Explaining the Variation of the Proton Radius in Experiments with Muonic Hydrogen

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Summary

In experiments for proton radius measurement that use muonic hydrogen, the value obtained was four percent below the expected standard value, which is not explained by quantum electrodynamics.
This article theoretically explains this results and presents an equation that calculates the proton radius, which coincides with the value obtained in muonic hydrogen experiments, with a difference of only 0.07 percent.
These results are based on Ulianov String Theory (UST), a new String Theory, which is able to model the most important particles in our universe as photons, protons, electrons, neutrons, muons and positrons.
The author believes that the experiment with Muonic Hydrogen represents a breakthrough in modern physics, because it points out flaws in the standard model and opens space for new theories that model the electron and proton as strings.
The experience with muonic hydrogen may lead to a model in which the electron is no longer a "small ball" orbiting the nucleus and it turns into a two-dimensional brane surrounding the nucleus. Thus, this experiment has the potential to be so important, such as the historical experience of the Michelson interferometer, which marked the end of the preponderance of the Newtonian mechanics.

1 – Introduction

This article was developed based on results obtained in the context of Ulianov String Theory [1] (UST), a new type of String Theory, which is the outcome of a solitary work performed by the author for about 20 years. This work was initially developed by the author as a hobby, seeking the construction of a "fictional universe", in other words, a complete and mathematically coherent universe (but not connected to our own universe) that can be simulated on a digital computer.
The UST was created from a few simple rules, such as the idea of "quadruple universe" proposed by Isaac Asimov in a scientific article published in 1966 [2]. In this article, Asimov presents an innovative explanation for the excess of matter in our universe. In that same year of 1966, the Russian physicist Andrei Sakharov has also proposed an explanation for the problem of antimatter "loss" in the creation of our universe. Sakharov proposed that a small imbalance in the formation and annihilation process of matter / antimatter would have led to the preponderance of matter.
The Sakharov solution was widely publicized and accepted, and it seems that no serious scientist has had leastways noticed the explanation proposed by Asimov. This may have occurred because Isaac Asimov had a great prominence as a science fiction writer, and his scientific articles (published in books and magazines aimed at an outsider audience) had been somehow "mixed" with his tales of science fiction.
However, Asimov's geniality in creating fictional stories was not an impediment so that he could have great ideas in science areas, such as the four-leaf clover universe[2], which gives base to the Ulianov String Theory.
The UST models use a very simple mathematics, but that is based on a powerful set of ideas that seem somehow related to the bases that form our universe. This observation was made by the author who, during the development of the UST, noticed the emergence of a series of structures that compose matter and energy particles that in some aspects are similar to particles observed in our universe. Moreover, the UST generates models that allow calculating some values that are considered physical constants in standard model, as the proton radius, hydrogen atom radius, muon mass, and the electric charge of the electron.
Thus, by modeling the proton at UST it was possible to generate an equation for calculating the proton size, but the value obtained is four percent below the standard value.
Coincidentally, the problem of obtaining a proton with radius lower than the expected was also

occurring in experiments with muonic hydrogen. These experiments use muons (particles with negative charge and mass 200 times greater than that of the electron) that are launched against hydrogen atoms. In some cases, a muon replaces an electron, forming a muonic hydrogen atom. Since the muon is heavier, it should, in principle, allow measuring the proton radius with greater precision. However, in the results obtained with muonic hydrogen, the radius value measured for the proton was four percent below the expected standard value.
Initially, physicists thought that the inconsistent results coming from some experimental problem, but after a long and meticulous work, a team of physicists led by Dr. Randolf Pohl [3], published in July 2010 an article, in which the results of the experiments with muonic hydrogen were accepted as true, raising questions on some points of the theory of the quantum electrodynamics, one of the "jewels" of the standard model of modern physics.
When the author became aware of the work published by Dr. Pohl's team, he verified that the value of the proton radius obtained in the experiment with muonic hydrogen was almost the same to the theoretical value obtained from the basic model of the proton defined in the UST. The author then contacted the Dr. Pohl team and submitted the UST equation, which allows calculating the proton radius. Dr. Pohl confirmed that the theoretical value obtained in UST equation was almost equal to that obtained experimentally by his team, but emphasized that the actual problem would be to explain the reason why different experiments were generating different results when measuring the radius of the proton.
The study of the experiment with muonic hydrogen in the context of UST was a big deal, because it concluded some aspects of this theoretical model and also generates a link with results of an important experiment, which is not currently explained by standard models of physics.

2 –Ulianov String Theory

Ulianov String Theory (UST) is a new type of string theory, in which all particles of matter and energy are composed of punctual particles that move in space in function of a complex time, composed of a real part (real time) and an imaginary part (imaginary time).
The collapse of the imaginary time transforms these particles into cords or strings, which can be viewed as sequences of small spheres (with diameter equal to the Planck distance), which align in sequence, like beads on a necklace, and wrap themselves in different forms, generating curved lines, areas (membranes) and also volumes.
In UST, all strings have the same length, thus the string that composes one photon is, in some aspects, very similar to the strings that form a proton or an electron.

3 – Complex Time in UST

One of the most basic aspects of Ulianov String Theory is the treatment of time as a complex variable (s) that can be defined by:

$$s = t + \mathrm{i}\, q \qquad (1)$$

Where t represents real time and q represents the imaginary time.
In UST, the complex time can be defined on a cylindrical surface, in which the dimension of imaginary time has a fixed length equal to the perimeter of a circular section defined in this cylinder.

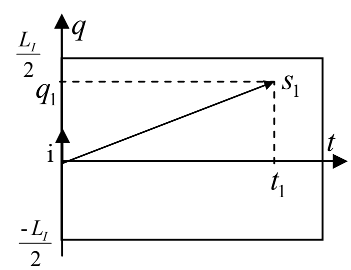

Figure 1 – Flattened representation of the complex time.

Figure 1 shows a flattened representation of complex time, where L_I represents the length of imaginary time. The real time, in turn, has no limits in this model, assuming a value that expands continuously.

4 – Fundamental particles in the UST model

A point particle (φ) defined in a three-dimensional space moving in a function (F) of a complex time, can be generally modeled by:

$$\varphi(x, y, z) = F(t, q) \tag{2}$$

Considering that this particle moves in space as a function of imaginary time, describing a non-null trajectory, the collapse of the imaginary time will transform this particle into a string, because the positions that the particle occupies in function of the variation of the imaginary time, will exist all at once.

All particles modeled in the UST move (in complex time) at speed of light (c). On this way, the string generated by the collapse of the imaginary time will have a length (L) given by the following equation:

$$L = c\, L_I \tag{3}$$

Considering that the particles which align to form a string have non-null size, each particle can be represented by a small sphere, or a small cube that contains this sphere. This cube can be defined by the size of your hand (α) which is also equal to the diameter of the considered sphere.

Assuming that the formed string is composed of the number (M) of aligned spheres, this value can be calculated by:

$$\mathrm{M} = \frac{c\, L_I}{\alpha} \tag{4}$$

Note: The small spheres forming strings in UST model are connected to punctual particles, called Ulianov Holes (uholes). Thus, a UST string is composed of uholes sequences, which can be classified into six major types, each containing different values of mass and electric charge. A more complete description of uholes can be observed in reference [1].

5 – The photon modeled by UST

In UST, the photon is a basic type of string which wraps itself in a circular ring, as shown in Figure 2. In this figure, the red circles represent uholes with null mass and negative electrical charge and the blue circles represent uholes with null mass and positive electrical charges. The black circle shown in this figure represents an uhole with null charge and positive mass, while the white circle represents an uhole with null charge and negative mass.

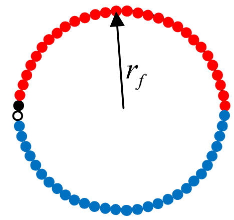

Figure 2 - Basic string modeling photon in UST.

The basic photon string shown in Figure 2 was denominated, in UST, as photonic ring. It has a radius r_f, that is associated to the wavelength of the photon (λ_f), by the following equation:

$$\lambda_f = 2\pi\, r_f \tag{5}$$

The length of the photonic ring is usually much smaller than the length *L,* which is defined by equation (3). This means that the photon basic string is rolled up in (N) overlapped turns.

From equations (3) and (5), the number N of turns of the photonic ring can be calculated by the equation:

$$\mathrm{N} = \frac{c\, L_I}{\lambda_f} \tag{6}$$

In the photon model adopted in UST shown in Figure 2, for each revolution of the photonic ring there are only two particles with mass. One of these particles has unitary positive mass (matter particle) and the other has unitary negative mass (antimatter particle).

Thus, the total mass in photons is zero but, even so, those particles with mass also have kinetic energy associated, which can be expressed by the basic equation that relates the energy (E) of a mass *(m)* moving at a velocity *(v):*

$$\mathrm{E} = |m| \frac{v^2}{2} \tag{7}$$

Note: The UST model considers that the antimatter has negative mass, but its kinetic energy is still positive. Thus, in UST it is necessary to use a module function over the mass value in all equations that relate the mass (matter and antimatter) to energy.

Since there are N turns in each photon, the positive mass of a photon (m_{fp}) is given by:

$$m_{fp} = \mathrm{N} m_u = \frac{c\, L_I}{\lambda_f} m_u \tag{8}$$

Where m_u is the mass associated to an uhole, given in kilograms, which can be calculated based on the value of L_I .

The negative mass of the photon (m_{fn}) has the same value given by equation (8), but with opposite sign:

$$m_{fn} = -\frac{c\, L_I}{\lambda_f} m_u \tag{9}$$

Thus, in the UST model, the kinetic energy of the photon is obtained by considering that both sets of particles with mass (matter and antimatter) move (obviously) at the speed of light:

$$\mathrm{E} = \left|m_{fp}\right|\frac{c^2}{2} + \left|m_{fn}\right|\frac{c^2}{2}$$

$$\mathrm{E} = m_{fp}\, c^2 \tag{10}$$

Thus, by applying the equation (8) into equation (10), we obtain:

$$\mathrm{E} = \frac{c\, L_I}{\lambda_f} m_u c^2$$

$$\mathrm{E} = \frac{c^3\, L_I}{\lambda_f} m_u \tag{11}$$

In standard model, the photon energy can be calculated by the following equation:

$$\mathrm{E} = \frac{h\, c}{\lambda_f} \tag{12}$$

Where h is Planck's constant.

Equaling the energy in equations (11) and (12), it is possible to obtain the following relation:

$$\mathrm{E} = \frac{h\, c}{\lambda_f} = \frac{c^3\, L_I}{\lambda_f} m_u$$

$$L_I = \frac{h}{c^2\, m_u} \tag{13}$$

6 – Proton model in UST

In UST, the proton is modeled by a string similar to that which forms the photon, but only containing particles (uholes) with positive mass and positive electrical charge, as shown in Figure 3.

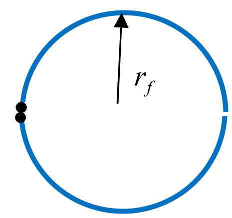

Figure 3 - Basic string which forms the proton.

In the case of the proton, the basic string shown in Figure 3 is rolled up in concentric turns, assuming the shape of a circular membrane, as shown in Figure 4.

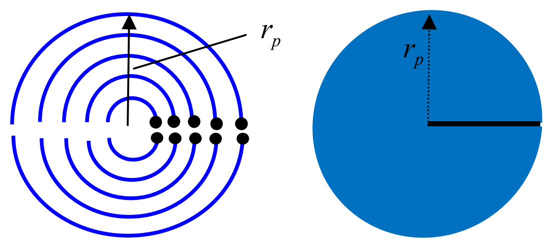

Figure 4 - Basic string which forms the proton in a more realistic representation.

Despite the fact that the basic string that forms the proton wraps composing a flat area, its overall length is still much smaller than the length L defined in equation (3).

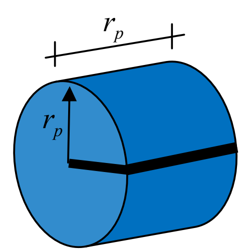

Figure 5 - Basic string which forms the proton with all turns represented.

Thus, the basic proton string will also manifest itself in several turns, which can be grouped on each other, generating a representation in cylindrical shape, as shown in Figure 5.

However, the UST representation of proton shown in Figure 5 is simplified, so that it does not consider a realistic distribution for the proton charge distribution in space.

In a more realistic model, the circular area forming the proton basic string tends to maintain the same central axis in space, assuming different rotation angles and fitting as the buds of an orange.

Figure 6 shows a top view of basic strings that form the proton, according to two distinct representations. In the 6-a representation, we have a simplified representation of the proton that has the shape of a massive cylinder (which was shown in Figure 5). In the 6-b representation, the proton string assumes the shape of a solid sphere, as shown in Figure 7.

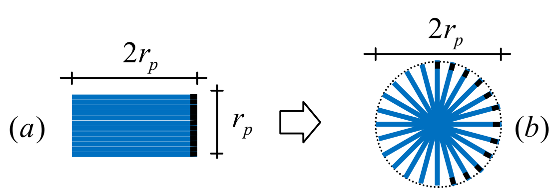

Figure 6 - Top view of the circular areas that form the proton. a) Represented in a cylindrical shape. b) Represented in a spherical shape.

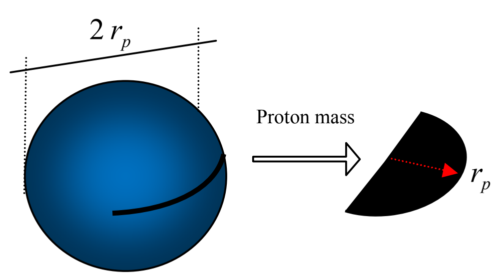

Figure 7 - Complete string that forms the proton in a more realistic spatial representation.

In the model shown in Figure 7, the proton can be observed as a perfect sphere, within which positive charges are distributed according to a uniform density. In this model, the proton mass assumes the shape of a semicircle that is inserted in the sphere "equatorial" section, represented in black in Figure 7.

In order to calculate the proton radius, it is more convenient to consider the simplified representation shown in Figure 5, instead of using a spherical representation presented in Figure 7. The usage of different representation of the particles in UST, is best discussed in item 7 of this article.

Based on Figure 5 proton representation, we can assume that it consists of a large number of small spheres (uholes) aligned in linear layers within the volume of the cylinder shown in this figure. In this case, it is possible to associate a cubic volume (α^3) for the total space occupied by a sphere, and thus the total number (M) of spheres can be directly calculated, considering the cylinder volume as the following equation:

$$\mathrm{M} = \frac{\pi\, r_p^3}{\alpha^3} \tag{14}$$

Since UST considers that all particles are formed by strings that have the same number (M) of uholes, we can equal the equations (4) and (14):

$$\begin{gathered} \frac{c\, \mathrm{L}_1}{\alpha} = \frac{\pi\, r_p^3}{\alpha^3} \\ c\, \mathrm{L}_1 \alpha^2 = \pi\, r_p^3 \end{gathered} \tag{15}$$

In addition, in Figures 4 and 5 we can observe that the proton mass is formed by two overlapping planes. Thus, we can calculate the proton mass (m_p) by using the following equation:

$$\begin{gathered} m_p = \frac{2\, r_p^2\, m_u}{\alpha^2} \\ r_p^2 = \frac{\alpha^2 m_p}{2 m_u} \end{gathered} \tag{16}$$

Applying equation (16) into equation (15):

$$\begin{gathered} c\, \mathrm{L}_1 \alpha^2 = \pi\, r_p r_p^2 \\ c\, \mathrm{L}_1 \alpha^2 = \pi\, r_p \frac{\alpha^2 m_p}{2 m_u} \\ c\, \mathrm{L}_1 = \pi\, r_p \frac{m_p}{2 m_u} \end{gathered} \tag{17}$$

Thus, applying equation (13) into equation (17), we obtain:

$$c\frac{h}{c^2\, m_u} = \pi\, r_p\, \frac{m_p}{2m_u}$$

$$\frac{h}{c} = \pi\, r_p\, \frac{m_p}{2}$$

$$r_p = \frac{2h}{\pi\, c\, m_p} \qquad (18)$$

Considering the following values for the used constants [4]:

$h = 6.62606896 \text{ x}10^{-34} \text{ kg m}^2 \text{ s}^{-1}$
$c = 299792485 \text{ m s}^{-1}$
$m_p = 1.67262\text{x}10^{-27} \text{ kg}$

By applying these constants into equation (18), the proton radius can be calculated as:

$$r_p = 8.41236382\text{x}10^{-16} \text{ m}$$

We observe that the proton radius measured in experiments with muonic hydrogen (8.4184 x10 -16 m) has a difference of only 0.07% in relation to the proton radius value, which was calculated by equation (18).

7 – The experimental problem

The UST model leads to a proton radius value almost equal to the one that the Dr. Pohl team obtained in the experiments with muonic hydrogen. But unfortunately it is not possible based only on this numerical result to affirm that somehow the proton model defined in the UST is correct.
The UST should also be able to explain the reason why the apparent size of the proton (measured in both hydrogen atoms, as in several experiments of electronic dispersion) differs so much from the value obtained with muonic hydrogen.
The author believes that the UST model has an answer to this question, and it will be presented in this work. But first we need to briefly present the UST models for the electron and the muon.

8 – The electron in UST model

In UST, the electron is modeled by a basic string, quite similar to the string that forms the proton (represented in Figure 3), but it is composed by negative electrical charges, as shown in Figure 8.

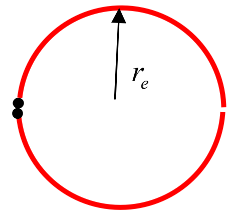

Figure 8 - Basic string which forms the electron.

In the case of electron, the basic string is also wrapped in several coils. In a more accurate spatial representation, these strings revolve around a common axis and generate a spherical surface as shown in Figure 9. In this figure, only three turns of the electron basic string are represented, thus in practice, there will be millions of turns, composing a membrane that takes the shape of a spherical shell.

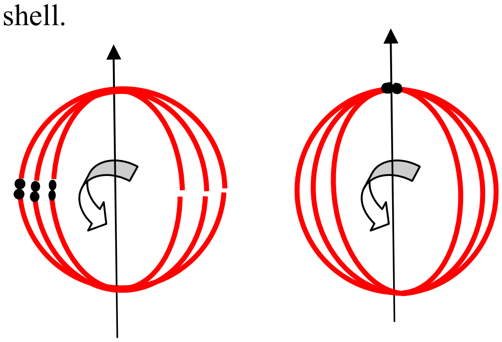

Figure 9 - Two types of representation for the spherical shell that forms the electron.

Figure 9 presents two forms of spin, in which the basic string of the electron (shown in Figure 8) can be organized in order to compose a spherical shell. In the first case, the negative charges forming the electron are distributed on a spherical surface, while its mass is concentrated in a line on the "equator" of the sphere, as shown in Figure 10.

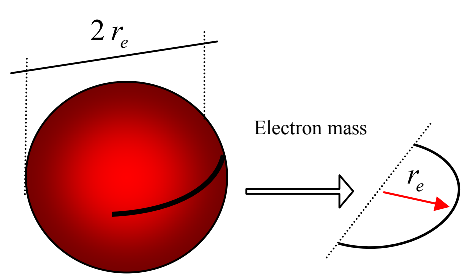

Figure 10 - Spatial representation for the membrane that forms the electron.

Figure 11, on the other hand, presents the case in which electron charges are also evenly distributed over a spherical shell, but in this case the mass is concentrated at a single point on one of the "poles" of the electron.

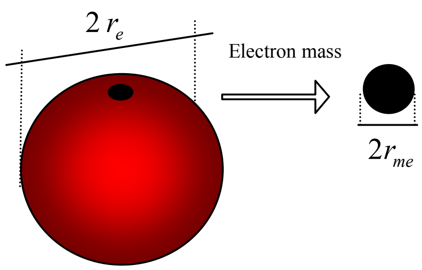

Figure 11 - Another spatial representation for the membrane that forms the electron.

In UST, in addition to the two spatial representations presented above, the string that forms the electron can also wrap up like a spherical calotte, as presented in Figure 12. This electron model is quite interesting because it explains how two electrons that have opposite spins can join in a same "orbital". In this case, a helium atom, for example, which will consist of two overlapping spherical calottes, united by its masses and occupying a unique sphere.

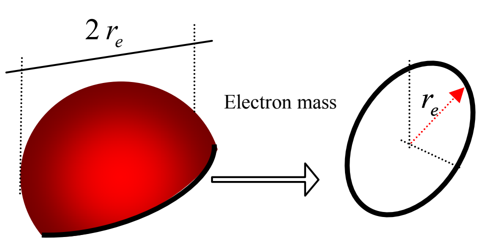

Figure 12 - Electron membrane composing a spherical calotte with its mass distributed in a circular ring.

It is important to observe that at UST, the most realistic spatial proton model, shown in Figure 7, also has alternative representations, as the one shown in Figure 13, in which the proton mass is modeled by a cylinder arranged in a radial direction, as shown in this figure .

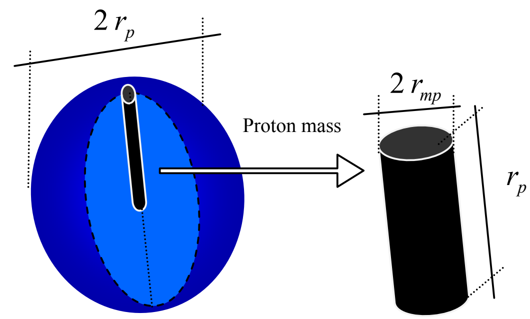

Figure 13 - Representation of the proton with its mass occupying a cylindrical arrangement.

A greater detailing of each spatial representation of electrons and protons considered by UST is beyond the scope of this article. However, it is important to note that the configurations of strings that can be used to examine some basic aspects of each particle do not directly depend on a realistic spatial representation.

This UST aspect can be observed on the analogy presented in Figure 14. This figure contains a photograph of a person in front of the artwork "Halo" produced by Anish Kappor [5]. Considering simultaneously Figures 6 and 14, we can establish some similarities, and observe that the spatial representation of the proton is analogous to the fragmented image of an object (a person) reflected on the mirrors of Halo.

Figure 14 - Photo of Halo, an artwork by Anish Kapoor.

In this analogy, if we want to study basic aspects of the object (or person), it is much easier to look at it directly than to deal with its fragmented image. Similarly, in order to study the proton it is easier to consider the simplified representation shown in Figure 5 than deal with more realistic spatial representations shown in Figures 7 and 13.
Thus, a key point for the study of any particle in the UST is to obtain its simplified representation.
For the case of the electron, Figure 15 shows a simplified representation which is basically a circular area with radius equal to r_e (electron radius) filled by uholes with negative charge. In this representation, the electron mass was grouped into a much smaller circular area with radius equal to r_{me} (radius of the electron mass) represented in black in the figure.

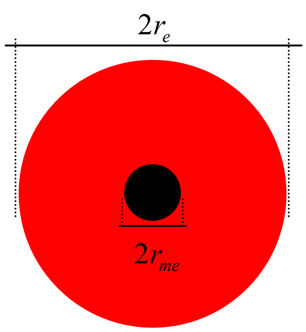

Figure 15 - Simplified representation of the membrane that forms the electron.

When analyzing Figure 15, we can infer that the number (M) of uholes forming the membrane of the electron can be calculated by dividing the area defined in the red circle by the area occupied by an uhole:

$$\mathrm{M} = \frac{\pi r_e^2}{\alpha^2} \tag{19}$$

In UST, the total number of uholes of the electron is equal to the proton´s, and thus the equation (14) can be equaled to the equation (19):

$$\frac{\pi r_p^3}{\alpha^3} = \frac{\pi r_e^2}{\alpha^2}$$

$$\alpha = \frac{r_p^3}{r_e^2} \tag{20}$$

Considering now the parameter ρ defined by the relation between the proton mass and the electron mass:

$$\rho = \frac{m_p}{m_e} \tag{21}$$

Since the standard value of ρ is 1836,165.

A similar relationship, represented by the parameter σ, can be defined considering the radius of these two particles:

$$\sigma = \frac{r_e}{r_p} \tag{22}$$

Noting that in UST, the radius of the electron is equivalent to the radius of a hydrogen atom ($1.06\text{x}10^{-10}$ m). Applying the standard value of the proton radius ($8.768\ \text{x}10^{-16}$) in equation (22) we obtain:

$$\sigma = 120894{,}16$$

Similarly, if we apply the value of the proton radius measured in experiments with muonic hydrogen ($8.4184\ \text{x}\ 10^{-16}$m) in equation (22) we have:

$$\sigma = 125914{,}66$$

According to UT the values of ρ and σ depend on the length of the imaginary time (L_I). Thus, these two constants can be related by one equation, that in the context of UT can be defined as follows:

$$\pi\sigma^2 = 8\rho^3 \tag{23}$$

And so we can calculate:

$$\sigma = \frac{r_e}{r_p} = \sqrt{\frac{(2\rho)^3}{\pi}} = 125556{,}08 \tag{24}$$

Note that the value obtained by equation (24) is 3.7% above the value obtained using the standard radius of the proton and 0.28% below the value obtained using the proton radius obtained in experiments with muonic hydrogen.

Applying the equation (24) in equation (20):

$$\alpha = r_p \frac{r_p^2}{r_e^2}$$

$$\alpha = r_p \frac{\pi}{(2\rho)^3} = \frac{r_e\sqrt{\pi^3}}{(2\rho)^{9/2}} \tag{25}$$

Being obtained:

$$\alpha = 5{,}561923\text{x}10^{-26}\ \text{m}$$

Applying the equation (25) in equation (14):

$$\mathrm{M} = \frac{\pi\, r_p^3}{(r_p \frac{\pi}{(2\rho)^3})^3}$$

$$M = \frac{(2\rho)^9}{\pi^2} \tag{26}$$

Being obtained:

$$M = 1{,}2307\text{x}10^{31}\ \text{m}$$

Similarly applying the equations (25) and (26) in equation (4), the length of imaginary time can be calculated as:

$$L_I = \alpha \frac{\mathrm{M}}{c} = r_p \frac{\pi}{(2\rho)^3} \frac{(2\rho)^9}{c\pi^2}$$

$$L_I = r_p \frac{(2\rho)^6}{c\pi} \tag{27}$$

Being obtained for the value of the standard proton radius:

$$L_I = 0{,}002283\ \text{s}$$

Defining the length of imaginary time in units of Planck time:

$$L_{IPlanck} = L_I \sqrt{\frac{c^5}{h\,G}}$$

$$L_{IPlanck} = 1.6896\text{x}10^{40}$$

The above value represents the number of point particles that form the strings in the model UST.

Applying equation (27) in equation (13):

$$m_u = \frac{h}{c^2\, L_I} = \frac{c\pi\, h}{c^2 r_p (2\rho)^6}$$

$$m_u = \frac{\pi\, h}{c\, r_p (2\rho)^6} \tag{28}$$

Being obtained:

$$m_u = 3{,}3628\text{x}10^{-48}\ \text{kg}$$

From Figure 15, we can also calculate the mass of the electron (m_e) through the equation:

$$m_e = \frac{\pi\, r_{me}^2\, m_u}{\alpha^2} \tag{29}$$

Applying the equations (18) and (21) we can relate the radius containing the mass of the electron (r_{me}) with the electron radius (r_e), as follows:

$$\rho\, m_e = \frac{\rho\pi\, r_{me}^2\, m_u}{\alpha^2} = m_p = \frac{2\, r_p^2\, m_u}{\alpha^2}$$

$$r_{me} = r_p \sqrt{\frac{2}{\rho\,\pi}} \tag{30}$$

Applying the equation (24) in equation (30):

$$r_{me} = \frac{r_e\sqrt{\pi}}{\sqrt{(2\rho)^3}} \sqrt{\frac{2\rho}{\rho\,\pi}}$$

$$r_{me} = \frac{r_e}{2\rho^2} \tag{31}$$

Equation (31) indicates that the radius containing the mass of the electron, shown in Figure 15 as a black circle is actually 6.7 million times smaller than the radius of the electron.

9 – The model of the muon in UST

In UST, the muon is basically modeled as an electron which spherical shell is composed of several layers. Thus, the radius of the muon tends to be much smaller than the electron's, and its mass tends to be much higher.

The muon can also be represented by a basic string presented in Figure 16, composed of negative charges and positive masses, characterized by the radius of the muon (r_m).

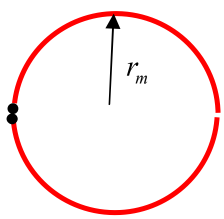

Figure 16 - String that forms the basic ring of the muon.

A more accurate spatial representation of the muon is shown in Figure 17. In this representation, we observe that the muon is composed of a spherical shell with a wall thicker than the electron's, because it is formed by several layers (several concentric spherical shells).

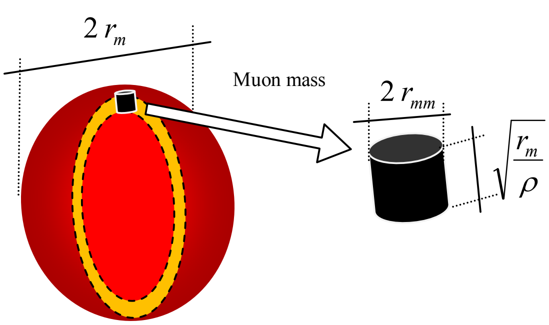

Figure 17 - Membrane forming the muon in a spatial representation.

In order to better modeling the muon, we must initially obtain its simplified representation. The charge distribution of the muon is similar to the electron's, and so, considering that the mass distribution in the muon is similar to the proton´s, the simplified representation of the muon can be obtained by the union of simplified UST representations of the electron (Figure 15) and proton (Figure 5), as shown in Figure 18.

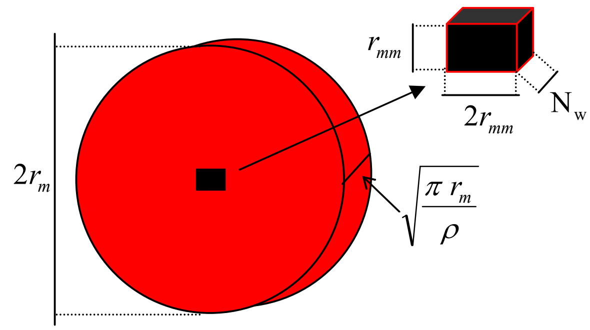

Figure 18 - Membrane that forms the simplified representation of the muon.

Note: The representation of the mass of the muon in a rectangular shape, shown in Figure 18, appears in function of the type of distribution of the considered spheres (uholes). For a same number of uholes, as shown in Figure 19, there are two basic types of distribution composing a more compact arrangement (Figure 19-a) or more "spaced" (Figure 19-b). Abstracting from the individual spheres, these arrangements can be associated to the circular and rectangular areas, which are observed in Figure 19.

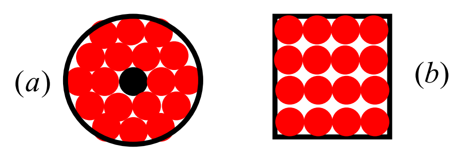

Figure 19 - Two types of arranged spheres in a circular and rectangular area.

When analyzing the muon simplified model in Figure 18, we can calculate the number (M) of uholes that forms the muon, as defined by:

$$\mathrm{M} = \frac{\pi\, r_m^2}{\alpha^2}\sqrt{\frac{r_m}{\alpha\rho}} \tag{32}$$

Applying the equation (19) into equation (32):

$$\frac{\pi\, r_m^2}{\alpha^2}\sqrt{\frac{\pi\, r_m}{\alpha\, \rho}} = \frac{\pi\, r_e^2}{\alpha^2}$$

$$r_m = \sqrt[5]{\frac{r_e^4 \alpha\rho}{\pi}} \tag{33}$$

Applying the equation (25) into equation (33):

$$r_m = \sqrt[10]{r_e^8 \rho^2 \frac{\alpha^2}{\pi^2}} = \sqrt[10]{r_e^8 \rho^2 \frac{r_e^2\, \pi^3}{\pi (2\rho)^9}}$$

$$r_m = r_e \sqrt[10]{\frac{\pi}{2^9 \rho^7}} \tag{34}$$

Likewise, by the muon representation presented on Figure 18, the muon mass (m_m) can be calculated by:

$$m_m = \frac{2\, r_{mu}^2}{\alpha^2} \mathrm{N_w}\; m_u \tag{35}$$

Where $\mathrm{N_w}$ is the number of spherical shells that form the walls of the muon and r_{mu} is the “radius” of the muon mass.

In UST model, the radius of the muon mass (r_{mu}) can be directly related to the radius of the electron mass ($r_{me} \cong r_{mu}$). This occurs because the electron mass present on the spherical shell is maintained almost at the same proportions in each spherical shell that forms the muon. Thus, the equation of form (35) can be written as:

$$m_m = \frac{2\, r_{me}^2}{\alpha^2} \mathrm{N_w}\; m_u \tag{36}$$

Dividing equation (36) by equation (29):

$$\frac{m_m}{m_e} = \frac{2\, r_{me}^2\, m_u}{\alpha^2} \mathrm{N_w} \frac{\alpha^2}{\pi\, r_{me}^2\, m_u}$$

$$\frac{m_m}{m_e} = \frac{2}{\pi} \mathrm{N_w} \tag{37}$$

Equation (37) indicates that the relation of the muon and electron masses is proportional to the number of "layers" of the muon. This is equivalent to say that the circular area containing mass that exists in the "pole" of an electron will also occur at each layer of the muon, but with a spatial distribution a little less compact, which generates the multiplication factor $2/\pi$.

In order to determine the value of $\mathrm{N_w}$ we can calculate the number of turns (of a same basic string) that exists in the electron ($\mathrm{N_e}$) and the number of turns that there is in the muon ($\mathrm{N_m}$):

$$\mathrm{N_e} = \frac{c\, \mathrm{L_I}}{r_e} \tag{38}$$

$$\mathrm{N_m} = \frac{c\, \mathrm{L_I}}{r_m} \tag{39}$$

Considering then that $\mathrm{N_e}$ rings of electrons generate a membrane of unitary thickness, the total number of layers in the membrane of the muon can be calculated using the following equation:

$$\mathrm{N_w} = \frac{\mathrm{N_m}}{\mathrm{N_e}} = \frac{r_e}{r_m} \tag{40}$$

Applying the equations (34) and (40) into equation (37):

$$\frac{m_m}{m_e} = \frac{2}{\pi}\frac{r_e}{r_m}$$

$$\frac{m_m}{m_e} = \frac{2}{\pi}\sqrt[10]{\frac{2^9 \rho^7}{\pi}}$$

$$\frac{m_m}{m_e} = \frac{4}{\pi}\sqrt[10]{\frac{p^7}{2\pi}} \tag{41}$$

Considering the default value of ρ, we can calculate from equation (41) the relation between the muon mass and the electron’s:

$$\frac{m_m}{m_e} = 204{,}09$$

Knowing that the default value for the above relation is equal to 206.7682, the difference between these two values is only 1.3%.

10 – Explaining the muonic hydrogen

After observing a small part[1] of the UST equations that model the photon and some material particles (electron, proton and muon), it is possible to explain why the protons in muonic hydrogen change its radius in relation to the other standard experiments.
Firstly, we need to observe that all analysis of particles made so far in this article only consider each particle separately.
Thus, for example, the radius of the proton calculated by equation (18) represents the value at rest, in which this proton does not interact with other particles.
This condition is not valid, for example, for a hydrogen atom, because as shown in Figure 20, the proximity of the opposite electrical charges of the proton and electron generates attraction forces (yellow arrows in the figure) so that the radius of the proton tends to increase as the electron radius tends to decrease.

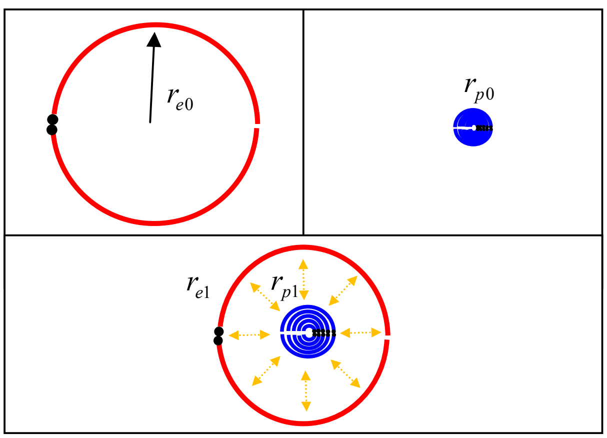

Figure 20 - Placing an electron and a proton together.

In the muonic hydrogen formation, the electron will be replaced by a muon, leading to the model shown in Figure 21.
However, by placing a proton "inside" a muon we observe a contradiction with the experimental results, because in this condition, in which the charges of the muon are closer, the proton radius would tend to grow even more.

1- For simplicity some additional points were not addressed, for example, the equations of the particles trajectories.

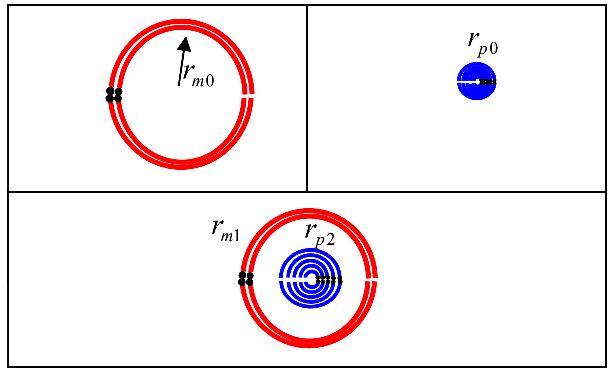

Figure 21 - Placing a muon and a proton together.

This occurs because although the model presented in Figure 21 is feasible, it does not represent the physical configuration observed in muonic hydrogen.
Observing the particles shown in Figures 20 and 21 in a more realistic representation, if the proton was the size of a pea, hence the electron would be the size of a football field, while the muon would be the size of a pizza.

Thus, in the UST model, an electron "capture" a proton in its interior is a relatively trivial event as easy as throwing a football in a field and hit the grass. Now try the same "shot" at a target that has the size of a pizza.

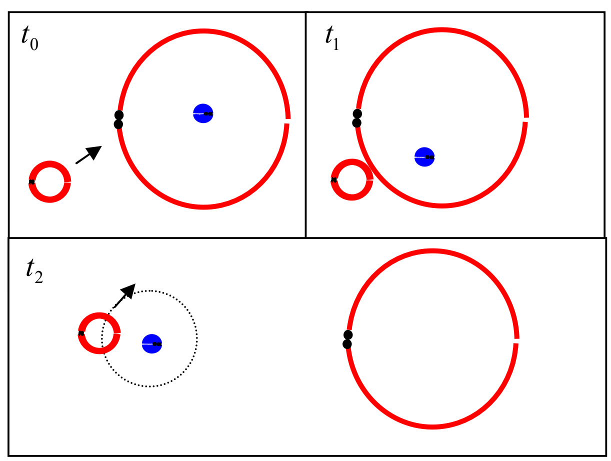

Figure 22 - Formation of muonic hydrogen.

What happens in the case of muonic hydrogen is that the muon does not "capture" the proton (inside it), but only gets in orbit around it, as shown in Figure 22. In this condition, the muon

charge affects the proton as a whole without generating significant forces to expand this radius.
Thus, the size of the proton in the muonic hydrogen is practically equal to the size of the proton in a resting condition, whose radius is modeled by the equation (18).
This explains the proton radius value obtained in the experiment with muonic hydrogen, but it is still missing to explain the size of the proton observed in a hydrogen atom, which will be presented in subsequent sections of this article.

11 – Variation of the proton mass in atomic nucleus

A basic aspect of the UST model is that all matter and energy particles are formed by strings that always have the same length.
These particles will assume different spatial configurations, by being wrapped in successive turns.
In addition, in UST models the number of turns is directly related to the particle mass. This aspect can be observed through the analogy presented in Figure 23, where a "real" string (represented in red in this figure) is supported by a set of pulleys (represented in blue), kept stretched by a set of weights (represented in black) attached at its base.
In this analogy, the total length of the string does not change, but the length L (of each turn of a basic string) will take only a few discrete values in function of the number of weights used. Thus, if it is necessary to increase the value of L, we must eliminate some weights (discard mass) until obtain the desired length. Moreover, in order to decrease the value of L, we need to use a larger number of weights (and pulleys).

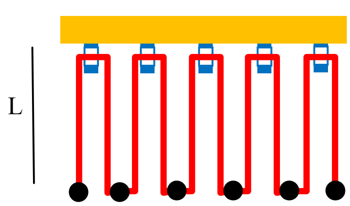

Figure 23 - Analogy of a real string supported by pulleys and hanged by the weights.

In the analogy of Figure 23, if the string is subjected to the forces that generate an increase in length, this implies that its mass must necessarily decrease. Likewise, if the forces generate a reduction in the basic string length, the mass shall increase.
For a proton removed from an isolated situation and placed into the nucleus of a hydrogen atom, as shown in Figure 20, the interaction of the opposite charges will cause the proton to increase its radius and, consequently, will generate a reduction in its mass.
This model can be odd to traditional physics, but we observe that the variation of the proton mass that occurs as a function of its radius variation perfectly explains the reason why the more complex atoms nucleus are heavier.
Despite the negative charges of an electron attracting all the protons inside the nucleus, it is possible to work with a simplified model, by associating each electron to only one proton.
Thus, if we could build atoms by adding electrons and protons (and neutrons) “one by one”, we would observe that for larger electrons (more external to the nucleus) the effect of attraction on the corresponding proton is smaller (because the negative charges are further away), and hence the proton expands itself less and becomes heavier.

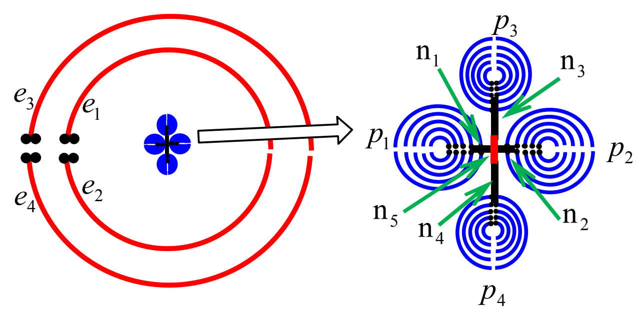

Figure 24 - Beryllium atom in the UST model. The fifth neutron was painted in red to facilitate the visualization.

Figure 24, for example, presents the UST model for the beryllium atom. This atom has four electrons, four protons and five neutrons. In this case, two electrons are closer to the nucleus (orbital 1s in the standard model) and the protons associated to them will be larger and lighter. The remaining electrons will have a radius slightly larger (orbital 2s) and the associated protons will be smaller and heavier. Thus, the average weight of protons in a beryllium atom tends to be higher than in the hydrogen or helium atom.

12 –The size of the proton in the hydrogen atom

Considering a hydrogen atom, we can calculate the new radius of the proton inside making a modification in equation (18):

$$r_{p1} = \frac{2h}{\pi\, c\, m_{p1}} = \frac{2h}{\pi\, c\,(m_{p0} - \Delta m_p)} \qquad (42)$$

Where:
r_{p0} = radius of a proton in a resting condition;
r_{p1} = radius of "stretched" proton (due to interaction with the electron);
Δm_p = proton mass variation that occurs due to its radius variation.

According to the UST, the Δm_p value can be estimated based on the Fermi energy of the atomic nucleus, whose typical value is 38 MeV [6].
Thus, we can consider the Δm_p value to be equal to this Fermi energy converted into a mass value:

$$\Delta m_p = \frac{38 \times 10^6}{c^2} \times 1{,}602 \times 10^{-19} = 6{,}77 \times 10^{-29}\,\text{kg}$$

Using this value in equation (42), we obtain:

$$r_p = 8{,}7674 \times 10^{-16}\,\text{m}$$

We can observe that the proton radius calculated above tends precisely to the proton standard radius (8.768×10^{-16}) with an error of only 0.068%.

Note: In the UST model, the proton turns around its polar axis, and thus it will have a kinetic energy that depends both on its mass and its radius and rotation speed. Thus, the mass loss observed when a proton combines with an electron to form a hydrogen atom is compensated by the variation in the proton radius and the rotation speed. Therefore, the total energy of the system remains almost constant, because the mass "lost" by the proton turns into kinetic energy.

13 – Conclusion

This article shows that the results obtained in the experiment of muonic hydrogen are correct and that the proton actually changes size when interacting with muons instead of electrons.
The difference in proton radius values obtained from the UST model and in the experiments performed by Dr. Randolf Pohl's team is only 0.07%, a value that could hardly be coincidental. In addition, the UST model is able to calculate the standard proton radius with a difference of only 0.068%.
Historically, the electron was modeled on the Bohr atom [7] as an infinitesimal "small ball" that concentrated all its negative charge and mass, and revolved around the atomic nucleus. This model generates a paradigm that we call "electron-small ball" and has remained valid even in the foundations of quantum mechanics, in which the electron came to be modeled as a wave function. This occurs because the electron wave functions are associated to the orbitals around the atomic nucleus and are interpreted as probability functions of the spatial distribution of this "electron-small ball".
In the electron model proposed in UST, what we see is a membrane composed of a large number of negative punctual charges (uholes), which exist simultaneously, therefore generating a paradigm known by the author as "electron-brane". For the hydrogen atom, this membrane takes the form of a spherical shell composed of negative charges with the electron mass concentrated in one pole of this sphere.
Although the illustrations presented in this article show the electron as an immobile spherical shell, indeed for UST, the membrane that forms the electron is not static, but it oscillates and rotates around the nucleus. This implies on a more advanced model, the region occupied by the electron around the atomic nucleus cannot be described by a static membrane, such as an ideal spherical shell. In this case, the electron membrane must also be described in terms of probability distribution, which for the electron in hydrogen atom generates a spatial distribution

function similar to the function defined in quantum mechanics for the orbital S.
In practical terms, this means that the "electron-brane" model used in UST and the wave functions from quantum mechanics lead to final results quite similar, but at specific points, such as the experiment with muonic hydrogen, the results are quite distinct.
This occurs because even more complete models, such as quantum electrodynamics, do not foresee that an electron will undergo a proton to a radial force field that tends to expand it. In other hand, the "electron-brane" model used in UST allows not only explaining the proton radius variation, but also to calculate accurately the values of the proton radius for the muonic hydrogen and for the conventional hydrogen.
Thus, the author considers that the experiment with muonic hydrogen represents a boundary in modern physics. The author compares this experiment to the "inverted bridging" shown in Figure 25, since it connects the "electron- small ball" model (which occurs when the muon turns around the proton in the muonic hydrogen) to the "electron-brane" model defined in UST context.

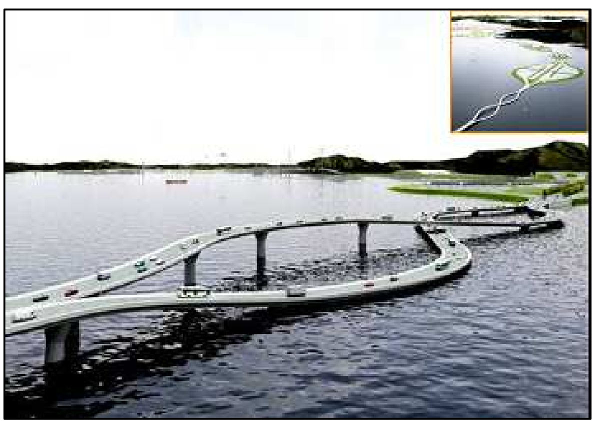

Figure 25- reversed Bridge, which connects China to Hong Kong, compatibilizing the traffic on the left that takes effect in Hong Kong, with the right traffic practiced in China.

The author believes that the correct interpretation of what is happening with the proton in the muonic hydrogen experiment should lead to a review of the meaning of wave functions used in quantum mechanics, considering a large number of negative charges that really exist simultaneously.

This new paradigm of "electron-brane", besides explaining the variation of the proton radius, has the potential to elucidate some "odd" behaviors, such as the fact that a single electron can interfere "with itself" in double slit experiments.
The UST models presented in this article are revolutionary as meaning that not only represent the electron and proton as membranes, but also calculate the number of punctual particles that form each of them (about 4×10^{32} particles). Moreover, as presented in this article, the UST is also able to explain that gravitational and electromagnetic forces have similar intensities, but since there are much more particles with electric charge (than particles with mass) composing the membranes, the total effect of electromagnetic field is much greater than the total effect of gravitational field.
The UST model is also able to calculate a series of values that are considered physical constants in other models, such as, the hydrogen atom radius (radius of the spherical membrane that forms the electron) and the muon mass.

It is important to emphasize that the UST models presented in this article represent only a small part of the work produced by the author, which is set in a broader scope named Ulyanov Theory (UT), also including:

- A cosmological model called Small Bang Theory [8], in which the universe is created in a "slow" way, because initially there is only the imaginary time.
- A representation of non-Euclidean spaces, named Ulyanov Sphere Network (USN) [9], which allows deducing results equivalent to the Einstein's general relativity, as well as Newton's gravitation law.

Thus, although the models defined in UT are still incomplete and possibly containing many errors and inconsistencies, they have some basic ideas quite innovative, such as the use of imaginary time, the paradigm "electron-brane" and the separation of particles with electric charges and masses in the membrane formation, which has the potential to revolutionize many areas of modern physics.

The author would like to invite open-minded physicists to work together in developing and testing UST models presented in this article, as well as in new models defined within the Ulianov Theory.

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Policarpo Yōshin Ulianov is an electrical engineer with Masters in electronic speckle holography and Doctorate degree in artificial intelligence area.

He studies theoretical physics as a hobby and throughout 20 years of research, he brought together a series of ideas he considered interesting, and developed a model called Ulianov Theory, which models a fictitious physical universe from a few basic concepts defined intuitively.

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Thanks and Congratulations

The author would like to congratulate Dr. Randolf Pohl and his staff for the rigorous work done in the muonic hydrogen experiments. Certainly, this is a historical experience that will enter into the annals of modern physics.

The author thanks **Solução Supernova** Staff Team (www.solucaosupernova.com.br) for all support and services regarding the translation of this paper from Portuguese to English.

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www.atomlig.com.br/poli/UST-muonic-IG.pdf