# Photon mass and ECE Theory.

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## Abstract

The 1924 de Broglie Einstein equations for photon mass are derived from Cartan geometry within the context of ECE theory. The latter produces the 1934 Proca wave equation straightforwardly, the main counter example to the obsolete twentieth century physics because it is not gauge invariant and signals the existence of finite photon mass, a counter example to the Higgs boson. The cosmological red shift is derived straightforwardly from the de Broglie Einstein equations as an implication of photon mass without an expanding cosmology. The photon mass is derived for the first time using light deflection by gravitation calculated with a Planck distribution for one photon, giving a consistent result. Compton scattering theory is worked out with finite photon mass, giving another method of measuring the mass.

*Keywords*: ECE theory, photon mass, Proca equation, cosmological red shift, Compton effect.

# 1. Introduction.

The de Broglie Einstein equations of 1923 and 1924 [1, 2] used the concept of photon mass to lock together the Planck theory of the photon as quantum of energy and the theory of special relativity. Louis de Broglie quantized the photon momentum, producing wave particle dualism. His papers of 1923 and 1924 led directly to the inference of the Schroedinger equation. Recently, in UFT 150B and UFT 155, photon mass has been shown to be responsible for light deflection and time change due to gravitation, the obsolete methods of calculating these were shown to be incorrect. This is an example of a pattern in which ECE theory has made the old physics entirely obsolete [3-12]. In this paper it is emphasized that finite photon mass is the main counter example to the standard model of physics, so called. This standard model was based to a large extent on the arbitrary and experimentally false assumption that the mass of the photon is identically zero. Unsurprisingly, this idea produces many well known problems, notably in canonical quantization of the electromagnetic field [13] and in gauge theory [14]. It is well known that the 1934 Proca equation [15] for finite photon mass is not gauge invariant, meaning that the use of a U(1) sector symmetry and Higgs mechanism is incompatible with finite photon mass. It follows that standard electroweak theory and standard attempts at a unified field theory are incompatible with photon mass, and in consequence that it is futile to search for a Higgs boson. Standard model unified field theory is bound to fail, it is a mixture of false assumptions. The Higgs boson does not exist because of finite photon mass. The latter implies that there is a cosmological red shift without an expanding universe. This red shift is derived in Section 2 directly from the original 1924 de Broglie Einstein equations without any further assumption. The de Broglie Einstein equations are derived straightforwardly in Section 2 from Cartan geometry in the context of ECE theory.

In Section 3, the existence of photon mass is proven with light deflection due to gravitation using the Planck distribution for one photon. The result is consistent with a photon mass of about $10^{-51}$ kg for a light beam heated to about 2,500 K as it grazes the Sun. This result proves the existence of photon mass for the first time. All previous estimates of photon mass are given as a value less than an upper bound, the best estimate [16] of the upper bound being of the order of $10^{-52}$ kg, close to the value obtained in this paper from light deflection due to gravitation. The obsolete theory of light deflection has been shown in UFT 150B and UFT 155 of this series (www.aias.us) to be incorrect and self-inconsistent. In retrospect this result is unsurprising because of the assumption in the old theory of an identically zero photon mass, a blatant self contradiction that introduces several mathematical flaws as discussed in UFT 155.

In Section 4 the simplest type of Compton scattering theory is developed using finite photon mass, showing that photon mass is observable in principle with Compton scattering and other types of particle scattering. Photon mass works its way through into all the experiments that signal the onset of quantum theory [17], notably black body radiation, specific heats, Compton scattering, the photoelectric effect, and atomic and molecular spectra.

Finally Section 5 gives some development of the Proca wave and field equations to show that there exists a potential of spacetime itself because of the existence of photon mass. This potential exists in the absence of any other type of mass, notably electron mass. This potential can be amplified by spin connection resonance to produce electric power from spacetime.

## 2. Photon mass and the cosmological red shift.

The de Broglie Einstein equations are the classical limit of the Proca wave equation of special relativistic quantum mechanics. The Proca equation has been shown in this series [3-12] to be itself the limit of the ECE wave equation of generally covariant quantum mechanics, the long sought unification of general relativity and quantum mechanics. Further details are found on www.aias.us, and in the notes accompanying this and other UFT papers on www.aias.us. The ECE equation of quantum electrodynamics [3-12] is:

$$(\Box + R)\, A_\mu^a = 0 \ , \tag{1}$$

where $R$ is a well defined scalar curvature and where:

$$A_\mu^a = A\, q_\mu^a \ . \tag{2}$$

Here $A$ is a scalar potential magnitude and $q_\mu^a$ is the Cartan tetrad [ 3-12]. Eq. (1) reduces to the 1934 Proca equation [15] in the limit:

$$R \longrightarrow \left(\frac{mc}{\hbar}\right)^2 \ , \tag{3}$$

where $m$ is the mass of the photon, $c$ is a universal constant and ħ is the reduced Planck constant. Note carefully that $c$ is not the velocity of the photon of mass $m$. In the photon mass theory of de Broglie [1, 2], $c$ is the maximum speed attainable in the theory of relativity. The old physics ignored the de Broglie Einstein theory and asserted erroneously that $c$ is the speed of light in a vacuum. By habit this verbiage became accepted uncritically, an example of Langmuir´s scientific pathology, the acceptance of dogma instead of fact.

Eq. (1) in the classical limit is the Einstein energy equation:

$$p^\mu\, p_\mu = m^2\, c^2 \ , \tag{4}$$

where:

$$p^\mu = \left(\frac{E}{c}, \ \right) \ , \tag{5}$$

and where $m$ is the mass of the photon. Here $E$ is the relativistic energy:

$$E = \gamma\, mc^2 \ , \tag{6}$$

and $\boldsymbol{p}$ is the relativistic momentum:

$$\boldsymbol{p} \doteq \gamma\, m\, \boldsymbol{v}_g \ . \tag{7}$$

The factor γ is the result of the Lorentz transform [3 -12] and was denoted by de Broglie [1,2] as:

$$\gamma = \left(1 - \frac{\boldsymbol{v}_g{}^2}{c^2}\right)^{-1/2} \tag{8}$$

where $\boldsymbol{v}_g$ is the group velocity:

$$\boldsymbol{v}_g = \frac{\partial \omega}{\partial \kappa} \ . \tag{9}$$

The de Broglie Einstein equations are:

$$p^\mu = \hbar \, \kappa^\mu \tag{10}$$

where the four wavenumber is:

$$\kappa^\mu = ( \frac{\omega}{c} \ , \ \boldsymbol{\kappa} ) \ . \tag{11}$$

Eq. (10) is a logically inevitable consequence of the Planck theory of the energy quantum of light later called "the photon", published in 1901 [18], and the theory of special relativity [3 - 12, 19]. The standard model has attempted to reject the inexorable logic of Eq. (10 ) by rejecting $m$. This is illogical and fallacious, delaying and greatly damaging the progress of natural philosophy. In retrospect it is farcical to reject the particle in wave particle duality, which the standard model accepts at the same time as rejecting $m$. Eq. (10) can be written out as:

$$E = \hbar \, \omega = \gamma \, mc^2 \tag{12}$$

and

$$\boldsymbol{p} = \hbar \, \boldsymbol{\kappa} = \gamma \, m \boldsymbol{v}_g \ . \tag{13}$$

In his original papers of 1923 and 1924 [1, 2] de Broglie defined the velocity in the Lorentz transform as the group velocity [12], which is the velocity of the envelope of two or more waves. For two waves:

$$v_g = \frac{\Delta \omega}{\Delta \kappa} = \frac{\omega_2 - \omega_1}{\kappa_2 - \kappa_1} \tag{14}$$

and for many waves, Eq. (9) applies. The phase velocity $v_p$ was defined by de Broglie [1, 2] as:

$$v_p = \frac{E}{p} = \frac{\omega}{\kappa} \ . \tag{15}$$

The phase velocity is the average velocity of the waves in a wave packet. It follows that:

$$v_g \ v_p = c^2 \tag{16}$$

which is an equation independent of the Lorentz factor $\gamma$ , and universally valid. The standard model makes the arbitrary and fundamentally erroneous assumptions:

$$m = ? \ 0 \ \ , \ \ v_g = v_p = ? \ c \ \ . \tag{17}$$

If there were no "standard model", these assumptions would be considered to be ludicrous, revealing the extent to which imposed pathology has supplanted science in the twentieth century.

In physical optics [14] the phase velocity is defined by

$$v_p = \omega / \kappa = c / n \tag{18}$$

where $n$ ($\omega$ ) is the frequency dependent refractive index, in general a complex quantity (UFT 49, UFT 118 and Omnia Opera on www.aias.us, OO 108). The group velocity in physical optics is [14]:

$$v_g = c \left( n + \omega \frac{dn}{d\omega} \right)^{-1} \quad . \tag{19}$$

It follows that:

$$v_p \, v_g = c^2 = \frac{c^2}{n\left( n + \omega \frac{dn}{d\omega} \right)} \quad , \tag{20}$$

giving the differential equation:

$$\frac{dn}{d\omega} = \frac{-n}{2\omega} \quad . \tag{21}$$

A solution of this equation is:

$$n = \frac{C}{\omega^{1/2}} \tag{22}$$

where $C$ is a constant of integration with the units of angular frequency. So:

$$n = \left( \frac{\omega_0}{\omega} \right)^{1/2} \tag{23}$$

where $\omega_0$ is a characteristic angular frequency of the electromagnetic radiation. Eq. (23) has been derived directly from the original papers of de Broglie [1, 2] using only the equations (18) and (19) of physical optics, or wave physics. The photon mass does not appear in the final Eq. (23), but the photon mass is basic to the meaning of the calculation. If $\omega_0$ is interpreted as the emitted angular frequency of light in a far distant star, then $\omega$ is the angular frequency of light reaching the observer. If:

$$n > 1 \tag{24}$$

then:

$$\omega < \omega_0 \tag{25}$$

and the light has been red shifted, meaning that its observable angular frequency ($\omega$) is lower than its emitted angular frequency ($\omega_0$), and this is due to photon mass, not an expanding universe. The refractive index $n$ ($\omega$ ) is the refractive index of the spacetime between star and observer. Therefore in 1924, de Broglie effectively explained the cosmological red shift in terms of photon mass. "Big Bang" (words in a derisory joke coined by Hoyle) is now

known to be erroneous in many ways, and was the result of imposed and muddy pathology supplanting the clear science of de Broglie.

In 1924 de Broglie also introduced the concept of least (or "rest") angular frequency:

$$\hbar\omega_0 = mc^2 \tag{26}$$

and kinetic angular frequency $\omega_\kappa$. The latter can be defined in the non relativistic limit:

$$\hbar\,\omega = mc^2\left(1 - \frac{{v_g}^2}{c^2}\right)^{-1/2} \sim mc^2 + \frac{1}{2}m{v_g}^2 \tag{27}$$

so:

$$\hbar\omega_\kappa \sim \frac{1}{2}m{v_g}^2\ . \tag{28}$$

Similarly, in the non relativistic limit:

$$\hbar\kappa \sim mv_g + \frac{1}{2}m\frac{{v_g}^3}{c^2}\ . \tag{29}$$

So the least wavenumber, $\kappa_0$ , is:

$$\hbar\kappa_0 \sim mv_g \tag{30}$$

and the kinetic wavenumber is

$$\hbar\kappa_\kappa \sim \frac{1}{2}m\frac{{v_g}^3}{c^2}\ . \tag{31}$$

The total angular frequency in this limit is:

$$\omega = \omega_0 + \omega_\kappa \tag{32}$$

and the total wavenumber is:

$$\kappa = \kappa_0 + \kappa_\kappa\ . \tag{33}$$

The kinetic energy of the photon was defined by de Broglie by omitting the least (or "rest") frequency:

$$T = \hbar\omega_\kappa \sim \frac{1}{2}m{v_g}^2 = \frac{p^2}{2m} \tag{34}$$

where:

$$p = m\,v_g\ . \tag{35}$$

Using Eqs. (26) and (30) it is found that:

$$v_p = \frac{c^2}{v_g} = \frac{\omega_0}{\kappa_0} \tag{36}$$

and using Eqs. (28) and (31):

$$v_p = \frac{c^2}{v_g} = \frac{\omega_\kappa}{\kappa_\kappa} \quad . \tag{37}$$

Therefore:

$$v_p = \frac{\omega}{\kappa} = \frac{\omega_0 + \omega_\kappa}{\kappa_0 + \kappa_\kappa} \tag{38}$$

a possible solution of which is:

$$\frac{\omega_\kappa}{\kappa_0} = v_p \quad . \tag{39}$$

Using Eqs. (30) and (28):

$$\frac{\omega_\kappa}{\kappa_0} = \frac{1}{2} v_g \quad . \tag{40}$$

So it is found that in these limits that:

$$v_g = 2\, v_p \tag{41}$$

This is the actual work of de Broglie [1, 2], which has been extended in this section to give a simple derivation of the cosmological red shift due to the existence of photon mass. Inter alia, the cosmological red shift is an experimental proof of photon mass. In standard model texts, photon mass is rarely discussed, and the work of de Broglie is distorted and never cited properly. In the next section it is shown that light deflection by gravitation is also a proof of photon mass. The de Broglie Einstein equations also apply to the every day phenomenon of refraction of light as in a prism. The refractive index is defined in the same way as the universal Eq. (23). So the light entering and emerging from a prism does not travel at *c*. As pointed out by Dr. Gareth J. Evans (AIAS group discussions), the speed of light leaving a prism cannot be "magically reverted to c". This violates conservation of energy and momentum. The de Broglie Einstein photon mass theory shows that the light does not "speed up to *c*" after leaving the prism. The same considerations apply in the Compton effect (see Section 4 below), where the correctness of the argument by Dr. G. J. Evans is proven mathematically using conservation of energy and momentum in a one photon one electron interaction.

## 3. Photon mass and light deflection due to gravitation.

The current best estimate of photon mass [15,16] is of the order $10^{-52}$ kg. In UFT 150B and UFT 155, the photon mass from light deflection was calculated as:

$$m = \frac{R_0}{ac^2} E \tag{42}$$

using:

$$E = \hbar\, \omega \,. \tag{43}$$

This gave a result:

$m = 3.35 \times 10^{-41}$ kg . (44)

Here $R_0$ is the distance of closest approach, taken to be the radius of the Sun:

$R_0 = 6.955 \times 10^{8}$ m (45)

and $a$ is a distance parameter computed to high accuracy:

$a = 3.3765447822 \times 10^{11}$ m. (46)

More realistically, the photon in a light beam grazing the Sun has a mean energy given by the Planck distribution [17]:

$$< E > = \hbar\, \omega \left( \frac{e^{-\hbar\, \omega/\mathrm{kT}}}{1 - e^{-\hbar\, \omega/\mathrm{kT}}} \right) \quad (47)$$

where k is Boltzmann´s constant and T the temperature of the photon. It is found that a photon mass of :

$m = 9.74 \times 10^{-52}$ kg (48)

is compatible with a temperature of 2,500 K. The temperature of the photosphere at the Sun´s surface is 5,778 K, while the temperature of the Sun´s corona is 1 - 3 million K. Using Eq. (12) it is found that

$v_g = 2.99757 \times 10^{8}$ m s$^{-1}$ (49)

which is less than the maximum speed of relativity theory:

$c = 2.9979 \times 10^{8}$ m s$^{-1}$ . (50)

As discussed in detail in note 157(13) accompanying this paper on www.aias.us, the mean energy $< E >$ is related to the beam intensity $I$ in joules per square metre by:

$$I = 8\, \pi \left(\frac{f}{c}\right)^2 < E > \quad (51)$$

where $f$ is the frequency of the beam in hertz. The intensity can be expressed as:

$$I = 8\, \pi\, f^2\, m \left( 1 - \frac{{v_g}^2}{c^2} \right)^{-½}. \quad (52)$$

The total energy density of the light beam in joules per cubic metre is:

$$U = \frac{f}{c}\, I \quad (53)$$

and its power density in watts per square metre (joules per second per square metre) is:

$$\Phi = c\, U = f\, I = 8\, \pi\, f^3\, m \left( 1 - \frac{{v_g}^2}{c^2} \right)^{-½}. \quad (54)$$

The power density is an easily measurable quantity, and implies finite photon mass through Eq. (54). In the standard model there is no photon mass, so there is no power density, an absurd result. The power density is related to the magnitude of the electric field strength (***E*** ) and magnetic flux density (***B***) of the beam by:

$$\Phi = \epsilon_0 \, c \, E^2 = c \, B^2/\mu_0 \ . \tag{55}$$

The units in S.I. are as follows:

E = volt $m^{-1}$ = J $C^{-1}m^{-2}$

B = tesla = $JsC^{-1}m^{-2}$

$\epsilon_0$ = 8.854188 x $10^{-12}$ $J^{-1}C^2m^{-1}$

$\mu_0 = 4\pi$ x $10^{-7}$ $Js^2C^{-2}m^{-1}$

where $\epsilon_0$ and $\mu_0$ are respectively the vacuum permittivity and permeability, defined by:

$$\epsilon_0 \mu_0 = \frac{1}{c^2} \ . \tag{56}$$

So:

$$\Phi = 8 \, \pi \, f^3 \, m \left( 1 - \frac{{v_g}^2}{c^2} \right)^{-½} = \epsilon_0 \, c \, E^2 = c \, B^2/\mu_0 \ . \tag{57}$$

## 4. Photon mass and Compton´s scattering.

Consider the collision of one photon of mass $m$ with one electron of mass $M$. The details of this calculation are written out in full in notes 157(5) and 157(8) accompanying this paper on www.aias.us. Let the initial angular frequency of the photon be $\omega_1$ and its angular frequency after collision be $\omega_2$. Then the de Broglie Einstein theory of Section 2 gives:

$$\hbar\omega_1 = \left( 1 - \frac{{v_1}^2}{c^2} \right)^{-½} mc^2 \ , \ \hbar\omega_2 = \left( 1 - \frac{{v_2}^2}{c^2} \right)^{-½} mc^2 \tag{58}$$

where $v_1$ and $v_2$ are the group velocities before and after collision with the electron. Consider the electron to be initially at rest, and define its relativistic momentum after collision to be $p$. The electron gains momentum after collision, so the photon loses momentum. So:

$$v_2 < v_1 \ . \tag{59}$$

This shows that the photon group velocity of de Broglie is lower after collision than before collision, a simple deduction that immediately proves the point made by Dr. Gareth J. Evans discussed in Section 2. By conservation of total energy (photon plus electron):

$$\hbar(\omega_1 - \omega_2) = (c^2p^2 + M^2c^4)^{½} - Mc^2. \tag{60}$$

By conservation of total momentum in the X and Y axes:

$$\hbar\kappa_1 = \hbar\kappa_2 \cos\theta + p \cos\theta' \ , \tag{61}$$

$$0 = \hbar\kappa_2 \cos\theta - p \cos\theta' , \tag{62}$$

where the initial momentum of the photon is $\hbar\kappa_1$ and its final momentum is $\hbar\kappa_2$. So

$$p^2 = \hbar^2(\kappa_1{}^2 + \kappa_2{}^2 - \kappa_1\kappa_2 \cos\theta) . \tag{63}$$

The photon is scattered at an angle $\theta$ to its incoming X axis.

Using the equations:

$$\omega_1{}^2 = c^2\kappa_1{}^2 + (\frac{mc^2}{\hbar})^2 \tag{64a}$$

and

$$\omega_2{}^2 = c^2\kappa_2{}^2 + (\frac{mc^2}{\hbar})^2 \tag{64b}$$

it is found that

$$\omega_1 - \omega_2 = \frac{\hbar}{Mc^2}\left(\omega_1\omega_2 - \left(\omega_1{}^2 - \omega_0{}^2\right)^{1/2}\left(\omega_2{}^2 - \omega_0{}^2\right)^{1/2}\cos\theta\right) + \frac{m^2c^2}{\hbar M} \ . \tag{65}$$

This is the one photon one electron Compton effect for a photon of mass $m$ colliding with an electron of mass *M*. The least frequency of the photon is defined by:

$$\omega_0 = \frac{mc^2}{\hbar} \ . \tag{66}$$

The only unknown in this experiment is $m$, which can be found given sufficient experimental precision. The usual theory of the Compton effect is developed with:

$$m = ?\ 0 \tag{67}$$

in which case Eq. (65) reduces to:

$$\omega_1 - \omega_2 = \frac{\hbar}{Mc^2}\,\omega_1\omega_2\,(1 - \cos\theta) \ . \tag{68}$$

Using:

$$\omega_1 = c\,\kappa_1 = c / \lambda_1 \ , \tag{69}$$

$$\omega_2 = c\,\kappa_2 = c / \lambda_2 , \tag{70}$$

the usual description [17] of the Compton effect is obtained:

$$\lambda_1 - \lambda_2 = 2 \frac{\hbar}{Mc} \sin^2 \frac{\theta}{2} \quad . \tag{71}$$

This theory is valid for the scattering of the photon of mass $m$ with any particle of mass $M$, including another photon (the case $M = m$). There are few if any data on photon-photon scattering.

## 5. Photon mass and electric energy from spacetime.

The calculations for this section are given in full in note 157(9) accompanying this paper on www.aias.us. The Proca wave equation (1) may be written for each sense of polarization, $a$ , as :

$$\Box A_\mu = \mu_0 J_\mu \tag{72}$$

where the charge current four density of spacetime itself is defined as:

$$J_\mu = - \frac{1}{\mu_0} \left( \frac{mc}{\hbar} \right)^2 A_\mu \quad . \tag{73}$$

The following definitions are used:

$$J_\mu = ( c\rho \ , - \boldsymbol{J} ) \tag{74}$$

and

$$A_\mu = ( \frac{\varphi}{c} , - \boldsymbol{A} ) \quad . \tag{75}$$

The existence of the current $J_\mu$ means that the inhomogeneous Proca field equation is [3 – 12]:

$$\partial_\mu F^{\mu\nu} = \mu_0 J^\nu \tag{76}$$

and this is a consequence of the inhomogeneous ECE field equation [3-12]. In vector notation:

$$\nabla . \boldsymbol{E} = \rho / \epsilon_0 \tag{77}$$

and

$$\nabla \times \boldsymbol{B} - \frac{1}{c^2} \frac{\partial \boldsymbol{E}}{\partial t} = \mu_0 \boldsymbol{J} \quad . \tag{78}$$

Here Eq. (77) is the Coulomb law of spacetime itself, and Eq, (78) is the Ampere Maxwell law of spacetime itself. Thus:

$$\rho = - \epsilon_0 \left( \frac{mc}{\hbar} \right)^2 \varphi \tag{79}$$

and

$$\boldsymbol{J} = -\frac{1}{\mu_0}\left(\frac{mc}{\hbar}\right)^2 \boldsymbol{A} \ . \tag{80}$$

Therefore the existence of photon mass means that there is a potential of spacetime itself which gives a charge density and current density of spacetime itself. This can be amplified with spin connection resonance [3-12] in devices (www.et3m.net) that take energy from spacetime. If spacetime itself can be polarized and magnetized, the equations are:

$$\nabla . \boldsymbol{D} = \rho \tag{81}$$

and

$$\nabla \times \boldsymbol{H} - \frac{\partial \boldsymbol{D}}{\partial t} = \boldsymbol{J} \ . \tag{82}$$

Here:

$$\boldsymbol{D} = \epsilon_0 \boldsymbol{E} + \mathbf{p} \tag{83}$$

and

$$\boldsymbol{B} = \mu_0 (\boldsymbol{H} + \mathbf{M}) . \tag{84}$$

The following is a summary of terms and S.I. units:

$\boldsymbol{E}$ = Electric field strength (volt $m^{-1}$ )

$\boldsymbol{B}$ = Magnetic flux density (tesla)

$\boldsymbol{H}$ = Magnetic field strength (A $m^{-1}$)

$\mathbf{p}$ = polarization ($Cm^{-2}$)

$\mathbf{M}$ = Magnetization ($Am^{-1}$).

So photon mass is central to all aspects of physics.

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