August 26, 2019

There Is Only Charge!

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A picture of the universe is presented where electric charge accounts for all observed phenomena. This picture is based on the Heisenberg relations of quantum mechanics. All the results obtained are consistent with electric charge being responsible for both what we classically identify as mass, and for the interactions required to keep intact the nucleons, and the nuclei of atoms. The approach is grounded in both quantum mechanics and general relativity.

There is only electric charge. That is the main idea of this work; it is meant in the sense that electric charge (charge) is enough to explain the observable universe. To establish this claim it will be shown that gravitational interactions and the interaction of subatomic particle can both be explained through relatively simple electromagnetism (EM). In this work we will completely ignore the angular, magnetic, and spin degrees of freedom. In that sense, besides charge there are also quanta of motion (e.g., spin), however this aspect is relegated for future studies. This is done to make as clear as possible the presentation that all interaction can be derived from EM but also since the problem of spin has not been completely worked out. This paper will be speculative at times and could probably upset some readers.

In simple terms we need to explain mass and nuclear forces using EM. Here, the results of relativity will be used. They include the relationships between mass and energy, between space/time/momentum/energy, and as a general theory for the interaction of mass. However, as will be shown, what we interpret as mass in the classical sense is the self EM energy contained in confined charge. Historically, mass entered physics at a very early stage since it is one of the most easily experienced physical measurements. Having the entrenched position in classical physics it is understandable how the notion that mass results from the quantum confinement of charge is difficult. Similarly, the first observations of nuclear interactions involved protons and neutrons confined to a nucleus tiny in comparison to the size of the electrons orbits. Hence, it was unclear how this positive charge is confined in the nucleus and the strong and weak nuclear forces were invented for an apparently needed "strong" attraction. However, as will be shown here, with the establishment of the quark model of the nucleons, it is possible to understand nuclear reactions as a quantum outcome of EM interactions without the need for any addition interactions. In what follows semi-classical and static approximations will be used for these dynamic quantum systems.

Possibly the most fundamental idea of quantum mechanics is the Heisenberg Uncertainly Relations (HUR):

$$\Delta x \Delta p \gtrsim \hbar. \tag{1}$$

$$\Delta t \Delta E \gtrsim \hbar. \tag{2}$$

These expressions describe the smallest possible quantum states, with x the position (the dimensionality of space is ignored here), p the momentum, t time, E the energy of a state, and $\hbar$ is Planck's constant. The HUR still conceals many exciting discoveries and no claim is made that much is contributed to their understanding here. Indeed, it is guessed that we completely do not understand the mathematics of space-time that is prescribed by the HUR. Here, their implications will be used. For one thing the HUR imply that nothing can be stationary in the quantum world. The HUR also point to a finite minimal quantum state. States as such will be refereed to here as Minimal Quantum States (MQS). For these states an equality will be assumed for the inequality in Eqs. 1 and 2. An MQS in a "point" particle occupying one quanta of space. It is proposed here that the electron and the quarks are such a MQS. As such they cannot be broken into any smaller pieces since this will violate Eqs. 1 and 2. Additionally, since Δx describes the smallest discernible distance, the densities inside an MQS (e.g., charge density) must be uniform. A non-uniform density would imply a discernible length scale smaller than Δx. As quanta of space

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the electron and quarks posses charge, contained in their minimal state. This will be used shortly.

One straightforward outcome of the HUR is Newton's second law. Since, $\Delta x \Delta p = \Delta t \Delta E$, one easily has that $\Delta p/\Delta t = \Delta E/\Delta x$, which is essentially Newton's second law in absolute value form. Another result of the HUR is for the photon, which obeys the relationship $E = cp$, and hence $\Delta E = c\Delta p$ with c the speed of light in vacuum. The minimal time required to travel a distance Δx is $\Delta t_{min} = \hbar/\Delta E = \hbar/c\Delta p = \Delta x/c$. This indicates that c is the fastest possible velocity as a result of the HUR. A comforting result considering it is assumed here that relativity is a valid representation of nature. A more complete model of the photon will be worked on in future publications. Since it is a massless spin 1 particle it seems natural to consider it as a traveling oscillating dipole of two MQS. The massless aspect can be due to a dipole configuration that balances the self energy of the dipole parts with the binding interaction between them. Planer MQS would posses this property. In this picture the wavelength of light is given by Δx and its time period by Δt.

How is charge confined in a MQS such as the electron? This question will not be explored here and it is conjectured that a new form of mathematics will need to be developed to consider it. A new mathematics that is not a crude discrete approximation to a classically conjured continuous space but rather is built from the clues quantum mechanics tells us about its structure. For example, discretization of continuous space implies an infinity sharp separation between states, in immediate violation of the HUR. For the rest of the work here it will be assumed that charge confinement such as for the electron or the quarks is a natural consequences of the quantization of space-time. A single particle is a discrete (unique) MQS.

Another place we can observe the discrete nature of space is in electron-positron reactions. If space was continuous we would expect to get a spectrum of energies, with occurrences of infinite energies at infinitesimal distances. We can call this the infinitesimal catastrophe, representing a problem of infinite energy. This is an unfortunate outcome of the continuity assumption and as is well known from experiments, electron-positron annihilation results in a photon whose energy is determined by the mass of the particles and their motion. This is another indication that these particles hit a hard constant limit on their ability to maintain separate quantum positions, as prescribed by Eqs. 1 and 2. Space-time itself is quantized.

The electron and quarks are examples of a MQS. The main claim here is that their mass is a quantum EM effect, resulting from the self energy of the confined charge. For a sphere with charge Q and radius r the self energy, the work in joules required to assemble the charged sphere, is $\frac{3}{5}\frac{KQ^2}{r}$, with $K = 9\cdot 10^9$ Jm/C^2 the Coulomb constant. The claim is that this is equal to the rest energy of the particle: mc^2. If we denote by $-e = -1.6\cdot 10^{-19}$C the charge of the electron, r_e its radius, and $m_e = 9.11\cdot 10^{-31}$kg its mass, then we have,

$$r_e = \frac{3K(-e)^2}{5m_e c^2} = 1.69\text{fm}. \tag{3}$$

This result is of the order of the size of a two nucleons and in that sense can be interpreted as reasonable. It is the first sign of the feasibility that mass is indeed self electrostatic energy. The size of the electron we get based on that assumption is consistent with the size of the atom.

Before estimating the mass and sizes of the quarks, one needs to understand how the configurations of the proton and neutron are feasible under a purely EM theory. To start, it is noted that the proton and neutron are not considered a MQS since they can be broken down, even if only conceptually, to their quark constituents. The quarks are considered a MQS, however there is no direct evidence for the mass of the quarks. There is good evidence for the masses and radii of the proton and neutron. Hence, the configuration of the quarks within the nucleons is critical.

To understand the stability of the proton under only EM interactions, first note that according to the quark model, the proton is composed of a two up quarks (u) with charge $+2e/3$ and one down quark (d) with charge $-e/3$. The total charge of the proton is the sum of the three quarks or $+e$. However, according to the standard model [1] the sum of the masses of the three quarks does not add up to the mass of the proton. This will be remedied in the present presentation, where it will be shown that the mass of the proton and neutron are the sum of the masses of their constituents quarks minus the energy of bonds between the quarks.

The most symmetric configuration for the proton is udu as in Fig. 1, i.e., with the d quark equidistant between the two u quarks. This configuration is classically unstable if the distances between the d quark and the two u quarks become unequal, as the d quark would then be increasingly attracted to the closer u quark. The stability of this configuration is a quantum effect. Schematically, as the d quark approaches one of the u quarks, the uncertainty in the position of the d quark is reduced, which according to Eq. 1 increases the uncertainty of the momentum, enabling events where the d quark escapes from the Coulomb field of one u quark to the Coulomb field of the other u quark. In such a way the d quark oscillates between the two u quarks. Effectively, we can consider it positioned symmetrically between them.

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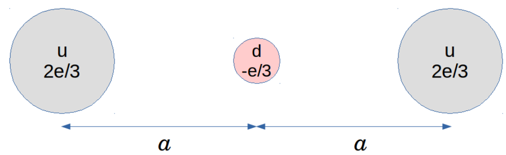

Figure 1 Cartoon of the structure of the proton.

For the stationary configuration, one can immediately surmise from symmetry that the force on the d quark is zero. The net Coulomb force on the right u quark is directed left and has a magnitude of $K \cdot (e/3) \cdot (2e/3)/a^2 - K \cdot (2e/3)^2/(2a)^2 = Ke^2/9a$ for any a. That is, there is a net attraction between the right u quark and the central d quark in this model. A similar result is obtained for the left u quark. Since this configuration is stable regardless of the value of a, under this model the proton is stable and the EM repulsion between the two u quarks is mediated by the d quark, resulting in an overall effective attraction between the two u quarks.

There are two important points to be made here. 1) If we perturb one u quark a distance Δy perpendicular to the line joining it to the other u quark (axis of symmetry), then assuming $\Delta y << a$, there is a restorative force proportional to Δy with the proportionality constant equal to $\frac{Ke^2}{6a^3}$. Hence, the u quark may undergo harmonic oscillations perpendicular to the line of joining the two u quarks. 2) If one assumes that the d quark is undergoing motion in the plane perpendicular to the line joining it to the two u quarks (symmetry plane), the result is to reduce the collapsing force on the two u quarks. To see this, assume the d quark will sample disk of radius b in the symmetry plane, if its charge is taken to be spread uniformly on this disk, then the field due to the charged disk at a distance a along its axis of symmetry (to the locations of the u quarks) is $\frac{2Ke}{3b^2}(1 - a/\sqrt{a^2+b^2})$. The field due to the other u quark is $\frac{Ke}{6a^2}$ and opposite in direction. Equating the magnitudes of the two fields and defining $\xi = (b/a)^2$ one obtains the equation $4(1 - 1/\sqrt{\xi+1}) = \xi$, which yields a solution $\xi = 1.438$, or $b = 1.199 \cdot a$. If the charge of the d quark is spread over a length scale defined by b, then the effective net force on all three quarks is zero.

So far it was shown that the proton is so stable that it would collapse on itself. Let us see why it does not. This is a combination of a classical effect and a quantum effect. Schematically, as the two u quarks approach the d quark, the lost energy due to the increased binding between them will correspond to an increase in the kinetic energy of the d quark, and this in turn will increase the motion of the d quark, reduce its charge density in the symmetry plane and hence the collapsing force. This is the classical part. Additionally, due to Eq. 1, as the u quarks are approaching the d quark the Δx of the d quark is reduced causing an increase in momentum according to Eq. 1, corresponding to an increase in kinetic energy, which results in a reduction of the charge density in the symmetry plane. Both these effects combine to achieve a balanced state for the two u quarks around the d quark. However, since the energy associated with the classical effect goes like $1/\Delta x$, while that of the quantum effect goes like $(1/\Delta x)^2$, as Δx approaches zero, the classical effect becomes negligible compared to the quantum one.

An upper-bond order of magnitude estimate for the size of the proton can be obtained if one assumes that all the increase in momentum due to the HUR translates into an increase in the kinetic energy of the d quark, and that at the radius of the proton, a_p, the EM interaction energy corresponds to the increase in momentum due to Eq. 1. In reality only part of the increase in momentum will go to spreading the charge of the d quark, which is why this is considered an upper-bond calculation. Using $p = \sqrt{2m_d E}$ for the relationship between the momentum and energy of the d quark, with m_d its mass, and using $E = 2 \cdot \frac{K \cdot e/3 \cdot 2e/3}{a_p} = \frac{4Ke^2}{9a_p}$ for the collapsing energy of the d quark due to the two u quark, one obtains from Eq. 1: $a_p = \frac{1}{3}\frac{9\hbar^2}{8Ke^2 m_d} = \frac{1.63 \cdot 10^{-41}\ \mathrm{kg \cdot m}}{m_d}$. The factor of $1/3$ in the previous equation comes since only a third of the energy will contribute to spreading the d quark in the radial direction in the symmetry plane. If one takes $m_d = m_p/3$, as will be discussed later, one finds $a_p \approx 29\,fm$. Although this value is more than an order of magnitude greater than the observed radius of the proton, a result of the crudeness of the assumptions made, it shows the ability of the prescribed approach to stabilize the proton under only EM interactions.

It is instructive at this point to reiterate that the stability of the proton was achieved here without mention of any "strong" nuclear force. The calculation for the neutron yields a similar stability analysis under the configuration dud. However, the collapsing force on the two d quarks composing the neutron is almost twice as strong as that of the proton. This result may be related to the beta decay of free neutrons and will be touched on briefly below. A more complete discussion of beta decay requires a treatment of spin and will be discussed in future work.

An estimate for the masses of the quarks and their sizes can be obtained from measurements of the mass and size of the proton and neutron. The radius of the

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proton, neutron, u quark, and d quark will be designated as r_p, r_n, r_u, and r_d, respectively. Note that r_p is equal to a in Fig. 1. Corresponding indexes will be used for their masses. Equating the relativistic inertial energy to the self EM energy, one has for the proton:

$$m_p c^2 = Ke^2\left(\frac{8}{15r_u} + \frac{1}{15r_d} - \frac{2}{9r_p}\right), \quad (4)$$

and for the neutron:

$$m_n c^2 = Ke^2\left(\frac{4}{15r_u} + \frac{2}{15r_d} - \frac{7}{18r_n}\right). \quad (5)$$

In Eqs. 4 and 5 the first term is the self EM energy of the u quark/s and the second is the self EM energy of the d quark/s. The third term represents the binding energy of the nucleon. Defining $\epsilon_p = m_p c^2 + \frac{2Ke^2}{9r_p}$ and $\epsilon_n = m_n c^2 + \frac{7Ke^2}{18r_n}$, and using $r_p = 0.88$fm and $r_n = 0.8$fm, one obtains: $\epsilon_p = 939.7$MeV and $\epsilon_n = 941.7$MeV. Additionally, using Eqs. 4 and 5 one has $\epsilon_p - 2\epsilon_n = -\frac{Ke^2}{5r_d}$, and $\epsilon_n - 2\epsilon_p = -\frac{4Ke^2}{5r_u}$. This gives: $r_d = 3.05 \cdot 10^{-19}$m, and $r_u = 1.23 \cdot 10^{-18}$m. It is worth noting that $r_u / r_d = 4.03 \approx 4$. We can also obtain an estimate for the masses of the quarks assuming, as done for the electron, that the mass results from the EM self energy of the contained charge: $m_d c^2 = (3/5) \cdot K \cdot (e/3)^2 / r_d$ for the d quark, and $m_u c^2 = (3/5) \cdot K \cdot (2e/3)^2 / r_u$ for the u quark. This gives $m_u c^2 = 313$MeV, and $m_d c^2 = 315$MeV, and $m_u / m_d = 0.99$. In general, $m_u / m_d = 4 r_d / r_u$. One should also note that these values for the mass of the quarks are a significant deviation from the standard model. [1] However, here the sum of the masses of the quarks composing a nucleon is greater than the mass of the nucleon, the difference being the binding energy. This is the case for the nuclei the nucleons make and the atoms the nuclei and electron make. Hence, it seems reasonable that this will also be the situation for the nucleons themselves.

So far it was shown that EM interactions can explain the stability of the nucleons and that mass can be consistently interpreted as self EM energy of MQS. Gravitational attraction between two particles can be interpreted as the response of one particle to the curved space-time created by the self EM energy of the other according to the laws of general relativity.

Now consider nuclear reactions. Since geometrically fission is a significantly more complicated problem than fusion, only fusion will be treated here. Since $r_u \approx 4r_d$, from Eq. 1 it can be expected that the d quark will have 4 times the momentum of the u quark. Before going into a discussion of assembly of the light nuclei, we need to address the stability of the neutron. As was shown, the collapsing force (the force on the outer quarks) for the neutron is almost twice as large as that for the proton, yet the mass of the quarks is essentially the same. This seems to indicate that the neutron is less stable than the proton, as is well known. In addition, the fact that the outer d quarks of the neutron have greater momentum than the central u quark induces a dumbbell rather than a spherical shape to the neutron and limits the ability of the u quark to spread its charge and reduce the collapsing force on the two d quarks. Finally, it seems plausible that a system with one moving part (the d quark in the proton) would be more stable than a system with two moving parts (the two d quarks in the neutron). As the two d quarks collapse on the u quark, enough energy is released to create a virtual proton-anti-proton pair, and as discussed in the next paragraph, the neutron decays into a proton.

A quantitative treatment of the instability of the neutron will not be carried here because it requires a treatment of the spin degree of freedom which is left for future work. The qualitative treatment and the rest of the discussion will use the following tri-symbol notation: The proton will be represented as d_u^u, and the neutron as u_d^d, where, as before, the letters u and d represent the up and down quarks, respectively. A bar above a letter or over the entire tri-symbol indicates the antiparticle. For example, the anti-proton is represented as $\bar{p} = \overline{d_u^u} = \bar{d}_{\bar{u}}^{\bar{u}}$. We can understand neutron decay with the aid of a virtual proton-anti-proton pair. This pair is virtual as its products are intermediaries that are used during the reaction. The overall energy of the process is conserved. Neutron decay can than be represented as: $u_d^d \to u_d^d + d_u^u + \overline{d_u^u} \to d_u^u + u_d^d + \bar{d}_{\bar{u}}^{\bar{u}} \to d_u^u + d\bar{u}$. It is proposed that since the combination $d\bar{u}$ is unstable, it explodes to form an MQS electron and an anti-neutrino. The neutrino is necessary for the conservation of angular momentum and its conjectured here that part of its energy/mass is due to a shockwave created in the transformation $d\bar{u} \to e^- + \overline{\nu_e}$. The quantitative energetics of this process will be presented elsewhere.

The deuteron is the simplest composite nucleus, composed of a proton and a neutron. Its creation is an exothermic process, releasing 2.22MeV upon the combination of the proton and neutron. $p + n \to {}^2\mathrm{H} + 2.22$MeV. Since for the electron the charge of the d quark is spread over the symmetry plane, it will act as a trap for the u quark of the neutron. The ability of the neutron to reduce the charge density in the symmetry plane also stablizes it, as does the attraction of its two outer d quarks to the two outer u quarks of the proton. Under this picture the deuteron can be represented as ${}_u^u d u_d^d$. For simplicity it will be assumed that the single contact between the central d and

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u quarks is responsible for the 2.22MeV of binding energy. The complete interaction between all six quarks leads to small corrections. If the distance between the central quarks is denoted by d, the following equation follows: $K\frac{e/3\cdot 2e/3}{d} = 2.2MeV$. This gives: $d = 0.15$fm. The order of magnitude of this value is consistent with observation of the size of the deuteron.

The next simplest stable nucleus is Helium 3. It is composed of two protons and a neutron, and follows the reaction ${}^{2}\mathrm{H} + {}^{1}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + 5.49\mathrm{MeV}$. Due to repulsion between the two protons a simple stable configuration in this case is a planner configuration ${}^{u}_{u}d\,u^{d}_{d}\,{}^{u}_{u}d$. The addition of another neutron will stabilize a three-dimensional compact configuration with a pn plane stacked on top of a np plane, forming a ^{4}He. For ^{3}He, we have essentially added three new contacts to the formation of ^{2}H. Again, for simplicity it will be assumed that these three new contacts account for the 5.49MeV of binding energy. Denoting by d' the distance between the ^{1}H and the ^{2}H after forming the ^{3}He, we have: $3 \cdot K\frac{2e/3\cdot e/3}{d'} = 5.49\mathrm{MeV}$. This yields $d' = 0.18$fm. Again, a value consistant with the known size of ^{3}He. One should note that since the planer configuration of ^{3}He is symmetric, both the internal configuration of ^{2}H and ^{1}H will change upon forming it, and one will have a symmetrical configuration ${}^{u}_{u}d\,\overset{d}{\underset{d}{u}}\,d^{u}_{u}$. One can estimate the various distances between the quarks using the mass of ^{3}He. However, for the purpose of showing that charge is sufficient to establish the stability of nuclear structure these calculations suffice.

In summary, a picture of the universe was presented where EM charge accounts for all observed phenomena. This picture is grounded in the Heisenberg relations of quantum mechanics. All the results obtained are consistent with EM charge being responsible for both what we classically identify as mass, and for the interactions required to keep intact the nucleons, and the nuclei of atoms.

Dedication

Dedicated to the memory of Moshe Faraggi and Crystal Marie Carreon.

Key words. Charge, Mass, Quark, Nucleon, General unified theory, Minimal quantum state, Heisenberg uncertainty

References

[1] S. Weinberg. *The quantum theory of fields*. Cambridge University Press, 1996.

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