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A Photon Density Theory Explaining Experiments on High-order Doppler Effect

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Abstract The special relativity theory predicts a relativistic or transverse Doppler effect. This effect is verified by many photon-emission experiments. However, when researchers tried to measure the Doppler effect of electromagnetic waves reflected from a transversely moving surface, they obtained a null result. This paper presents a photon density theory to explain these mixed results. The theory can explain the relativistic phenomena predicted by the special relativity theory, as well as the negative results of transverse Doppler effect from rotating mirrors. Contrary to the prediction from the special relativity, the photon density theory suggests that the Doppler effect of light is asymmetric.

Keywords: *photon density, relative mass, relativistic Doppler effect, mass energy equation*

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1. Introduction

When Einstein proposed his relativity theory, he was fiercely criticised by various people. Over time, the general and special relativity theories have finally conquered the physics world through its successful explanations and predictions of various phenomena, such as the increasing mass of high-speed particles, the Fizeau water-tube experiment, precessions of Mars and other planets, gravitational lensing, and gravity waves. Nowadays, nuclear power plants and the GPS system act as daily testimony of the success of Einstein's theory. The attitude toward the relativity theories is also totally reversed. Any criticism to relativity theories becomes a taboo partly because of the failed criticisms in the past and partly because of the belief that the relativity theories are the most tested theories in the world so their correctness is beyond any doubt.

However, there are experimental results that the relativity theories cannot explain. The special relativity predicted a transverse Doppler effect caused by time dilation. The effect has been confirmed by some experiments [1-8], but it has been rejected but other experiments. Jennison and Davies [9,10] used a very sensitive Michaelson Interferometer to measure the transverse Doppler effect from a rotating mirror but reported a null result. With the advancement of technology, the experiment of Thim [11] can detect frequency change as small as 10^{-3} Hz, which corresponds to the value of $(v/c)^2$ in the order of 10^{-14}. Thim tried to accurately measure the Doppler shift of microwave reflected from a transversely moving/rotating antennas but also reported absence of transverse Doppler shift. These experiments perplexed researchers and cast doubts on the special relativity theory.

The key concept in the special relativity related to transverse Doppler effect is time dilation. This concept results from Lorentz transformation between inertial frames. Since Lorentz transformation formula provides the time and position link between two frames, given a common initial time and position of an object, the transformation will lead subsequently different times and distances in both frames of different speeds. Comparing the results for two frames, we can find that the time passes slower and the distance appears shorter in the frame of higher speed if they are viewed from the other frame. It is apparent that both time dilation and length contraction are an effect perceived from the stationary frame, so it is not a real effect.

Since Einstein did not say explicitly whether time dilation and length contraction are real or perceived effect, some physicists [12,13,14,15] interpret them as perceived or apparent effect while many others [16,17,18,19,20] believe they are real effect. However, both groups would encounter problems in explaining relativistic effects. The believers of real effect cannot explain logically why the apparent or perceived effect from the derivation becomes a real effect. On the other hand, if one believes time dilation and length contraction are only a perceived effect, he/she is unable to use the relativity theory to explain some observations.

The GPS clock adjustment is a good example. If the time dilation effect of a GPS clock caused by the differences in speed (based on the special relativity) and in gravitational potential (based on the general relativity) is a purely perceived effect, the GPS clock should not slow down when it is boarded on satellites, so no adjustment is needed. In reality, we do need to adjust the GPS clock frequency before putting it into space. This indicates the effect is real. Chou et al [21] provided direct experimental evidence that the change in GPS frequency is real. They built two nearly identical optical clocks (GPS clock is also a type of optical clock) and raised one to a higher elevation (about 33cm) than the other. The experiment shows that the frequency of the clock at higher elevation is greater than that of the other clock.

One may argue that the GPS clock adjustment may show that the time dilation in general relativity is real, but the time dilation in special relativity can still be only a perceived effect. This argument is not entirely valid. Although GPS clock adjustment is mainly due to the impact of gravity field, it also needs to take into account the time dilation effect due to the speed of satellite. If the speed induced time dilation predicted by special relativity was ignored, the GPS system would be less accurate. This indicates if Einstein's theory is correct, the time dilation predicted by both the general and special relativity must be real.

The mixed experimental results and ambiguous explanations show that even though the special relativity theory has many successful predictions, the theory is still questionable. It is well known that incorrect theories can produce correct formulas and predictions, and can explain numerous events. When these theories are unable to explain one phenomenon or experimental results, they are disproved partially or totally. The examples include the flat earth theory, geocentric model, Aristotle's wisdom of heavier object falling faster, Fresnel drag coefficient for explaining water tube experiments, and Sommerfeld's formula for hydrogen spectra. In this reasoning, the inability of relativity theories to explain the null results of transverse Doppler effect signals that something in the theory is not quite right. Historical experience tells us that a new theory should, and eventually will, come up to upgrade or replace the existing theory. This paper is an attempt in this direction.

The paper is organized as follows. Section 2 shows the inability of the special relativity to explain the null results of experiments by Jennison and Davies [9,10] and Thim [11]. Section 3 lists and explains the assumptions which the photon density theory is based on. Section 4 defines important physical concepts and derives the basic physical quantities, include relative and rest mass, momentum, different types of energy, and energy-momentum relation. Section 5 applies the photon density theory to explain the results of Ives-Stilwell experiments and other experiments/observations on transverse Doppler effect. Section 6 concludes the paper.

2. Attempts to Explain Null Experimental Results of Transverse Doppler Effect

The null experimental results of the transverse Doppler effect from a rotating mirror are at odds with special relativity, but they are largely neglected because of vast other evidence supporting the relativity theories. The only discussion about them is an explanation by Sfarti [22] that the null result in Thim's experiment is expected because both the light source and detector are stationary. However, Sfarti apparently mixed the ordinary Doppler effect with high-order Doppler effect. He applied the relativistic Doppler effect formula wrongly in his eq. (2) and got a blue-shifted relativistic Doppler effect, which is against the common wisdom that relativistic Doppler effect is due to time dilation which always causes a red-shift. By assuming a blue shift (time contraction) viewed from the transversely moving mirror, Sfarti's reasoning also is against Einstein's belief of equivalence of reference frame. These contradictions can be demonstrated with the aid of Figure 1.

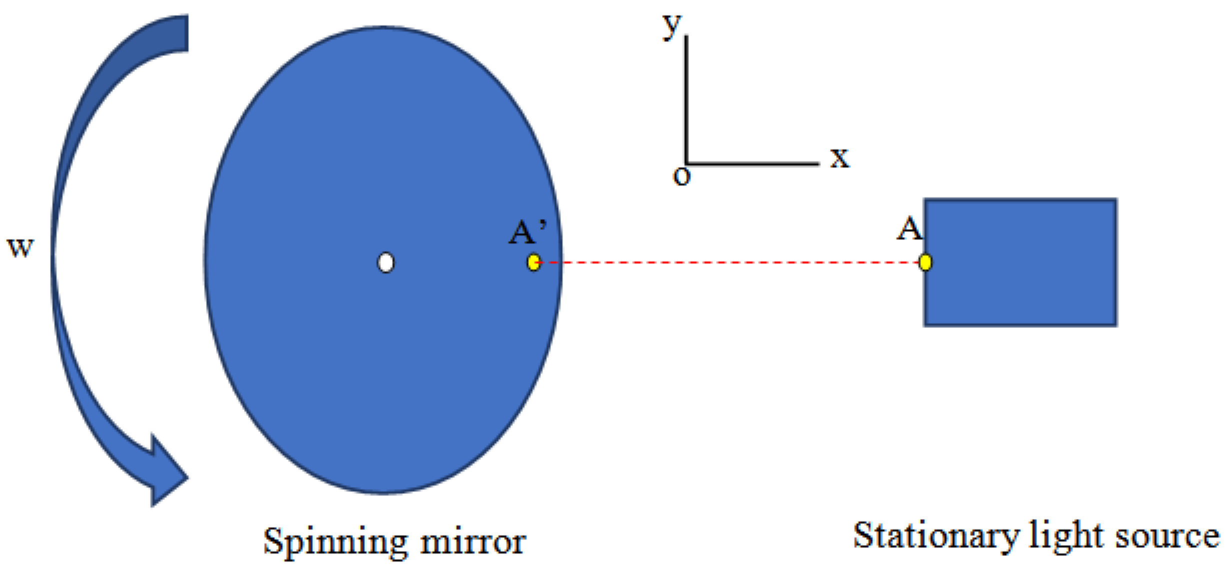

Figure 1. Lorentz transformation and equivalence of reference frame

Figure 1 shows a stationary light source at the right and, a mirror at the left spinning at an angular speed w. The face of the mirror is perpendicular to the light path AA', so the point A' on the mirror surface experiences an upward speed v. in other words, relative to the reference frame of the light source (e.g. the point A), point A' on the mirror keep moving up. Assuming the direction of AA' as x axis and the vertical direction as y axis, we have the following 2D Lorentz transformation formula to transform the stationary frame of A (txy) to the moving frame of A' (t'x'y'):

$$y' = \beta(y - vt),\ x' = x,\ t' = \beta\left(t - \frac{vy}{c^2}\right),\ \beta = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad \text{(i)}$$

From the above formulas we can calculate the time t' in the new reference frame A' as:

$$t' = \beta\left(t - \frac{vy}{c^2}\right) = \frac{t}{\beta} - \frac{vy'}{c^2} \quad \text{(i')}$$

Using A' itself as the new reference frame, point A' is stationary, so y' is constant for point A. Since v is less than c, β>1, so Δt'= β Δt <Δt (y' is constant when t changes, so the second term in (I') is cancelled out during the differencing). This means smaller amount of change in t' is equivalent to more change in t, i.e. the time in reference frame (t'x'y') elapses slower than in the frame (txy). This is the time dilation effect claimed in special relativity.

When the photon is reflected from point A', we need to use point A' as the original reference and point A as the new frame (t''x''y''). From the perspective of reference frame A', point A is moving downwards at speed v. The Lorentz transformation formula from the original frame of A' (t'x'y') to the new frame of A (t''x''y'') is:

$$y'' = \beta(y' + vt'),\ x'' = x',\ t'' = \beta\left(t' + \frac{vy'}{c^2}\right),\ \beta = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad \text{(ii)}$$

The time t'' in the new reference frame A(t''x''y'') is:

$$t'' = \beta\left(t' + \frac{vy'}{c^2}\right) = \frac{t'}{\beta} + \frac{vy''}{c^2} \quad \text{(ii')}$$

Using A(t''x''y'') as the new reference frame, point A is stationary, so y'' is constant and thus we can also conclude that from A'(t'x'y') to A(t''x''y''), the time is also dilated. These two transformations indicates that it does not matter what reference frame is chosen as the original frame, the time dilation effect is symmetrical. This is consistent with the belief of equivalence of reference frame maintained in the special relativity.

The reader needs to be reminded that when the photon is reflected back to point A, it presents a new reference frame (t''x''y''), which is different from A(txy). The reason is that even though the space coordinates may be the same, the time coordinates have changed, so the spacetime changes. One may mistakenly assume that the new reference frame (t''x''y'') is the same as the old one (txy), so the Lorentz transformation becomes:

$$y = \beta(y' + vt'),\ x = x',\ t = \beta\left(t' + \frac{vy'}{c^2}\right),\ \beta = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad \text{(iii)}$$

With the above equation, we can obtain:

$$t = \beta\left(t' + \frac{vy'}{c^2}\right) = \frac{t'}{\beta} + \frac{vy}{c^2} \quad \text{(iii')}$$

Plugging the t' in eq. (i) into (iii'), we have a null transverse Doppler effect of reflected photons:

$$t = \beta\left(t' + \frac{vy'}{c^2}\right) = \frac{t'}{\beta} + \frac{vy}{c^2} = t - \frac{vy}{c^2} + \frac{vy}{c^2} = t \quad \text{(iii'')}$$

This approach is flawed because it ignores the implicit assumption for derivation: the moving object becomes stationary in the frame after transformation because the object and the frame move at the same speed. For (iii) and (iii') to hold, we require that y is constant because of the stationary object in the new reference frame. Similarly, for (i) and (i') to hold, we require that y' is constant. However, we cannot set both y and y' to be constant simultaneously in our derivation because they belong to two reference frames of different speeds. As such, two Lorentz transformations (i) and (iii) cannot be used at the same time.

A similar mistake is to use the Lorentz transformation to transform reference frame (txy) to (t'x'y') and then use the inverse Lorentz transformation to transform reference frame (t'x'y') back to frame (txy). This is approach used by Sfarti [22]. Since eq.(iii) is in fact an inversed Lorentz transformation formula, this approach is essentially the same as previous approach and will achieve the same result. In this approach, using inverse Lorentz transformation for the reflected photon is mistaken. By definition, the inverse transformation is used to transform the new frame back to the original frame. In this way, both Lorentz transformation and inverse Lorentz transformation assume the object is stationary in the new frame, i.e. y' is constant, so they are consistent transformations. However, when a photon arrives point A', reference frame A' becomes an original frame and the frame A becomes the new reference. This does not fit with the definition of the inverse Lorentz transformation, so it is not applicable.

This mistake can be confirmed by its transformation results. From the inverse transformation formulas (iii), y' indicates the stationary position of A' on the new reference frame (t'x'y') and is thus constant, so it is apparent that Δt=βΔt'>Δt'. This means the time t runs faster than t', or t is contracted compared to time t'. This gives us a term 'time contraction', which is never heard of and is certainly against the special relativity. Moreover, Sfarti's transformation results shows that the time dilation effect or relativistic Doppler effect is dependent on if the light source is moving (causing time dilation by applying Lorentz transformation) or the observer is moving (causing time dilation by applying inverse Lorentz transformation), so it is at odd with the symmetrical relativistic Doppler effect claimed by special relativity. From another point of view, Sfarti's results shows that the time in frame (txy) always elapses faster than the time in frame (t'x'y'), which means the frame (x'y') is a preferred frame (e.g. because of time dilation, one can live longer). This is against the principle of equivalence of reference frames.

Sfarti's mistake is a quite common one. Many still explain the null results based on a Lorentz transformation (or Lorentz boost) to change the laboratory reference frame to transversely-moving mirror frame for incoming photons and an inverse Lorentz transformation (or inverse Lorentz boost) for reflected photons. An inverse transformation will reverse the results of previous transformation and thus will produce a null effect, but this is an impropriate procedure. One can reverse the position coordinates but not the time coordinates. The analogy of twin brother paradox of special relativity can illustrate this point. When one of the twin travels into space at high speed (i.e. photons contact the reflecting mirror) and then travel back to the Earth, his position reverses back, but he will be younger than his twin brother because his dilated time during travel does not reverse back. By the same reasoning, Einstein's special relativity necessitates that the dilated photon frequency due to reflection contact cannot be reversed back.

In considering the emission experiments on transverse Doppler effect [3,4,7,8], one should be absolutely convinced that it is impossible to have a time contraction effect for the photons reflected from the transversely moving surface. The emission experiments clearly show that the photons emitted from the transversely moving surface have a dilated frequency. If this is caused by a time dilation effect, the photons reflected from the transversely moving mirror should also have a time dilation effect. Since nobody disagree that the frequency of photons arriving the transversely moving surface is dilated, the time dilation effect of reflected photons should further dilate the photon frequency. However, no such dilation is detected.

The other possible argument in defending the relativity theory in this case may be that the spinning mirror/plate is not an inertial frame so one should apply the general relativity rather than the special relativity. This argument is not valid for the reflection experiments. Because the reflected photons (or electromagnetic waves) contact only the surface of the mirror/plate, they have not entered the spinning system and have experienced no attractive force from the system. The part of touching surface moves at an almost constant speed in the transverse direction, so it should be viewed as an inertial frame.

3. Assumptions

The proposed photon density theory requires the following intuitive assumptions, which are consistent with, or extended from, physical observations in an inertial frame of reference. The fundamental assumption is that light consists of periodically emitted photons, so light is basically particles with the periodicity giving the wave property. Due to historical reasons, most physicists believe light is electromagnetic waves. If the reader holds this belief, he/she can temperately put it aside and examine how a photon theory can explain the relativistic phenomena so well.

(1) Light (photon) speed is independent of the speed of the source.

This assumption is the same as a part of assumptions in the special relativity. The assumption is supported by observations and experiments such as stellar aberration, the Doppler effect of light, the observation of the movement of binary stars, the speed of γ rays from mesons, and the one-way Michelson and Morley experiments.

(2) All material objects emit photons evenly in all directions (isotropic emission), and the number of photons emitted per second is proportional to the amount of mass at rest.

The isotropic emission assumption suggests that the number of photons emitted in each direction for any period of time are equal. Photon emission is a common phenomenon and we observe that emission intensity of a light source is the same in all directions, so isotropic emission is plausible. All materials emit light at high temperature, but it seems that some objects do not emit photons at low temperature. This may be because the emission frequencies at low temperature is too low to be detected by the current technology. Other things being equal (e.g. temperature and volume), an object with a larger mass tends to produce a proportionally higher light intensity, which indicates that the photon numbers per emission are proportional to the magnitude of the rest mass.

Considering that matter emits photons evenly in all directions, we focus on the photon emission rates in one representative direction. The number of photons emitted per second in any direction can be calculated as:

$$N = f * e * m_0 \tag{1}$$

where m_0 is mass at rest, e is the number of photons per emission by one unit of mass, f is emission frequency (the number of emissions per second), and N is the number of photons per second emitted by total mass m_0.

If the first photon emitted by an object travels a distance of s in t seconds, given N is the photon numbers emitted per second, there are N*t number of photons covering the distance s, so the line density can be expressed as:

$$d = Nt / s = f * e * m_0 t / s$$

Apparently, the line density d is also proportional to rest mass m_0.

(3) Inertia of matter is proportional to its photon density.

This assumption is a natural extension of the common wisdom that mass at rest is the measurement of the inertia of a matter. Based on assumption 2, the density of photons is proportional to the amount of mass at rest, so the density can serve as a measurement of mass and thus a measurement of inertia. One may further argue that photon density may result in the inertia of the emitter through photon pressure or photon matter interaction. This argument implies that photon density may be the cause of inertia.

When a photon emitter moves, the photon density changes: it increases in front of the emitter and decreases behind the emitter. This change in density structure may change the average density and thus affect the amount of inertia.

We use the concept of relative mass as the indicator for the changing inertia of the object. For an object at rest, its relative mass equals its rest mass, m_0, and the corresponding photon density is denoted d_0. When the object starts to move, the relative mass m is different from m_0, and the photon density d is different from d_0. Since we assume inertia or relative mass is proportional to photon density, we can write:

$$m = k * d \ and \ m_0 = k * d_0,$$

where k is a constant.

By utilizing the above equations, assumption (3) can be crystalized as:

$$m = m_0 d / d_0 \tag{2}$$

(4) Emission frequency is proportional to the inverse of photon density.

Photon pressure can adversely affect the further emission of photons from the emitter, so photon density and emission frequency are inversely related to each other. This assumption can be expressed as:

$$f \propto \frac{1}{d} \ or \ fd = constand$$

If the rest mass m_0 has the emission frequency of f_0 and the photon density of d_0, the assumption can be further expressed as:

$$fd = f_0 d_0 \ or \ f = f_0 d_0 / d \tag{3}$$

4. Basic Physical Quantities and Concepts

Using the four assumptions in the previous section, we can derive important physical quantities for stationary and moving objects.

(1) Mass

We formally define rest mass as the mass measured when an object is stationary in the measurement frame, denoted as m_0. When the object is moving, the measured mass is called relative mass, denoted as m. Given the emission frequency f_0 for the object at rest, its photon emission rate (photon number per second) N_0 can be obtained by applying equation (1) to the case:

$$N_0 = f_0 e m_0 \tag{1'}$$

Before we proceed further, we need define photon density more specifically. Due to the symmetry of a stationary point emitter, one may consider photon density in a volume of a sphere centred on the emitter. However, as photon density decreases as the radius of the sphere increases, this is not a good way to measure the overall photon density. If the emitter starts to move, the measurement become even more troublesome.

Considering the fact that a moving emitter does not affect the photon speed and thus photon density in the directions perpendicular to the movement, we can use a cylinder volume along the direction of movement to measure overall photon density. This approach (see appendix) shows that the average photon-density impact of moving emitter is similar to the impact on the photon density in and opposite to the direction of the movement, as shown in Figure 2.

Denoting c as the speed of light in vacuum shown in the panel (a) of Figure 2, we can infer that if N_0 photons are emitted in 1 second cover the distance of c in any direction, the line density of photons can be calculated for the object at rest:

$$d_0 = N_0 / c \tag{4}$$

When the object is moving, the structure of the photon density will change. As shown in the panel (b) of Figure 2, a light source of speed v will have denser photons in the front and sparser photons behind. The change in photon density structure may also affect the average photon density and thus affect the photon emission frequency. Based on equations (1) and (1'), we have:

$$N = f e m_0 = \left(f / f_0 \right) * \left(f_0 e m_0 \right) = N_0 f / f_0 \tag{5}$$

The photon density ahead and behind can be calculated respectively as:

$$d_1 = N / \left(c - v \right) \text{ and } d_2 = N / \left(c + v \right)$$

As such, the average line density of the light source can be expressed as:

$$d = \left(d_1 + d_2 \right) / 2 = Nc / \left(c^2 - v^2 \right) \tag{6}$$

One may argue that the average density can be calculated by 2N photons (N photons ahead and N photons behind the object) covering a distance of (c+v)+(c-v). This approach is invalid or inaccurate because it gives more weighting (i.e., longer distance) to the photons behind the source.

Plugging equations (4) and (5) into equation (6), we have:

$$d = \left(N_0 f / f_0 \right) c / \left(c^2 - v^2 \right) = d_0 \left(f / f_0 \right) c^2 / \left(c^2 - v^2 \right) \tag{7}$$

Plugging equation (3) into equation (7), we have:

$$d^2 = {d_0}^2 c^2 / \left(c^2 - v^2 \right)$$

Solving the above equation and use equation (3) again, we obtain:

$$d = d_0 / \sqrt{1 - \frac{v^2}{c^2}} \tag{8}$$

$$f = f_0 \sqrt{1 - \frac{v^2}{c^2}} \tag{9}$$

Using equations (2) and (8), we have relative mass:

$$m = m_0 d / d_0 = m_0 / \sqrt{1 - \frac{v^2}{c^2}} \tag{10}$$

The difference between relative mass and resting mass can be named as kinetic mass, which can be calculated as:

$$m_k = m - m_0 = m_0 / \sqrt{1 - \frac{v^2}{c^2}} - m_0 \tag{11}$$

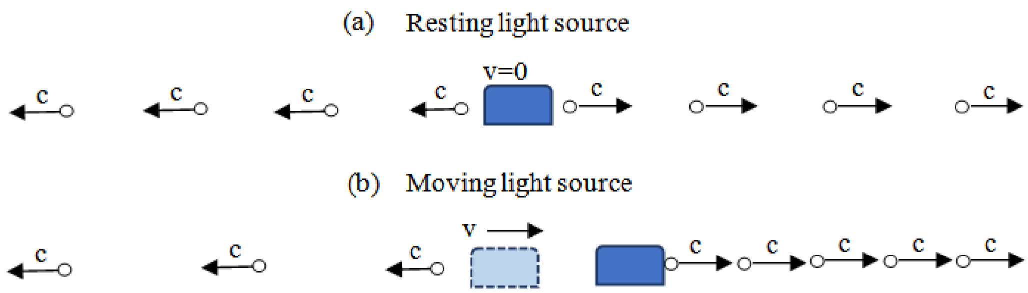

Figure 2. Speed of the light source, photon density, and relative mass

A word of caveat is necessary here. Figure 2 is very similar to a graph explaining the longitude/ordinary Doppler effect, while the resulting equation (9) is similar to the transverse/relativistic Doppler effect. This may cause confusion for some readers. It is important to highlight that here we are dealing with photon density rather than photon frequency. Although the ordinary Doppler effect or the PERCEIVED frequency/wavelength change at the observer can be demonstrated by a similar graph, Figure 2 and the resulting equations (8) and (9) concern the resultant change in photon density, which is OBJECTIVE regardless of the state of the observer. Later we will show that this objective impact is the source of the so-called relativistic Doppler effect. We also will show that if the observer is not at the same speed of the light source, the ordinary Doppler effect will be added on the top of the frequency change shown by equation (9).

(2) Momentum

Since relative mass changes with speed, the definition and the formula for momentum in classical physics needs to be upgraded to reflect the changing relative mass. The general formula for momentum can be expressed as:

$$p = \int F dt = \int d(mv) = \int (mdv + vdm) = mv$$

Using equation (10) and integration by parts, one can easily verify that this general formula holds for relative mass:

$$p = \int (mdv + vdm) = \int \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} dv + \int vd \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$= \int \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} dv + v \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} - \int \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} dv = mv$$

(3) Energy

The calculation of kinetic energy also needs to be based on relative mass:

$$K = \int F dx = \int (dx/dt) F dt = \int v d(mv) = \int \left(mvdv + v^2 dm \right) \tag{12}$$

Equation (10) can be rewritten as:

$$m^2 \left(c^2 - v^2 \right) = m_0{}^2 c^2$$

Differentiating above equation, we have:

$$c^2 dm - v^2 dm - mvdv = 0$$

or

$$v^2 dm + mvdv = c^2 dm \tag{13}$$

Plugging equation (13) into equation (12), we have:

$$K = \int c^2 dm$$

Equation (10) shows that when the speed increases from zero to v, the mass increases from m_0 to m. The above calculus in this range can be evaluated as:

$$K = mc^2 - m_0 c^2$$

The term m_0c^2 indicates the amount of energy related to rest mass, so we call it rest energy or internal energy E_0:

$$E_0 = m_0 c^2 \tag{14}$$

Similarly, the term mc^2 indicates the energy related to relative mass, so we call it relative energy:

$$E = mc^2 \tag{15}$$

The difference between relative and rest energy is kinetic energy, which is related to kinetic mass:

$$K = m_k c^2 = (m - m_0) c^2 = E - E_0$$

Alternatively, we have

$$\mathrm{E} = \mathrm{K} + E_0 = \mathrm{K} + m_0 c^2 = mc^2$$

From the mass-energy equation and the definition of momentum we can easily derive the energy- momentum relationship. Squaring the equation for momentum definition we have:

$$p^2 = (mv)^2 = \frac{m_0^2 v^2}{1-\frac{v^2}{c^2}}$$

We can solve the above equation for v to obtain:

$$v^2 = \frac{p^2 c^2}{p^2 + m_0^2 c^2}$$

Plugging this into equation (15) and squaring both sides, we have:

$$E^2 = \left(mc^2 \right)^2 = \frac{m_0^2 c^4}{1-\frac{v^2}{c^2}} = \frac{m_0^2 c^4}{1-\frac{p^2}{p^2 + m_0^2 c^2}}$$

$$= (pc)^2 + \left(m_0 c^2 \right)^2 = (pc)^2 + E_0^2$$

This is the energy-momentum equation.

(4) Space, time and speed

The change in photon density and thus in relative mass can explain seemingly unusual phenomena in classical physics, such as unmatchable speed of light, mass increasing with velocity, and relativistic Doppler effect. As a result, most features of classical physics are preserved, including absolute space, universal time, and Galilean relative speed. As such, the Galilean transformation works well. For example, the distance between the photon and the source can be obtained through the Galilean transformation:

$$x = (c - v)t$$

Here, the speed of the object (v) cannot be greater than the speed of light (c). This limit is not addressed by the above Galilean transformation, but it is mandated by the relative mass formula. As shown in equation (10), if speed v approaches the speed of light c, the relative mass m approaches infinity, so no force can push an object of infinite mass to reach the speed of light.

5. Explaining Experimental Results on Transverse Doppler Effect

Since there are many predictions from the special relativity theory, it is impractical to examine all of them in limited space. Here we only concern the high-order Doppler effect, focusing on Ives and Stilwell [5,6].

The experiments by Ives and Stilwell were intended to examine time dilation from the Thomar-Lorentz theory. Since this theory is also based on the Lorentz transformation, its predicted time dilation effect is similar to that of the special relativity theory. The time-dilation explanation of Doppler effect in the Ives and Stilwell experiments can be briefly shown as follows.

The formula for the ordinary Doppler effect is:

$$\frac{\lambda}{\lambda_0} = \frac{c - v * cos\theta}{c} = 1 - \frac{v}{c} cos\theta \tag{16}$$

where v is the speed of the moving light source and θ is the angle between v and the light ray towards the observer.

The Lorentz transformation necessitates that for the moving object, time slows down by the amount of the Lorentz factor γ, so the relativity theory predicts a high-order Doppler effect due to time dilation:

$$\frac{\lambda'}{\lambda_0} = \gamma\left(1 - \frac{v}{c} cos\theta\right) = \frac{1 - \frac{v}{c} cos\theta}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{17}$$

The high-order effect can be obtained quantitatively by applying binominal approximation to equation (17). For the direct light ray (θ= 0), the equation becomes:

$$\frac{\lambda 2}{\lambda_0} = \frac{1 - \frac{v}{c}}{\sqrt{1 - \frac{v^2}{c^2}}} \approx \left(1 - \frac{v}{c}\right)\left(1 + \frac{1}{2}\frac{v^2}{c^2}\right) = 1 - \frac{v}{c} + \frac{1}{2}\frac{v^2}{c^2} - \frac{1}{2}\frac{v^3}{c^3} \tag{18}$$

For the reflected light (θ= π), we have:

$$\frac{\lambda 1}{\lambda_0} = \frac{1 + \frac{v}{c}}{\sqrt{1 - \frac{v^2}{c^2}}} \approx \left(1 + \frac{v}{c}\right)\left(1 + \frac{1}{2}\frac{v^2}{c^2}\right) = 1 + \frac{v}{c} + \frac{1}{2}\frac{v^2}{c^2} + \frac{1}{2}\frac{v^3}{c^3} \tag{19}$$

Since measuring the wavelength of a spectrum line is more difficult and less accurate than measuring the amount of shift of the spectrum line, Ives and Stilwell measured the average of the two shifted spectrum lines and compared it with the original spectrum line caused by atoms at rest. The average wavelength of the Doppler shifts of both rays can be calculated as:

$$\bar{\lambda} = \frac{\lambda 1 + \lambda 2}{2} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\lambda_0 \approx \left(1 + \frac{1}{2}\frac{v^2}{c^2}\right)\lambda_0 > \lambda_0$$

For 0<v<c, the average wavelength is greater than the original wavelength λ_0, indicating that the spectrum line of the reflected ray redshifts more than the blue-shift of the direct ray. This asymmetric shift can be expressed explicitly by the difference between this average and the original wavelength, which consisted of the relativistic Doppler effect in Ives and Stilwell [5]:

$$\Delta\lambda = (\bar{\lambda} - \lambda_0) \approx \frac{1}{2}\frac{v^2}{c^2}\lambda_0$$

The positive relativistic Doppler effect Δλ is regarded as time dilation effect. The Ives and Stilwell experiment confirmed the asymmetrical Doppler shift and also showed that the size of relativistic shift from the original wavelength is consistent with the prediction of the time dilation effect shown in equation (17). As a result, this experiment is viewed as a confirmation of time dilation. However, as Christov [23] pointed out, the only problem with the analysis of Ives and Stilwell [5] is that they assumed that the light frequency emitted by the atoms was independent of the speed of the atoms.

As discussed in Section 4, photon density around atoms can cause pressure on atoms and thus affect photon emission frequency. The photon emission frequency of moving atoms is described by equation (9). In terms of wavelength, the equation can be written as:

$$\lambda_M = \lambda_0 / \sqrt{1 - \frac{v^2}{c^2}} \tag{20}$$

where λ_0 is the wavelength from a stationary light source and λ_M is the wavelength from a moving light source.

The change in wavelength described by equation (20) will also be perceived by the observer, so the ordinary Doppler effect in equation (16) should be upgraded to:

$$\lambda' = \frac{\lambda}{\lambda_0} * \lambda_M = \frac{c - v * cos\theta}{c}\frac{\lambda_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1 - \frac{v}{c} * cos\theta}{\sqrt{1 - \frac{v^2}{c^2}}}\lambda_0 \tag{21}$$

This equation is exactly the same as equation (17), which is derived based on time dilation. Using equation (21), we can produce the same relativistic effect as that from the special relativity theory. As such, the photon density theory can explain the Ives-Stilwell experiment equally well, and this explanation makes the counter-intuitive time dilation redundant.

Using equation (21), we can also explain the positive transverse Doppler effect as good as the special relativity theory did. Moreover, since the transverse Doppler effect in equation (21) comes from reduced emission frequency of moving object, this effect is not applicable to reflected photons. As a result, there is no frequency change at the transversely moving mirror and this leads to the null result.

6. Conclusions

The paper presents a photon density theory to explain relativistic phenomena. Without invoking counter-intuitive concepts such as time dilation and length contraction, the theory can explain most relativistic phenomena such as unmatchable speed of light, relative mass, energy-mass relations, and energy momentum relations. The paper shows that the Ives-Stilwell experiment, the key experiment supporting time dilation, can be explained by the change in light frequency when atoms are moving. The current paper also examines the mixed results of experiments on transverse Doppler effect and explains not only the positive results but also the negative results, which the relativity theory is unable to explain.

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Appendix: measuring photon density of a moving emitter

A. Line density of photons

As explained in the text, a sphere volume is not suitable to measure overall photon density of a moving emitter, so we use a cylindric volume, shown in Figure 3. When the emitter moves along the axis of the cylinder, the photon density on the cross section is not affected (to be explained in section B), so we focus on line density of photons at (or parallel to) the direction of cylinder axis x.

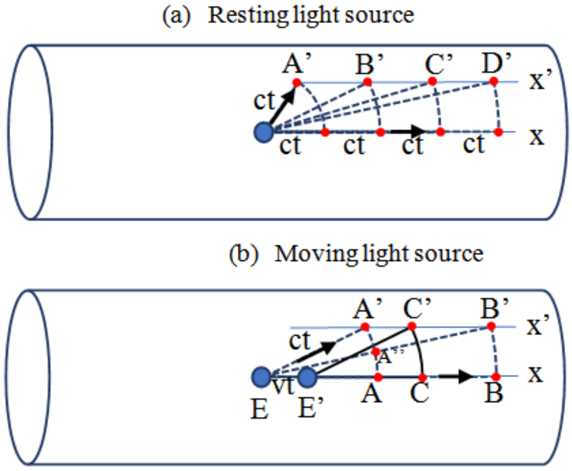

Figure 3. Longitude density of photons

Panel (a) shows the case of a resting light source. Assume an emission period of t (or emission frequency f=1/t) and photon speed of c. In the photon travelling direction such as the x axis, photons are distributed evenly with the length of the neighbouring photons being ct. On any line parallel to the x axis, e.g. the x’ line, we can find the same number of photons corresponding to those on the x axis by drawing the arcs of various radii. The photons on x’ are not distributed evenly. However, since the length of the cylinder can go to infinity, we can always find a right length so that x’ contains the same number of photons as those on the x axis. As such, the average length of neighbouring photons is also ct, i.e. <A’B’>=(A’B’ + B’B’ + C’D’ +…)/n=ct.

The situation of a moving emitter is shown in panel (b). For the easiness of demonstration, we have only showed two pairs of photons and increased the length of the neighbouring photons. If the emitter is stationary, with a first set of photons traveling to B and B’ and the second set of photons traveling to A and A’. As discussed above, AB=<A’B’>=ct.

Now we consider that, after emitting the first set of photons, the emitter starts to move to right at a speed v. When it starts to emit the second set of photons, the emitter has travelled a distance vt to E’ and the first set of photons travel to A and A’’. When the second set of photons travel to C and C’, the first set of photons arrive at B and B’. Because of the parallelly shift of shape EAA’ to E’CC’, it is obvious that AC=A’C’=vt. As a result, the new distance of neighbouring photons is BC = <B’C’> = ct - vt.

The line density of photons at the right of the emitter at E’ can be expressed as: d1=c/(ct-vt)=cf/(c-v). Similarly, the density at the left of E’ is d2=c/(ct+vt)=cf/(c+v), the average density is $d=(d1+d2)/2=c^2f/(c^2-v^2)$.

B. photon density in the perpendicular cross section.

Since the cross section is perpendicular to the movement of the emitter, by intuition we know the photon density at cross section should not be affected by the speed of emitter. This section provides a discussion on this.

The case of resting emitter is shown in panel (a) of Figure 4. Although the photon density is higher in the area close to the emitter, the photon densities on any radius in the cross section are equal.

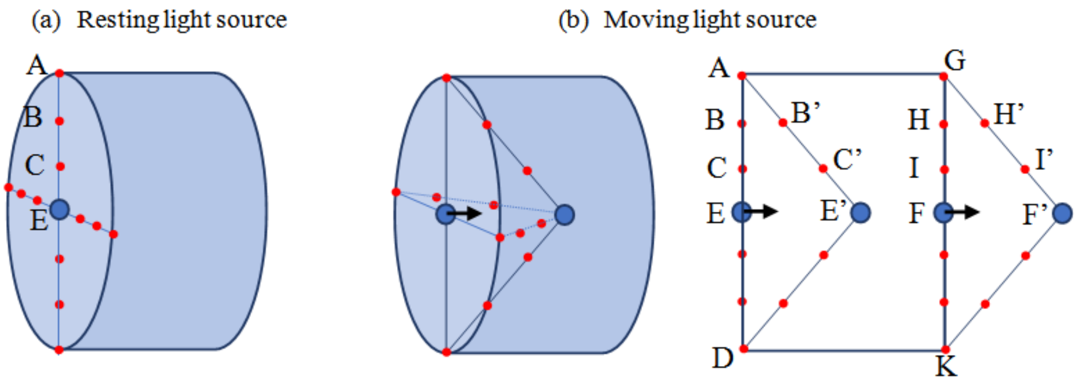

Figure 4. Photon density at the cross section

When the emitter starts to move to right, the photons with a speed perpendicular to the speed of the emitter will also move to the right of cross section. The cross section deformed to a cone surface, shown in the panel (b). Although the line density of photons on the cone surface (e.g. density on AE') is less than that on the perpendicular cross section (e.g. density on AE) when the emitter is stationary, i.e. AB'>AB, B'C'>BC, etc., the projection of photon density of the cone surface onto the cross section will be unchanged, e.g. the project of photons at B' and C' in panel (b) will be B and C. The longitude cross section view in panel (b) shows that the perpendicular cross sections AD and GK deform to cone surfaces ADE' and GKF' respectively, but the volume of the deformed new shape is the same as the cylinder of the same length in panel (a), so photon density can be calculated by using the projections of photons in the cone surface onto the cross section. In other words, the average cross section density is the flattened density on the cone surface. In short, as the speed and position of photons in the direction perpendicular to the cylindric axis are not affected by the speed of emitter, the projected photon density on the perpendicular cross section and thus the cross section density are not affected.