Physics of Elemental Space-Time – A Theoretical Basis For the New "Planck Element" Scale

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Abstract Our space-time is postulated to have the following characteristics: (1) the space is an ocean filled with the "Gamma elements" having energy and mass and of a certain size; (2) both time and distance are discretized by the process of light propagation from one Gamma element to the next in some process of relativistic boost of the internal energy. These postulates provide us with a theoretical basis to explain why the speed of light, *c*, should remain constant in all inertial reference frames. The discrete process of light propagation leads us to a set of natural units. As a result, new physically based "Planck element units" may be defined with the new mass scale being ~7.37 x 10^{-51} kg (~4.14 x 10^{-15} eV/c^2). The length scale is estimated from the wavelength of the highest energy gamma rays, in the range of 1 x 10^{-19} m – 1 x 10^{-25} m, and the new time scale then being in the range of 3.34 x 10^{-28} s – 3.34 x 10^{-34} s. The Planck element units are shown to relate with the fundamental constants, *c* (speed of light), *G* (gravitational constant), and *h* (Planck constant) with the same dimensional relationship as the conventional Planck units, but the length and time units are larger than those of the latter by 10^9 – 10^{16} orders of magnitude while the mass is smaller by whopping 10^{-43} orders of magnitude.

Keywords Space · Time · Element · Particle · Wave · Planck scale

1 Introduction

The special theory of relativity [1] is in part based upon the constancy of the speed of light. On the one hand, our understanding of light propagation is based upon the space being empty so that the photons travel without hindrance with the speed of light. On the other, from the perspective of the field theory Feynman [2] observes that the electromagnetic field can carry waves; some of these waves are light, but that at higher frequencies they behave much like particles, and that quantum mechanics unifies the idea of the field and its waves, and the particles all into one. Wilczek [3] describes a vision of the primary ingredient, the "grid," that fills our space and time, is alive with quantum activity albeit spontaneous and unpredictable, contains material components, gives space-time rigidity, causes gravity, and weighs. With the light-bearing aether hypothesis failing some of the critical tests, in particular the speed of light, it is clear that our understanding of the "empty" space is far from complete. In this paper, a model of space is presented along with one of the first results of the model, the "Plank Element" scale, in the hope that it may eventually be developed to incorporate all the essential ideas of the above.

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2 Elemental Space-Time - The Definition of Time and Distance

That the speed of light is constant in all inertial frames of reference was shown by experiments but this counter-intuitive truth has never been convincingly explained. Furthermore, even as we find all matters are quantized, the continuity of space and time appears to be so obvious that to the author's knowledge we seldom question the validity of that assumption. We argue below that if both space and time are discretized, we, the observers of light, will see the speed of light to be constant regardless of the frames of reference.

Newton's laws for gravity and optics were built on an absolute space and time, prohibiting an observer's participation. The theory of relativity, on the other hand, was derived by requiring that a phenomenon obey the same law of physics regardless of an observer's system of reference frames. This powerful tool of using an observer led to the discovery of the more general laws of physics that Newton's laws are only a special case for. We recognize now that the role of an observer is critically important to our understanding of the physical world.

When we hear sound, we discern the frequency of the sound waves or the tone. When we see light, we discern the frequency of the light or the color. In both cases, we the observers only have to count the peaks and valleys of the sound waves and of light waves and compare the frequency with those with some reference sound waves and reference light waves, respectively. The same may be assumed to be true with time and distance. We can measure the distance between any two points by counting the number of wavelengths a reference light takes to travel between them. We may postulate that our internal bio-clock has the ability to count the frequencies of the reference light and indeed we function and age based upon such bio-clocks.

Among all observed electromagnetic wave spectra, we know the Gamma-rays reach the highest energy state having the highest frequency and the shortest wavelengths. We still don't know if we have observed the limit yet but if the space is discretized, we take a view that there should be a limit and that there are fundamental elements associated with it. (We ignore the conventional Planck scales for the moment for the reasons to be apparent below.)

We now postulate that the universe is full of these elements that we shall call Gamma elements. Space is an ocean filled with the Gamma elements. Light propagates through the Gamma elements by energizing them, say by means of relativistic boost of the internal energy. The Gamma elements then must be the medium for the light energy to propagate through. The Gamma elements are a form of matter having energy and mass. In this respect, the Gamma element space differs from the abandoned absolute aether space. We live in the space filled with the Gamma elements but unaware of their existence because their density is extremely low. (We will discuss their density in another paper.)

Even though they are assumed to exist in the above sense, much of the properties of the Gamma elements may well be left for future research, including the detailed relationships between the Gamma elements and electromagnetic, quantum, and gravitational fields. Here we only postulate that each Gamma element occupies a cubicle of space with a linear dimension l_p (hence a volume l_p^3.) Then the distance between two neighboring Gamma elements is also l_p. Furthermore, the time required for light energy to propagate from one Gamma element to the next is the elemental time interval, which we shall denote t_p. Thus t_p and l_p are the elemental units of time and length, respectively, and $l_p/t_p \equiv c$ defines the speed of light propagation, which is constant regardless of an observer's frame of reference by definition.

The principle of relativity and that c is constant in all inertial frames leads to the theory of the special relativity. These two conditions of special relativity are both captured by the assumption that our space-time is discretized and that $l_p/t_p \equiv c$ by definition in all inertial frames. We shall call the latter the principle of elemental space-time (EST), or simply the EST condition. This asserts that the elemental length and time are the smallest units of length and time, respectively, and that we, the observers, merely count the number of l_p and t_p to perceive the distance and time, respectively. The magnitudes of l_p and t_p may change by the relativistic effect but their counts don't, hence the constancy of the speed of light regardless of the observers' inertial frames of reference.

To explore this further, let us build the bridge between the continuum physics and the elemental space-time. Now let n_s be the number of the Gamma elements energized in sequence per "second" by light, i.e., 1 second = $n_s t_p$. The distance traveled by light (energy) in one second then is $n_s l_p$. The speed of the light propagation is still calculated to be

$$c = \frac{n_s l_p}{n_s t_p} = \frac{l_p}{t_p} \tag{1}$$

which is constant in all inertial frames.

The special theory of relativity tells us that l_p and t_p can vary in different inertial frames but that n_s is constant in all inertial frames. EST tells us that the absolute magnitudes of l_p or t_p are immaterial to us, the observers, since the only thing we perceive is n_s for both time and distance.

But n_s is unknown since we have yet to determine the dimensions of the Gamma elements. In the next section, we will infer the dimension of the Gamma elements to the first approximation from observed wavelengths of gamma-rays and neutrino sizes.

The following analysis which we will call "discretizing" transforms an equation having the measurement units meter (m), kilogram (kg), and second (s) to one having the elemental units l_p, M_p, and t_p according to the principle of the elemental space-time. (M_p is elemental mass as will be defined later.) First we explicitly write an equation to include the customary units, converts the customary units to the elemental units, and then apply the EST condition. It is not a mere dimensional analysis but an exact analysis.

For convenience, let $c\ (m/s) = c_o\ m/s$, i.e., c_0 is dimensionless number. We then have one light-second length = $c_0\ m = n_s\ l_p$. We will also frequently use 1 m = $n_m\, l_p$ where $n_m = n_s/c_0$.

Let $h = h_0\ kg\ m^2 s^{-2} s$ and $\nu = \nu_0 s^{-1}$ where h is the Planck constant, ν the frequency, and h_0 and ν_0 are dimensionless numbers. The energy of a "photon" (denoted by the subscripts $_{ph}$) with the frequency ν is [4]

$$E_{ph} = h\nu \tag{2}$$

$$= h_o\nu_0\ kg\ m^2 s^{-2}$$

$$= h_o\nu_0\ kg\ (n_m l_p)^2 (n_s t_p)^{-2}$$

$$= h_o\nu_0\ kg\ (n_m/n_s)^2\ (l_p/t_p)^2.$$

But $n_m/n_s = 1/c_0,\ l_p/t_p = c$, thus

$$E_{ph} = (h_o\nu_0/c_0^2)\ kg\ c^2.$$

One recognizes that $h_0\nu_0/c_0^2\ kg$ is a mass, hence let $M_{ph} \equiv h_0\nu_0/c_0^2\ kg = h\nu/c^2$, then

$$E_{ph} = h\nu = M_{ph}c^2. \tag{3}$$

This derivation at once shows (1) the wave-matter equivalence and (2) the energy-mass conversion. How did we get this equation so easily? This shows the power of the EST principle, $l_p/t_p=c$ which simplifies the mechanics of special relativity. (In this paper, we shall denote mass to be M to distinguish it from the length unit meter denoted by m. This is necessary since we will include physical units in our discretized equations.) Thus from the Planck relation and the elemental space-time model, we have derived the mass of the photon to be $M_{ph} = h\nu/c^2$. Such a prediction was already made previously by De Broglie [5]. This apparently contradicts with the prevailing relativistic physics which generally believes and mathematically treats that photons travel with velocity c, are massless, and their energy is all kinetic. It is because in the EST model, light energy propagates as "elemental waves," from one Gamma element to the next in sequence with the phase velocity, c, in a way that is indistinguishable from the apparent photon particles traveling in vacuum.

3 Estimate of Elemental Properties

For brevity, here we shall drop the subscripts "*ph*" from the designation of photon energy and photon mass, respectively. The Planck-Einstein relation $E = h\nu$ states that the energy of light is discretized. We can rewrite Eq. **(3)** as

$$E(\nu) = h\nu = M(\nu)c^2. \tag{4}$$

This expresses the fact that the energy of a photon is a function of frequency and its mass then is also a function of frequency. We then visualize a photon as ν_0 number of Planck elements arriving in series. More correctly, we visualize a photon as a Gamma element beating ν_0 times per second (same as ν_0 Planck elements) with ν_0 originating from an electron that emits energy, $E=h\nu$ at a time.

Since ν_0 is a positive integer, one recognizes that the elemental energy, E_p, is obtained when this is the smallest, i.e., when the frequency is one per second,

$$E_p \equiv E(1) = \frac{h}{s} = \frac{h}{n_s t_p} \equiv \frac{h_p}{t_p}, \tag{5}$$

where we define

$$h_p \equiv \frac{h}{n_s}. \tag{6}$$

h_p may be called "time-discretized" Planck constant.

From Eq. **(3)** we also define the corresponding mass,

$$M(\nu) = \frac{h\nu}{c^2}. \tag{7}$$

This states that the energy of light may be converted to mass, a function of frequency ν with an elemental value when $\nu=1$:

$$M_p \equiv M(1) = \frac{h}{c^2}\frac{1}{s} = \frac{h_p}{c^2}\frac{1}{t_p} = \frac{E_p}{c^2}. \tag{8}$$

M_p is the mass of a Gamma element loaded with the light energy for a period of t_p. For distinction, we shall call an energized Gamma element to be a Planck element. The lifetime of Planck element is t_p. The Gamma elements are associated with the maximum energy Gamma-ray and sized from its wavelength.

Thus M_p is the mass of a Planck element. Its value may be calculated from the above,

$$M_p = \frac{h}{c^2}\frac{1}{s} = 7.37 \times 10^{-51}\ \text{kg}, \text{ or}$$

$$1\ kg = 1.36 \times 10^{50}\ M_p.$$

We shall define an integer, $N_{kg} = 1.36 \times 10^{50}$, so we may discretize any mass,

$$M = M_o\ kg = M_o\ N_{kg}\ M_p.$$

We can also write for the energy of a Planck element,

$$E_p = M_p c^2 = \frac{1kg}{N_{kg}} c^2 . \tag{9}$$

The mass of the Planck element in the above is directly related to the Planck constant, an experimentally measured value, hence is easily found. We note that l_p is the theoretical low limit for the wavelength of electromagnetic waves. Researchers do not claim we have observed the low limit experimentally yet but projected the low limit value of the ultrahigh energy gamma rays [6, 7, 8, 9] in the range,

$$\lambda_{\gamma\text{-}ray} \approx 1 \times 10^{-19}\ \text{m} - 1 \times 10^{-25}\ \text{m}.$$

Interestingly the smallest diameter of neutrinos [10] is also estimated to be

$$\Lambda_{D\text{-}nutrino} \approx 1 \times 10^{-19}\ \text{m}.$$

Even lower wavelengths are observed for cosmic rays [11] which are known to be proton particles with the energy greater than even that of the highest gamma rays,

(a) GZK limit:

$$\lambda_{gzk} = 2.48 \times 10^{-26}\ \text{m},$$

(b) Ultra High Energy Cosmic Rays:

$$\lambda_{uhe} = 4.13 \times 10^{-27}\ \text{m, and}$$

(c) 300 EeV cosmic rays:

$$\lambda_{300EeV} = 1.24 \times 10^{-27}\ \text{m}.$$

Since protons are composite particles, however, these wavelengths of the proton matter waves and their energy levels do not represent the electromagnetic waves carried by the Gamma-Planck elements. We, therefore, estimate l_p to be in the range,

$$l_p = 1 \times 10^{-19}\ \text{m} - 1 \times 10^{-25}\ \text{m},$$

to hence t_p in the range,

$$t_p = l_p/c = 3.34 \times 10^{-28}\ \text{s} - 3.34 \times 10^{-34}\ \text{s}.$$

4 The EST vs. Conventional Planck Units

A set of natural units called the Planck units may be derived from the "fundamental" universal constants, c, G, and h. The natural units for length, time, and mass denoted as l_q, t_q, and M_q, respectively, may be derived by writing their dimensional relationship,

$$c = l_q / t_q, \qquad G = \frac{l_q^3}{M_q t_q^2}, \text{and} \qquad h = \frac{M_q l_q^2}{t_q} \tag{10}$$

with the results being:

$$l_q = \sqrt{\frac{hG}{c^3}} \approx 4.05 \times 10^{-35}\ \text{m},$$

$$M_q = \sqrt{\frac{hc}{G}} \approx 5.46 \times 10^{-8}\ \text{kg, and}$$

$$t_q = \sqrt{\frac{hG}{c^5}} \approx 1.35 \text{ x } 10^{-43} \text{ s.}$$

The above may be called the conventional Planck units to distinguish from the natural units to be derived according to the present elemental space-time. The conventional Planck scale influences our understanding of the universe in both profound and confounding ways. The conventional Planck units [12] represent a scale far smaller in distance than what is currently accessible at high energy particle accelerators at approx. 10^{-20} times the proton radius but far heavier than a proton at approx. 10^{19} times the proton mass. A "Planck particle" [13] is a hypothetical particle defined as a tiny black hole whose mass is thus approximately the Planck mass, and its Compton wavelength and Schwarzschild radius are about the Planck length. They play a role in some models of the evolution of the universe during the "Planck epoch." One of the difficulties of "quantum gravity" is that quantum gravitational effects are only expected to become apparent near the Planck scale.

It is interesting to note that the above includes a feature, $l_q = ct_q$, which is similar to $l_p = ct_p$, a fundamental relationship of the present theory. One might deduce from this that the conventional Planck units implicitly present the idea of the elemental space and time. No such significance was previously described, however, to the best of the author's knowledge.

Eq. **(10)** merely represents dimensional relationships hence the solutions also merely represent the dimensional relationships. To obtain more meaningful natural units for the present elemental space-time, let us discretize the gravitational constant, G,

$$\begin{aligned} G = G_0 \frac{m^3}{kg \cdot s^2} = \frac{G_0}{c_0^2} \frac{m}{kg} c^2 = \\ \frac{G_0}{c_0^3} \frac{n_s l_p}{N_{kg} M_p} c^2 \equiv K^2 \frac{n_s l_p}{M_p} c^2 \end{aligned} \tag{11}$$

where G_0 and K are both dimensionless constants with K defined by

$$K^2 \equiv \frac{G_0}{c_0^3 N_{kg}}. \tag{12}$$

The three equations to solve, then, are the following;

$$\begin{aligned} c &= l_p / t_p, \\ G &= K^2 \frac{n_s l_p}{M_p} c^2, \text{ and} \\ h &= M_p n_s t_p c^2. \end{aligned} \tag{13}$$

The last of the above three equations comes from Eq. **(8)**.

The results, including the relationship with the conventional Planck units, are

$$\begin{aligned} l_p &= \frac{1}{Kn_s} \sqrt{\frac{hG}{c^3}} \left(= \frac{l_q}{Kn_s},\right) \\ M_p &= K \sqrt{\frac{hc}{G}} (= KM_q,) \text{ and} \\ t_p &= \frac{1}{Kn_s} \sqrt{\frac{hG}{c^5}} \left(= \frac{t_q}{Kn_s}.\right) \end{aligned} \tag{14}$$

These are the natural units from the elemental space-time model. They retain the same dimensional relationships with respect to the fundamental constants, c, G, and h, as the conventional Planck units, with the estimated numerical values to be,

$$l_p = \frac{c_0 m}{n_s} \approx 1 \text{ x } 10^{-19} \text{ m} - 1 \text{ x } 10^{-25} \text{ m},$$

$$M_p \approx 7.37 \text{ x } 10^{-51} \text{ kg (or } \sim 4.14 \text{ x } 10^{-15} \text{ eV/c}^2\text{,) and}$$

$$t_p = \frac{1s}{n_s} \approx 3.34 \text{ x } 10^{-28} \text{ s} - 3.34 \text{ x } 10^{-34} \text{ s.}$$

We note that M_p is the mass of a Planck element, l_p is the linear dimension of a single Gamma or Planck element, and t_p is time taken for light energy to propagate from one Gamma element to the next. t_p is also the lifetime of a Planck element. We may therefore call the above "Planck element units." The Planck element units represent a distance scale at approx. $10^{-5} - 10^{-11}$ times the proton radius and approx. 10^{-24} times the proton mass - much more amenable for our particle physics than the conventional Planck units.

We also note that the length and time element ranges are still approximate, so the value of n_s is not yet precisely known. From the above estimate, we can back-calculate n_s and K, the constants appearing in Eq. **(14)** as follows:

$$n_s = 3.00 \text{ x } 10^{27} - 3.00 \text{ x } 10^{33}$$

$$K=1.35 \text{ x } 10^{-43}$$

Note that the properties of the Planck element come from an entirely different origin than that of the conventional "Planck particle" discussed in the above, although their dimensional relationship with the three fundamental constants, c, G, and h, are the same. This justifies our calling the former by the name "Planck element" rather than by the name of the conventional "Planck particle."

5 Summary and Concluding Remarks

The EST model may be viewed as an evolution of our understanding of the space-time, from aether-filled to vacuum to now a matter-filled space. In a sense, we bring the aether back anyway, only this time the aether is not absolute, but comprised of material elements having energy and corresponding mass. We call them Gamma elements. They transmit light and define the very concept of our time and distance. Time and distance are discretized, with the ratio of discrete length over discrete time, $l_p/t_p \equiv c$, to be the speed of light propagation by definition. The energized Gamma elements are called Planck elements with the life time, t_p. The energy of a Planck element is given by the Planck constant (per second) and its size is given by the wavelength of the γ-rays of the highest possible energy, estimated to be within the observed range of $1 \text{ x } 10^{-19}$ m – $1 \text{ x } 10^{-25}$ m.

A photon is now understood to be a Gamma element beating with a frequency v or equivalently a series of Planck elements "arriving" to a point with a frequency v. The mass of a stationary photon is given by $M=hv/c^2$ although a photon may be treated mathematically as particle of mass zero, energy hv and always travelling with the speed, c.

The discreteness of elemental space-time naturally leads us to new fundamental units at the "Planck element scale." A set of "Planck element units" are derived by discretizing the fundamental constants, c, G, and h, and shown to have the same dimensional relationship with respect to them as the conventional Planck units. The

Planck element mass, however, is smaller than the conventional Planck mass by whopping 10^{-43} orders of magnitude while the Planck element length and time units are estimated to be larger than those of the conventional Planck units by $10^9 – 10^{16}$ orders of magnitude. It is to be noted that the Planck element units comes from the Gamma/Planck element with a physical basis described in this paper whereas the conventional Planck units comes only from a dimensional analysis with no such physical basis.

References

1. Einstein, A.: On the Electrodynamics of Moving Bodies, English translation of the original 1905 German-language paper (published as Zur Elektrodynamik bewegter Körper, in Annalen der Physik. 17:891, 1905) in The Principle of Relativity, Methuen and Company, Ltd. of London, (1923).
2. Feynman, R. P.: *Feynman's Lectures on Physics, Volume 1, Chapter 2.* Caltech. (1963).
3. Wilczek, F.: *The Lightness of Being*, *Chapter 8*, Basic Books (2008).
4. Einstein, A.: On a Heuristic Point of View about the Creation and Conversion of Light, in The Old Quantum Theory, Pergamon Press, pp. 91–107 (1967).
5. Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Louis_de_Broglie (2013).
6. http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970412e.html, Ask an Astrophysicist: Is there an upper limit to the Electromagnetic Spectrum?
7. Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Ultra-high-energy_gamma_ray (2014).
8. Aharonian, F.: et al, *The time averaged TeV energy spectrum of Mkn 501 of the extraordinary 1997 outburst as measured with the stereoscopic Cherenkov telescope system of HEGRA*, arXiv:astro-ph/9903386v2 (Jul 1999).
9. H.E.S.S. Collaboration, A. Abramowski, et al., *HESS J1640-465 - an exceptionally luminous TeV gamma-ray supernova remnant*, arXiv:1401.4388v2 [astro-ph.HE] (Feb 2014).
10. Stecker, F.W.: *Exploring the ultrahigh energy neutrino universe*, arXiv:astro-ph/0003459v1 (Mar 2000).
11. Stecker, F.W.: *The curious adventure of the ultrahigh energy cosmic rays*, arXiv:astro-ph/0101072v2 (11 Jan 2001).
12. Wikipedia, the free encyclopedia, http://*en.wikipedia.org/wiki/Planck_units,* Jan. 2015.
13. Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Planck_particle, Dec. 2011.