# Can Varying Light Speed Explain Photon-Particle Interactions?

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Photon-particle interactions, both 'classical,' such as Compton Scattering, and 'speculative,' such as ones associated with 'tired light' theories of the cosmological red-shift, are explained with the assumption of the constancy of the speed of light. For classical interactions, reciprocal variations in light frequency and wavelength occur under the constraint that their product always equals constant speed 'c.' Proponents of a cosmological red-shift claim that the universe is expanding due to expansion of space (or space-time) itself as light, traveling at 'c,' is stretched as the distance between the source and observer increases due to this space (or space-time) expansion. Counter arguments to this interpretation often fall into the realm of 'tired light,' dismissed by mainstream physicists for various reasons, but still advocated by various 'dissident' physicists, since the term was first coined by Zwicky in 1929. In this paper, I examine a classical photon-particle interaction, Compton Scattering, and one of the more popular 'tired light' theories to show that the assumption of a constant speed of light is unnecessary, i.e., similar results evolve from assuming a variable light speed.

## 1. Introduction

Classical Compton Scattering and the alleged cosmological red-shifting of light are based on the assumption that the light wave maintains a constant speed while the waveform is altered by reciprocal variations in frequency and wavelength. For the cosmological red-shift, it is space (or space-time) itself that expands, increasing the distance between the source and observer. In classical wave theory, the wave's behavior is determined by its medium of transmission. Since its speed is constant due to the medium itself (assuming the medium is not moving), either the waveform is stretched if receding from the observer or remains the same if stationary but the observer is receding from the wave, an analogous effect; or a combination of both effects if both source and observer are mutually receding. Unless you adhere to an aether theory or one such as Calkins' where the electromagnetic medium itself is light's medium that propagates with it [1], there is no *a priori* reason why the speed of light need be constant for a moving source or independent of a moving observer even if the light source remains stationary. This is an assumption based on Einstein's relativity or, in some cases, claimed to be required by Maxwell's equations. For the latter, I believe that the only requirement is that light speed be 'c' relative to its emission from a stationary source. If that source is moving, light acquires the source velocity as well. In this paper, I examine Compton Scattering and one of the more prevalent 'tired light' theories to show that the assumption of a constant speed of light is unnecessary for the phenomena, i.e., the phenomena will still occur with a variable light speed.

## 2. Re-examination of Compton Scattering

Classical Compton Scattering (including its low-energy limit where a photon's energy [frequency] is much less than the particle mass, known as Thomson Scattering [2]) evolved from "early 20th century research … [where it] was observed that, when X-rays of a known wavelength interact with atoms, the X-rays are scattered through an angle θ and emerge at a different wavelength related to θ. Although classical electromagnetism predicted that the wavelength of scattered rays should be equal to the initial wavelength, multiple experiments had found that the wavelength of the scattered rays was longer (corresponding to lower energy) than the initial wavelength. In 1923, Compton published a paper in the *Physical Review* that explained the X-ray shift by attributing particle-like momentum to light quanta (Einstein had proposed light quanta in 1905 in explaining the photo-electric effect, but Compton did not build on Einstein's work.) [3] The energy of light quanta depends only on the frequency of the light. In his paper, Compton derived the mathematical relationship between the shift in wavelength and the scattering angle of the X-rays by assuming that each scattered X-ray photon interacted with only one electron. His paper concludes by reporting on experiments which verified his derived relation:

$\lambda' - \lambda = h(1 - \cos\theta)/(m_e c)$

where $\lambda$ is the initial wavelength, $\lambda'$ is the wavelength after scattering, h is the Planck constant, $m_e$ is the electron rest mass, c is the speed of light, and θ is the scattering angle (Figure 1)." [4]

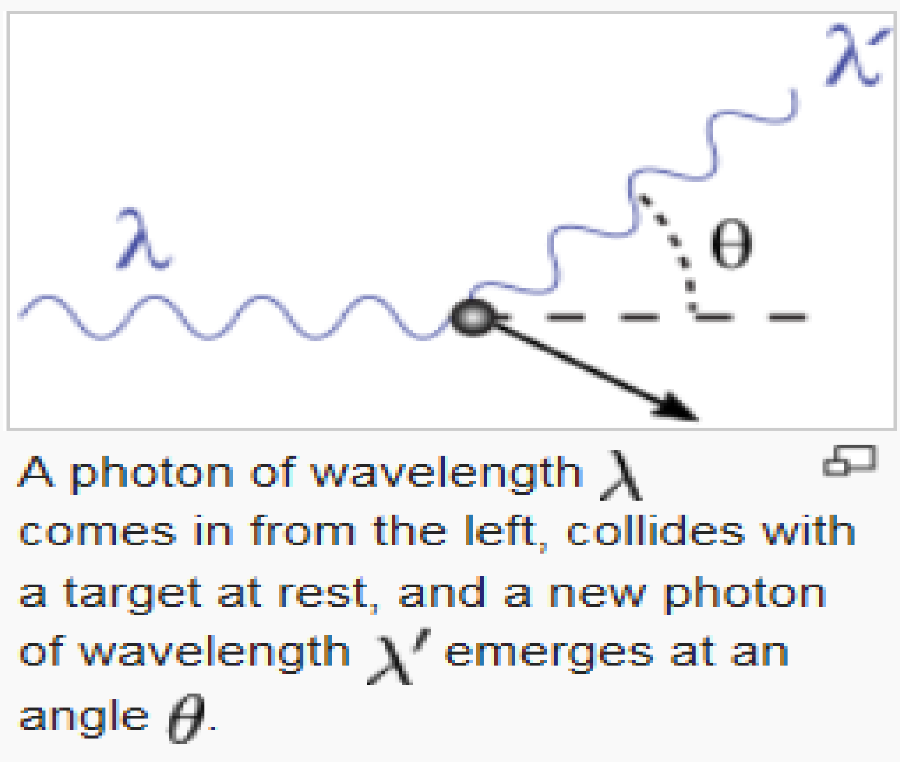


**Figure 1**. **Classical Compton Scattering**

## 2.1. Derivation of Classical Compton Scattering

The derivation is reproduced below [4] so that I can follow it with my altered assumption of a variable speed of light where the waveform remains unchanged (i.e., λ remains constant) and the energy loss resulting from the reduced speed is characterized by a reduction in the frequency 'f.'

"A photon with wavelength λ collides with an electron in an atom, which is treated as being at rest. The collision causes the electron to recoil, and a new photon with wavelength λ' emerges at angle θ from the photon's incoming path … Compton allowed for the possibility that the interaction would sometimes accelerate the electron to speeds sufficiently close to the velocity of light and would require the application of Einstein's special relativity theory to properly describe its energy and momentum.

"At the conclusion of Compton's 1923 paper, he reported results of experiments confirming the predictions of his scattering formula thus supporting the assumption that photons carry directed momentum as well as quantized energy. At the start of his derivation, he had postulated an expression for the momentum of a photon from equating Einstein's already established mass-energy relationship of $E = mc^2$ to the quantized photon energies of hf which Einstein has separately postulated. If $mc^2 = hf$, the equivalent photon mass must be $hf/c^2$. The photon's momentum is then simply this effective mass times the photon's frame-invariant velocity c. For a photon, its momentum $p = hf/c$, and thus hf can be substituted for pc for all photon momentum terms which arise in course of the derivation below. The derivation which appears in Compton's paper is terser, but follows the same logic in the same sequence as the following derivation.

"The conservation of energy E merely equates the sum of energies before and after scattering.

$$E_{photon\text{-}before} + E_{electron\text{-}before} = E_{photon\text{-}after} + E_{electron\text{-}after}$$

Compton postulated that photons carry momentum; thus from the conservation of momentum, the momenta of the particles should be similarly related by

$$P_{photon\text{-}before} = P_{photon\text{-}after} + P_{electron\text{-}after}$$

in which the electron's initial momentum is omitted on the assumption it is effectively zero. The photon energies are related to the frequencies by: $E_{photon\text{-}before} = hf$; $E_{photon\text{-}after} = hf'$. Before the scattering event, the electron is treated as sufficiently close to being at rest that its total energy consists entirely of the mass-energy equivalence of its rest mass: $E_{electron\text{-}before} = m_e c^2$. After scattering, the possibility that the electron might be accelerated to a significant fraction of the speed of light, requires that its total energy be represented using the relativistic energy–momentum relation:

$$E_{electron\text{-}after} = ([P_{electron\text{-}after}c]^2 + [m_e c^2]^2)^{0.5}$$

Substituting these quantities into the expression for the conservation of energy gives,

$$hf + m_e c^2 = hf' + ([P_{electron\text{-}after}c]^2 + [m_e c^2]^2)^{0.5} \qquad (1)$$

This expression can be used to find the magnitude of the momentum of the scattered electron,

$$(P_{electron\text{-}after}c)^2 = (hf – hf' + [m_ec^2])^2 – (m_ec^2)^2 \qquad (2)$$

"Equation (1) relates the various energies associated with the collision. The electron's momentum change includes a relativistic change in the mass of the electron so it is not simply related to the change in energy in the manner that occurs in classical physics. The change in the momentum of the photon is also not simply related to the difference in energy but involves a change in direction. Solving the conservation of momentum expression for the scattered electron's momentum gives,

$$P_{electron\text{-}after} = P_{photon\text{-}before} - P_{photon\text{-}after}$$

Then by making use of the scalar product,

$$(P_{electron\text{-}after})^2 = (\underline{P}_{electron\text{-}after}) \text{ dot } (\underline{P}_{electron\text{-}after}) = (\underline{P}_{photon\text{-}before} - \underline{P}_{photon\text{-}after}) \text{ dot } (\underline{P}_{photon\text{-}before} - \underline{P}_{photon\text{-}after}) = (P_{photon\text{-}before})^2 + (P_{photon\text{-}after})^2 - 2(P_{photon\text{-}before})(P_{photon\text{-}after}) \cos\theta \qquad (3)$$

Anticipating that $P_{photon\text{-}before}c$ is replaceable with hf, multiply both sides by $c^2$ … After replacing the photon momentum terms with hf/c, we get a second expression for the magnitude of the momentum of the scattered electron:

$$(P_{electron\text{-}after}c)^2 = (hf)^2 + (hf')^2 – 2(hf)(hf') \cos\theta \qquad (4)$$

Equating both expressions for this momentum gives

$$(hf – hf' + [m_ec^2])^2 – (m_ec^2)^2 = (hf)^2 + (hf')^2 – 2(hf)(hf') \cos\theta$$

which after evaluating the square and then canceling and rearranging terms gives

$$2hfm_ec^2 - 2hf'm_ec^2 = 2h^2ff'(1 – \cos\theta)$$

Then dividing both sides by $2h^2ff'm_ec$ yields

$$c/f' – c/f = h(1 – \cos\theta)/(m_ec)$$

Finally, since $f\lambda = f'\lambda' = c$,

$$\boldsymbol{\lambda' – \lambda = h(1 – \cos\theta)/(m_ec)}."$$

## 2.2. Derivation with Variable Light Speed

As discussed in my papers [5-7], I contend that light need not be constrained, unless there is an aether (or a medium that moves with light itself, as per Calkins [1]), to a constant speed. I postulate that it is light's waveform, not its speed, that remains invariant such that, in Compton Scattering, the reduction in energy translates into a reduction in speed (c → c') of the 'scattered' photon (which, in 'tired light' theory, still proceeds in its incident direction via other phenomena), characterized solely by a reduction in its frequency, i.e., f → f'. Following the previous derivation, I show that a similar result can be obtained from this assumption.[1]

My approach follows the previous up through Equation (2), rewritten and expanded here:

$$(P_{electron\text{-}after}c)^2 = (hf – hf' + [m_ec^2])^2 – (m_ec^2)^2 = h^2(f – f')^2 + 2h(f – f')m_ec^2 \qquad (5)$$

Next I rewrite Equation (3), substituting hf/c and hf'/c' for the photon momenta before and after scattering:

$$(P_{electron\text{-}after})^2 = (P_{photon\text{-}before})^2 + (P_{photon\text{-}after})^2 - 2(P_{photon\text{-}before})(P_{photon\text{-}after}) \cos\theta = (hf/c)^2 + (hf'/c')^2 – 2(hf/c)(hf'/c') \cos\theta$$

Multiplying both sides by $c^2$ yields:

$$(P_{electron\text{-}after}c)^2 = (hf)^2 + (hf'c/c')^2 – 2h^2ff'(c/c') \cos\theta \qquad (6)$$

Equating Equations (5) and (6) produces:

$$h^2(f^2 – 2ff' + [f']^2) + 2hfm_ec^2 – 2hf'm_ec^2 = (hf)^2 + (hf')^2(c/c')^2 – 2h^2ff'(c/c') \cos\theta$$

which reduces to

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1 It is a common misconception that 'color' can be equivalently characterized by wavelength or frequency. The fact that there is no 'color' change during refraction demonstrates that 'color' is really a function solely of frequency. Therefore, there is no change in 'color' (using this term loosely to apply to non-visible light as well) unless there is a change in frequency.

$$2h^2ff'([c/c'][\cos\theta] - 1) + (hf')^2(1 - [c/c']^2) + 2h(f - f')m_e c^2 = 0$$

Eliminating c and c' via the substitutions $c = f\lambda$ and $c' = f'\lambda$ transforms this into the following:

$$2h^2f(f\cos\theta - f') - h^2(f + f')(f - f') + 2h(f - f')m_e c^2 = 0.$$

Since the reduction in photon speed (and therefore energy and frequency) is essentially negligible, assume $f + f' \approx 2f$, thereby simplifying this equation as follows:

$$2h^2f(f\cos\theta - f') - 2h^2f(f - f') + 2h(f - f')m_e c^2 = 0.$$

Dividing by 2h and rearranging yields:

$$f - f' = (h[1 - \cos\theta]/m_e)(f/c)^2$$

which, with $c = f\lambda$, reduces to:

$$\mathbf{f - f' = h(1 - \cos\theta)/(m_e\lambda^2)}.$$

This has the same form as the equation for classical Compton Scattering, but in terms of the reduction in frequency (vs. an increase in the wavelength) with the constant speed of light c now replaced by the square of the constant wavelength λ.[2]

## 3. Re-examination of One 'Tired Light' Theory

Claims that the universe is expanding due to expansion of space (or space-time) itself are based on the assumed cosmological red-shift in which light, traveling at constant speed 'c,' is stretched as the distance between the source and observer increases due to this space (or space-time) expansion. Counter arguments to this interpretation often fall into the realm of 'tired light,' dismissed by mainstream physicists for various reasons, but still advocated by various 'dissident' physicists, since the term was first coined by Zwicky in 1929. [8] Among the many of these, I particularly note those by the father and son pairing of Paul and Louis Marmet, and the popular 'New Tired Light' Theory of Lyndon Ashmore, which I examine further below. [9-11] These theories have in common phenomena whereby an interacting photon retains its incident direction so as not to 'blur' the source image, an alleged inevitable result of 'tired light' behavior by which mainstream physicists dismiss the theories since such blurring is not observed.

### 3.1. Ashmore's 'New Tired Light' Theory

"In this 'New Tired Light' theory, [Ashmore] explains the increase in wavelength as being due to photons of light interacting, or colliding, with the electrons in the plasma of inter-galactic [IG] space and thus losing energy. The more interactions they make, the more energy they lose and the lower their frequency becomes. As the frequency reduces the wavelength increases and thus the photons are red-shifted. Photons of light from galaxies twice as far away travel twice as far through the intergalactic medium, undergo twice as many collisions with the electrons, lose twice as much energy, have their frequency reduced by twice as much and their wavelength increased by twice as much. Hence galaxies twice as far away have twice the red-shift. Doesn't this make more sense than an expanding Universe stretching the photons?" [11]

The details of Ashmore's analysis are found in his paper on the "Recoil Between Photons and Electrons Leading to the Hubble Constant and the CMB [Cosmic Microwave Background]." [12] They are summarized here, as with the analysis for classic Compton Scattering, to pave the way for my re-examination of the derivation with my assumption of a variable light speed with invariant waveform.

### 3.2. Derivation for Ashmore's 'New Tired Light'

Ashmore [12] contends that "[t]he plasma of intergalactic space acts as a transparent medium and photons of light, as they travel through space, will be absorbed and re-emitted by the electrons in this plasma. At each interaction where the momentum of the photon is transferred to the electrons, there will be a delay. So the electron will recoil both on absorption and reemission - resulting in inelastic collisions. A double Mössbauer effect will occur during each interaction between photon and electron. Some of the energy of the photon will be transferred to the electron, and since the energy of the photon has been reduced, the frequency will reduce and the wavelength will increase. It will have 'undergone a red-shift'."

"Energy lost to an electron during emission or absorption is equal to $Q^2/2m_ec^2$, where Q is the energy of the incoming photon ($hc/\lambda$), $m_e$ is the rest mass of the electron and c is the speed of light. This energy calculation must be applied twice for absorption and re-emission. Hence, total energy lost by a photon is $Q^2/m_ec^2 = h^2/\lambda^2m_e$, [i.e.,] (energy before interaction) – (energy after) = $h^2/\lambda^2m_e$,

$$hc/\lambda - hc/\lambda' = h^2/\lambda^2m_e \qquad (7)$$

where λ is the initial wavelength of the photon and λ′ is the wavelength of the re-emitted photon. Multiplying through by $\lambda^2\lambda'm_e$ and dividing by h gives:

[2] Using $c = f\lambda$ and $c' = f'\lambda$, this can also be expressed as $\mathbf{c - c' = h(1 - \cos\theta)/(m_e\lambda)}$.

$\lambda\lambda' m_e c - \lambda^2 m_e c = h\lambda'$

Increase in wavelength is $\delta\lambda = \lambda' - \lambda$, so:

$$\lambda(\delta\lambda + \lambda)m_e c - \lambda^2 m_e c = h(\delta\lambda + \lambda) \Rightarrow \lambda m_e c\delta\lambda + \lambda^2 m_e c - \lambda^2 m_e c = h\delta\lambda + h\lambda \Rightarrow \delta\lambda(\lambda m_e c - h) = h\lambda$$

Then since $h << \lambda m_e c$, $\delta\lambda = h/m_e c$."

Ashmore [11] continues: "On their journey through IG space, photons will [experience] many such interactions where they are absorbed and re-emitted each time (photons of light make, on average, one collision every 70,000 light year[s]). Each time they will lose energy and be red-shifted a little more. Total shift in wavelength, $\Delta\lambda = N\delta\lambda$, [w]here, $\Delta\lambda$ is the total shift in wavelength, N is the total number of interaction[s] made by the photon on its journey and $\delta\lambda$ is the increase in wavelength at each interaction ... With red-shift, we find that the longer the wavelength, $\lambda$, the greater the shift in wavelength, $\Delta\lambda$. In fact, experiment tells us that the shift in wavelength, $\Delta\lambda$ is proportional to the wavelength, $\lambda$, i.e., ... $\Delta\lambda = z\lambda$, where z is a constant called the 'red-shift.' We usually write this as: $z = \Delta\lambda/\lambda$. For a particular galaxy, the red-shift, z, is a constant for all wavelengths.

"… In the 'New Tired Light' theory, the number of collisions made by each photon depends upon its collision cross-section, $\sigma$. This represents the probability of a photon being absorbed by the electron.[3] We know the photo-absorption collision cross-section for a photon - electron interaction from experiments carried out by the interaction of low energy X-rays with matter and it depends upon the radius of the electron and the wavelength of the photon:

collision cross-section, $\sigma = 2$ x (classical radius of electron, r) x (wavelength of photon, $\lambda$), or $\sigma = 2r\lambda$.

The number of collisions the photon makes on its journey depends both on the probability of the photon 'bumping' into an electron and upon how densely packed the electrons are in IG space. The greater either of these quantities are, then the more likely it is for a photon to bump into an electron and be absorbed and re-emitted. The average distance between collisions is called the 'mean free path' and this can be calculated [as] mean free path = $(n\sigma)^{-1}$, or $(2nr\lambda)^{-1}$, … [w]here 'n' is the number of electrons in each cubic metre of IG space.

"… The number of collisions, N, made by the photon in travelling from a galaxy a distance 'd' away is simply the distance 'd' divided by the average distance between each collision (the mean free path), [i.e.,]

Number of collisions by photon, $N = d/(2nr\lambda)^{-1}$, or $N = 2nr\lambda d$

As we have seen before, the shift in wavelength, $\delta\lambda$, at each interaction is the same for all wavelengths and equal to $h/(m_e c)$. The total shift in wavelength experienced by the photon during its entire journey is found by multiplying the total number of collisions, N, by the shift in wavelength at each collision.

Total shift in wavelength, $\Delta\lambda = N\delta\lambda$, or $\Delta\lambda = (2nr\lambda d)(h/[m_e c])$.

The red-shift z is defined as $z = \Delta\lambda/\lambda$. Rearranging … gives:

$\mathbf{z = \Delta\lambda/\lambda = (2nhrd)/(m_e c)}$."

## 3.3. Derivation with Variable Light Speed

I begin with Equation (7) for total energy lost by a photon, i.e.,

(energy before interaction) – (energy after) = $hc/\lambda - hc/\lambda' = h^2/\lambda^2 m_e$

but assume that the light speed (and therefore just the frequency, since I consider $\lambda$ constant) is reduced, using the symbols from Section 2.2 to rewrite this as:

(energy before interaction) – (energy after) = $hc/\lambda - hc'/\lambda = hf - hf' = h^2/\lambda^2 m_e$.

Paralleling Ashmore, I define $\delta f = f - f'$, the decrease in frequency of the photon due to the interaction with the electron (unlike Ashmore's wavelength, the primed value here is the lower one). Then this easily rearranges into: $\delta f = f - f' = h/(m_e\lambda^2)$.

Continuing to parallel Ashmore, but with my variable light speed assumption (and changes in *italics*): "On their journey through IG space, photons will [experience] many such interactions where they are absorbed and re-emitted each time … [to] lose energy and be red-shifted a little more. Total shift in *[frequency]*, $\Delta f = N\delta f$, [w]here, $\Delta f$ is the total shift in *[frequency]*, N is the total number of interaction[s] made by the photon on its journey and $\delta f$ is the *decrease in frequency* at each interaction ... With red-shift, we find that the *slower the light speed*, … the greater the *shift in frequency,* $\Delta f$. In fact, *experiments could also be interpreted* to tell us ***not*** that the shift in wavelength, $\Delta\lambda$ is proportional to the wavelength, $\lambda$, i.e., ... $\Delta\lambda = z\lambda$, where z is a constant called the 'red-shift,' *but rather that the shift in frequency,* $\Delta f$*, is proportional to the frequency, f, i.e., ...* $\Delta f = zf$. We *can* write this as: $z = \Delta f/f$. For a particular galaxy, the red-shift, z, is a constant for all *frequencies*."

[3] Louis Marmet (personal communication) would term this a 'scattering' cross-section since electrons do not have internal degrees of freedom and cannot absorb a photon.

As before, "… the [n]umber of collisions by [the] photon, $N = d/(2nr\lambda)^{-1}$, or $N = 2nr\lambda d$ … [T]he shift in *[frequency], $\delta f$,* at each interaction is the same for all *[frequencies]* and equal to *$[h/(m_e\lambda^2)]$*. The total shift in *[frequency]* experienced by the photon during its entire journey is found by multiplying the total number of collisions, N, by the shift in *[frequency]* at each collision.

Total shift in *[frequency]*, $\Delta f = N\delta f$, or $\Delta f = (2nr\lambda d)(h/\{m_e\lambda^2\}) = (2nhrd)/\{m_e\lambda\})$.

The red-shift z is defined as $z = \Delta f/f$. Rearranging with $c = f\lambda$ … gives:

$\mathbf{z = \Delta f/f = \Delta f/(c/\lambda) = (2nhrd/\{m_e\lambda\})/(c/\lambda) = (2nhrd)/(m_e c)}$."

This matches Ashmore's red-shift formula.

## 4. Summary

My analyses sought to show that, for Compton Scattering and one of the more popular 'tired light' theories, Ashmore's 'New Tired Light,' the implicit assumption of constant light speed need not be retained to derive similar results. Light can be assumed to lose energy during Compton Scattering or a 'tired light' interaction via a decrease in speed, with a corresponding decrease in frequency, holding the wavelength constant. Note that this does not preclude the possibility that a decrease in light speed may be accompanied by both a decrease in frequency and increase in wavelength, provided the decrease in frequency more than counteracts the increase in wavelength so as to result in the lower speed.

## 5. Acknowledgment

I would like to thank both Lyndon Ashmore and Louis Marmet for their insightful reviews of my paper and recommended improvements. Note that this does not imply agreement with my views regarding variable light speed or the conclusions drawn.

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# CAN VARYING LIGHT SPEED EXPLAIN PHOTON-PARTICLE INTERACTIONS?

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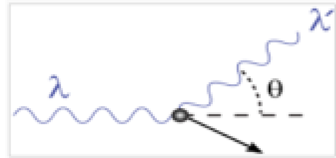
## ISSUE BOTH "CLASSICALLY" & "DISSIDENTLY"

- Both 'classical' Compton Scattering and some 'dissident' tired light theories of the cosmological red-shift are explained assuming constancy of light speed.
  - Classically, frequency and wavelength must vary reciprocally to preserve 'c.'
    - Universal expansion of space(-time) 'stretches' the distance between source and observer, thus 'stretching' light's wavelength (red-shift).
  - Counter arguments via tired light, dismissed by mainstream physics, but still advocated by 'dissident' physicists, continue to prosper since first proposed by Fritz Zwicky in 1929.
- Examine classical Compton Scattering and one popular 'tired light' theory (Lyndon Ashmore) to show that assuming constant light speed is unnecessary, i.e., similar results evolve from with variable light speed.

# COMPTON SCATTERING




**With constant light speed**

- Via conservation of energy (E) and momentum (P), E = hν (photon) and E = $m_e c^2$ ([e]lectron) post-collision ('):
  - $(P'_e c)^2 = (h\nu - h\nu' + [m_e c^2])^2 - (m_e c^2)^2$ [Eq. 1]
- Using scalar product: [Eq. 2]
  - $(P'_e c)^2 = (\boldsymbol{P'} \bullet \boldsymbol{P'})c^2 = (h\nu)^2 + (h\nu')^2 - 2(h\nu)(h\nu')\cos\theta$
- Setting Eq. 1 = Eq. 2: [Eq. 3]
  - $\boldsymbol{\lambda - \lambda' = h(1 - \cos\theta)/(m_e c)}$

**With variable light speed ($c' = \lambda\nu'$)**

- Expand Eq. 1:
  - $(P'_e c)^2 = h^2(\nu - \nu')^2 + 2h(\nu - \nu')m_e c^2$ [Eq. 1*]
- Rewrite Eq. 2, using $P^{(')} = h\nu^{(')}/c$ for pre/post-collision:
  - $(P'_e c)^2 = (h\nu)^2 + (h\nu' c/c')^2 - 2h^2\nu\,\nu'(c/c')\cos\theta$ [Eq. 2*]
- Setting Eq. 1* = Eq. 2*, with $c^{(')} = \nu^{(')}\lambda$ & ν + ν' ≈ 2ν: [Eq. 3*]
  - $\boldsymbol{\nu - \nu' = h(1 - \cos\theta)/(m_e c)^2}$

    Also expressable as

    $\boldsymbol{c - c' = h(1 - cos\,\theta)/(m_e \lambda)}$

    **Note similarity with Eq. 3**



# ASHMORE'S "NEW TIRED LIGHT"

- Increase in wavelength is due to photons interacting with plasma electrons in inter-galactic [IG] space, thus losing energy.
  - More interactions → more energy lost (lower frequency, higher wavelength → red-shift).
    - IG plasma acts as a transparent medium in which photons are absorbed and re-emitted by electrons with momentum transfer, thus causing a delay. Electron recoil both on absorption and re-emission = inelastic collisions (double Mössbauer effect).
    - Reduced energy of photon reduces frequency and increases wavelength.
  - (see L. Ashmore, 2006. "Recoil Between Photons and Electrons Leading to the Hubble Constant and CMB," *Galilean Electrodynamics*, Vol. 17, Special Issues No. 3, pp. 53-56.)

# ASHMORE (CONT.)

**With constant light speed**

- With Q = energy of incident photon (hc/λ), energy loss to electron (once each for absorption and re-emission):
  - $hc/\lambda - hc/\lambda' = h^2/(\lambda^2 m_e)$
  - With δλ = λ' − λ and h << λ$m_e$c, $\delta\lambda = h/m_e c$ [Eq. 1]
- Total shift in wavelength after N interactions = Δλ = Nδλ, where interaction X-section σ = 2rλ, r = electron radius

**With variable light speed ($c' = \lambda\nu'$)**

- Eq. 1, but with reduction in light speed (i.e., frequency):
  - $hf - hf' = h^2/(\lambda^2 m_e)$[Eq. 1*]
  - With δf = f − f', $\delta f = h/(m_e\lambda^2)$
- Same for both: 'Mean free path' between interactions = $(n\sigma)^{-1}$ = $(2nr\lambda)^{-1}$, n = number of electrons/$m^3$ of IG space
  - Over distance 'd,' $N = d/(2nr\lambda)^{-1} = 2nr\lambda d$ [Eq. 2]



# ASHMORE (CONT.)

**With constant light speed**

- Combining Eq. 1 and Eq. 2 with Δλ = Nδλ: [Eq. 3]
  - $\Delta\lambda = (2nr\lambda d)(h/[m_e c])$
- Red-shift (cosmological) z = Δλ/λ, so from Eq. 3:
  - $\boldsymbol{z = \Delta\lambda/\lambda = (2nhrd)/(m_e c)}$

**With variable light speed ($c' = \lambda\nu'$)**

- Combining Eq. 1* and 2:
  - $\Delta\nu = N\delta\nu = (2nhrd)/(m_e\lambda)$ [Eq. 3*]
- Red-shift (cosmological) z = Δν/ν, so from Eq. 3*:
  - $\boldsymbol{z = \Delta\nu/\nu = \Delta\nu/\frac{c}{\lambda} = (2nhrd)/(m_e c)}$

Equivalent

# CONCLUSION

- For both Compton Scattering and a popular 'tired light' theory, the implicit assumption of constant light speed need not be retained to derive similar results.
  - Light can be assumed to lose energy during Compton Scattering or a 'tired light" interaction via a decrease in speed, with a corresponding decrease in frequency, holding the wavelength constant.
    - Note that a decrease in light speed may still be accompanied by both a decrease in frequency and increase in wavelength, provided the decrease in frequency more than counteracts the increase in wavelength so as to result in the lower speed.



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