One Clue to the Proton Size Puzzle: The Emergence of the Electron Membrane Paradigm

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Abstract

Recent experiments for proton radius measurement [1] [2], based on muonic hydrogen, confirmed that the proton size obtained by muon interaction is 4% smaller than the standard value. These results generated a new problem that was called “the proton size puzzle”.
This author believes that it occurs because the proton radius changes, depending on the particle with which it is interacting.
In this context the author proposes that the standard proton radius be defined in conditions, where a proton is isolated in space, without interacting with any other particle. In this condition the standard proton radius seems very close to the value obtained in muonic hydrogen experiments.
If this new standard proton radius value is accepted, one solution to "the proton size puzzle" must answer two basic questions:
a) Why does the proton increase its size, when interacting with an electron in a hydrogen atom?
b) Why does the proton maintain the (new) standard radius value, when interacting with the muon to form a muonic hydrogen atom?
Question (a) can be answered, in a context where the electric force that appears between the opposite charges (of the electron and the proton) may be affecting the proton and expanding its radius.
Considering the Heisenberg uncertainty principle, with the proton as an "observer" of the electron position, the proton also will not "know" where the electron position is. Thus the proton is simultaneously attracted to all positions where the electron might be, which are defined by orbital wave function.
Thus, the uncertainty principle could explain that the proton is subjected to a radial force field, which tends to increase its size.
Another solution for the proton size puzzle, proposed by the author, considers a change in the physical interpretation of orbital wave functions. These functions are currently connected to the probability density of the presence of the electron in a given volume of space. In this new interpretation, the wave function equations are the same, but their given values (that can be expressed in C/m3) can be associated with an effective density of electric charge, that exists simultaneously, composing a negative charge membrane, which are distributed in space around the atomic nucleus, as defined by the orbital wave function charge densities.
The author calls this new model the “Electron Membrane Paradigm” (EMP), because in it the “electron particle” turns as into an “electron membrane”.
The EMP has the potential to solve ’the proton size puzzle’, allowing the emergence of new theories, that can model both, electrons and other particles, in the form of strings and membranes.

1 – Introduction

In 2010, Dr. Randolf Pohl [1], from the Max Planck Institute of Quantum Optics in Germany, presented the results of experiments based on muonic hydrogen, where the electron is replaced by a muon particle with a negative charge equal to that of the electron, but with a mass 206 times greater. These experiments obtained a proton radius of 0.8418(67) fm, a value that is 4% lower than the standard proton radius (0.8775(51)fm).
In early 2013, the team of Dr. Aldo Antognini [2], from the Paul Scherrer Institut in Switzerland, presented results of more accurate muonic hydrogen experiments, that gives a proton radius value of 0.84087(39)fm. This new value confirms Dr. Pohl's team's results and virtually eliminates the possibility of experimental errors.
Currently, physicists around the world are looking for a solution to this problem, which now is commonly referred to as " the proton radius puzzle".
Many scientists investigate theoretical measurment errors, that may explain proton radius variation, but a plausible explanation for the new proton size is that muons do not interact with the protons in the same way they do with electrons. This means that proton radius changes, depending on the particle with which it is interacting.
For this author, the first clue to solving the proton size puzzle is to consider that the proton radius value, obtained by muonic hydrogen (0.84087fm), should be used as the new proton standard radius. The author believes that a proton isolated in space, without interacting with any other particle, presents this new standard radius value.
In this way the proton radius does not change when forming muonic hydrogen, incurring an increase of 4% when the proton interacts with the electron in a hydrogen atom.
One possible explanation for this proton radius increase is due to the electron-proton charge interation, thereby generating forces which tend to stretch the proton. For this to happen the proton should be subjected to a radial force field. This kind of field can appear when electron charges are distributed in the space surrounding the proton.
Thus, the author believes that the electron model in the hydrogen atom must be reviewed, considering two main lines of thought:

a) The Heisenberg uncertainty principle must be applied to a proton, acting as an electron "observer". In this way the proton is unable to determine the electron's position. This means that the proton is attracted simultaneously to all points where the electron may be;
b) The electron "wave/particle" model, illustrated by orbital wave functions, should be revised, considering that these equations calculate not only the electron position density probability. Thus the values defined by the orbital wave functions could be associated with real electric charge densities, with electrons being modeled by some type of membrane.

Option (a) is more conservative and can effectively explain why the proton radius increases when it forms a hydrogen atom, but does not explain why the size of the proton does not change when it interacts with a muon.
Option (b) leads to a new model of electron shaped membrane, called an "Electron Membrane Paradigm" (EMP) by the author.

The EMP maintains all the equations of an orbital wave function, including keeping the final unit (C/m3) used in some equations, modifying only the physical interpretation of this function.
In the EMP the electron ceases to appear as a point-like particle that revolves around the proton and starts to form a negatively charged membrane, where the total charge is equal to the electron charge. Thus when the electron receives energy and make an orbital change, in fact, the electron membrane assumes the new orbital shape.
In this new model when the electron is ejected from the atom, it continues to maintain a spherical membrane shape, which can explain, for example, the fact that a single electron can interact with itself in a double-slit experiment.
In an EMP expansion, a muon also assumes a membrane shape, but much smaller than an electron membrane.
Thus in muonic hydrogen, the muon does not "capture" the proton inside its membrane, but only orbits the proton, and so, not generating any radial force on the proton, which maintains its (new) standard radius.

1 – Electron Particle/Wave Paradigm

Figure 1 illustrates the historical advances of the atomic model. The Figure 1(a) shows the model proposed by Thomson in 1897, where the atom form is a "plum pudding". Figure 1(b) shows the atomic model proposed by Rutherford in 1911, known as the planetary model, where electrons are represented as small dots orbiting an atomic nucleus.
The experimental impossibility of simultaneously determining the position and velocity of the electron, led Heisenberg to formulate the principle of uncertainty, creating one of the foundations of quantum mechanics. Due to this principle the electron position in one orbital is modeled by a probability density function. This function gives us the probability of finding an electron in some region of space.

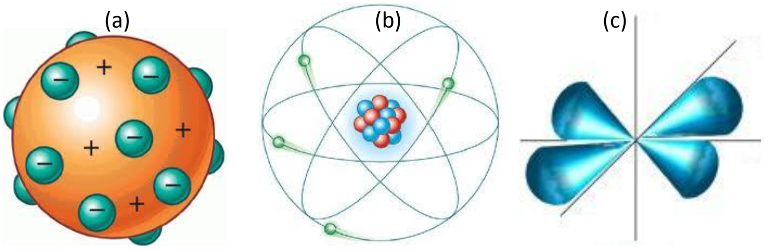

Figure 1 - Historical evolution of the atomic model.

Thus the current electron model considers the Particle/Wave Paradigm (PWP) in which the uncertainty principle is applied and the equations defined by Schrödinger are used in the definition of atomic orbital wave functions, as represented in Figure 1(c).
It is important to note that the model of Rutherford’s electron remains in the basis of the PWP, because orbital wave functions define a density probability distribution of the electron is in a given space volume. Thus, until today, the electron is still interpreted as a "small ball" orbiting an atomic nucleus.

Figure 2 shows a graphical representation of PWP, where the s-orbital wave function is represented as a spherical shell, which defines where the probability of finding an electron is increased.

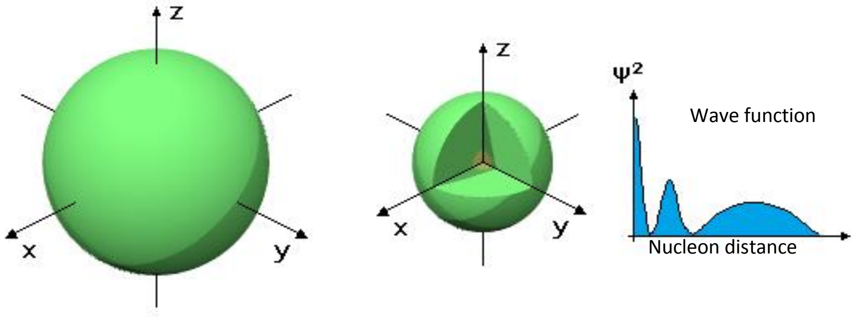

Figure 2 - Representation of the wave function of the s-orbital.

Figure 3 shows an alternative representation, where the wave function is associated with a "cloud" of points, defining where it is more probable that an electron will be found. Thus in a temporal analysis, the orbital wave function also defines an average density value of an electric charge that is expressed in C/m3.

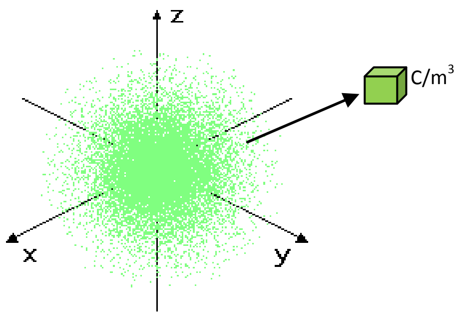

Figure 3 - The s-orbital seen as a cloud of negative particles.

2 – Heisenberg principle applied to electron-proton interaction

The first contribution of this paper to 'the proton size puzzle' considers the Heisenberg uncertainty principle applied in a context where a proton "observes" an electron when it is forming a hydrogen atom.

Figure 4 (a) shows a schematic diagram of the electron orbiting the proton, in which it is usually considered that attracting forces exist between the two particles.

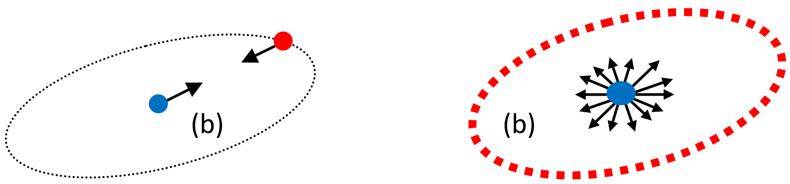

Figure 4 - Forces that arise between an electron and a proton in a hydrogen atom.

Figure 4 (b) represents the application of the uncertainty principle to the proton, that is not capable of determining the electron position, and so the proton does not know in what direction the electron is. In this way the proton is subjected to a radial force field, made up of forces that link this proton to all positions where the electron could be located. Thus when forming a hydrogen atom, the proton increases its size, which partially responds to the proton size puzzle. But this model does not explain why the proton does not increases its size when interacting with a muon.

3 – Electron Membrane Paradigm

The Electron Membrane Paradigm (EMP), proposed by the author, abandons the Rutherford electron model and sees the electron as being composed of a membrane, taking the shape of an atomic orbital wave function.
It is important to note that the EMP has the same formulas defined in the electron particle/wave paradigm, changing only the physical interpretation of the wave functions. So in the EMP an orbital wave function does not represent probability density distribution, and becomes associated with a real electrical charge density distribution, defining thus a membrane composed of negative charges surrounding the atomic nucleus.

The EMP proposes a solution to ‘the proton size puzzle’’ , which is shown in Figure 5.

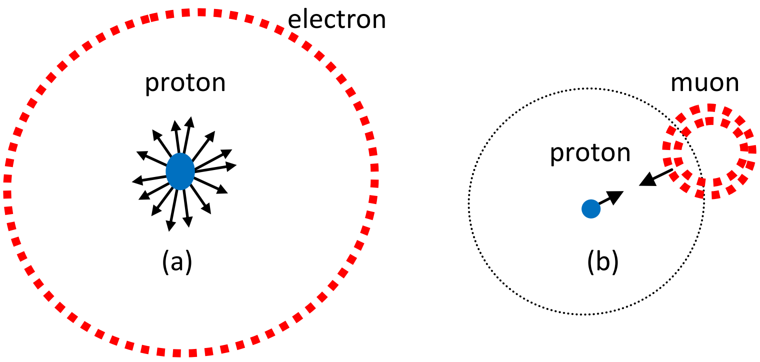

Figure 5 - Forces that arise between proton: (a) In a normal hydrogen atom; (b) In a muonic hydrogen.

In Figure 5(a) we can observe that the electron membrane generates attractive forces that stretch the proton in all directions, tending to increase the proton radius.
The muonic hydrogen case is represented in Figure 5(b), where the muon also forms a membrane, but is much smaller than the electron membrane. Thus the muon cannot “capture” the proton inside its membrane, and so it orbits around the proton as proposed in the standard model. In this condition the muon charge cannot generate forces that increase the proton’s radius.
If Figure 5 were drawn on a scale where the proton has the size of a marble, the electron membrane could cover a football field, while the muon membrane would be the size of a pizza. Thus, in the hydrogen atom, the electron "captures"the proton within its membrane, whereas in muonic hydrogen, the muon only orbits the proton, as shown in Figure 5.

4 – And even if the electron is in fact a membrane?

In the particle/wave paradigm the electron is related with a point-like particle, but due to Heisenberg's uncertainty principle, it can only be studied in a statistical way, being associated with a wave function, which defines regions with the highest probability density of the electron to be found.
However the assumption that the electron is composed by a negative charge membrane sheds new light on the historical evolution of atomic models. If this hypothesis is true, the Rutherford atom planetary model becomes as distant from reality as the "plum pudding" atom model proposed by Thomson.
In addition to an electron shaped membrane, the questions "What is the position of the electron?" and "What is the speed of the electron?" stop of making sense, because in these membranes exist sets of negatively charged particles, each one assuming a certain position and speed.
In a simple analogy, we can for example, ask: “What is the position of the Eiffel tower, in relation to the earth's surface?”, hoping to get an answer of a pair of coordinates (latitude and longitude).
Moreover in the EMP, asking what is the position of an electron in an atom’s orbit is the equivalent to asking what is the Europe’s position, in relation to the earth's surface, hoping to receive a pair of numeric values in response. In this analogy we could say that there is some “uncertainty” in Europe’s position, setting a probability function that describes where Europe can be found, resulting in a world map where the European continent is highlighted.

This author believes that for the case of electrons orbiting the atomic nucleus in the uncertainty principle, proposed by Heisenberg, becomes the "right answer" to the "wrong question."
Trying to get a point on the map we and found a continent, and precisely define its contours and its relief, but for historical reasons we are not yet able to accept the results, and so we continue thinking that this continent is just a dot on the map.

5 – EMP opens points

The EMP allows some variation in electron membrane representations, such as:

- The electron can be considered as a gelatinous membrane which occupies exactly the region defined by the wave function, somewhat similar to that shown in Figure 2.
- The electron may be composed of a cloud of points, similar to that shown in Figure 3. These points would be associated with "micro-electrons", particles formed by punctual negative charges;
- The electron is formed by a two dimensional spherical shell (or with very little thickness, for example equal to Planck length). Thus the electron only partially takes the shape one orbital wave function. In this way the electron spherical shell would tend to rotate and oscillate, slightly varying its position around the proton.

Each of these models can be linked with certain orbital wave functions, and the final value of charge density (C/m3) may either be due to some electrical charges that exist simultaneously, but also can be associated with the movement of these charges in space.

It is important to mention that the EMP also has some critical points, such as: If the electron is in fact made up of a set of negative charges, how does their charge remain together, despite the electrical repulsion forces? This type of problem can be solved in several ways, like the definition of a new type of force that holds the electron membrane together.

Moreover, the EMP has the potential to clarify some aspects of the electron's behavior. For example, an electron moving in a vacuum in the standard model is considered as a point particle, while in the EMP this electron assumes the shape of a spherical shell, with a diameter slightly larger than a hydrogen atom, which could be explained better as a single electron able to generate the phenomenon of diffraction in a double-slit experiment.

6 – Conclusion

The Rutherford planetary atom model has just completed a century of existence, and until today, gives some basis for the particle/wave paradigm that defines the electron. Even Schrödinger´s equations, which define orbital wave functions, are interpreted as density probability distribution functions of finding the Rutherford "planetary electron" in a certain region of space.

In the hypothesis that the electron is effectively a membrane, a relatively small step is needed from the particle/wave paradigm to the adoption of an electron membrane paradigm. In fact the EMP uses the same equations and the same units (C/m3) needing only a new physical interpretation for orbital wave functions, where it defines a real density of electrical charge distribution. But the planetary atom model is deep rooted in the foundations of physics, and so a new electron membrane paradigm isn't easily accepted.

In this scenario the author believes that the experiments with muonic hydrogen performed by Dr. R. Pohl´s and Dr. Antognini´s teams should in future become a landmark in modern physics, with the potential of being important, as the historical experiment of the Michelson-Morley interferometer, which marked the end of the preponderance of Newtonian mechanics.

In fact the experiments with muonic hydrogen give us the first opportunity in the history of physics to overcome the Rutherford atom model, laying aside the naive attempt to adapt the patterns that we observe in our solar system, in order to describe the atom's behavior.

It should be noted that the EMP generates a series of new challenges, such as explaining why the repulsive forces that appear between the negative charges do not break the electron membrane.

Besides this, the EMP opens up a new possibility of the emergence of new types of theories that may, for example, model some particles, including the protons electrons and neutrons, through strings and membranes.

This author proposes a new string theory [1], which relies on the existence of a complex time, where the collapse of imaginary time transforms point-like particles into strings and membranes.
In the context of this theory, the author has developed a model [4] in which the proton is also seen as a membrane, with positive charge shells forming a solid structure, like the layers of an onion.
This model allows calculating the radius of a proton isolated in space, using the following equation:

$$r_p = \frac{4\hbar}{c\, m_p} \tag{1}$$

Where $\hbar$ is the reduced Planck constant, c is light speed and m_p proton mass, obtaining:

$$r_p = 0.841235641(47) \text{ fm}$$

This value is only 0.043% higher than the proton radius obtained in the experiment with muonic hydrogen [2], and only 0.015% higher than the average value of the proton radius (0,84137045fm), given in [1] and [2].
An error so small seems to demonstrate that the new models presented by the author in [3] and [4] have some validity.
However, acceptance of equation (1) demands physicists to break a large number of paradigms, including the existence of complex time, the possibility of modeling protons, electrons and muons as membranes, and the possibility that the mass of a particle is related to the "number of loops" on the string that defines its membrane.
These innovative concepts can currently only be fanciful ideas, but there is also the possibility of them being true, and so equation (1) can be used in the future as the basis to defining the standard proton size.

7 – References

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