Proton and Electron Mass-Energy Equivalence to Displaced Vacuum Energy

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Abstract
Two of the great mysteries of physics are the origin of mass, and the mysterious mass ratio between the proton and electron of ~1836. In this paper it is shown that the mass-energy of the proton is equivalent to the vacuum energy excluded by a spherical shell with an average radius equal to the charge radius of a proton. Likewise the electron mass is shown to be equivalent to the vacuum energy excluded by a spherical shell with an average diameter equal to the Compton wavelength of the electron. The ratio ~1836 is derived as a natural consequence of the vacuum energy exclusion.

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Introduction

There is considerable theoretical and experimental basis behind the idea that the vacuum of space is filled with numerous vacuum fluctuations. The total amount of energy in space due to these vacuum fluctuations has be calculated to be on the order of 10^{118} GeV/cm3, based on the assumption that the highest energy or shortest wavelength vacuum fluctuations are on the order of the Plank Length ~1.6 X 10^{-33} cm. One of the more important examples of a property of vacuum energy, the Casimir Effect, is based on the idea that the presence of matter interferes with the local vacuum fluctuations.[1,2] Given a cavity, wavelengths that are larger than the cavity will not be present inside of it. With the Casimir effect, if there are two plates close together, generally on the order of a micron or less to be measurable, the pressure due to the vacuum between the plates pushing the plates apart will be reduced becoming less than the outer pressure pushing the plates together. Consequently the plates are pushed together.

A spherical shell can also be considered as a Casimir cavity. Wavelengths of vacuum fluctuations shorter than the inner radius of the shell exist inside it. Vacuum fluctuations with a wavelength larger than the outer diameter of the shell exist outside it. The vacuum fluctuations with wavelengths between the inner diameter and outer diameter of a spherical shell are excluded. Based on this physical model it was thought that it would be constructive to compare the vacuum energy excluded by a spherical shell the diameter of a proton and compare that to the proton's mass energy.

Vacuum Energy of a Proton

The spherical shell simulating a proton was taken to have a radius equivalent to the proton charge radius as published in CODATA 2010, 0.8775(51) x 10^{-15} m (10^{-15} m = femtometers = fm). Likewise the CODATA 2010 value for the mass-energy 938.272046(21) MeV was used. From those values the mass-energy density of the proton was computed to be 3.315 x 10^{38} GeV/cm^3.

The vacuum energy density excluded by a spherical shell can be computed using Equation 1.[3] The angular frequencies ω_1 and ω_2 are related to the outer diameter d_o and inner diameter d_i respectively, where $\omega_1 = 2\pi c/d_o$ and $\omega_2 = 2\pi c/d_i$. The speed of light is designated as c and $\hbar$ is the reduced Planck's constant.

1)

$$\rho = \frac{\hbar(\omega_2^4 - \omega_1^4)}{8\pi^2 c^3}$$

To get a first approximation we can initially ignore the ω_1 term and compute the energy density for all wavelengths from the proton diameter, 1.755 fm and larger. This initial result is 4.106×10^{38} GeV/cm^3. Right away we can see that the excluded vacuum energy of a proton sized spherical shell is a good approximation of the mass energy of the proton. If we then set ρ equivalent to the mass-energy density of the proton and solve for ω_1 we find a value for d_o of 2.649 fm.

If we instead assume that the measured diameter of the proton based on the charge radius is the average of the inner and outer diameters and set the vacuum energy density equal to the known mass-energy density of the proton, we can calculate those inner and outer diameters. In this case $d_i = 1.586$ fm and $d_o = 1.924$ fm. The difference in diameters is 0.338 fm, which equates to a shell thickness of 0.169 fm.

Note that the exclusion of wavelengths on the order of the shell thickness was not considered. This is due to the idea that the proton shell must itself be a virtual structure composed of vacuum fluctuations. This is necessary because of the spin of the proton and the speed of light limit, for if the proton were composed of stable matter, the outer shell would reach velocities greater than the speed of light. The logically simplest way around this difficulty is to assume that the proton shell is a virtual structure with pair production and annihilation events progressing sequentially around the circumference of the shell in a manner simulating high velocity rotation. Smaller, higher energy vacuum fluctuations still exist in and around this structure as well, so they are not being excluded and therefore do not contribute to the mass-energy.

The value of the difference in diameter is interesting in that it is similar to the wavelength of a virtual proton-antiproton pair at the pair production energy, 0.330 fm = $\lambda_{p\text{-}a} = hc/4m_p$, where m_p is the mass-energy of the proton. The shell thickness is essentially what we would expect if the shell were composed of vacuum fluctuations.

Based on these simple computations it is readily apparent that the proton rest mass-energy is equivalent to the energy of the excluded vacuum fluctuation wavelengths if we assume that the proton is, or is surrounded by, a virtual spherical shell. It is important to note that the solution for a given radius or shell thickness is unique, since the density of a sphere varies with the radius cubed and the vacuum energy density varies with the diameter to the fourth power. Also note that at this stage of development, this mass origin theory does not preclude the concept that the proton contains additional dimensionless particles carrying other properties of the proton.

Vacuum Energy of an Electron

The electron is a bit more trouble as there are several radii associated with it, or possibly none at all for a bare electron. In the minds of most physicists of today the point-like particle model is favored, but to Quote MacGregor from *The Enigmatic Electron*, "a rather compelling case can be made for an opposing viewpoint: namely *that the electron is in fact a large particle which contains an embedded point-like charge*."[4] Unfortunately an experimental value for the electron radius in the realm of Compton scattering has never been firmly established. What is known is that the scattering radius of the electron with respect to photons and other electrons is many orders of magnitude larger than the scattering radius due to protons and other high-energy particles.

Using Equation 1, if we allow the mass-energy density of the electron to vary by trying various diameters while computing the vacuum energy for the same diameters we quickly find that the mass-energy density and excluded vacuum energy density numbers coincide at or near an electron diameter equivalent to the Compton wavelength. This is not too terribly surprising as the Compton wavelength is associated with both the scattering of photons by an electron and also with mass by the relationship $\lambda_c = h/m_e c$, where m_e is the rest mass of the electron. It is commonly accepted that the Compton wavelength equates to the rest mass-energy of an electron.

We can then compute the mass-energy density of the electron using the Compton wavelength as the electron diameter, CODATA 2010 value 2.4263102389(16) x 10^{-10} cm (10^{-10} cm = picometers = pm), and the CODATA 2010 value for the electron's mass-energy 0.510998928(11) MeV. The energy density of the electron is then calculated to be 6.833 x 10^{25} GeV/cm^3.

If we initially set d_i equal to the Compton wavelength, the energy density of the excluded wavelengths from that point and larger is 1.124 x 10^{26} GeV/cm^3, which we can see is very close to the electron mass-energy density. Then by setting the vacuum energy density equal to the mass-energy density of the electron we can solve for d_o = 3.066 pm, which is only slightly larger than the Compton wavelength. This first approximation is in good agreement with the electron rest mass, and gives a reasonable diameter relative to the Compton wavelength.

Then as before we can set the average diameter of the electron shell equal to the Compton wavelength and solve for the inner and outer diameter and we find they are d_i = 2.123 pm and d_o = 2.472 pm. The difference between those two diameters is 0.349 pm, giving a shell thickness 0.175 pm.

The electron Compton shell must likewise be a virtual structure so that it does not violate the speed of light limits when rotating and is transparent to shorter wavelength higher energy particles such as a proton. The difference between the inner and outer diameters when the electron diameter is set equal to the Compton wavelength is however a little over half the virtual electron-positron wavelength of 0.6066 pm = $\lambda_{e\text{-}p} = hc/4m_e$ at the pair production energy. This is inconsistent with the equivalent ratio that was found for the proton, by a factor of two. If instead we set the shell thickness equal to $\frac{1}{2}\lambda_{e\text{-}p}$ to match the proton and solve for the average radius where the vacuum energy density equals the mass-energy density we find that r = 1.592 pm, d_i = 2.880 and d_o = 3.487. This leads to the intriguing possibility that the proton and electron could have identical shell structures composed of their virtual particle counterparts.

Discussion

Having a fundamentally electromagnetic description of mass brings up some additional questions, the biggest of which is that if mass is a purely electromagnetic phenomena then gravity must be as well. This will certainly give those in search of a grand unified theory some hope. Having a simple electromagnetic description of mass should point us in the right direction.

Additionally a closer examination of Casimir-van der Waals forces needs to be made such that they are consistent with a shell model. In particular the van der Waals force between two protons when the minimum distance a between them is in the range $d_i < a < d_o$ needs to be analyzed in greater detail taking into account a shell structure, exclusion of vacuum fluctuation wavelengths over that range, and the transparency of the particles to shorter wavelengths. If the van der Waals force were to vary in proportion to $1/a^4$, for example, it would be equivalent to the nuclear force strength over that range. The Casimir force would diminish as the distance a becomes less than the wavelength that makes up the shell structure, allowing Coulomb repulsion to exceed Casimir attraction at smaller separation distances.

Conclusion

It has been shown that the mass of the proton is equal to the vacuum energy it displaces if it were a spherical shell structure with an average radius equal to its charge radius. The electron mass can also be derived based on the vacuum energy it excludes if it were a spherical shell with an average diameter equal to its Compton wavelength. Alternatively the electron could have a radius of ~1.6 pm if it has a virtual particle structure that is geometrically equivalent to the proton, with each being comprised of its virtual counterpart. Experimental verification of the electron charge radius will be necessary to determine the actual radius of the electron. The proton to electron mass ratio of ~1836 is also accounted for in the process. The simplicity of the technique is compelling even though a major re-evaluation of what we think we know about particles will be necessary to make this result consistent with a broader particle theory.

[1] Casimir, H.B.G., Polder D., "The Influence of Retardation on the London-van der Waals Forces", Nature 158, 787-788 (30 November 1946) | doi:10.1038/158787a0

[2] Casimir, H.B.G., Polder D., "The Influence of Retardation on the London-van der Waals Forces", Phys. Rev. 73, 360-372 (1948).

[3] Milonni P.W., The Quantum Vacuum, Academic Press LTD, London (1994), p. 49

[4] MacGregor M. H., The Enigmatic Electron, Kluwer, Dordrecht, Netherlands (1992) p. 5