Qeios

The Compton Wavelength Is the True Matter Wavelength, Linked to the Photon Wavelength, While the de Broglie Wavelength is Simply a Mathematical Derivative, Understanding this leads to Unification of Gravity and New Quantum Mechanics

Espen Gaarder Haug
https://orcid.org/0000-0001-5712-6091
Norwegian University of Life Sciences, Norway
e-mail espenhaug@mac.com

November 29, 2024

Abstract

We demonstrate that the Compton wavelength mathematically corresponds exactly to the photon wavelength of rest mass energy. On the other hand, the de Broglie wavelength is not defined for a rest-mass particle, but if the particle is nearly at rest, then the de Broglie wavelength approaches infinity, and the corresponding photon wavelength of the rest-mass energy is then this length times $\frac{v}{c}$ again, that is it approaches zero when v approaches zero. Our analysis indicates that the de Broglie wavelength appears to be a pure mathematical derivative of the Compton wavelength. Everything that can be expressed with the de Broglie wavelength can essentially be expressed by the Compton wavelength. We also demonstrate how spectral lines from atoms and chemical elements are linked to the Compton wavelength of the electron and that the Rydberg constant is not needed.

Furthermore, we demonstrate that the Compton frequency is embedded in the Schrödinger equation, the Dirac equation, and the Klein-Gordon equation, where the Planck constant actually cancels out, and the de Broglie wavelength is not present in these equations. The Compton frequency seems to be linked to the quantization in quantum mechanics rather than the Planck constant. Additionally, we discuss recent literature that shows a remarkably simple but overlooked way to quantize Newton's and General Relativity theories, as well as other gravity theories, and also how to link them to the Planck scale. This, once again, leads to the conclusion that the Compton wavelength and Compton frequency are related to the quantization of matter and, thereby, the quantization of gravity. In addition, the Planck length plays a crucial role in quantum gravity, as demonstrated.

Viewing physics through the de Broglie wavelength is like looking at the world through a distorted lens; switch to the Compton wavelength, and the distortion is removed, allowing us to see simplicity and clarity even in complex phenomena such as quantum gravity. Remarkably, Heisenberg's uncertainty principle seems to need modification to a Certainty-Uncertainty Principle when one understands that the Compton wavelength is the true wavelength of matter. Gravity is related to the Planck mass particle and is again related to absolute rest,

https://doi.org/10.32388/OZ0IRU.5

which lasts for the Planck time. This certainty-uncertainty principle leads to the unification of gravity and quantum mechanics.

Key Words: Compton wavelength, de Broglie wavelength, photon wavelength, matter wavelength, Rydbergs formula, quantum mechanics, quantum gravity, unification.

1 The Compton wavelength and the photon wavelength in rest masses

We will in this section present a very simple, yet we believe, very important mathematical relationship that surprisingly has not to our knowledge been shown directly before. We think the reason it has not been discovered before is that the research community has primarily associated mass with the de Broglie wavelength rather than the Compton wavelength. After demonstrating this important yet straightforward mathematical relationship, we will discuss how the Compton wavelength is likely the true matter wavelength, while the de Broglie wavelength is likely just a mathematical derivative of the actual physical matter wavelength.

Compton [1] in 1923 gave the Compton wavelength as:

$$\lambda_c = \frac{h}{mc}. \tag{1}$$

Furthermore, the reduced Compton wavelength is defined as $\bar{\lambda}_c = \frac{\lambda_c}{2\pi}$, and we therefore have:

$$\bar{\lambda}_c = \frac{\hbar}{mc}, \tag{2}$$

where $\hbar = \frac{h}{2\pi}$ is the reduced Planck constant, also known as the Dirac constant. Additionally, the relativistic Compton wavelength [2] is given by:

$$\lambda_c = \frac{h}{mc\gamma}, \tag{3}$$

where $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ is the Lorentz factor, and the relativistic reduced Compton wavelength is given by:

$$\bar{\lambda}_c = \frac{\hbar}{mc\gamma}. \tag{4}$$

The rest mass energy is given by Einstein's [3] most famous formula:

$$E = mc^2. \tag{5}$$

If all the mass is turned into pure energy, then we must have:

$$E = h\frac{c}{\lambda} = mc^2, \tag{6}$$

where λ simply is the photon wavelength. Next, let us go back to the Compton wavelength formula and solve it with respect to m. This gives:

$$m = \frac{h}{\lambda_c}\frac{1}{c}. \tag{7}$$

Now we replace this expression for the mass into Eq. (6), and we get:

$$
\begin{aligned}
E &= mc^2 \\
h\frac{c}{\lambda} &= \frac{h}{\lambda_c}\frac{1}{c}c^2 \\
\lambda &= \lambda_c.
\end{aligned} \tag{8}
$$

This means that the Compton wavelength is identical to the photon wavelength for rest-mass energy. This may seem trivial when someone first demonstrates it and points it out. However, we will soon move to the de Broglie wavelength, where we obtain quite a different result. The result above could indicate that rest mass consists of standing photon waves with very short wavelengths, exactly at the length of the Compton wavelength. This idea that the Compton wavelength is identical to the photon wavelength for rest mass (rest-mass energy) has been suggested by Haug [4, 5] in a theory under rapid development. Likely, only elementary particles such as electrons have a Compton wavelength. Still, as has been recently demonstrated, the kilogram mass of any mass from protons to astronomical masses can be expressed with the formula $m = \frac{h}{\lambda}\frac{1}{c}$, and the Compton wavelength can be found for any mass, even astronomical, without even knowing the Planck constant or the kilogram mass, see [6, 7]. However, the Compton wavelength in a composite mass reflects an aggregate of the Compton wavelengths of all masses and energies making up the composite mass. We have that the Compton wavelength of a composite mass is given by

$$
\lambda_c = \frac{1}{\sum_{i=1}^{n}\frac{1}{\lambda_{c,i}} \pm \sum_{j=1}^{N}\frac{1}{\lambda_{c,j}}}. \tag{9}
$$

Where λ_i is the Compton wavelength of a fundamental particle or from rest-mass energy. This is fully consistent with

$$
\begin{aligned}
m &= \sum_{i=1}^{n} m_i \pm \sum_{j=1}^{N}\frac{E_i}{c^2} \\
\frac{h}{\lambda_c}\frac{1}{c} &= \sum_{i=1}^{n}\frac{h}{\lambda_{c,i}}\frac{1}{c} \pm \sum_{j=1}^{N}\frac{h\frac{c}{\lambda_{c,j}}}{c^2} \\
\lambda_c &= \frac{1}{\sum_{i=1}^{n}\frac{1}{\lambda_{c,i}} \pm \sum_{j=1}^{N}\frac{1}{\lambda_{c,j}}}.
\end{aligned} \tag{10}
$$

In other words, this is consistent with aggregating all elementary particles and energies making up the rest-mass m, binding energies etc., naturally fully consistent also with the conservation of energy.

When it comes to that the Compton wavelength is identical to the rest-mass energy photon wavelength as demonstrated in this section one can ask how relavant this is since it is typically assumed photons have no mass. One can naturally still argue that photons can be treated as equivalent of mass since we have $m = \frac{E}{c^2}$

2 The Compton wavelength and the wavelengths of a spectral lines

The well-known Rydberg [8] formula is given by:

$$\frac{1}{\lambda} = R_\infty Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right). \tag{11}$$

Here, n_1 is the principal quantum number of an energy level, and n_2 is the principal quantum number of an energy level for the atomic electron transition. Furthermore, the Rydberg constant is defined as:

$$R_\infty = \frac{m_e e^2}{8\epsilon_0^2 h^3 c}. \tag{12}$$

In this equation, m_e represents the electron mass, ϵ_0 is the vacuum permittivity, h is the Planck constant, and e is the elementary charge. However, Haug [9] has shown that Equation (11) is both non-relativistic and that the Rydberg constant is not needed. The relativistic formula that can replace the Rydbergs formula and already has been taken in use [10–12] is given by

$$\frac{1}{\lambda} = \frac{1}{\lambda_{c,e}} \left(\frac{1}{\sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}} - \frac{1}{\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}}} \right). \tag{13}$$

Here, $\lambda_{c,e}$ represents the Compton wavelength of the electron. This shows that there is no need for the Rydberg constant. As Suto [13] correctly has discussed and pointed out, the Rydberg constant is not rooted in anything physical, or in his own words:

> *"the physical constant that is important for determining the wavelengths of the line spectra of a hydrogen atom is not the Rydberg Constant, but rather the Compton wavelength of the electron."* – Koshun Suto

It is indeed the Compton wavelength of the electron that is of importance for the observed and predicted photon spectral wavelengths of atoms; the Rydberg constant is never needed to predict these. The Rydberg constant is a composite constant, not itself related to anything physical; only some of its components are. It is the electron, when transitioning between different energy levels, that emits photons, and the wavelength of these photons is directly related to the Compton wavelength of the electron, as we also demonstrated in the previous section. This again demonstrates the importance of the Compton wavelength in matter.

Equation 13 can also be expressed as:

$$\lambda = \lambda_{c,e} \frac{\sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}}}{\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}} - \sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}}. \tag{14}$$

This means we can also find the Compton wavelength of the electron from the wavelengths of the line spectra in atoms, as we must have:

$$\lambda_{c,e} = \lambda \frac{\left(\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}} - \sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}\right)}{\sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}}}. \tag{15}$$

That is, observed spectral lines from electron transitions in atoms can just as well be used to find the Compton wavelength of electrons as Compton scattering. Finding the mass of the electron based on spectral line observations by using the standard Rydberg formula will slightly overestimate the mass if one does not understand the original Rydberg formula is a non-relativistic approximation. The same is true from the standard Compton scattering formula, as this is also non-relativistic in the sense it does not assume that electrons move at impact. If using spectroscopy of Hydrogen atoms and not taking into account the relativistic corrections needed, one will overestimate the electron mass by approximately $m_e/\sqrt{1-\alpha^2} - m_e \approx 2.43 \times 10^{-35}$ kg (0.0027%).

3 The Compton wavelength of the electron and other masses can be found totally independently of knowledge of the Planck constant and the electron mass

The most common way to express the Compton wavelength in university text books (see for example [14, 15]) is $\lambda_c = \frac{h}{m_e c}$, and multiple researchers[1] therefore mistakenly assume that one always needs to know the Planck constant and the electron mass to find the Compton wavelength of the electron. There is absolutely nothing wrong with this formula, but there is a deeper level to it so to say. So it is actually not the case that we need to know the Planck constant and the electron mass to find the Compton wavelength of the electron as has been demonstrated in recent years; see [6, 7]. Since this is such an important point for understanding the various points of this article, we will repeat here how to find the Compton wavelength without any knowledge of the Planck constant or the electron mass by using Compton scattering (and look at it from a deeper perspective).

In the original paper by Compton [16], published in 1923, Compton gives the formula:

$$\lambda_1 - \lambda_2 = \frac{h}{m_e c}(1 - \cos\theta), \tag{16}$$

where h is the Planck constant, m_e is the mass of the electron, and θ is the angle between the primary and the scattered beams (photon λ_1 and photon λ_2). Since we can write $m_e = \frac{h}{\lambda_{c,e}}\frac{1}{c}$, we can replace m_e with this in equation 16 and solve for λ_c. This gives:

$$\lambda_{c,e} = \frac{\lambda_1 - \lambda_2}{1 - \cos\theta}. \tag{17}$$

That means to find the Compton wavelength of the electron, all we need to do is measure the wavelength of the two photons in the scattering experiment and the angle between them. There is no need to know the Planck constant or the electron mass to find the Compton wavelength of the electron, contrary to what many even experienced researchers think, so this alone we think is a significant.

In addition, in this paper, we have theoretically demonstrated that the Compton wavelength can be found by observing spectral lines from hydrogen atoms using the following formula:

$$\lambda_{c,e} = \lambda \frac{\left(\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}} - \sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}\right)}{\sqrt{1 - \frac{Z^2\alpha^2}{n_1^2}}\sqrt{1 - \frac{Z^2\alpha^2}{n_2^2}}}.$$

[1] Thanks to Dr. Christian Brand for useful comments making us aware that many experienced researchers may not yet be aware that the Compton wavelength can be found independently of knowledge of the Planck constant or the electron mass. The reason for this is not as strange as it has been demonstrated first in recent years that this is possible.

As we can see from the formula, only the photon wavelength from the spectral line of the hydrogen atom is needed, in addition to the fine-structure constant. However, a fair question to ask is whether this also works in practice. The answer is yes, and we do not even need to physically perform the experiment to demonstrate it, as others have already conducted the experiments needed.

For example, we will look at one of the transitions in the well-known Lyman series. We will look at when the electron in a hydrogen atom goes from $n_2 = 2$ to $n_1 = 1$. The observed photon wavelength from the experiment is approximately 121.56701 nanometers. We can now simply input this value into the formula above, and we get:

$$\lambda_{c,e} = 121.56701 \times 10^{-9} \times \frac{\left(\sqrt{1-\frac{1^2\alpha^2}{2^2}} - \sqrt{1-\frac{1^2\alpha^2}{1^2}}\right)}{\sqrt{1-\frac{1^2\alpha^2}{1^2}}\sqrt{1-\frac{1^2\alpha^2}{2^2}}} \approx 2.427 \times 10^{-12} \text{ m},$$

which is very close to the official CODATA NIST (2019) Compton wavelengh of the electron $2.42631023867 \times 10^{-12}$ m. Again it is important that we can find the Compton wavelengh of the electron totally independent of knowledge of the Planck constant or the electron mass.

Next, we can use the found Compton wavelength of the electron together with the fine-structure constant to accurately predict the spectral lines of any atom. This leads us back to the Rydberg constant. Some may possibly claim that we are too harsh in our criticism in the previous section when we say we never need the Rydberg constant. It is well known that the Rydberg constant is a composite constant, and some may think that we have simply replaced some constants with other constants. This is not the case. If one uses the traditional Rydberg formula, $R_\infty = \frac{m_e e^2}{8\epsilon_0^2 h^3 c}$, one needs to know the electron mass, the elementary charge, the Planck constant, and the speed of light. We, on the other hand, only need the Compton wavelength of the electron that we found from spectral lines themselves (or alternatively from Compton scattering, also with no knowledge of other constants) and the fine-structure constant. In other words, we achieve a reduction in constants, which is one of the great aims of modern fundamental physics.

In the coming pages, it will become clear that we can perform many quantum mechanics calculations with only the knowledge of one constant: the speed of light as well as knowledge of the Compton wavelength of the mass in question. In some cases, we also need to know the fine-structure constant. When it comes to quantum gravity and providing the same predictions as general relativity theory, we only need the speed of light (for gravity) and the Planck length. Both can be easily found experimentally without knowing any other constants.

We can next even find the Compton wavelengh of a composite mass, namely the proton without any knowledge of the Planck constant or knowledge of the mass of the electron. We will take advantake of that the cyclotron frequency is given by

$$f = \frac{qB}{2\pi m}, \tag{18}$$

where q is the charge and B is the uniform magnetic field and m is the mass of the particle in question, for example an electron or proton. Since electrons and protons have the same absolute value of the charge their cyclotron frequency ratio is given by

$$\frac{\frac{|e|B}{2\pi m_e}}{\frac{|e|B}{2\pi m_{pr}}} = \frac{m_{pr}}{m_e} \approx 1836.15 \tag{19}$$

Which is why cyclotrons indeed have been used to find the proton electron mass ratio, see for example [17, 18]. However we will go one step further and replace the electron mass with $m_e = \frac{h}{\lambda_{c,e}}\frac{1}{c}$ and the proton mass with $m_{pr} = \frac{h}{\lambda_{c,pr}}\frac{1}{c}$, this gives

$$\frac{\frac{|e|B}{2\pi m_e}}{\frac{|e|B}{2\pi m_{pr}}} = \frac{m_{pr}}{m_e} = \frac{\lambda_{c,e}}{\lambda_{c,pr}} \approx 1836.15 \tag{20}$$

So, to find the proton Compton wavelength independently of any knowledge of the kilogram mass or the Planck constant, all we need to do is first find the electron Compton wavelength, as described in this section. Then, we can divide the electron Compton wavelength by the observed cyclotron frequency ratio obtained from running a cyclotron on electrons as well as protons. Thus, we can determine the Compton wavelength of the proton without relying on knowledge of the Planck constant and the proton's kilogram mass.

Now, to find the Compton wavelength for larger macroscopic masses, we can simply count the number of atoms in the object. This is not an easy task, but it is fully possible and was actually one of the proposed methods to define the kilogram (see [19, 20]). Other methods also exist; for example as pointed out by Wang [21]. As we know the number of protons and neutrons in each atom, we can, for simplicity, treat the neutrons as protons and then divide the Compton wavelength of a single proton by the total number of protons and neutrons in the macroscopic mass. This provides us with a quite accurate estimate of the Compton wavelength within the macroscopic mass. Further refinements can be made by considering the number of electrons and accounting for the slight mass difference between neutrons and protons, as well as accounting for binding energies.

When it comes to finding the Compton wavelength of astronomical objects, practicality prevents us from directly counting the number of atoms in, for example, the Earth. Fortunately, this is unnecessary. We can instead utilize the following relation:

$$\frac{g_1 r_1^2}{g_2 r_2^2} = \frac{\lambda_{c,2}}{\lambda_{c,1}}. \tag{21}$$

So, we can now use a Cavendish apparatus to first determine the gravitational acceleration of the macroscopic silicon sphere for which we have accurately counted the number of atoms. The gravitational acceleration field in a Cavendish apparatus is simply given as:

$$g_1 = \frac{2\pi^2 L r^2 \theta}{T^2}, \tag{22}$$

where L is the distance between centers of small balls, r is the distance between centers of large and small balls when balance is deflected, and θ is the deflection angle of torsion balance beam from its rest position, and T the period of oscillation of torsion balance. Pay attention to that also here we do not relay on the Planck constant, nor do we need to know the kilogram mass of the balls in the apparatus, nor do we need to know the gravity constant G.

Next, we can find the gravitational acceleration on Earth's surface by simply dropping a ball from a height H and measuring the time it takes for it to hit the ground. The gravitational acceleration is then calculated as:

$$g_2 = \frac{2H}{T_d^2}. \tag{23}$$

Again, no knowledge of G, the Planck constant, or the mass of the Earth in kilograms is needed. Next, we can determine the Compton wavelength of the Earth using the following formula:

$$\lambda_{c,E} = \lambda_{c,c}\frac{g_2}{g_1}, \tag{24}$$

where $\lambda_{c,c}$ is the Compton wavelengh of the large ball in the Cavendish apparatus that we already found.

Similarly, we can find the Compton wavelength for any astronomical object without needing to know their kilogram mass or the Planck constant. This even holds for the mass (including its equivalent mass, as it also includes energy) of the observable universe, as we have demonstrated in [22, 23].

Naturally, we could have also found the Compton wavelength formula for any of these masses by first determining their kilogram mass and the Planck constant and then using the formula $\lambda_c = \frac{h}{mc}$. However, in this case, we would need to know more constants, specifically the Planck constant. As we will see, the Planck constant may not be required in significant portions of quantum mechanics and is not needed in the recent new type of quantum gravity theory, which produces the same predictions as general relativity theory and provides a quantization methodology applicable to various gravity theories. What becomes evident is that the Compton wavelength will play a central role.

The Compton wavelength of the critical mass in the universe can be readily calculated using only the measured CMB temperature and the Hubble constant. It is given by (see [23]):

$$\bar{\lambda}_c = \frac{H_0^3}{T_{CMB}^4}\frac{\hbar^4 c}{k_b^4 512\pi^4} \approx 3.79 \times 10^{-96}\ m \tag{25}$$

4 The de Broglie wavelength

By 1905, it was clear that photons had both particle properties and wavelike properties, today known as particle-wave duality. Most physicists at this point in time thought that matter consisted of particles with particle properties. However, it was now 'natural' to ask if matter could also have wavelike properties. This is exactly what Louis de Broglie [24] suggested in his PhD thesis in 1924. He also proposed that this wavelength was given by

$$\lambda_b = \frac{h}{mv}, \tag{26}$$

which actually is only a good approximation when $v \ll c$. For the relativistic case, de Broglie [25] gave the formula:

$$\lambda_b = \frac{h}{mv\gamma}, \tag{27}$$

where $\gamma = 1/\sqrt{1 - v^2/c^2}$ is the Lorentz factor. In 1927, Davisson and Germer [26] (at Bell labs) published experimental results of electron diffraction that strongly supported the idea that electrons also had wavelike properties. This immediately was credited as confirming the de Broglie's hypothesis. However, we must distinguish between Broglie's hypothesis that matter also had wavelike properties and his formula for predicting these waves. It was actually only his hypothesis that matter also had wavelike properties that was confirmed, not the prediction of wavelength from his formula. This has been overlooked and therefore ignored by the physics community. Today, physicists assume that the de Broglie wavelength is the matter wavelength and that the Compton wavelength mostly has something to do only with Compton scattering, even if a potential Compton wavelength of the proton also are discussed [27, 28].

That Einstein had basically endorsed the Ph.D. thesis of de Broglie could be one of the reasons why one automatically assumed that de Broglie was right on both his hypotheses: that matter has wavelike properties and, in addition, that his formula for this matter wavelength was almost "instantaneously" accepted as the real matter wavelength after the Davisson and Germer experiment. No one asked if de Broglie could simply be right on his first point that matter had wavelike properties, but that the matter wavelength could actually be the Compton wavelength. We will argue that the Compton wavelength is the one and only matter wavelength, and that the de Broglie wavelength is simply a mathematical derivative of this.

It is important to be aware that the de Broglie wavelength is always equal to the Compton wavelength times $\frac{c}{v}$ (as possibly first explicitly pointed out in [4]); that is, we always have:

$$\lambda_b = \lambda_c \frac{c}{v} \text{ and } \bar{\lambda}_b = \bar{\lambda}_c \frac{c}{v}, \tag{28}$$

and, naturally, further:

$$\lambda_c = \lambda_b \frac{v}{c} \text{ and } \bar{\lambda}_c = \bar{\lambda}_b \frac{v}{c}. \tag{29}$$

First of all, the de Broglie wavelength formula is not mathematically valid when $v = 0$, as this leads to division by zero, which is mathematically undefined. This can be seen from all the equations above in this section.

We demonstrated in section 1 that the Compton wavelength is identical to the photon wavelength of the rest-mass energy; is this also the case with the de Broglie wavelength? To find out, we first solve the de Broglie wavelength formula: $\lambda_b \approx \frac{h}{mv}$ for m; this gives

$$m \approx \frac{h}{\lambda_b} \frac{1}{v}. \tag{30}$$

Next, we do the following derivation

$$\begin{aligned} E &= mc^2 \\ E &\approx \frac{h}{\lambda_b} \frac{1}{v} c^2 \\ h\frac{c}{\lambda} &\approx \frac{h}{\lambda_b} \frac{1}{v} c^2 \\ h\frac{c}{\lambda} &\approx \frac{h}{\lambda_b} \frac{c}{v} \\ \lambda &\approx \lambda_b \frac{v}{c}. \end{aligned} \tag{31}$$

We have an approximation sign from the second line as the de Broglie wavelength is not defined for rest-masses, but we can use the derivation above as a good approximation when v is very close to 0. It means that, when we rely on the de Broglie wavelength, then the equivalent photon wavelength for rest mass approaches zero, as this formula is only a good approximation when $v \approx 0$. Not only that, but the de Broglie matter wavelength: $\lambda_b = \frac{h}{mv}$ also approaches infinity when the mass approaches rest. This absurdly close to infinite de Broglie wavelength has led to a series of different interpretations among researchers, something that is fully understandable until one discovers that the true matter wavelength is the Compton wavelength. For example, Lvovsky [29] has stated:

"The de Broglie wave has infinite extent in space." – A. I. Lvovsky

and Chauhan et al [30] has stated

> *De Broglie had an extremely strong and concrete physical justification for the infinite wavelength of matter waves, corresponding to the body at rest. .... Therefore, the infinite wavelength of matter waves, for zero velocity of body, becomes essentially evident."* –H. Chauhan et al.

Shanahan [31] writes

> *"But as this wave was understood by de Broglie, it has a velocity that is superluminal and becomes infinite as the particle comes to rest and becomes infinite as the particle comes to rest"* –Shanahan

Further Max Born [32] interpretation make some more sense

> *Physically, there is no meaning in regarding this wave as a simple harmonic wave of infinite extent, we must on the contrary, regard it as a wave packet consisting of a small group of indefinitely close wave-numbers, that is, of great extent in space."* –Max Born (1936)

Still, what's most important here is that no one seems to be able to fully explain how the de Broglie wavelength is related to something physical.

The relation between the Compton wavelength and photon wavelength that we derived in the previous section is mathematically exact and logically sound, with a rest mass having a photon wavelength identical to the Compton wavelength. On the other hand, the relation between the de Broglie wavelength and photon wavelength does not make much logical sense in our view. It is actually not mathematically valid for rest-mass particles. However, many, if not most, physicists will argue that, due to Heisenberg's uncertainty principle [33, 34], a particle never comes to absolute rest (even inside its rest-frame). Later in the paper (section 12), when we come to quantum gravity theory, we will demonstrate that it is quantum mechanics that actually needs modification, including Heisenberg's uncertainty principle. Modifying the uncertainty principle to take into account that the Compton wavelength is the real matter wavelength turns it into a certainty-uncertainty principle. That is, for non Planck-mass particles , it is an uncertainty principle, and for Planck mass particles that must be at at absolute rest, it is a certainty principle, agains the possibility for this is discussed in section 12.

Nevertheless even before we look at rest-mass, this still leads to a prediction of a nearly infinite de Broglie wavelength and a nearly zero-length equivalent photon wavelength. No such nearly infinite wavelength has been measured. What would the interpretation be? As we have seen, there is no full agreement on the interpretations.

For example, if an electron only moved at 8.3×10^{-31} m/s, then the de Broglie wavelength is outside the diameter of the observable universe (assuming it is 8.8×10^{26} m) even if the electron were at the center of the universe. In other words, the de Broglie wavelength spreads out further than light could have moved since the Big Bang, and it extends even outside the expansion of space over the same period, or we can naturally try to fall back on the Max Born interpretation, but still, it seems to open more questions than answers.

One could argue that a particle moving as slowly as 8.3×10^{-31} m/s is unrealistic. For a dilute gas of Rubidium atoms, the lowest temperature achieved yet is in the low picokelvin regime, see for instance Deppner et. al [35]. The corresponding velocities are in the μm/s regime. Thus, preparing something to move at 8.3×10^{-31} m/s is (25 orders of magnitude smaller) is currently practically unrealistic. However, there are multiple issues with such reasoning. To measure velocities of 8.3×10^{-31} m/s or lower, we would likely need much more precise measurement devices so we cannot at all exclude that particles move at this or lower velocity over a small time interval, a temperature measure is a kind of average measure, not a direct velocity measure of individual particles over very short time intervales. Second, even if, for example, a proton were not moving slower than in the μm/s regime, then the de Broglie wavelength of the proton would be $\lambda_b = \frac{h}{m_{pr}\times 1\times 10^{-6}} \approx 0.4$ m. This means that a protons in front of us cooled down to the low picokelvin regime, if the de Broglie wavelength were physically should each be spread out over almost half a meter. We find this absurd, even if it cannot be totally excluded.

A much more likely scenario is that the physical wavelength is the Compton wavelength of the proton, which is always, for a proton would be $\lambda_c = \frac{h}{m_{pr}} \approx 2.1 \times 10^{-16}$ m or shorter. The Compton wavelength contracts for a moving object so the rest mass Compton wavelength is the maximum Compton wavelength, in contrast to for the de Broglie wavelength where there is no theoretical limit for how long it can be ass we approaches a velocity of zero. So, there is a significant difference between the Compton wavelength and the de Broglie wavelength. The de Broglie wavelength for slowly moving protons and other particles is predicted to be of macroscopic scale, on the order of meters, which, in our view, is absurd. On the other hand, the Compton wavelength for any atom always falls within the length scales of the atomic scale.

If the de Broglie wavelength is physical and of macroscopic scale for very slow-moving particles, it should be possible to measure it directly. However, this has never been done, and we believe it never will be done, as we hold the conjecture that the de Broglie wavelength is a pure mathematical derivative of the Compton wavelength.

5 Finding the de Broglie wavelengh from spectroscopy

SSince the de Broglie wavelength is a mathematical derivative of the Compton wavelength, $\lambda_b = \lambda_c \frac{c}{v}$, we can also easily determine the de Broglie wavelength from spectral lines. By using our results from equation 15, we must have

$$\begin{aligned}
\lambda_b &= \lambda_c \frac{c}{v} = \frac{\lambda \frac{c}{v}\left(\sqrt{1-\frac{Z^2\alpha^2}{n_2^2}} - \sqrt{1-\frac{Z^2\alpha^2}{n_1^2}}\right)}{\sqrt{1-\frac{Z^2\alpha^2}{n_1^2}}\sqrt{1-\frac{Z^2\alpha^2}{n_2^2}}} \\
\lambda_b &= \lambda_c \frac{c}{Z\alpha c} = \frac{\lambda \frac{c}{Z\alpha c}\left(\sqrt{1-\frac{Z^2\alpha^2}{n_2^2}} - \sqrt{1-\frac{Z^2\alpha^2}{n_1^2}}\right)}{\sqrt{1-\frac{Z^2\alpha^2}{n_1^2}}\sqrt{1-\frac{Z^2\alpha^2}{n_2^2}}} \\
\lambda_b &= \lambda \frac{\left(\sqrt{\frac{1}{Z^2\alpha^2}-\frac{Z^2}{n_2^2}} - \sqrt{\frac{1}{Z^2\alpha^2}-\frac{Z^2}{n_1^2}}\right)}{\sqrt{1-\frac{Z^2\alpha^2}{n_1^2}}\sqrt{1-\frac{Z^2\alpha^2}{n_2^2}}}. \qquad (32)
\end{aligned}$$

So all we need to know about constants to find the de Broglie wavelength is the fine structure constant when using spectroscopy. However, we will assert that the de Broglie wavelength is simply a mathematical derivative of the real matter wavelength, namely the Compton wavelength.

6 The Compton frequency in matter

We will claim anything with rest-mass ticks at the reduced Compton frequency; this has some support also in recent research, [36, 37]. The Compton frequency is given by

$$f_c = \frac{c}{\bar{\lambda}_c}. \tag{33}$$

For an electron, this has some similarities with the trembling motion (zitterbewegung) suggested by Schrödinger [38], where he proposed a frequency of $\frac{2m_e c^2}{\hbar} = 2\frac{c}{\bar{\lambda}_{c,e}}$, which is twice the reduced Compton frequency and also twice the de Broglie electron clock rate, as he suggested in his 1924 dissertation. This view that electrons are trembling has recently also been investigated by multiple researchers. For example, Santos [39] suggests that zitterbewegung is *a light speed "trembling-along-the-way" electron motion, to be a real oscillatory motion of the electron*"

Interestingly, we can also express the Compton frequency in the form of the de Broglie wavelength by utilizing the relation $\lambda_c = \lambda_b \frac{v}{c}$, which leads to:

$$f_c = \frac{c}{\lambda_c} = \frac{c}{\lambda_b \frac{v}{c}} = \frac{c^2}{\lambda_b v}. \tag{34}$$

So, we can see that it not only leads to excessive complexity but also is not strictly mathematically valid when $v = 0$.

The de Broglie frequency can be expressed as:

$$f_b = \frac{c}{\bar{\lambda}_b}. \tag{35}$$

This is not valid for a rest mass because the de Broglie wavelength is not defined for $v = 0$. The de Broglie wavelength itself is given by $\bar{\lambda}_b = \frac{\hbar}{mv\gamma}$, which is not even mathematically defined for $v = 0$. We can also look at this from another perspective by expressing the de Broglie frequency through the Compton wavelength. We can do this as $\bar{\lambda}_b = \bar{\lambda}_c \frac{c}{v}$. This means the de Broglie frequency is also given by:

$$f_b = \frac{c}{\lambda_b} = \frac{c}{\lambda_c \frac{c}{v}} = \frac{v}{\lambda_c}. \tag{36}$$

Now we see that this frequency is zero when $v = 0$, which is when the mass is at rest. This is consistent with the de Broglie wavelength approaching infinity as v approaches zero. So even if the frequency is linked to the speed of light, it would take light an infinite time to travel an infinite length; therefore, it gives a frequency of zero when the mass is at rest, $v = 0$.

If mass has a frequency, then a zero frequency means no mass. So, in the de Broglie wavelength world based on mass as frequency, rest-masses cannot exist. But we think this is a mistake, since matter is related to the Compton wavelength and not the de Broglie wavelength. Again, the de Broglie wavelength is just a mathematical derivative (artifact) of the Compton wavelength.

7 The Compton wavelength plays a central role in quantum mechanics

Even if we personally think quantum mechanics is incomplete because it does not take into account gravity, it is clear that quantum mechanics has been very successful within its domain, which is to describe non-gravitational phenomena in the atomic and subatomic world. The central role of the Compton wavelength in quantum mechanics can be seen by rewriting some of the most famous equations in quantum mechanics to what we will call a deeper, more fundamental level. Let's start with the Schrödinger [40] equation, typically written as:

$$i\hbar\frac{\partial}{\partial t}\psi = \left(\frac{i\hbar^2}{2m}\nabla^2 + V\right)\psi, \tag{37}$$

where V is the energy potential; for example, we can have $V = mc^2$ then we get

$$i\hbar\frac{\partial}{\partial t}\psi = \left(\frac{i\hbar^2}{2m}\nabla^2 + mc^2\right)\psi. \tag{38}$$

Since any kilogram mass can be written as $m = \frac{\hbar}{\bar{\lambda}_c}\frac{1}{c}$, we can rewrite the Schrödinger equation as:

$$i\frac{\partial}{\partial t}\psi = \left(\frac{ic\bar{\lambda}}{2}\nabla^2 + \frac{c}{\bar{\lambda}_c}\right)\psi. \tag{39}$$

This result was shown by Haug [4], but it has been hardly discussed. What is important to notice is that the Planck constant has canceled out. The visible Planck constant in the Schrödinger equation, we will claim, is needed to cancel out the Planck constant embedded in the kilogram mass. Pay also attention to the fact that we now have the reduced Compton frequency $\frac{c}{\bar{\lambda}_c}$ in the Schrödinger equation.

In case we set up the Schrödinger equation for the Hydrogen atom, as usual, we have:

$$i\hbar\frac{\partial}{\partial t}\psi = \left(\frac{i\hbar^2}{2\mu}\nabla^2 + k_e\frac{ee}{r}\right)\psi, \tag{40}$$

where $\mu = \frac{m_e m_{pr}}{m_e + m_{pr}}$, e is the electron charge, $\mathbf{r}$ is the position of the electron relative to the nucleus, and r is the magnitude of the relative position. We can re-write $m_e = \frac{\hbar}{\bar{\lambda}_{c,e}}\frac{1}{c}$ and $m_{pr} = \frac{\hbar}{\bar{\lambda}_{c,pr}}\frac{1}{c}$, further $e = \sqrt{\frac{\hbar}{c}\alpha 10^7}$ and $k_e = c^2 10^{-7}$ so we end up with

$$\begin{aligned}
i\hbar\frac{\partial}{\partial t}\psi &= \left(\frac{i\hbar^2}{2\frac{m_e m_{pr}}{m_e+m_{pr}}}\nabla^2 + c^2 10^{-7}\frac{\sqrt{\frac{\hbar}{c}\alpha 10^7}^2}{r}\right)\psi \\
i\hbar\frac{\partial}{\partial t}\psi &= \left(\frac{i\hbar^2}{2\frac{\frac{\hbar}{\bar{\lambda}_{c,e}}\frac{1}{c}\frac{\hbar}{\bar{\lambda}_{c,pr}}\frac{1}{c}}{\frac{\hbar}{\bar{\lambda}_e}\frac{1}{c}+\frac{\hbar}{\bar{\lambda}_{pr}}\frac{1}{c}}}\nabla^2 + c\frac{\hbar\alpha}{r}\right)\psi \\
i\hbar\frac{\partial}{\partial t}\psi &= \left[\frac{i\frac{\hbar}{c}\left(\frac{1}{\bar{\lambda}_{c,e}}+\frac{1}{\bar{\lambda}_{c,pr}}\right)}{2\frac{1}{\bar{\lambda}_{c,e}}\frac{1}{\bar{\lambda}_{c,pr}}\frac{1}{c^2}}\nabla^2 + c\frac{\hbar\alpha}{r}\right]\psi \\
i\frac{\partial}{\partial t}\psi &= \left[\frac{ic\left(\bar{\lambda}_{c,e}+\bar{\lambda}_{c,pr}\right)}{2}\nabla^2 + \frac{c\alpha}{r}\right]\psi.
\end{aligned} \tag{41}$$

The distance between the electron and the nucleus is the Bohr radius: $a_0 = \frac{4\pi\epsilon_0\hbar^2}{em_e} = \frac{\bar{\lambda}_{c,e}}{\alpha}$; this means that the Schrödinger equation for the Hydrogen atom, from the deepest perspective, is given by:

$$i\frac{\partial}{\partial t}\psi = \left[\frac{ic\left(\bar{\lambda}_{c,e}+\bar{\lambda}_{c,pr}\right)}{2}\nabla^2 + \frac{c}{\bar{\lambda}_{c,e}}\alpha^2\right]\psi. \tag{42}$$

Again, we observe that the Planck constant has disappeared, and the reduced Compton frequency of the electron, $\frac{c}{\bar{\lambda}_{c,e}}$, is embedded in the equation.

We could also try to express the Schrödinger equation through the reduced de Broglie wavelength instead of the reduced Compton wavelength by utilizing that we have $\bar{\lambda}_b = \bar{\lambda}_c\frac{v}{c}$, which would give:

$$\begin{aligned} i\hbar\frac{\partial}{\partial t}\psi &= \left(\frac{i\hbar^2}{2m}\nabla^2 + mc^2\right)\psi \\ i\frac{\partial}{\partial t}\psi &= \left(\frac{ic\bar{\lambda}}{2}\nabla^2 + \frac{c}{\bar{\lambda}_c}\right)\psi \\ i\frac{\partial}{\partial t}\psi &= \left(\frac{ic\bar{\lambda}}{2}\nabla^2 + \frac{c^2}{\bar{\lambda}_b v}\right)\psi. \end{aligned} \tag{43}$$

Now, we suddenly have the velocity v in the formula, and if this is zero, the Schrödinger equation is no longer valid. If it is not zero, what value should we assign to it? It seems that only the Compton wavelength is, in reality, linked to the Schrödinger equation, or at least trying to write it in relation to the de Broglie wavelength makes things unnecessarily complex.

We can see that the Planck constant has been eliminated from the Schrödinger equation when one writes the mass from its Compton wavelength formula. Then, the Planck constant visible in the formula cancels out. This means the Planck constant was needed there in the first place to cancel out the Planck constant embedded in the kilogram mass. We can now see that the quantization in the Schrödinger equation likely comes from the Compton frequency $\frac{c}{\bar{\lambda}}$.

The Dirac equation [41], as given by:

$$\left(\beta mc^2 + c\sum_{n=1}^{3}\alpha_n p_n\right)\psi = i\hbar\frac{\partial}{\partial t}\psi, \tag{44}$$

can also be rewritten, as any kilogram mass can be expressed as $m = \frac{\hbar}{\bar{\lambda}_c}\frac{1}{c}$, this gives

$$\left(\beta\frac{c}{\bar{\lambda}_c} + \frac{c}{\hbar}\sum_{n=1}^{3}\alpha_n p_n\right)\psi = i\frac{\partial}{\partial t}\psi. \tag{45}$$

In the Dirac equation, it still appears that we have a Planck constant left, but this cancels out with the Planck constant embedded in the momentum p_n. This means that the quantization in the Dirac equation is ultimately linked to the Compton frequency $\frac{c}{\bar{\lambda}_c}$, similar to the Schrödinger equation.

The Klein-Gordon equation, a relativistic quantum equation, is normally written as:

$$\frac{1}{c^2}\frac{\partial^2}{\partial t^2}\psi - \nabla^2\psi + \frac{m^2c^2}{\hbar^2} = 0. \tag{46}$$

Since any kilogram mass can be written as $m = \frac{\hbar}{\bar{\lambda}_c}\frac{1}{c}$, we can re-write the Klein-Gordon equation as:

$$\frac{1}{c}\frac{\partial^2}{\partial t^2}\psi - c\nabla^2\psi + \frac{c}{\bar{\lambda}_c} = 0. \tag{47}$$

Again, the Planck constant is eliminated, as the visual Planck constant in the traditional way of writing the equation is actually needed to cancel out the Planck constant embedded in the kilogram mass definition.

8 The Planck constant is linked to a Compton frequency of 1 divided by the reduced Compton frequency of one kilogram

We have already seen how the Planck constant cancels out the Schrödinger equation, the Dirac equation, and the Klein-Gordon equation, so it basically does not seem to play a role in these quantum mechanical equations. We have written in detail about what the Planck constant truly represents, in particular in [42], but also in the book chapter [43].

We have already shown that the Planck constant appears to not play a role in the Schrödinger, Dirac, and Klein-Gordon equations when understood from a deeper perspective. Second, the Compton wavelength and the Compton frequency seem to play a central role. We will soon demonstrate how the Planck constant plays no role in quantum gravity, not even in observed gravitational phenomena where serious and clever researchers have claimed there is a sign of the Planck constant. When we delve into gravity, we will see that the Compton frequency is even more evidently connected to the quantization of gravity, as well as the Planck scale. The Planck scale must not be confused with the Planck constant; the Planck scale is related to the Planck length and Planck time, not the Planck constant.

The Planck constant is also linked to the quantum of energy. In our view, from a deeper perspective, it is the Compton frequency of one, which is the smallest possible observable frequency in an observational time interval of one second divided by the Compton frequency in one kilogram over a second multiplied by c^2, that is: $\hbar = \frac{1}{f_{c,1kg}}c^2 = \frac{1}{\frac{c}{\frac{\hbar}{1kg\times c}}}c^2 = \hbar$. We will discuss this in more detail below.

The reduced Compton frequency of an electron is

$$f_e = \frac{c}{\bar{\lambda}_{c,e}} \approx 7.76 \times 10^{20} \text{ frequency per second.} \tag{48}$$

For one kilogram, the reduced Compton frequency per second must be

$$f_{1kg} = \frac{c}{\bar{\lambda}_{c,1kg}} = \frac{c}{\frac{\hbar}{1kg\times c}} \approx 8.52 \times 10^{50} \text{ frequency per second.} \tag{49}$$

The Compton frequency of the electron relative to the Compton frequency in one kilogram is

$$\frac{f_e}{f_{1kg}} = 9.11 \times 10^{-31}. \tag{50}$$

This is a dimensionless number that is otherwise identical to the kilogram mass of the electron. This is no coincidence. The kilogram is an arbitrary human-selected clump of matter we have called a kilogram; the electron mass in kilograms is relative to this. When we say the mass of the electron is 9.11×10^{-31} kilograms, this is the mass in the form of the fraction of one kilogram. This means the kilogram also, at a deeper level, can be seen as the reduced Compton frequency in the electron divided by the reduced Compton frequency in one kilogram. That is, the kilogram mass of any mass can be seen as a Compton frequency ratio. This ratio is typically independent of the observational time window, but as we will see, it is not always. If we look at the frequency in half a second instead of a second, then both the kilogram frequency is reduced by half, and the electron Compton frequency is reduced by half, so their ratio will still be 9.11×10^{-31}, so the electron mass is independent on observational time-window (as long as the observational time window is $t \gg \frac{\bar{\lambda}_{c,e}}{c}$, which is the Compton time).

The shortest frequency one can observe in any selected time window is one. Observable frequencies come as integers. An interesting question is, therefore, what is the mass of a Compton frequency of one in a one-second time window? It is:

$$m_m = \frac{1}{f_{1kg}} = \frac{1}{\frac{c}{\frac{\hbar}{m_{1kg}c}}} = \frac{1}{\frac{c}{\frac{\hbar}{1 \times c}}} = \frac{\hbar}{c^2} \approx 1.17 \times 10^{-51}. \tag{51}$$

This, we will claim, is the kilogram mass of the smallest possible mass. So, it is basically the mass gap, the smallest possible mass above zero. This mass is in line with the predicted classical and quantum approaches to the photon mass; see Spavieri et al. [44]. Some may protest here, as the frequency ratio should be dimensionless and not give kilograms. The issue is that the kilogram is a kind of arbitrary unit; any mass relative to the kilogram is the mass relative to the one-kilogram mass, so the kilogram is not a real dimension like time or length; it is a ratio. For example, an electron divided by the kilogram mass gives the kilogram mass of the electron, so the kilogram mass is a mass ratio; in other words, it is kind of dimensionless. Well, the kilogram is also an arbitrarily chosen clump of matter (that since 2019 has been directly linked to the Planck constant), but we could just as well have selected the Compton frequency of that arbitrary clump of matter and called it the kilogram, so there is nothing wrong with calling the Compton frequency of a mass divided by the Compton frequency in one kilogram the kilogram.

To get the smallest energy unit in Joule, we simply need to multiply the smallest mass by c^2, so we must have $E = m_m c^2 = \frac{1}{f_{1kg}} c^2 = \hbar \times 1 \approx 1.05 \times 10^{-34}$ Joule. However, we have looked at the smallest mass over the time interval of one second. A frequency of one cannot be smaller than one, so if we cut the time in half, we cannot say the smallest mass is half a Compton frequency divided by the Compton frequency in one kilogram over half a second. The smallest frequency is still one. So, the most essential mass is observational time-dependent. Assume now the shortest possible meaningful time interval is the Planck time, which is assumed by most physicists (but not all). Then, the reduced Compton frequency in one kilogram is:

$$8.52 \times 10^{50} \times t_p \approx 45994327 \text{ frequency per Planck time.}$$

The smallest mass observed in one Planck time is therefore:

$$\frac{f_1}{f_{1kg}} \approx \frac{1}{45994327} \approx 2.17 \times 10^{-8} \text{ kg.}$$

That is, the smallest of all masses is both 1.17×10^{-51} as observed over one second, and it is the Planck mass if observed in the Planck time. We will claim all masses consist of Planck masses coming in and out of existence at the reduced Compton frequency of the mass in question, but that this Planck mass at the end of each Compton periodicity only lasts the Planck time. This means the electron mass is

$$m_e = f_e m_p t_p = \frac{c}{\bar{\lambda}_e} m_p t_p \approx 9.11 \times 10^{-31} \text{ kg}. \tag{52}$$

The reduced Planck constant contains embedded information about how the minimum energy or mass level is related to the reduced Compton frequency of one. However, it says nothing alone about, for example, the duration of this one event. In short, the Planck constant does not have the full information about this one event. The full information is needed in gravity, where the full information is related to the Planck units, such as the Planck length. This is only needed for gravity and is why gravity always contains the Planck scale as well, as we will see in the next section.

9 The Compton frequency in matter is the quantization of gravity

Einstein's [45] field equation is given by:

$$R_{\mu v} - \frac{1}{2} g_{\mu v} R + \Lambda g_{\mu v} = \frac{8\pi G}{c^4} T_{\mu v}. \tag{53}$$

We can replace G with its composite form: $G = \frac{l_p^2 c^3}{\hbar}$ (see [46]), where l_p is the Planck length. This leads to the following equation (see [23, 47, 48]):

$$R_{\mu v} - \frac{1}{2} g_{\mu v} R + \Lambda g_{\mu v} = \frac{8\pi l_p^2}{\hbar c} T_{\mu v}. \tag{54}$$

The Planck units were first described by Max Planck [49] in 1899. Einstein, already in 1916, suggested that the next big step in gravity would be to get a quantum gravity theory. Eddington, in 1918, was the first to claim that the Planck length likely would play an important role in such a quantum gravity theory. It was suggested in 1984 by Cahill [50, 51] that one could express the gravitational constant using Planck units. However, in 1987, Cohen [52] pointed out that this led to a circular argument, as no one had found a way to derive the Planck units without relying on G, $\hbar$, and c. This view was consistently held and repeated in the physics literature until at least 2016 (see the interesting paper by McCulloch [53]). However, in recent years, it has been demonstrated that the Planck units can be determined without any prior knowledge of G or even without knowledge of G, $\hbar$, and c, see [6, 7, 54], and also see to Haug [46] for an overview and discussion of the composite view of G.

It is also important to note that Newton [55] never used or introduced the gravitational constant that has been attributed to his name. The gravitational constant was first introduced in 1873 by Cornu and Baille [56], at about the same time when it was decided to use the kilogram mass definition also for astronomical objects. Maxwell [57] used Newton's original gravity framework without the gravitational constant, even as late as early in 1873. For example, the gravitational acceleration is then simply given by $g = \frac{M_n}{r^2}$, but with a different mass definition than the kilogram definition. See [58] for more details.

Looking at the re-written Einsteins field equation (Eq. 54), it now appears that the Planck constant suddenly plays a role in gravity, and some may find this intriguing. However, the Planck constant is simply necessary to cancel out the Planck constant embedded in the joule energy or kilogram mass within the stress-energy tensor. This becomes clearer when we examine exact solutions of Einstein's field equation.

Tthe Schwarzschild [59] metric is given by:

$$ds^2 = -\left(1-\frac{2GM}{c^2r}\right)c^2dt^2+\left(1-\frac{2GM}{c^2r}\right)^{-1}dr^2+r^2(d\theta^2+\sin^2\theta d\phi^2). \tag{55}$$

However, by replacing G with its composite form $G=\frac{l_p^2c^3}{\hbar}$ and the kilogram mass with its composite form $M=\frac{\hbar}{\bar{\lambda}_{c,M}}\frac{1}{c}$, where $\bar{\lambda}_{c,M}$ is simply the reduced Compton wavelength of the mass M, we obtain:

$$\begin{aligned} ds^2 &= -\left(1-\frac{2\frac{l_p^2c^3}{\hbar}\frac{\hbar}{\bar{\lambda}_{c,M}}\frac{1}{c}}{c^2r}\right)c^2dt^2+\left(1-\frac{2\frac{l_p^2c^3}{\hbar}\frac{\hbar}{\bar{\lambda}_{c,M}}\frac{1}{c}}{c^2r}\right)^{-1}dr^2+r^2(d\theta^2+\sin^2\theta d\phi^2) \\ ds^2 &= -\left(1-\frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}\right)c^2dt^2+\left(1-\frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}\right)^{-1}dr^2+r^2(d\theta^2+\sin^2\theta d\phi^2). \end{aligned} \tag{56}$$

In this metric, there is no Planck constant embedded, but there is the Compton frequency per Planck time, represented by the term $\frac{l_p}{\bar{\lambda}_{c,M}}$. Table 1 provides an overview of a series of formulas often used for gravity predictions, most of which have been well-tested against observations. They are all, at a deeper level, dependent on the Planck length and the Compton wavelength, and some also depend on the speed of light, which is identical to the speed of gravity.

Prediction	**Formula:**
Gravity acceleration	$g=\frac{GM}{r^2}=\frac{c^2l_p}{r^2}\frac{l_p}{\bar{\lambda}_{c,M}}$
Orbital velocity	$v_o=\sqrt{\frac{GM}{r}}=c\sqrt{\frac{l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}}$
Orbital time	$T=\frac{2\pi r}{\sqrt{\frac{GM}{r}}}=\frac{2\pi r}{c\sqrt{\frac{l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}}}$
Velocity ball Newton cradle	$v_{out}=\sqrt{2\frac{GM}{r^2}H}=\frac{c}{r}\sqrt{2Hl_p\frac{l_p}{\bar{\lambda}_{c,M}}}$
Frequency Newton spring	$f=\frac{1}{2\pi R}\sqrt{\frac{GM}{x}}=\frac{c}{2\pi r}\sqrt{\frac{l_p}{x}\frac{l_p}{\bar{\lambda}_{c,M}}}$
Gravitational red shift	$z=\frac{\sqrt{1-\frac{2GM}{r_1c^2}}}{\sqrt{1-\frac{2GM}{r_2c^2}}}-1=\frac{\sqrt{1-\frac{2l_p}{r_1}\frac{l_p}{\bar{\lambda}_{c,M}}}}{\sqrt{1-\frac{2l_p}{r_2}\frac{l_p}{\bar{\lambda}_{c,M}}}}-1$
Time dilation	$T_R=T_f\sqrt{1-\frac{2GM}{rc^2}}=T_f\sqrt{1-\frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}}$
Gravitational deflection	$\theta=\frac{4GM}{c^2R}=4\frac{l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}$
Advance of perihelion	$\sigma=\frac{6\pi GM}{a(1-e^2)c^2}=\frac{6\pi l_p}{a(1-e^2)}\frac{l_p}{\bar{\lambda}_{c,M}}$
Schwarzschild radius	$r_s=\frac{2GM}{c^2}=2l_p\frac{l_p}{\bar{\lambda}_{c,M}}$

Table 1: The table shows a series of gravity predictions given by general relativity theory in their standard formulas, but at the deeper level we see all gravity phenomena are linked to the Planck length and the Compton wavelength of matter. The term $\frac{l_p}{\bar{\lambda}_{c,M}}$ is actually the Compton frequency per Planck time. This gives the quantum frequency in matter related to gravity, but relative to quantum mechanics, the Planck length also plays a central role in gravity.

It is worth noting that the Schwarzschild radius can be rewritten as:

$$r_s = \frac{2GM}{c^2} = 2l_p \frac{l_p}{\bar{\lambda}_{c,M}}. \tag{57}$$

Similarly, the event horizon in a black hole, arising from the extremal solutions of the Reissner-Nordström [60, 61], Kerr [62], and Kerr-Newman [63, 64] metrics, is given by:

$$r_h = \frac{GM}{c^2} = l_p \frac{l_p}{\bar{\lambda}_{c,M}}. \tag{58}$$

This implies that the Schwarzschild radius and the black hole horizon, derived from other solutions of Einstein's field equations, inherently contain quantization in the form of the Compton frequency per Planck time, represented by $f = \frac{c}{\bar{\lambda}} t_p = \frac{l_p}{\bar{\lambda}_{c,M}}$.

Some may argue that quantum quantization cannot be linked to the Compton frequency but must be linked to the Planck constant. In 1975, Colella, Overhauser, and Werner [65] observed what is known as gravitationally induced quantum interference using neutrons. They claimed that this phenomenon was related to both the gravitational acceleration field g and the Planck constant. This observation has been replicated and confirmed, for example, by [66, 67]. In recent years, Abele and Leeb [68] conducted a similar experiment with neutrons and claimed, "*the outcome depends on both the gravitational acceleration g and the Planck constant* $\hbar$". However, it can be easily demonstrated, as we [69] have done recently, that the Planck constant in their equations is actually required to cancel out another Planck constant embedded in the kilogram mass in their formula. Thus, we are left with the conclusion that the prediction of quantum-related gravity phenomena is related to the Compton frequency in matter and the Planck scale (Planck length).

10 The extremal Reissner-Nordström metric and a new perspective on the Planck mass particle and the graviton

The extremal solution of the Reissner-Nordström metrics for charged black holes [60, 61] as well as the new Mass-Charge metric of Haug-Spavieri metric [70] is given by

$$\begin{aligned} ds^2 &= -\left(1 - \frac{2GM}{c^2 r} + \frac{G^2M^2}{c^4 r^2}\right) c^2 dt^2 + \left(1 - \frac{2GM}{c^2 r} + \frac{G^2M^2}{c^4 r^2}\right)^{-1} dr^2 + r^2\Omega^2 \\ ds^2 &= -\left(1 - \frac{GM}{c^2 r}\right)^2 c^2 dt^2 + \left(1 - \frac{GM}{c^2 r}\right)^{-2} dr^2 + r^2\Omega^2. \end{aligned} \tag{59}$$

Assume we have a Planck mass black hole this can in this metric be described as:

$$ds^2 = -\left(1 - \frac{Gm_p}{c^2 r}\right)^2 c^2 dt^2 + \left(1 - \frac{Gm_p}{c^2 r}\right)^{-2} dr^2 + r^2\Omega^2 \tag{60}$$

The event horizon for the extremal solution is $r_h = \frac{GM}{c^2}$ so half the Schwarzschild radius $r_s = \frac{2GM}{c^2}$, so the event horizon of the Planck mass black hole in the extremal solution is $r_h = \frac{Gm_p}{c^2} = l_p$. Important is also that the electromstatic and gravity force perfectly offset each other in a extremal Reissner-Nordstrom black hole, see for example Zee [71]. This means the mass of the extremal black hole do not collapse into a center sigularity like in a Schwarzschild black hole. Also the parralell to the Hawking temperature for a extremal Reissner Nordström black hole has been derived by Sorkin and Piran [72] and also [73]):

$$T_{RN} = \frac{\hbar c\sqrt{r_h^2 - r_Q^2}}{k_b 2\pi r_h^2} \tag{61}$$

Where $r_h = \frac{GM}{c^2} + \sqrt{\frac{G^2M^2}{c^4} - r_Q^2}$. We can see that in the special case of no charge $r_Q = 0$, it corresponds to the Hawking radiation, which is very high for a Planck mass Schwarzschild black hole. However, here we assume we are dealing with an extremal Planck mass black hole, and then $r_Q = r_h = \frac{GM}{c^2}$, and we see that the black hole radiation is zero.

Edery and Constantineau [74] have demonstrated that extremal black holes have zero entropy and, furthermore, that they are time-independent throughout spacetime and even correspond to a single microstate. This seems to contradict what we typically expect in physics: zero entropy and time-independence throughout spacetime—how can this be possible?

We conjecture that the extremal solution for real objects is valid only for the Planck mass particle. Furthermore, we conjecture that the Planck mass particle is a photon-photon collision that lasts for the Planck time. We already know the radius of this extremal black hole is the Planck length. For a photon to travel the Planck length takes the Planck time. So, we will assume the photon-photon collision lasts for the Planck time, and the mass created during this Planck time, existing only for the Planck time, has a radius equal to the Planck length. The only way to observe this extremal micro black hole (photon-photon collision) is to be one of the photons participating in the collision. If one attempts to observe this micro black hole even from a distance of two Planck lengths, it would have already dissolved before a light signal could be sent to detect it, as it only last the Planck time. We conclude with an important observation: one can only observe an extremal micro black hole (the Planck mass particle) directly from its own rest frame.

This also implies that an extremal black hole is always at rest relative to the observer, as it can only be observed from its own reference frame. This is not in conflict with the principle of relativity in general, nor with special relativity, except that we impose a maximum limit on length contraction at the reduced Compton wavelength of elementary particles. Special relativistic length contraction is given by $L = L_r\sqrt{1 - \frac{v^2}{c^2}}$. Here, we are specifically interested in the reduced Compton wavelength of elementary particles and propose that they cannot be observed to contract below the Planck length. This means we must have:

$$l_p \leq \bar{\lambda}_c\sqrt{1 - \frac{v^2}{c^2}} \tag{62}$$

Solved with respect to v this gives

$$v \leq c\sqrt{1 - \frac{l_p^2}{\bar{\lambda}_c^2}} \tag{63}$$

This formula has been presented before by Haug [75] and also during a presentation by Haug at the Royal Institution in London in 2015. For any observed elementary particle, the maximum velocity obtained from this formula is very close to the old speed limit of $v < c$. Moreover, the speed limit given by this new formula, for example, for an electron, is far above the velocities achieved in experiments such as those at the Large Hadron Collider, making it fully consistent with observations so far. However, for elementary particles close to the Planck mass, and particularly for the Planck mass particle, something remarkable occurs. For the Planck mass particle, the maximum velocity is then:

$$v \leq c\sqrt{1 - \frac{l_p^2}{l_p^2}} \leq 0 \tag{64}$$

And since we cannot have negative velocities, this means the Planck mass particle always remains stationary. At first, this might seem absurd, as one might typically think that observing it from a reference frame moving relative to the Planck mass particle would make it appear to move, implying it must have a speed greater than zero. However, this perspective overlooks the key idea we have outlined: the Planck mass particle has a radius equal to the Planck length, and we conjecture that it only lasts for the Planck time. Therefore, it can only be observed from its own reference frame.

This also explains why it is time-independent throughout spacetime, as the relevant space and time are confined to the Planck length and Planck time. The extremal solution of the Reissner-Nordström metric aligns well with this interpretation.

Furthermore, it is important to note that the Schwarzschild metric can be understood as a weak-field approximation of this scenario.

At a deeper perspective, the extremal Reissner-Nordstrom metric can also be rewritten by substituting G with $G = \frac{l_p^2 c^3}{\hbar}$ and M with $M = \frac{\hbar}{\bar{\lambda}_{c,M}} \frac{1}{c}$, resulting in:

$$\begin{aligned} ds^2 &= -\left(1 - \frac{\frac{l_p^2 c^3}{\hbar} \frac{\hbar}{\bar{\lambda}_{c,M}} \frac{1}{c}}{c^2 r}\right)^2 c^2 dt^2 + \left(1 - \frac{\frac{l_p^2 c^3}{\hbar} \frac{\hbar}{\bar{\lambda}_{c,M}} \frac{1}{c}}{c^2 r}\right)^{-2} dr^2 + r^2\Omega^2 \\ ds^2 &= -\left(1 - \frac{l_p}{r} \frac{l_p}{\bar{\lambda}_{c,M}}\right)^2 c^2 dt^2 + \left(1 - \frac{l_p}{r} \frac{l_p}{\bar{\lambda}_{c,M}}\right)^{-2} dr^2 + r^2\Omega^2. \end{aligned} \tag{65}$$

Further the Reissner-Nordström metric can also be expressed as:

$$ds^2 = -\left(1 - \frac{2GM}{c^2 r} + \frac{r_Q^2}{r^2}\right) c^2 dt^2 + \left(1 - \frac{2GM}{c^2 r} + \frac{r_Q^2}{r^2}\right)^{-1} dr^2 + r^2\Omega^2. \tag{66}$$

In the special case of the extremal solution, where $\frac{r_Q^2}{r^2} = k_e \frac{q^2}{r^2} \frac{G}{c^4}$, one has $\frac{r_Q}{r} = k_e \frac{q^2}{r^2} \frac{G}{c^4} = \frac{G^2 M^2}{c^2 r^2}$. This condition holds true only when:

$$\begin{aligned} \frac{r_Q^2}{r^2} &= \frac{GM^2}{r^2} \frac{G}{c^4} \\ &= \frac{\frac{l^2 c^3}{\hbar} \frac{\hbar}{\bar{\lambda}_{c,M}} \frac{1}{c} \frac{\hbar}{\bar{\lambda}_{c,M}} \frac{1}{c}}{r^2} \\ &= c^2 \times 10^{-7} \times \frac{\sqrt{\frac{\hbar}{c} 10^7} \sqrt{\frac{\hbar}{c} 10^7} \frac{l_p^2}{\bar{\lambda}_{c,M}^2}}{r^2} \frac{G}{c^4} \\ &= k_e \frac{q_p \frac{l_p}{\bar{\lambda}_{c,M}} q_p \frac{l_p}{\bar{\lambda}_{M,c}}}{r^2} \frac{G}{c^4}. \end{aligned} \tag{67}$$

Furthermore, it is widely recognized that $k_e \frac{q_p q_p}{r^2} = G \frac{m_p m_p}{r^2} = \frac{\hbar c}{r^2}$, meaning the Coulomb force between two Planck charges equals the Newton gravitational force between two Planck masses, which is equivalent to $\frac{\hbar c}{r^2}$. This implies that electromagnetism and gravity unify at the Planck scale. Additionally, it suggests that gravity consistently operates at the Planck scale, and macroscopic gravitational phenomena are merely manifestations of numerous Planck-scale gravitational events aggregated together. Consequently, the extremal solution can be expressed as:

$$\begin{aligned} ds^2 &= -\left(1 - \frac{2Gn_p m_p}{c^2 r} + k_e \frac{n_p q_p n_p q_p}{r^2} \frac{G}{c^4}\right) c^2 dt^2 \\ &\quad + \left(1 - \frac{2Gn_p m_p}{c^2 r} + k_e \frac{n_p q_p n_p q_p}{r^2} \frac{G}{c^4}\right)^{-1} dr^2 + r^2 \Omega^2. \end{aligned} \tag{68}$$

Where $n_p = \frac{l_p}{\bar{\lambda}_{c,M}}$, which represents the reduced Compton frequency per Planck time in the gravitational mass under consideration. We can further rewrite the metric in the following form:

$$\begin{aligned} ds^2 &= -\left(1 - \frac{2Gn_p m_p}{c^2 r} + \frac{Gn_p m_p n_p m_p}{c^4 r^2}\right) c^2 dt^2 \\ &\quad + \left(1 - \frac{2Gn_p m_p}{c^2 r} + \frac{Gn_p m_p n_p m_p}{c^4 r^2}\right)^{-1} dr^2 + r^2 \Omega^2 \\ ds^2 &= -\left(1 - \frac{Gn_p m_p}{c^2 r}\right)^2 c^2 dt^2 + \left(1 - \frac{Gn_p m_p}{c^2 r}\right)^{-2} dr^2 + r^2 \Omega^2 \end{aligned} \tag{69}$$

This indicates that gravity fundamentally operates at the Planck scale, and that macroscopic gravitational phenomena are essentially observations resulting from a massive aggregation of these Planck scale events. Therefore, understanding gravity at its most fundamental level is crucial, necessitating a comprehension of micro black holes at the Planck mass scale.

This implies that gravity can be viewed as comprising quantized Planck mass events, where $\frac{l_p}{\bar{\lambda}_{c,M}}$ again represents the reduced Compton frequency per Planck time. For a Planck mass, $\frac{l_p}{\bar{\lambda}_{c,M}} = \frac{l_p}{l_p} = 1$, as expected, since the event horizon in the extremal solutions is l_p for a Planck mass black hole.

This suggests that all gravitational masses, which provide a comprehensive description of mass at the Planck scale, can be understood as being composed of micro black holes, or as the most fundamental particles—Planck mass particles—fluctuating into and out of existence at the reduced Compton frequency.

The Schwarzschild metric can also be seen as a weak gravitational field metric approximation of the extremal Reissner-Nordstrom metric.

11 Collision space-time theory

Why is G always multiplied by M in both Newtonian gravity (post-1873) and general relativity theory for predictions of phenomena that can actually be checked with observations? In multiple papers [4, 5, 43, 48], we have suggested that the reason is to transform the incomplete kilogram mass into a complete mass that also includes information about gravity. The more fundamental mass definition is collision-time mass, and this mass is defined as

$$\bar{M} = \frac{G}{c^3}M = t_p\frac{l_p}{\bar{\lambda}_{c,M}}. \tag{70}$$

We do not need to know G or the kilogram mass to determine this mass. This mass can be found directly from gravitational observations. For example, the collision-time mass of the Earth is given by

$$\bar{M} = g\frac{r^2}{c^3}. \tag{71}$$

And energy is simply given as $\bar{E} = \bar{M}c$. Be aware that g can be found by simple experiments without knowing G and M, for example, by simply dropping a ball and measuring the time it took to hit the ground and the high it was dropped from. We have $g = \frac{2H}{T_d^2}$, where H is the height of the drop and T_d is the time it took for the ball from the drop to the moment it hit the ground.

At first glance, $\bar{E} = \bar{M}c$ may appear inconsistent with Einstein's $E = Mc^2$, but this is not the case; it is fully consistent with Einstein's formula. The reason for the difference in our energy-mass relation is that energy is associated with collision length, and collision length is equal to joule energy by the formula $\bar{E} = \frac{G}{c^4}E$. This means $E = \bar{E}\frac{c^4}{G}$ and $M = \bar{M}\frac{G}{c^3}$, so we have

$$\begin{aligned} E &= Mc^2 \\ \bar{E}\frac{c^4}{G} &= \frac{c^3}{G}\bar{M}c^2 \\ \bar{E} &= \bar{M}c. \end{aligned} \tag{72}$$

If we try to formulate an Einstein-inspired gravitational field equation rooted in this mass and energy definition, we get (see Haug [76])

$$R_{\mu v} - \frac{1}{2}g_{\mu v}R + \Lambda g_{\mu v} = 8\pi E_{\mu v}, \tag{73}$$

where $E_{\mu v}$ is now an energy-stress tensor linked to collision-time mass and collision-length energy and not to the kilogram mass and joules. This field equation then gives all the same predictions as general relativity theory, but it does not need any information about the kilogram mass of the object nor the gravitational constant G. This should not be confused with just using a unit system setting $G = c = 1$. This is not what we have done, which is clear if we solve the field equation for a static spherical object; this gives

$$\begin{aligned} ds^2 &= -\left(1 - \frac{2\bar{E}}{r}\right)c^2dt^2 + \left(1 - \frac{2\bar{E}}{r}\right)^{-1}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) \\ ds^2 &= -\left(1 - \frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}\right)c^2dt^2 + \left(1 - \frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}\right)^{-1}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2). \end{aligned} \tag{74}$$

This is identical to the Schwarzschild metric we got from general relativity theory when looked at from a deeper perspective. We also get the following metric from our field equation (corresponding and predicting exactly the same as the extremal solution of the Reissner-Nordstöm, Kerr and Kerr-Newman metric when understood from a deeper perspective:

$$\begin{aligned} ds^2 &= -\left(1-\frac{2\bar{E}}{r}+\frac{\bar{E}^2}{r^2}\right)c^2dt^2+\left(1-\frac{2\bar{E}}{r}+\frac{\bar{E}^2}{r^2}\right)^{-1}dr^2+r^2d\Omega^2 \\ ds^2 &= -\left(1-\frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}+\frac{l_p^2}{r^2}\frac{l_p^2}{\bar{\lambda}_{c,M}^2}\right)c^2dt^2+\left(1-\frac{2l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}+\frac{l_p^2}{r^2}\frac{l_p^2}{\bar{\lambda}_{c,M}^2}\right)^{-1}dr^2+r^2d\Omega^2 \\ ds^2 &= -\left(1-\frac{l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}\right)^2c^2dt^2+\left(1-\frac{l_p}{r}\frac{l_p}{\bar{\lambda}_{c,M}}\right)^{-2}dr^2+r^2d\Omega^2. \end{aligned} \tag{75}$$

The extremal solution of the Reissner-Nordstöm metric as well as the Haug-Spavieri metric will give exactly the same as the last line in the equation above, but after we replace G with $G=\frac{l_p^2c^3}{\hbar}$ and M with $M=\frac{\hbar}{\bar{\lambda}_{c,M}}\frac{1}{c}$, however the Planck constant cancels out in the GM terms so it will not appear when gravity truly is expressed in quantum form related to the Planck scale as done here.

However, we must admit we think a 4-D space-time formalism is likely not the final answer, but a 6D formalism with three-time and three-space dimensions that are essentially two sides of the same coin. This is briefly discussed in [5], but it is outside the scope of this paper. Initially, we thought this 6-D formalism might yield considerably different predictions than Einstein's field equation, but it basically gives the same predictions for spherical objects as the extremal solution of Einstein's field equation. This is something we will have to address in future papers.

12 Unification of gravity and quantum mechanics, absolute rest is the missing point in standard quantum mechanics

In the previous section, we demonstrated that all gravitational formulas depend on the rest-mass reduced Compton wavelength $\bar{\lambda}_c=\frac{\hbar}{mc}$, as well as the Planck length (or Planck time), and $\frac{l_p}{\bar{\lambda}_c}$ which is the reduced Compton frequency per Planck time. This indicates, in our view, that gravity at the quantum level is related to rest and we will even claim to absolute rest. Absolute rest is easy to dismiss before one thinks very carefully about it. If something were at absolute rest in one frame, would it not, for sure, be observed as not at rest from another frame of reference, as motion is relative? First of all, the speed of light is always c as observed from any frame of reference, so the speed of light is absolute, so to speak. Would it then be so remarkable if one also had absolute rest? Haug [77] has discussed this to some extent, but we will go beyond that here. If gravity is Planck mass particles coming in and out of existence, the Planck mass particle only has a radius of the Planck length. So one must indirectly be part of the Planck mass particle to observe it. If the Planck mass particle is the very collision point between two indivisible photon particles that stand still relative to each other for the Planck time during collision, then one must be part of this rest-frame to observe them. Gravity is an indirect way to observe such Planck mass events that in our view are photon-photon collisions. As we have seen from the sections above, gravity is simply the sum of such events over the Planck time.

But then, does the Heisenberg uncertainty principle not tell us that standing absolutely still at the quantum level is impossible? Before rejecting our view of absolute rest as what could be lacking in quantum mechanics for unification with gravity, let us closely look at Heisenberg's uncertainty principle again when we relate it to the de Broglie wavelength, which is the assumed matter wavelength. We have discussed at length why the de Broglie wavelength likely only is a mathematical derivative of the Compton wavelength. We always have $\lambda_b = \frac{c}{v}\lambda_c$, where λ_b is the de Broglie wavelength and λ_c is the Compton wavelength. First of all, we see that the de Broglie wavelength approaches infinity as we approach rest. This alone is absurd. Second, the de Broglie wavelength is not even mathematically defined for a rest-mass particle as this would mean division by zero. This can also be seen from the standard de Broglie formula $\lambda_b = \frac{h}{mv\gamma}$. However, this is brushed under the carpet by proponents of non-modified standard quantum mechanics as not relevant, as the Heisenberg uncertainty principle says we cannot have $v = 0$ according to Heisenberg uncertainty principle. And they are right in some sense as this is what the Heisenberg uncertainty principle tells us. We do not disagree on that the Heisenberg uncertainty principle not is consistent with absolute rest. However we will soon see when a similar certanity-uncertainty principle is rooted in the Compton wavelength it allow rest.

In standard quantum mechanics, one does not allow anything to stand absolutely still; this can be seen from Heisenberg's uncertainty principle:

$$\Delta p \Delta x \geq \hbar \tag{76}$$

For this to be true, the momentum must be greater than zero, $\Delta p > 0$. In classical mechanics, momentum is given by $p = mv$. If we were certain that $v = 0$, there would be no uncertainty in Δv and no uncertainty in the momentum for a given mass m.

To incorporate gravity, we claim we must take into account absolute rest, that is $v = 0$ which is not really consistent with the Heisenberg uncertainty principle. We could naturally claim $v \approx 0$ is consistent with it as we then leave some room for uncertainty in v. To incorporate gravity in quantum mechanics implies under our new hypothesis that the Heisenberg uncertainty principle, needs to be modified. We will first start with re-writing it as:

$$\begin{aligned} mv\gamma x &\geq \hbar \\ mv\gamma \bar{\lambda}_b &\geq \hbar \end{aligned} \tag{77}$$

So far, we have merely substituted x with the de Broglie wavelength of the particle m in Heisenberg's uncertainty principle. We have also omitted to write Δx, using only x instead and the momentum $mv\gamma$ rather than Δp. Equation (77) cannot hold true when $v = 0$ so we must have $v > 0$ for this equation to be true.

Within a Planck time window, we assert that the uncertainty in where the particle can be observed, assuming the de Broglie wavelength is the matter wavelength, equals the de Broglie wavelength. Next, we will further revise this uncertainty principle taking advantage that the Compton wavelength is equal to the de Broglie wavelength based on the formula $\bar{\lambda}_b = \bar{\lambda}\frac{c}{v}$, yielding:

$$\begin{aligned} mv\gamma \bar{\lambda}_b &\geq \hbar \\ mv\gamma \bar{\lambda}_c \frac{c}{v} &\geq \hbar \\ mc\gamma \bar{\lambda}_c &\geq \hbar \end{aligned} \tag{78}$$

This means that the standard momentum $p = mv\gamma$ is substituted with what we previously termed the total Compton momentum $p_t = mc\gamma$, and the distance x is now diminished by the Compton wavelength. Since the mass m can be expressed as $m = \frac{\hbar}{\bar{\lambda}}\frac{1}{c}$, we must have:

$$
\begin{aligned}
mc\gamma\bar{\lambda}_c &\geq \hbar \\
\frac{\hbar}{\bar{\lambda}_c}\frac{1}{c}c\gamma\bar{\lambda}_c &\geq \hbar \\
\gamma &\geq 1 \\
\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} &\geq 1
\end{aligned} \tag{79}
$$

We see that the two sides are equal only when $v = 0$, which is the case for rest mass, or we can even say absolute rest, for $\Delta v > 0$ (and $v \geq 0$) then we must have $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} > 1$. However, this is not the case for the uncertainty principle if we assume the de Broglie wavelength is the true matter wavelength. Then we must have:

$$
\begin{aligned}
p\bar{\lambda}_b &> \hbar \\
mv\gamma\bar{\lambda}_b &> \hbar \\
\frac{\hbar}{\bar{\lambda}_c}\frac{1}{c}v\gamma\bar{\lambda}_b &> \hbar \\
\frac{\bar{\lambda}_b\gamma}{\bar{\lambda}_c}\frac{v}{c} &> 1 \\
\frac{\bar{\lambda}_b}{\bar{\lambda}_c\sqrt{1-\frac{v^2}{c^2}}}\frac{v}{c} &> 1
\end{aligned} \tag{80}
$$

As the de Broglie wavelength is not defined for $v = 0$, we cannot have $v = 0$ now, which is essentially what the standard Heisenberg uncertainty principle indirectly tells us. Furthermore, it is evident that we have:

$$
\begin{aligned}
mc\gamma\bar{\lambda}_c &= mc\gamma\bar{\lambda}_c \\
mc\gamma\bar{\lambda}_c &= mv\gamma\bar{\lambda}_c\frac{c}{v} \\
mc\gamma\bar{\lambda}_c &= mv\gamma\bar{\lambda}_b
\end{aligned} \tag{81}
$$

However, the last two lines are only applicable for the domain $0 < v < c$. This clarifies that if one mistakenly assumes the de Broglie wavelength is the true matter wavelength, then one is unable to examine the special case when $v = 0$ in quantum mechanics. Furthermore, since gravity is associated with absolute rest for the ultimate particle that, in our view, comprises all other particles, namely the Planck mass particle, which exists and remains at absolute rest, as it can only be directly observed from its own reference frame due to its Planck length radius and dissolves within the Planck time.

The Compton wavelength is valid in the domain $0 \leq v < c$, while the de Broglie wavelength is only valid in the domain $0 < v < c$. Heisenberg [78] explicitly stated that he based his uncertainty principle on the de Broglie wavelength as the true matter wavelength. This implies that the Heisenberg uncertainty principle cannot be valid for $v = 0$.

To incorporate gravity into our new Certainty-Uncertainty principle, we have to multiply the kilogram mass by $\frac{G}{c^3}$ or $\frac{l_p^2}{\hbar}$, which is the same thing. Then we get:

$$\begin{aligned} \frac{G}{c^3} m c \gamma \bar{\lambda}_c &\geq \hbar \frac{G}{c^3} \\ \bar{m} c \gamma \bar{\lambda}_c &\geq l_p^2 \end{aligned} \tag{82}$$

where $\bar{m} = t_p \frac{l_p}{\bar{\lambda}_c}$, where $\frac{l_p}{\bar{\lambda}_c}$ is the reduced Compton frequency per Planck time and t_p is the Planck time. This is what we have called collision-time mass (see section 11) and it describe how many internal photon-photon collisions in the mass of interest over the Planck time and where each collision last the Planck time.

The particle of interest for gravity is the Planck mass particle, which is a collision between two building blocks of photons lasting for the Planck time. It only exists for $v = 0$, and it has a reduced Compton wavelength equal to the Planck length. This means we always have:

$$\bar{m}_p c \gamma l_p = l_p^2 \tag{83}$$

And this holds true as: $\bar{m}_p = t_p \frac{l_p}{\bar{\lambda}} = t_p \frac{l_p}{l_p} = t_p$, which means we have:

$$\begin{aligned} t_p c \gamma l_p &= l_p^2 \\ \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} &= 1 \end{aligned} \tag{84}$$

And since we always for the Planck mass particle have $v = 0$ (as it is a collision between photons) and its maximum velocity is given by equation (64), this holds true. We could have found this just as well by using kilograms and joules; however, then gravity is not really incorporated. Still, let us look at it without incorporating gravity. Then we have:

$$\begin{aligned} m_p c \gamma \bar{\lambda}_c &= \hbar \\ \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} &= 1 \end{aligned} \tag{85}$$

Which is the same as before and can only be valid when $v = 0$, which is the maximum velocity of a Planck mass particle.

We must conclude this section by stating that the view suggesting that the de Broglie wavelength is the 'matter wavelength,' while in reality, it is likely the Compton wavelength, has led to an incomplete uncertainty principle. When derived from the assumption that the Compton wavelength is the true matter wavelength, one obtains a Certainty-Uncertainty principle that is consistent with quantum gravity.

13 Conclusion

We have demonstrated that the Compton wavelength plays a very central role in foundational physics when understood from a deeper perspective. The Compton wavelength of matter is identical to the photon wavelength of the rest-mass energy of the mass. This is not the case for the de Broglie wavelength. The de Broglie wavelength is strictly not even mathematically defined for a rest-mass particle, as it would lead to division by zero. When assuming the rest-mass particle is almost stationary, the de Broglie wavelength of the rest-mass particle approaches infinity, and the photon wavelength corresponding to the rest-mass energy is approaching zero, namely, the de Broglie wavelength multiplied by $\frac{v}{c}$, with v approaching zero.

There seems to be no need for both a Compton wavelength and a de Broglie wavelength of matter. We suggest that the Compton wavelength is the real matter wavelength, and that the de Broglie wavelength is, in reality, a mathematical derivative of this. One can choose whether to predict and analyze particle waves as Compton wavelength or de Broglie wavelength, but the de Broglie wavelength, since it is only a mathematical derivative of the real matter wavelength, will lead to a series of problematic or, we could say, strange interpretations, while the Compton wavelength always has a length we could expect for the atomic and subatomic scale.

Furthermore, when viewed from a deeper perspective, we can quantize Newton's and general relativity theories. This quantization reveals that the Compton frequency is fundamental in the context of gravity. Additionally, in quantum mechanics, when we examine the Schrödinger, Dirac, and Klein-Gordon equations more profoundly, they appear to be interconnected with the Compton frequency in matter, and surprisingly, the Planck constant cancels out. This cancellation of the Planck constant occurs both in gravitational predictions related to observed phenomena and in quantum mechanics. There is also no longer a need for the gravitational constant. This even has practical implications, as it can be demonstrated that relying on the gravitational constant in gravitational predictions results in unnecessarily large prediction errors, as already discovered, for example, by the US defense [79, 80]. Furthermore, the Heisenberg Uncertainty Principle, when considering that the real wavelength of matter is the Compton wavelength, can be extended into a Certainty-Uncertainty Principle. This principle describes the certainty associated with the Planck mass particle, which is the ultimate building block of matter and the cause of gravity.

Acknowledgment

I would like to thank Ying Liu, Clara Rojas, Mykola Maksyuta, Shidong Liang, James Boweryn, and Eric Bittner for useful comments on a earlier version of this paper.

References

[1] A. H. Compton. A quantum theory of the scattering of x-rays by light elements. *Physical Review*, 21(5):483, 1923. URL https://doi.org/10.1103/PhysRev.21.483.

[2] E. G. Haug. Derivation of a relativistic Compton wave. *European Journal of Applied Physics*, 4:24, 2022. URL http://dx.doi.org/10.24018/ejphysics.2022.4.4.190.

[3] A. Einstein. On the electrodynamics of moving bodies. *Annalen der Physik, English translation by George Barker Jeffery 1923*, 322(10):891, 1905. URL https://doi.org/10.1002/andp.19053221004.

[4] E. G. Haug. Collision space-time: Unified quantum gravity. *Physics Essays*, 33(1):46, 2020. URL https://doi.org/10.4006/0836-1398-33.1.46.

[5] E. G. Haug. Unified quantum gravity field equation describing the universe from the smallest to the cosmological scales. *Physics Essays*, 35:61, 2022. URL https://doi.org/10.4006/0836-1398-35.1.61.

[6] E. G. Haug. Finding the Planck length multiplied by the speed of light without any knowledge of G, c, or h, using a Newton force spring. *Journal Physics Communication*, 4:075001, 2020. URL https://doi.org/10.1088/2399-6528/ab9dd7.

[7] E. G. Haug. Demonstration that Newtonian gravity moves at the speed of light and not instantaneously (infinite speed) as thought! *Journal of Physics Communication.*, 5(2):1, 2021. URL https://doi.org/10.1088/2399-6528/abe4c8.

[8] J.R. Rydberg. On the structure of the line-spectra of the chemical elements. *Philosophical Magazine*, 29:331, 1890.

[9] E. G. Haug. The two relativistic Rydberg formulas of Suto and Haug: Further comments. *Journal of Modern Physics*, 11:1938, 2020. URL https://doi.org/10.4236/jmp.2020.114035.

[10] A. Thorman et al. . Visible spectroscopy of highly charged tungsten ions with the jet charge exchange diagnostic. *Physica Scripta*, 96(12):125631, 2021. URL https://doi.org/10.1088/1402-4896/ac387b.

[11] C. Swee and et al. Impurity transport study based on measurement of visible wavelength high-n charge exchange transitions at W7-X. *Nuclear Fusion*, 64:086062, 2024. URL https://doi.org/10.1088/1741-4326/ad5aad.

[12] C. Swee and et al. High-n Rydberg transition spectroscopy for heavy impurity transport studies in W7-X (invited). *Review of Scientific Instruments*, 95:093539, 2024. URL https://doi.org/10.1063/5.0219589.

[13] K. Suto. The physical constant called the Rydberg constant does not exist. *Journal of Applied Mathematics and Physics*, 11(9):2621, 2023. URL https://doi.org/10.4236/jamp.2023.119171.

[14] J. S. Walker. *Physics, Fourth Edition*. Addison-Wesley, 2010.

[15] P. A. Tipler and G. Mosaca. *Physics for Scientists and Engineers, fifth edition*. W. H. Freeman and Company, New York, 2004.

[16] A. H. Compton. The scattering of x-rays. *Advancement of Science*, 198:1183, 1923.

[17] G. Gräff, H. Kalinowsky, and J. Traut. A direct determination of the proton electron mass ratio. *Zeitschrift für Physik A Atoms and Nuclei*, 297(1):35, 1980. URL https://link.springer.com/article/10.1007/BF01414243.

[18] R.S. Van-Dyck, F.L. Moore, D.L. Farnham, and P.B. Schwinberg. New measurement of the proton-electron mass ratio. *International Journal of Mass Spectrometry and Ion Processes*, 66(3):253, 1985. URL https://doi.org/10.1016/0168-1176(85)80006-9.

[19] P. Becker and H. Bettin. The Avogadro constant: determining the number of atoms in a single-crystal ^{28}Si sphere. *Phil. Trans. R. Soc. A*, 369:3925, 2011. URL https://doi:10.1098/rsta.2011.0222.

[20] P. Becker. The new kilogram definition based on counting the atoms in a ^{28}Si crystal. *Contemporary Physics*, 53:461, 2012. URL https://doi.org/10.1080/00107514.2012.746054.

[21] O. Wang, Z. W. and. Toikkanen, F. Yin, Z.Y. Li, B. M Quinn, and R. E. Palmer. Counting the atoms in supported, monolayer-protected gold clusters. *J. Am. Chem. Soc.*, 132:2854, 2010. URL https://pubs.acs.org/doi/pdf/10.1021/ja909598g.

[22] E. G. Haug. Extraction of the planck length from cosmological redshift without knowledge off G or $\hbar$. *International Journal of Quantum Foundation, supplement series Quantum Speculations*, 4(2), 2022. URL https://ijqf.org/archives/6599.

[23] E. G. Haug. CMB, hawking, Planck, and Hubble scale relations consistent with recent quantization of general relativity theory. *International Journal of Theoretical Physics*, 63(57), 2024. URL https://doi.org/10.1007/s10773-024-05570-6.

[24] L. de. Broglie. Recherches sur la théorie des quanta. *PhD Thesis (Paris)*, 1924.

[25] L. de. Broglie. *An introduction to the Study of Wave Mechanics.* Metheum & Co., Essex, 1930.

[26] C. Davisson and L. H. Germer. Diffraction of electrons by a crystal of nickel. *Physical Review*, 30(705):705, 1927. URL https://doi.org/10.1103/PhysRev.30.705.

[27] L.S. Levitt. The proton Compton wavelength as the 'quantum' of length. *Experientia*, 14: 233, 1958. URL https://doi.org/10.1007/BF02159173.

[28] O. L. Trinhammer and H. G. Bohr. On proton charge radius definition. *EPL*, 128:21001, 2019. URL https://doi.org/10.1209/0295-5075/128/21001.

[29] A. I. Lvovsky. *Quantum Physics: An Introduction Based on Photons.* Springer, 2018.

[30] H. Chauhan, S. Rawal, and R. K. Sinha. Wave-particle duality revitalized: Consequences, applications and relativistic quantum mechanics. *https://arxiv.org/pdf/1110.4263.pdf*, 2011.

[31] D. Shanahan. Reverse engineering" the de Broglie wave. *International Journal of Quantum Foundation, supplement series Quantum Speculations*, 9:44, 2023. URL https://ijqf.org/wp-content/uploads/2023/01/IJQF2022v9n1p2.pdf.

[32] Max Born. *The Restless Universe.* Harper & Brothers, New York, 1936.

[33] W. Heisenberg. Über den anschaulichen inhalt der quantentheoretischen kinematik und mechanik. *Zeitschrift für Physik*, (43):172–198, 1927. URL https://doi.org/10.1007/BF01397280.

[34] E. H.. Kennard. Zur quantenmechanik einfacher bewegungstypen. *Zeitschrift für Physik*, (44):326–352, 1927.

[35] C. Deppner and et. al. Collective-mode enhanced matter-wave optics. *Physical Review Letters*, 127:100401, 2021. URL https://doi.org/10.1103/PhysRevLett.127.100401.

[36] S. Lan, P. Kuan, B. Estey, D. English, J. M. Brown, M. A. Hohensee, and Müller. A clock directly linking time to a particle's mass. *Science*, 339:554, 2013. URL https://doi.org/10.1126/science.1230767.

[37] D. Dolce and A. Perali. On the Compton clock and the undulatory nature of particle mass in graphene systems. *The European Physical Journal Plus*, 130(41):41, 2015. URL https://doi.org/10.1140/epjp/i2015-15041-5.

[38] E. Schrödinger. Über die kräftefreie bewegung in der relativistischen quantenmechanik. *Sitzungsberichte der Preußischen Akademie der Wissenschaften. Physikalisch-mathematische Klasse*, 1930.

[39] I. U. Santos. The zitterbewegung electron puzzle. *Physics Essays*, 36:299, 2023.

[40] E. Schrödinger. An undulatory theory of the mechanics of atoms and molecules. *Physical Review*, 28(6):104–1070, 1926. URL https://doi.org/10.1103/PhysRev.28.1049.

[41] P. Dirac. On the theory of quantum mechanics. *Proc. Roy. Soc. A London*, (112):661, 1926. URL https://doi.org/10.1098/rspa.1926.0133.

[42] E. G. Haug. The Planck constant and its relation to the Compton frequency. *Journal of Applied Mathematics and Physics*, 12:168, 2024. URL https://doi.org/10.4236/jamp.2024.121013.

[43] E. G. Haug. *Quantum Gravity Hidden In Newton Gravity And How To Unify It With Quantum Mechanics*. in the book: The Origin of Gravity from the First Principles, Editor Volodymyr Krasnoholovets, NOVA Publishing, New York, page 133-216, 2021.

[44] G. Spavieri, J. Quintero, G.T. Gilles, and Rodriguez M. A survey of existing and proposed classical and quantum approaches to the photon mass. *The European Physical Journal D*, 61: 1, 2011. URL https://doi.org/10.1140/epjd/e2011-10508-7.

[45] A. Einstein. Näherungsweise integration der feldgleichungen der gravitation. *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften Berlin*, 1916.

[46] E. G. Haug. Progress in the composite view of the Newton gravitational constant and its link to the Planck scale. *Universe*, 8(454), 2022. URL https://doi.org/10.3390/universe8090454.

[47] E. G. Haug. Planck quantization of Newton and Einstein gravitation. *International Journal of Astronomy and Astrophysics*, 6(2):206, 2016. URL https://doi.org/10.4236/ijaa.2016.62017.

[48] E. G. Haug. Different mass definitions and their pluses and minuses related to gravity. *Foundations*, 3:199–219., 2023. URL https://doi.org/10.3390/foundations3020017.

[49] M. Planck. *Natuerliche Masseinheiten*. Der Königlich Preussischen Akademie Der Wissenschaften: Berlin, Germany, 1899. URL https://www.biodiversitylibrary.org/item/93034#page/7/mode/1up.

[50] K. Cahill. The gravitational constant. *Lettere al Nuovo Cimento*, 39:181, 1984. URL https://doi.org/10.1007/BF02790586.

[51] K. Cahill. Tetrads, broken symmetries, and the gravitational constant. *Zeitschrift Für Physik C Particles and Fields*, 23:353, 1984. URL https://doi:10.1007/bf01572659.

[52] E. R. Cohen. *Fundamental Physical Constants, in the book Gravitational Measurements, Fundamental Metrology and Constants.* Edited by Sabbata, and Melniko, V. N., Netherland, Amsterdam, Kluwer Academic Publishers, 1987.

[53] M. E. McCulloch. Quantised inertia from relativity and the uncertainty principle. *Europhysics Letters (EPL)*, 115(6):69001, 2016. URL https://doi.org/10.1209/0295-5075/115/69001.

[54] E. G. Haug. Planck units measured totally independently of big G. *Open Journal of Microphysics*, 12:55, 2022. URL https://doi.org/10.4236/ojm.2022.122004.

[55] I Newton. *Philosophiae Naturalis Principia Mathematica.* London, UK, Jussu Societatis Regiae ac Typis Josephi Streater, 1686.

[56] A. Cornu and J. B. Baille. Détermination nouvelle de la constante de l'attraction et de la densité moyenne de la terre. *C. R. Acad. Sci. Paris*, 76, 1873.

[57] C. Maxwell. *A Treatise on Electricity and Magnetism.* Macmillan and Co., Oxford, UK, 1873.

[58] E. G. Haug. Newton did not invent or use the so-called Newton's gravitational constant; G, it has mainly caused confusion. *Journal of Modern Physics*, 13:179, 2022. URL https://doi.org/10.4236/jmp.2022.132014.

[59] K. Schwarzschild. über das gravitationsfeld einer kugel aus inkompressibler flussigkeit nach der einsteinschen theorie. *Sitzungsberichte der Deutschen Akademie der Wissenschaften zu Berlin, Klasse fur Mathematik, Physik, und Technik*, page 424, 1916.

[60] H. Reissner. Über die eigengravitation des elektrischen feldes nach der einsteinschen theorie. *Annalen der Physics*, 355:106, 1916. URL https://doi.org/10.1002/andp.19163550905.

[61] G. Nordström. On the energy of the gravitation field in Rinstein's theory. *Koninklijke Nederlandsche Akademie van Wetenschappen Proceedings*, 20:1238, 1918.

[62] R. P. Kerr. Gravitational field of a spinning mass as an example of algebraically special metrics. *Physical Review Letters*, 11:237, 1963. URL https://doi.org/10.1103/PhysRevLett.11.237.

[63] E. T. Newman and A. I. Janis. Note on the Kerr spinning-particle metric. *Journal of Mathematical Physics*, 6:915, 1965. URL https://doi.org/10.1063/1.1704350.

[64] E. Newman, E. Couch, K. Chinnapared, A.; Exton, A. Prakash, and R. Torrence. Metric of a rotating, charged mass. *Journal of Mathematical Physics*, 6:918, 1965. URL https://doi.org/10.1063/1.1704351.

[65] R. Colella, A. W. Overhauser, and S. A. Werner. Observation of gravitationally induced quantum interference. *Physical Review Letters*, 34:1472, 1975. URL https://doi.org/10.1103/PhysRevLett.34.1472.

[66] J. L. Staudenmann, S. A. Werner, R. Colella, and A. W. Overhauser. Gravity and inertia in quantum mechanics. *Phys. Rev. A*, 21:1419, 1980. URL https://link.aps.org/doi/10.1103/PhysRevA.21.1419.

[67] S.A. Werner, H. Kaiser, M. Arif, and R. Clothier. Neutron interference induced by gravity: New results and interpretations. *Physica B+C*, 151:22, 1988. URL https://doi.org/10.1016/0378-4363(88)90141-6.

[68] H. Abele and H. Leeb. Gravitation and quantum interference experiments with neutrons. *New Journal of Physics*, 14:055010, 2012. URL https://doi.org/10.1088/1367-2630/14/5/055010.

[69] E. G. Haug. Quantized Newton and general relativity theory. *Qeios*, 2023. URL https://orcid.org/0000-0001-5712-6091.

[70] E. G. Haug and G. Spavieri. Mass-charge metric in curved spacetime. *International Journal of Theoretical Physics*, 62:248, 2023. URL https://doi.org/10.1007/s10773-023-05503-9.

[71] A. Zee. *Einstein gravity in a nutshell*. Princeton University Press, Princeton, NJ, 2013.

[72] E. Sorkin and T. Piran. Formation and evaporation of charged black holes. *Physical Review D*, 63:124024, 2001. URL https://doi.org/10.1103/PhysRevD.63.124024.

[73] E. G. Haug and G. Spavieri. The micro black hole cellular battery: The ultimate limits of battery energy density. *Journal of High Energy Density Physics*, 51:1, 2024. URL https://doi.org/10.1016/j.hedp.2024.101099.

[74] A. Edery and B. Constantineau. Extremal black holes, gravitational entropy and nonstationary metric fields. *Classical and Quantum Gravity, Volume 28, Number 4*, 28:045003, 2011. URL https://doi.org/10.1088/0264-9381/28/4/045003.

[75] E. G. Haug. The ultimate limits of the relativistic rocket equation. the planck photon rocket. *Acta Astronautica*, 136, 2017. URL https://doi.org/10.1016/j.actaastro.2017.03.011.

[76] E. G. Haug. Quantum gravitational energy simplifies gravitational physics and gives a new Einstein inspired quantum field equation without G. *Journal of High Energy Physics, Gravitation and Cosmology*, 9:626, 2023. URL https://doi.org/10.4236/jhepgc.2023.93052.

[77] E. G. Haug. Planck speed: the missing speed of physics? absolute still without breaking Lorentz symmetry! *European Journal of Applied Physics*, 4(1):15, 2022. URL https://www.ej-physics.org/index.php/ejphysics/article/view/144.

[78] W. Heisenberg. *The Physical Principles of Quantum Theory*. Translated by Carl Eckart and F. C. Hoyt, Dover Publications, University of Chicago, 1930.

[79] E. G. Haug. Not relying on the Newton gravitational constant gives more accurate gravitational predictions. *Journal of Applied Mathematics and Physics*, 11:3124, 2023. URL https://doi.org/10.4236/jamp.2023.1110205.

[80] NIMA. *Department of Defence World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems, technical report, third version*. The National Imagery and Mapping Agency (NIMA), 2000.