A Theory of the Quiescent Proton

Robert T. Longo PhD

[1]Ph.D. Physicist and Technical Fellow, retired

[2]Boeing Aircraft Company, Torrance, California 90509, USA

*Independent Researcher, rtlongo370@gmail.com

Abstract A quiescent proton is a proton that is not involved in high-energy interactions. As is well known, the baryons in which the Proton is the most stable are described in the quantum mechanics system by a theory of QuantumChromo-Dynamics (QCD). QCD describes the details of interactions due to the scattering of protons with protons and other particles. In these energetic states, it works well. How is the internal structure of the proton described when it is in a passive state, not interacting energetically with other particles? In the passive, or quiescent state after year of effort using QCD has not yielded a solution. The passive state is the subject of this paper. Protons, as well as neutrons, are the heaviest stable particles and are largely responsible for contributing mass that generates the global gravitation of the large Universe, leaving out dark matter and dark energy momentarily. This paper will explore how GR gravitation theory and the basic foundation of quantum mechanics can be used to describe the proton in the quiescent state. Due to the stability of the at-rest proton, this paper studies the proton in this quiet state. The Neutron is known to be stable when part of a more complex atomic nucleus but decays, when free, into a proton, electron, and electron-antineutrino. Due to this instability, neutrons will not be included in this study.

Keywords Proton, General Relativity, Gravitation, Quantum Chromodynamics, Planck Law

1 Introduction

It is well known that a quantum mechanics program called Quantum ChromoDynamics (QCD)[1], describes baryons and hadrons. In this paper, a story will be presented that looks at the proton at rest, which will be denoted as the quiescent proton. The use of QCD in the low energy regime does not work well, as remarked in the following quote

A challenge for QCD [2]

> After many decades of theoretical and experimental work, low energy QCD remains the most challenging frontier in the physics of the Standard Model.

Our story suggests that QCD is not the appropriate tool for the low-energy domain. An approach will be discussed, highlighting the importance of gravitation in this regime. Our story will discuss how the quiet proton at rest can be understood in part by General Relativity. Further, it suggests that it is unnecessary to describe in detail the internal wave functions for each internal entity to determine their momentum and energy. All that is necessary is to recognize quantum mechanics by its foundation, which is Planck's law, and that, along with General Relativity, provides a reasonable story.

In an earlier paper[3], it was found that the nature of time could be introduced by looking toward philosophy for ways of thinking; this led to how the NOW of time could be introduced into physics, whereas Einstein thought the NOW could not be part of science in general. In this paper, instead of looking to philosophy for ways of thinking, this time, it is the unit system that will provide a new way of thinking. This then will provide the starting point for this work.

The Physical Experiments that led in part to this way of thinking were the high-energy scattering of electrons with quiet protons. Done at Stanford's linear accelerator[4],[5],[6] and other accelerators. The results were interpreted by Feynman[7], who called the inner structure of the protons Partons[7]. His work ultimately became known as The Sea of Quarks. The proton's interior is filled with quarks, antiquarks, and gluons coming and going from the vacuum state.

The proton is the only massive stable particle and is collectively responsible for generating gravitation that permeates the entire Universe, leaving aside dark matter and energy if they actually exist[3]. If protons are the main baryons that curve space-time, they should be connected to General Relativity (GR). This paper will suggest a path toward that solution without quantizing gravitation. QCD provides good results for particle physics describing high-energy interactions, but as noted in the above quote[2], QCD appears unable to describe the quiescent state. In this work, we will put forth a different approach to the quiescent state. The work laid out is not meant to suggest a final theory, it is just basic ideas that I believe have not been considered.

PART I

2 The Structure of the Proton

The quark theory was introduced by Murray Gell-Mann[11] and independently by George Zweig[12]. In 1964, Gell-Mann published his "A Schematic Model of Baryons and Mesons"[13], he introduced the idea of quarks as fundamental constituents of hadrons, such as protons. During this period, a quantum theory called Quantum ChromoDynamics was developed to describe hadron particle interactions.

Gell-Mann's quark model describes the internal structure of protons and other hadron particles as particles that contain quarks, gluon, and color charge. There are six kinds of quarks: Up, Down, Strange, Charm, Top, and Bottom. The proton consists of two Up quarks and one Down quark. The Up quark has a fractional electric charge of $+2/3$, and the Down quarks have a fractional electric charge of $-1/3$. Therefore, the proton has one unit of electrical charge. The gluons carry a strong force through color charge, analogous to photons, and electromagnetic charge force.
The key observation that prompted Feynman's development of partons was that the observed scattering experiments done at Stanford's linear accelerator[4],[5],[6], these exhibited scaling behavior, which means that the cross-section (measure of scattering probability) remains relatively constant over a wide range of energies and angles. This was contrary to the expectations based on the prevailing model of that time, where protons were assumed to be fundamental particles. His idea of partons laid the foundation for the modern understanding of the internal structure of protons. It paved the way for discovering quarks as the constituent particles within protons.

Feynman's partons and QCD eventually led to the concept of a sea of quarks in the proton. The sea is composed of quarks and antiquarks popping in and out of existence from the vacuum that emerged from the theoretical framework of quantum chromodynamics (QCD), which describes the quarks that constantly exchange gluons between quarks, transmitting the strong force that binds quarks together. Because gluons are responsible for transferring strong force, they carry energy like other force-carrying particles, such as photons that exchange electromagnetic force between charged particles, this analogy will be used later to describe the quiescent proton.

2.1 The Quiescent Proton

Quiescent Protons exist in chemical compounds at low energies, for example, within molecules of life forms. QCD is satisfactory at higher energies, but as quoted in the introduction, QCD struggles to describe low-energy effects[2]. In this regime, Feynman's works are based on the theoretical understanding of the proton's internal structure [8]. The internal structure of the proton was discovered through several experimental studies[4],[5],[6]. These experiments fired high-energy electrons at target protons; the scattered electrons are influenced by the electric charge of the internal quarks and led Feynman to introduce partons[8]. This not only helped solidify the Gell-Mann quark theory but also introduced the concept of the sea of quarks, in which many quarks and anti-quarks pop in and out of existence from the vacuum, along with the gluons and color charge that interact with them.

PART II

3 The Protons Connection to General Relativity

To begin, we assume that General Relativity describes the space-time that all imagined aspects of the world we know must adhere to [9], i.e., Observable space-time must be included in the GR manifold, space-time not on the manifold are abstract spaces [9][10], and not directly observable.
To begin the discussion, let us look at the unit system. The units of the constants and parameters that make up the General Relativistic theory of gravitation. The Gravitation constant, G, has units of $m^3/M\ s^2$ where m is the meter and M is Kilogram. Next, consider the mass density ρ_M, with units of M/m^3 and when they are multiplied, the result is a squared frequency, thus

$$G \times \rho_M = \frac{m^3}{Ms^2}\frac{M}{m^3} = s^{-2}, \tag{1}$$

or

$$G \times \rho_M = f^2, \tag{2}$$

From this, the mass density can be written

$$\rho_M = \frac{f^2}{G}. \tag{3}$$

In General Relativity, the Energy Momentum Tensor, $T_{\nu\mu}$, requires energy density instead of mass density. The energy density is easily obtained by multiplying the mass density by the square of the speed of light,

$$\rho_E = \rho_M c^2 \tag{4}$$

3.1 The GR space that defines the Proton

It will be assumed that the space-time where the proton is thought to exist is independent of the space-time of the general Universe. It is a GR space-time that can independently move in the general Universe, somewhat analogous to the absolute and relative space Newton imagined. We envision that each proton resides in its own GR space-time. To determine the space-time of the individual protons, we start with the Einstein GR Field equations

$$R_{\nu\mu} = -\frac{8\pi G}{c^4}(T_{\nu\mu} - \frac{1}{2}g_{\nu\mu}T^{\lambda}_{\lambda}), \tag{5}$$

Expanding T^{λ}_{λ}, and using the metric and inverse metric tensors, which is diagonal, i.e., $g_{\mu,\nu} = 0$ for $\mu \neq \nu$, and $g_{\mu\nu}g^{\mu\nu} = 1$. Eq(5) then becomes

$$R_{\nu\mu} = -\frac{4\pi G}{c^4}\, T_{\nu\mu} \tag{6}$$

Then introducing the energy density $T_{\nu\mu} = \rho_M c^2$ gives

$$R_{\nu\mu} = -\frac{4\pi G}{c^2}\, \rho_M \tag{7}$$

Using equ (3) for ρ_M, the Gravitational constant drops out and is replaced by the square of a frequency. Thus we get

$$R_{\nu\mu} = -4\pi\frac{f^2}{c^2} \tag{8}$$

Which takes the form of

$$R_{\nu\mu} = -4\pi\frac{1}{\lambda^2} \tag{9}$$

Where λ is the wavelength that is the length within the space that defines the proton, if we imagine the proton is a sphere, then the wavelength is the radius of the proton sphere. To proceed with the GR solution for the proton space, we start with the line element.

$$ds^2 = A[r]dr^2 + r^2 d\Omega^2 + B[r]dt^2 \tag{10}$$

where

$$d\Omega^2 = d\theta^2 + Sin^2(\theta)d\phi^2 \tag{11}$$

To determine the metric coefficients A[r] and B[r] we determine all of the Ricci tensors. Following [16] we get Einstein's equations

$$R_{rr} = -4\pi T_{rr}A[r], \tag{12}$$
$$R_{\theta\theta} = -4\pi T_{\theta\theta}r^2, \tag{13}$$
$$R_{tt} = -4\pi T_{tt}B[r]. \tag{14}$$

Then, expanding the Ricci tensor in terms of the metric tensor, the components are

$$R_{rr} = \frac{B[r]''}{2B[r]} - \frac{B[r]'}{4B[r]}(\frac{A[r]'}{A[r]} + \frac{B[r]'}{B[r]}) - \frac{A[r]'}{rA[r]}, \tag{15}$$
$$R_{\theta\theta} = -1 + \frac{r}{2A[r]}(-\frac{A[r]'}{A[r]} + \frac{B[r]'}{B[r]}) + \frac{1}{A[r]}, \tag{16}$$
$$R_{tt} = -\frac{B[r]''}{2A[r]} + \frac{B[r]'}{4A[r]}(\frac{A[r]'}{A[r]} + \frac{B[r]'}{B[r]}) - \frac{B[r]'}{rA[r]}. \tag{17}$$

The component $R_{\phi\phi}$ is the same as $R_{\theta\theta}$ differing only by a $Sin(\theta)$, so it will not be used. The prime indicates the derivative with respect to r.

Where

$$T_{rr} = T_{\theta\theta} = T_{tt} = \rho_E = \rho_M c^2. \tag{18}$$

The solution to finding the metric tensor starts with

$$\frac{R_{rr}}{2A[r]} + \frac{R_{\theta\theta}}{r^2} + \frac{R_{tt}}{2B[r]} = -8\pi\frac{G\times\rho_M c^2}{c^4} = -8\pi\frac{\nu^2}{c^2} = -\frac{8\pi}{\lambda^2} \tag{19}$$

The maximum radius of the proton R_p is equal to the longest wavelength λ. therefore, we set $R_p = \lambda$ and eq(19) becomes

$$\frac{R_{rr}}{2A} + \frac{R_{\theta\theta}}{r^2} + \frac{R_{tt}}{2B[r]} = -\frac{8\pi}{R_p^2} \tag{20}$$

Combining eqs (15),(16),(17) with equ (20) yields the differntial equation for $A[r]$

$$\frac{A[r] - A[r]^2 - rA[r]'}{r^2A[r]^2} = \frac{-8\pi}{{R_p}^2} \tag{21}$$

The solution is

$$A[r] = \frac{1}{1-(\frac{r}{R_p})^2} \tag{22}$$

The time component, B[r] is obtained from, Equ(13) and Equ(16) devided by r^2

$$-\frac{1}{r^2} + \frac{1}{2A[r]r}(-\frac{A[r]'}{A[r]} + \frac{B[r]'}{B[r]}) + \frac{1}{A[r]r^2} = -4\pi\frac{G}{c^4}T_{\theta\theta} \tag{23}$$

Using Equ(22) and its derivative, then Equ(23) is solved for B[r]

$$B[r] = \frac{1}{\sqrt{1-(\frac{r}{R})^2}} \tag{24}$$

The line element can be written as either the proper distance or the proper time.

$$ds^2 = A[r]dr^2 + r^2d\Omega^2 - B[r]c^2dt^2 \tag{25}$$

Or

$$d\tau^2 = B[r]dt^2 - \frac{A[r]}{c^2}dr^2 - \frac{r^2}{c^2}d\Omega^2 \tag{26}$$

The proton space is flat at the center and has a singular surface at the proton's radius. Therefore, all the contents of the proton are isolated from the "Grand Universe."

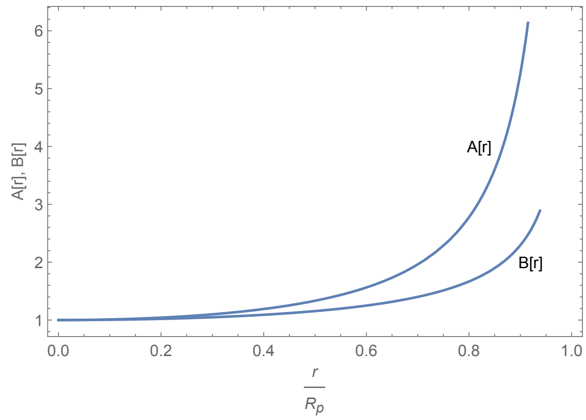

Figure 1. The metric tensor of the proton-space is flat at the proton's center and has a singular surface at the radius in both space and time metric components. Objects inside this space are confined and can not escape; quarks and gluons live in their own universe.

The neutron is stable when it is a part of an atomic nucleus because it benefits from the strong nuclear force. The strong nuclear force, one of the four fundamental forces of nature, is responsible for binding nucleons (protons and neutrons) together in the atomic nucleus.

Inside the nucleus, the strong nuclear force is stronger than the electromagnetic repulsion between protons, which would otherwise lead to the nucleus scattering apart. The strong force acts on both protons and neutrons, but protons also experience electromagnetic repulsion due to their positive charge. Neutrons, on the other hand, do not experience electromagnetic repulsion, allowing them to maintain stability in the nucleus.

When a free neutron is not part of an atomic nucleus, it becomes unstable.

This is because neutrons comprise quarks, specifically two Down quarks and one Up quark. In isolation, these quarks have a higher energy state compared to when they are confined within a nucleon. As a result, the free neutron can undergo a process of beta decay, where one of its Down quarks is transformed into an Up quark, emitting an electron and an electron antineutrino. This transforms the neutron into a proton, which is stable.

The free neutron has a half-life of approximately 14 minutes and 42 seconds. This means that after this time has passed, half of the initial number of free neutrons will undergo beta decay and transform into protons. The remaining half will continue to decay in subsequent half-lives.

PART III

4 The dynamics of quarks and gluons in the quiescent proton space

As noted in section 2, the results of high-energy electrons interacting with protons can be interpreted as a sea of quarks filling the interior proton space, with virtual quarks and anti-quarks coming and going and gluons interacting with all these multitudes of virtual quarks and antiquarks.

In the sea of quarks, the details of the interactions are not directly measurable and, therefore, we consider them unnecessary. The interaction of quarks and gluons determines the total energy density. The energy of a gluon is related to its wavelength or frequency. In the quantum mechanical framework, gluons are described by wave-like properties, and the energy is quantized. These quantized energy levels correspond to the different possible states or modes of the gluons and quarks. This is analogous to photons interacting with atoms in a black body. It is well known that a black body radiator is independent of the shape of the wall of the vessel as well as its material. Stars are thought to radiate as a black body despite having no walls; the atoms are mixed in with the radiation. This is the picture that Feynman's Partons and the Sea of Quarks presents. Therefore, it is postulated that Planck's law, i.e., the spectral energy density, which is the foundation of quantum mechanics, is sufficient to describe the sea of quarks in the interior of the quiescent proton.

The simplest way to start is to use the energy density ρ_E, obtained from the energy of the proton, which, in turn, is the total of the quarks and gluons. The radius of the proton is taken to be $0.8418 \times 10^{-15} m$ and its volume is $2.499 \times 10^{-45} m^3$, the Energy Density $\rho_E$is then $6.0161 \times 10^{34} Joule\ m^{-3}$

to determine the interior temperature of the proton, thus

$$\rho_E = \int_0^\infty u(f,T)df = \frac{4\sigma}{c}T^4. \tag{27}$$

Where $\sigma = 5.6703 \times 10^{-8} Watt\ m^{-2}K^{-4}$ is the Stefan-Boltzmann constant, and $u(f,T)$ is defined by Planck's law.

$$u(f,T) = \frac{8\pi h f^3}{c^3}\frac{1}{(e^{\frac{hf}{kT}} - 1)}. \tag{28}$$

The interior temperature of the quiescent proton is given by

$$T = (\frac{\rho_E c}{4\sigma})^{\frac{1}{4}}. \tag{29}$$

The interior temperature of the proton is $2.89 \times 10^{12} K$.

4.1 Employing Physical Time

Employing physical time[3], the key parameter is the speed of light, which is taken to be dependent on local brightness in the proton. However, energy density, Temperature, and the transformation factor all depend on the speed of light[3] and, therefore, change. This requires that a search for the correct values be performed, and an iterative process must be conducted to look for convergence because a temperature change will cause the other parameters, and constants to change, see[3]. There are several ways the iteration can be accomplished.

Scenario 1, which is the starting point for the other two scenarios. In this scenario, the speed of light is held fixed, to its accepted value, and the Stefan - Boltzmann is held at its known value. The proton internal temperature is $2.896 \times 10^{12} K$, the speed of light is $2.9979 \times 10^8 m/s$ and the Stefan-Boltzmann constant is $5.6703 \times 10^{-8} Wm^{-2}K^{-4}$. The energy density is $6.0161 \times 10^{34} Joule\ m^{-3}$, and the volume of the proton is $2.499 \times 10^{-45} m$.

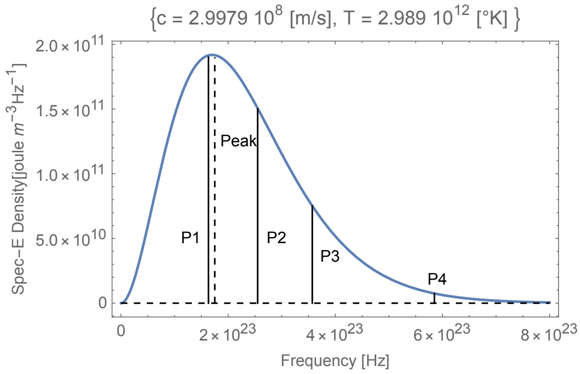

Figure 2. The Black Body spectrum of the mixed quarks and gluons in the quiescent proton. The intensity and spectral energy density on the vertical axis.

Table 1. A few energy states in the sea quark (Feynmann, figure 6, p545 [7]), Using The universal constant speed of light 2.9979×10^8. The dashed vertical line is the peak, and the peak frequency is $5.8802 \times 10^{10} \times 2.989^{12} = 1.758 \times 10^{23} Hz$.

ID	Bev	frequency [Hz]	SED [J m$^{-3}Hz^{-1}$]
P1	0.675	1.632 10^{23}	1.910 10^{11}
P2	1.056	2.550 10^{23}	1.510 10^{11}
P3	1.477	3.570 10^{23}	7.510 10^{10}
P4	2.419	5.849 10^{23}	7.480 10^{9}

Scenario 2 In this scenario, the speed of light depends on temperature, as in Physical time[3]. The energy density changes, as does the calculated temperature and the the transform factor, TFF. The Stefan Boltzmann constant remains fixed at its known value.

Scenario 3 In this scenario, the speed of light depends on temperature, as in Physical time[3]. The energy density changes, as does the calculated temperature and the TFF. The Stefan Boltzmann constant chances with the speed of light, as does the Planck Law. When iterated, the speed of light goes to zero, and the temperature diverges.

There is one further thing that must be added that is not included in Physical time[3] and will be expanded upon in Appendix II., we show that Planck's constant also changes with temperature, by TFF, as does the speed of light.

That leaves scenario2 as the correct iteration to add Physical Time to the problem. This suggests that because it was indicated in physical time, the speed of light is no longer a fundamental constant. Planck's Law, however, is the foundation of quantum theory, and therefore it is fundamental. This suggests that we look upon the Stefan-Boltzmann constant as a fundamental constant. The convergence gives $c = 3.16 \times 10^{-3} m/s$ and the temperature is $T = 1.67 \times 10^9 K$, see Figures 3 and 4. for the iteration convergence.

Using Physical Time[3] instead of Newton's time, the speed of light is not a universal constant. Therefore, we get a different result. From eq(28), the energy density depends on the speed of light. The temperature will be different. Figure 3 and Figure 4 shows how the speed of light varies with iterations and converges to $c = 3.16 \times 10^{-3} m/s$, and the Temperature converges to $T = 1.67 \times 10^9 K$. See Appendix I for details of the iteration calculations.

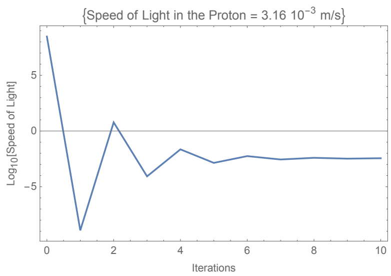

Figure 3. The convergent value of the speed of light in QP

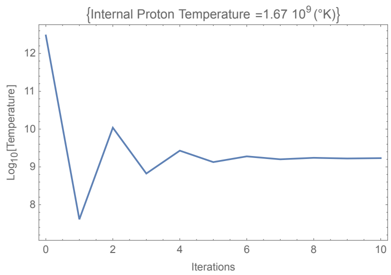

Figure 4. The convergent value of the internal temperature in QP

The resulting Spectral Energy Density is

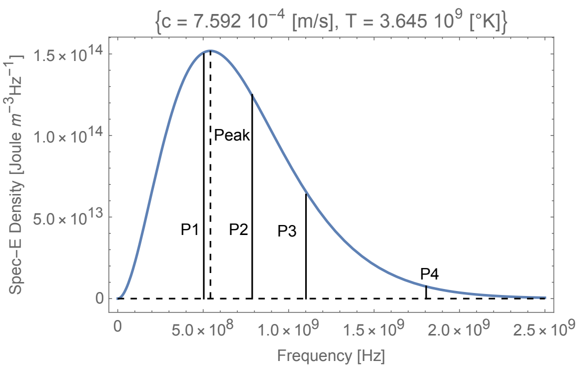

Figure 5. The Black Body spectrum of the mixed quarks and gluons in the quiescent proton. The intensity, and spectral energy density on the vertical axis.

The frequencies in Table 2 are obtained from Table 1 by scaling with the ratio of the peak frequencies. The energies of states P1 to P4 in Table 2. are obtained by using the transformed value of Planck's constant, as indicated in Appendix II.

Table 2. A few energy states in the sea quark (Feynmann, figure 6, p545 [7]), Using Physical time[2] which yields $c = 6.13 \times 10^{-3}$ m/s and Temperature $T = 1.67 \times 10^9$. The dashed vertical line is the peak, and the peak frequency is $5.8802 \times 10^{10} \times 1.67 \times 10^9 = 5.4253 \times 10^8$. The ratio of the peak frequencies is used to scale the frequencies for the NOW time in this Table and Figure 5

ID	Mev	frequency [Hz]	SED [J m$^{-3} Hz^{-1}$]
P1	0.823	5.0365 10^8	1.50 10^{14}
P2	1.285	7.8694 10^8	1.25 10^{14}
P3	1.799	1.1017 10^9	6.38 10^{13}
P4	2.948	1.8050 10^9	0.75 10^{13}

This is where we need the dependence of the Planck constant on the transformation factor TFF, defined in [3], to obtain the energies. See Appendix II for details.

5 Discussion

In this work, we postulate a description of the quiescent proton from General Relativity using the foundation of quantum mechanics. We argue that it is unnecessary to know the detailed, moment-by-moment knowledge of the wave function or energy/ momentum of each entity in the sea of quarks in the quiet proton. Instead, we fold the energy density and internal pressure into a Planck law, the foundation of existing quantum mechanics. We further structure the GR space-time of the quiet proton, which naturally confines the quarks and gluons to that space since it has a singular surface with a singular Riemann curvature at the proton's radius and zero curvature at the center. This proton GR space-times is unique for every proton in the universe. Further, we envision the proton GR space as not being attached to any point in the Universe but as one that can move independently. We have concentrated on the proton because it is a heavy, stable particle, whereas the free neutron is unstable and decays to a proton and two other particles.

In this story, it is found that the proton's interior has a high temperature and a reduced speed of light, when applying the NOW of time[3]. The quarks and gluons behave as a black body with spectral energy density in its confined space, which is due to a singular surface at the proton's radius. Nothing can escape the proton's singular surface; thus, the proton is stable. Philosophically, the proton can be considered its own small universe, collectively. A true multiverse in the grand Universe. In effect, the proton space resembles a Black hole turned inside out; nothing can get out due to the singular surface. However, the entire proton space can be shattered by energetic particle interactions. QCD describes this effect. Therefore, it might be said the totality of protons represents a true multiverse. When a quark or gluon, in a proton space reaches the singular surface, it must be reflected back toward the center to conserve energy and momentum.

6 Appendix I, Iterations for speed of light and temperature

To determine the speed of light and the internal temperature in the proton, when applying the physical time[3], we start the iteration by assuming Einstein's spacetime, which assumes the speed of light $c0$ is the usual universal constant value. The internal temperature is determined as seen in Figure 4. The temperature is used to find the new transform factor, TFF.

$$TFF = (\frac{T}{T_{Sun}})^2 \tag{30}$$

Then, the speed of light is re-calculated $c = c0/TFF$ as defined in [3]. A new temperature is then determined using the Stefan-Boltzmann constant, followed by a new transform factor TFF. This iteration continues until the result converges, as seen in Figures 3 and 4.

7 Appendix II, Physical Time and Schrodinger equation

In [3], where the Schrodinger equation is considered, the decomposition of the wave function into a product of two new wave functions, one dependent on space and the other dependent on time, reveals energy as the only measurable quantity, so the time derivative transformed factor, TFF was associated with the energy. In this work, we don't decompose the wave function but keep the Schrodinger equation in its original form

$$H\Psi = i\hbar \frac{d\Psi}{dt} TFF, \tag{31}$$

Therefore, the Planck constant is the only measurable quantity and is transformed $\hbar \rightarrow \hbar\ TFF$. This is similar to the transformation of ϵ and μ in Electrodynamics [3], which removed the speed of light as a universal constant when applying physical time.

In this work, since Planck's law, i.e., the Spectral Energy Density distribution, is the foundation of quantum mechanics, it is a universal law, and therefore, the Stefan-Boltzmann constant derived from it is also a universal constant. This means the speed of light quantity c that appears in Planck's law, and the Stefan-Boltzmann constant is not modified by the trans form factor TFF.

8 References

[1] The Creation of Quantum Chromodynamics and the effective Energy, V.N. Gribov, G 't Hooft, G. Veneziano, V.F. Weisskopf, World Scientific Series in 20th Century Physics, Vol 25

[2] Resonances in QCD, Nuclear Physics A Volume 948, April 2016, Pages 93-105,https://doi.org/10.1016/j.nuclphysa.2016.01.070

[3] R. T Longo, A Theory of Physical Time and its Impact on Physics Applications, Journal of Modern and Applied Physics Vol 6, No 3, September 2023, DOI: 10.37532.2023.6.3.1-14

[4] http://www.slac.stanford.edu/pubs/slacpubs/0500/slac-pub-0650.pdf ?https://doi.org/10.1103/PhysRevLett.23.935

[5] R. J. Ecclestone et al. (1992). Deep inelastic scattering of electrons from protons and bound neutrons. Physics Letters B, 298(1-2), 458-468, http://www.slac.stanford.edu/pubs/slacpubs/0500/slac-pub-0650.pdf ?https://doi.org/10.1103/PhysRevLett.23.935

[6] Breidenbach, M. et al. (1969). Observed Behavior of Highly Inelastic Electron-Proton Scattering. Physics Review Letters, 23, 935-939.

[7] Feynman, R. P. (1969). "Partons." Physical Review Letters, 23(24), 1415. doi:10.1103/PhysRevLett.23.1415 2

[8] R.P. Feynman selected Papers, World Scientific Series in 20th Century Physics Vol 27

[9] C.W. Misner, K.S. Thorne, J.A. Wheeler, Gravitation, 1970, W.H. Freeman and Company, San Francisco

[10] F.T.Dyson, Why is Maxwell's theory so hard to understand?

[11] Murray Gell-Mann, Selected Papers, World Scientific Series in 20th Century Physics Vol 40, Harald Fritzsch editor.

[12] G. Zweig, "An SU3 model for strong interaction symmetry and its breaking," CERN Report No. TH 412 (CERN, Geneva, 1964); in Symmetries in Elementary Particle Physics, A. Zichichi, Ed. (Academic Press, New York, 1965), p. 192.

[13] Gell-Mann, M. (1964). "A Schematic Model of Baryons and Mesons." Physics Letters, 8(3), 214-215. doi:10.1016/S0031-9163(64)92001-3

[14] R.P. Feynman, "Very High-Energy Collisions of Hadrons," Physical Review Letters, Vol. 23, Issue 24, p. 1415 (1969).

[15] Nakamura, K., et al. (Particle Data Group) (2010). Review of particle physics. Journal of Physics G: Nuclear and Particle Physics, 37(7A), 075021.

[16] S. Weinberg, Gravitation and Cosmology, John Wiley Sons, Inc New York London Sydney Toronto.