrödinger (1926) equation for such a system is [Paper (II)]:

$$-\frac{\hbar^2}{2m_p}\boldsymbol{\nabla}^2\Psi_p+V\Psi_p=-i\hbar\frac{\partial\Psi_p}{\partial t}, \tag{3.3}$$

where Ψ_p is the Schrödinger (1926) wavefunction of the Proton in the Electron's Coulomb potential. Just as is the case with the Hydrogen atom, the energy levels $[E_{n_p}(\mathscr{N})]$ of the Proton inside the Electron's Coulomb potential are such that:

$$E_n(\mathscr{N})=-\left(\frac{m_p e^4}{8\pi^2\varepsilon_0^2\hbar^2}\right)\frac{1}{n_p^2}=\left(\frac{m_p}{m_e}\right)E_n(H)=\mu_{pe}E_n(H), \tag{3.4}$$

where[2]:

$$\mu_{pe} = \frac{m_p}{m_e} = 1836.15267389(17), \tag{3.5}$$

is the Proton-Electron mass ratio. The spacing $[r_{n_p}(\mathscr{N})]$ of these energy levels is such that:

$$r_{n_p}(\mathscr{N}) = \left(\frac{a_B}{\mu_{pe}}\right) n_p^2 \text{ where } (n_p = 1, 2, 3, \dots, 42). \tag{3.6}$$

The state $(n_p = 43)$ corresponds to the Hydrogen atom, therefore, the Neutronium system has only 42 energy states. The total amount of energy released by the Neutronium – as the Proton is forced to the energy level $(n_p = 42)$ – by the *all-and-ever* muzzling gravitational force – and thereafter falling down to the ground state $(n_p = 1)$ of the Neutronium atom; is $\sim 0.02\,\text{MeV}$.

4 Neutronium as a Neutron

The above described Neutronium atom is wholly under the action of the Coulomb potential, Φ_{e0}. To this Coulomb potential, we are now going to introduce the new potential Φ_{e1} to operate in the Neutronium region, *i.e.* $[\mu_{pe}^{-1} a_B < r < a_B]$. We shall do this by way of assumption about the strength of these three potentials, Φ_{e0}, Φ_{e1} and Φ_{e2}. That is to say, we shall assume the following:

1. For the region $[r > a_B]$, the Coulomb electric force Φ_{e0} is the most dominate, the meaning of which is that the other two potentials (Φ_{e1}, Φ_{e2}) can be neglected in this region.
2. For the region $[\mu_{pe}^{-1} a_B < r < a_B]$, the Φ_{e1}-force is stronger than the Coulomb electric force $\Phi_e^{(1)}$. While this is the case, its influence is significant in the region and must be considered while Φ_{e2} is neglected.
3. For the region $[r < \mu_{pe}^{-1} a_B]$, the Yukawa (1935) potential Φ_{e2} is stronger than both the Coulomb electric potential Φ_{e0} and the new sinusoidal Φ_{e1} potential. In the present investigations, we are not interested in what happens in this region, so, we shall not bother about the physics of this region – at least for the present reading.

Now – from the foregoing, the resultant potential under both the Coulomb electric potential energy $e\Phi_{e0}$ and the $e\Phi_{e1}$ potential energy for the Neutronium in the region $[(\mu_{pe}^{-1} a_B < r < a_B]$, is:

$$V_{\text{eff}}(r,t) = -\frac{e^2}{4\pi\varepsilon_0 r} - \frac{e^2 \cos(\omega_1 t + \theta)\cos(\mu_1 r + \phi)}{4\pi\varepsilon_1 r}. \tag{4.1}$$

We shall not work with this potential energy (4.1) in its exact form but considered its first order approximation under two specially chosen conditions. To that end:

[2] See "CODATA Value: proton-electron mass ratio" at: `https://physics.nist.gov/cgi-bin/cuu/Value?mpsme`

Case (1): Let us consider the case where $(\theta = \phi \equiv 0)$ and $(\mu_1 r \lll 1)$. For these conditions, we will have $[\cos(\mu_1 r + \phi) \simeq 1]$, hence:

$$V_{\text{eff}}(r,t) \simeq -\frac{e^2}{4\pi\varepsilon_0 r} - \frac{e^2\cos(\omega_1 t)}{4\pi\varepsilon_1 r} = -\frac{e^2\left[1+\kappa_{01}\cos(\omega_1 t)\right]}{4\pi\varepsilon_0 r}. \tag{4.2}$$

where[3] $[\kappa_{01} = \varepsilon_0/\varepsilon_1 \ggg 1]$. If we submit this potential energy into the Schrödinger (1926) equation of the Neutronium, we obtain the energy $\tilde{E}_{n_p}(\mathscr{N})$ of the Neutronium under the additional action of the Φ_{e1}-generated force, we obtain:

$$\tilde{E}_{n_p}(\mathscr{N}) = \left[1+\kappa_{01}\cos(\omega_1 t)\right]^2 E_{n_p}(\mathscr{N}), \tag{4.3}$$

and the orbits are located at:

$$\tilde{r}_{n_p}(\mathscr{N}) = \frac{1}{\mu_{pe}}\left(\frac{a_B}{1+\kappa_{01}\cos(\omega_1 t)}\right)n_p^2, \tag{4.4}$$

and under the above stated conditions, the corresponding force (F_{eff}) acting in this region is given by:

$$F_{\text{eff}}(r,t) \simeq -\frac{e^2\left[1+\kappa_{01}\cos(\omega_1 t)\right]}{4\pi\varepsilon_0 r^2}. \tag{4.5}$$

This force (4.5) will periodically (with a period of $2\pi/\omega_1$) change from being a repulsive to being attractive. What this means is that during the cycle when $[F_{\text{eff}}(r,t) < 0]$, the Proton will orbit the Electron and once $[F_{\text{eff}}(r,t) < 0]$, the Proton will be ejected out of its orbit, hence – in this instance, the Neutronium will be unable on time-scales determined by the period $2\pi/\omega_1$.

Case (2): Let us consider the case where $(\theta = \phi \equiv \pi/2)$ and $(\mu_1 r \lll 1)$. For these conditions, we will have $[\cos(\mu_1 r + \phi) \simeq \mu_1 r]$, hence:

$$V_{\text{eff}}(r,t) \simeq -\frac{e^2}{4\pi\varepsilon_0 r} - \frac{\mu_1 e^2\sin(\omega_1 t)}{4\pi\varepsilon_1}. \tag{4.6}$$

If we submit this potential into the Schrödinger (1926) equation of the Neutronium, we obtain the energy $\tilde{E}_n(\mathscr{N})$ of the Neutronium under the additional action of the Φ_{e1}-Force, we obtain:

$$\tilde{E}_{n_p}(\mathscr{N}) = E_{n_p}(\mathscr{N}) - \frac{\mu_1 e^2\sin(\omega_1 t)}{4\pi\varepsilon_1} = E_{n_p}(\mathscr{N}) - \epsilon\sin(\omega_1 t). \tag{4.7}$$

where $(\epsilon = \mu_1 e^2/4\pi\varepsilon_1)$ and the orbits are located at:

$$\tilde{r}_{n_p}(\mathscr{N}) = \left(\frac{a_B}{\mu_{pe}}\right)n_p^2 = r_{n_p}(\mathscr{N}), \tag{4.8}$$

and under the above stated conditions, the corresponding force (F_{eff}) acting in this region is given by:

[3]This condition is required if in the region $[\mu_{pe}^{-1}a_B < r < a_B]$, the Φ_{e1} potential energy is to be much stronger than the Coulomb potential energy.

$$F_{\text{eff}}(r,t) \simeq -\frac{e^2}{4\pi\varepsilon_0 r^2}. \tag{4.9}$$

Unlike the force (4.5), the force (4.9) is not periodic – it is the typical Coulomb attractive force between a Proton and an Electron. In this instance – despite the periodicity in the energies of the energy levels, we expect the Neutronium to be 'stable', that is, unlike in the Case (1), the Proton will not be eject out of its orbit.

If the stated conditions leading to equations (4.2) and (4.6) are what obtains in the Neutronium atom – then, what equations (4.2) and (4.6) are telling us is that, the energy of the energy levels of the Neutronium will vary sinusoidally with time and this directly translates to the fact that these energy levels have no fixed energies like happens in the typical Hydrogen atom. Of these two conditions presented leading to equations (4.2) and (4.6), the most desired for us are the conditions leading to equations (4.2), because these lead to an unstable Neutronium atom which ejects the Proton out of its orbit. The Neutronium atom is unstable on the time scale, τ: $(\tau = 2\pi/\omega_1)$. If τ is set such that it equals the lifetime of the Neutron that we are used to know *i.e.* $\tau \sim 882.00 \pm 2.00\,s$ (see *e.g.*, Nakamura & Particle Data Group 2010), then, the Neutronium (free or bound) will be unstable on this timescale. It is this property that 'seduces' us in the direction of thinking that the Neutronium can be thought of as being a Neutron, and not just some strange form of matter belonging perhaps to the realm and domains of science fiction movies.

5 General Discussion

We have here-in shown that an equanimous and meticulous application of Maxwell's Extended Theory of Electrodynamics can lead one to a description of the Neutronium that fits that of the Neutron under carefully chosen conditions. What this means is that – until such a time that the existence of the Neutroniun state is proved or disproved – we can, in the meantime, think of the Neutronium as being a Neutron or a *quasi*-Neutron.

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