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Michelson–Morley Result, a Voigt–Doppler Effect in Absolute Space-Time

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Voigt's 1887 explanation of the Michelson–Morley result as a Doppler effect using absolute space-time is examined. It is shown that Doppler effects involve two wave velocities: (1) the phase velocity, which is used to account for the Michelson–Morley null result, and (2) the velocity of energy propagation, which, being fixed relative to absolute space, may be used to explain the results of Roemer, Bradley, Sagnac, Marinov, and the 2.7°K anisotropy.

1. INTRODUCTION

Considering the dissatisfaction with *special relativity*(1–3) and the accumulation of experimental evidence that does not appear to be compatible with *special relativity*,(4–8) it is of some interest to investigate Voigt's 1887 research(9) in which he explains the Michelson–Morley result as a Doppler effect appropriate for light using absolute space-time. The classical absolute space-time physics of Newton and the great physicists of the past deserves consideration today.(10)

Absolute space is defined here as the space established by physical observations anywhere in the universe that makes the universe appear isotropic in the large.(11) For example, the frame of reference in which the 2.7°K thermal cosmic background appears isotropic defines ansolute space. *Absolute time* is defined here as the time registered by standard clocks anywhere in the universe.(12) For example, the frequency of the 2.7°K background peak provides in principle a standard universal clock (actually, a single unique clock for the whole universe) that defines absolute time.

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Voigt assumed that a moving observer should see an electromagnetic wave that is also a solution to Maxwell's equations in his own coordinate system. Voigt thereby obtained the relations that are today inappropriately called the *Lorentz transformation*. Voigt represented his Doppler effect mathematically in terms of space and time variables, whereas the Doppler effect can involve the propagation constant and frequency only. Voigt's unfortunate mathematical representation of his Doppler effect in terms of space and time apparently led Lorentz and others to naively conclude that space and time themselves might actually change in a moving system.

The Voigt–Doppler effect for a stationary source and a moving observer in terms of the propagation constant and frequency has been presented in a previous paper(10) without, however, giving due credit to the original research of Voigt. In this quoted paper the phase velocity was also presented as being indeterminate within certain limits; but this cannot be true. The phase velocity is uniquely prescribed as indicated below.

One of the difficulties in space-time research has been the assumption of a unique *velocity of light*. However, Doppler effects necessarily involve *two* velocities and not *one*: the phase velocity and the velocity of energy propagation. These two velocities need not have the same magnitude nor direction. The phase velocity appears in the wave equation; the velocity of energy propagation is given by the Poynting vector divided by the energy density. Nothing physical need be propagated with the phase velocity in contrast to the velocity of energy propagation. A similar situation exists for the propagation of light in a crystal, the phase and energy velocities being in general different.

Voigt offered no explanation as to why his Doppler effect, appropriate for light, should differ from the classical Doppler effect. The explanation has been indicated in the previous paper(10). The classical Doppler effect is an idealization that neglects the physical coupling of the source and the observer to the wave field. The observer must extract energy and momentum from a light wave in order to detect the light wave. The process of observation, thus, alters the nature of the wave observed. In particular, the Voigt–Doppler effect differs from the classical Doppler effect due to the mechanical recoil of the observer.

2. CLASSICAL DOPPLER EFFECT

2.1. Water Waves Viewed from an Airplane

To stress the fact that *two* wave velocities are involved and not merely *one*, the Doppler effect for an observer flying in an airplane looking down upon water waves is considered. The situation is familiar to most of us. There is no coupling between the water waves and the observer, so that only kinematics is involved.

Letting the airplane fly in the positive x direction with a velocity $\mathbf{v}_o$ and letting the water waves have a phase velocity $\mathbf{c}$ as measured on the stationary earth, where $\mathbf{c}$ makes an angle with respect to the x axis, as shown in Fig. 1, the resultant phase velocity observed from the airplane may be readily deduced as

$$\mathbf{c}'(\text{phase}) = \mathbf{c}(1 - \mathbf{v}_o \cdot \mathbf{c}/c^2) \tag{1}$$

using the fact that by definition the phase velocity is perpendicular to the wave crests, or parallel to $\mathbf{c}$, and that the observed wavelength λ remains unchanged.

White caps that occur occassionally on the wave crests move with the physical wave velocity, the velocity of energy propagation. As observed from the stationary earth, this velocity of energy propagation is identical to the phase velocity $\mathbf{c}$. As observed from the airplane, the velocity of energy propagation is simply the vector difference

$$\mathbf{c}^*(\text{energy}) = \mathbf{c} - \mathbf{v}_o \tag{2}$$

as indicated in Fig. 1. As viewed from the airplane the white caps seem to

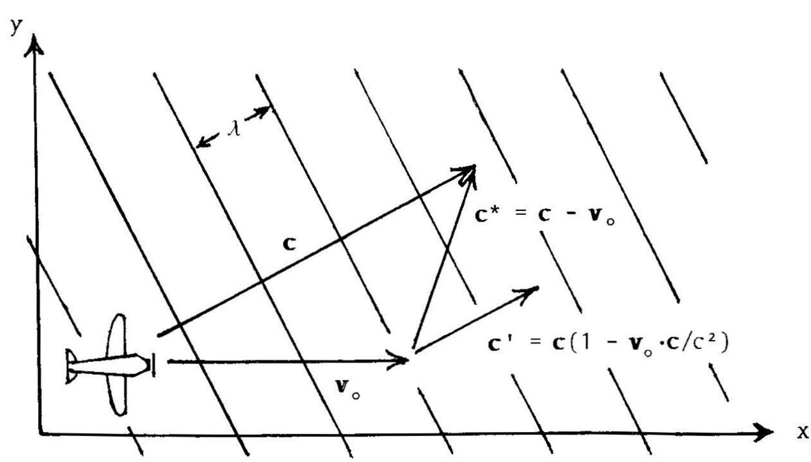

Fig. 1. Classical Doppler effect for water waves observed from an airplane indicating the wavelength λ and the *two* wave velocities: the phase velocity $\mathbf{c}'$ and the velocity of energy propagation $\mathbf{c}^*$.

slip sidewise along the wave crests. The Doppler-shifted frequency is given by

$$\omega' = c'/\lambda = \omega(1 - \mathbf{v}_o \cdot \mathbf{c}/c^2) \tag{3}$$

2.2. The General Classical Doppler Effect

The classical Doppler effect is an idealized pure kinematical effect where the physical coupling of the source and observer to the wave field is neglected. It is best derived as a time retardation effect. Considering an origin fixed in absolute space, an observer at the position $\mathbf{r}_o$ sees a signal which was emitted by the source at the position $\mathbf{r}_s$ at an earlier time $|\mathbf{r}_o - \mathbf{r}_s|/c$ due to the finite velocity of transmission c in absolute space. A source varying sinusoidally with time with the angular frequency $(-\omega)$ is then observed as

$$\sin(-\omega t^*), \qquad \text{where} \quad t^* = t - |\mathbf{r}_o - \mathbf{r}_s|/c \tag{4}$$

For the source and observer moving with constant absolute velocities $\mathbf{v}_s$ and $\mathbf{v}_o$, the positions $\mathbf{r}_s$ and $\mathbf{r}_o$ become

$$\mathbf{r} = \mathbf{s} + \mathbf{v}_s t, \qquad \mathbf{r}_o = \mathbf{r} + \mathbf{v}_o t \tag{5}$$

where $\mathbf{s}$ and $\mathbf{r}$ are positions at time $t = 0$.

Introducing the unit vector $\mathbf{c}/c$ in the direction of the instantaneous arrival of the wave as seen in absolute space, where

$$\mathbf{c}/c = [\mathbf{r}_o(t) - \mathbf{r}_s(t^*)] \, | \, \mathbf{r}_o(t) - \mathbf{r}_s(t^*)| \tag{6}$$

the retarded time t^* from Eqs. (4) and (5) is given by

$$t^* = t - \mathbf{c} \cdot (\mathbf{r} - \mathbf{s} + \mathbf{v}_o t - \mathbf{v}_s t^*)/c^2 \tag{7}$$

Substituting t^* from Eq. (7) into the first of Eqs. (4) yields

$$\sin\left\{\omega \, \frac{[\mathbf{c} \cdot (\mathbf{r} - \mathbf{s})/c - c(1 - \mathbf{c} \cdot \mathbf{v}_o/c^2)\, t]}{c(1 - \mathbf{c} \cdot \mathbf{v}_s/c^2)}\right\} \tag{8}$$

Since $\mathbf{s}$ is a constant, it merely indicates a change of the arbitrary origin for $\mathbf{r}$ and may be dropped. The observed wave is then of the form

$$\sin(\mathbf{k}' \cdot \mathbf{r} - \omega' t) \tag{9}$$

where

$$\mathbf{k}' = k\mathbf{c}/c(1 - \mathbf{v}_s \cdot \mathbf{c}/c^2), \qquad \omega' = \omega(1 - \mathbf{v}_o \cdot \mathbf{c}/c^2)/(1 - \mathbf{v}_s \cdot \mathbf{c}/c^2) \tag{10}$$

where $k = \omega/c$. This result (10) is the classical Doppler effect for uniformly moving source and observer. To complete the description, the two wave velocities, the phase velocity $\mathbf{c}'$ [Eq. (1)] and the velocity of energy propagation relative to the moving observer $\mathbf{c}^*$ [Eq. (2)], need to be mentioned. It may be noted from Eqs. (10) and (1) that $\mathbf{c}'/c'^2 = \mathbf{k}'/\omega'$, as it should.

3. VOIGT–DOPPLER EFFECT FOR LIGHT

3.1. Voigt–Doppler Effect for Stationary Source and Moving Observer

In order to predict the null Michelson–Morley result and similar standing wave experiments, the reasonable empirical assumption can be made that the magnitude of the phase velocity remains the same in a moving system. This is apparent from the fact that interference patterns are determined using the phase velocity. Following Wesley,[10] it is convenient to consider the invariant $c^2k^2 - \omega^2$. Linearizing this invariant symmetrically such that the component of $\mathbf{k}$ transverse to the direction of motion remains the same yields

$$\begin{gathered} c'k'_x = c\gamma_o(k_x - \omega v_o/c^2), \qquad c'k'_y = ck_y \\ c'k'_z = ck_z, \qquad \omega' = \gamma_o(\omega - k_x v_o) \end{gathered} \tag{11}$$

where

$$\gamma_o = 1/\sqrt{1 - v_o^2/c^2} \tag{12}$$

where the primed system is moving with the absolute velocity $\mathbf{v}_o$ in the positive x direction. This result (11) and (12) is best regarded as simply an empirical result to avoid questions as to the rigor of the derivation.

In order for the phase velocity to equal the velocity of energy propagation when $\mathbf{v}_o$ is parallel to $\mathbf{c}$ and to agree with the classical Doppler effect, the magnitude of the phase velocity $|\mathbf{c}'|$ is necessarily given by Eq. (1). The Voigt–Doppler effect for light for a stationary source and moving observer from Eqs. (1) and (2) is then uniquely

$$\begin{aligned} \mathbf{k}' &= k\,\frac{\gamma_o(c_x - v_o)\,\mathbf{e}_x + c_y\mathbf{e}_y + c_z\mathbf{e}_z}{c(1 - \mathbf{v}_o\cdot\mathbf{c}/c^2)} \\ \omega' &= \omega\gamma_o(1 - \mathbf{v}_o\cdot\mathbf{c}/c^2) \end{aligned} \tag{13}$$

where $\mathbf{e}_x$, $\mathbf{e}_y$, and $\mathbf{e}_z$ are unit vectors in the coordinate directions. The two wave velocities relative to the moving observer are then

$$\begin{aligned} \mathbf{c}'(\text{phase}) &= [\gamma_o(c_x - v_o)\,\mathbf{e}_x + c_y\mathbf{e}_y + c_z\mathbf{e}_z]/\gamma_o \\ \mathbf{c}^*(\text{energy}) &= \mathbf{c} - \mathbf{v}_o \end{aligned} \tag{14}$$

This result (13) and (14) may be compared with the classical Doppler effects, Eqs. (10), (1), and (2). It may be readily shown that Eqs. (13) yield a null result for the Michelson–Morley experiment for the case of a stationary source and a moving observer, which corresponds to the use of starlight as a source.

3.2. Voigt–Doppler Effect for Moving Source and Stationary Observer

From symmetry the roles of ω' for the moving observer and ω for the stationary source may be reversed in the second of Eqs. (13); so the frequency observed by a stationary observer ω_o produced by a moving source of frequency ω_s, with the absolute velocity $\mathbf{v}_s$, becomes

$$\omega_o = \omega_s/\gamma_s(1 - \mathbf{v}_s \cdot \mathbf{c}/c^2), \qquad \text{where} \quad \gamma_s = 1/\sqrt{1 - v_s^2/c^2} \tag{15}$$

Since the observer is stationary, the phase velocity relative to the observer is $\mathbf{c}' = \mathbf{c}$. From $\boldsymbol{k}_o = \mathbf{c}\omega_o/c^2$ the propagation constant from Eqs. (15) becomes

$$\mathbf{k} = k_s\mathbf{c}/c\gamma_s(1 - \mathbf{v}_s \cdot \mathbf{c}/c^2) \tag{16}$$

This result (15) and (16) is identical to the classical Doppler effect, Eqs. (10) for $\mathbf{v}_o = 0$, except for the v_s in the denomenator.

Since the invariance of $c_o^2 k_o^2 - \omega_o^2$ is preserved for a uniformly moving source, the Michelson–Morley null result is predicted whether the source moves or not.

3.3. Voigt–Doppler Effect for Both Source and Observer Moving

Substituting Eqs. (16) and (15) into (13), where $\boldsymbol{k}_o$ and ω_o replace $\mathbf{k}$ and ω, yields the Voigt–Doppler effect for a source moving with the absolute velocity $\mathbf{v}_s$ and an observer moving with the absolute velocity $\mathbf{v}_o$; thus,

$$\begin{aligned} \mathbf{k}' &= k_s \frac{\gamma_o(c_x - v_o)\,\mathbf{e}_x + c_y\mathbf{e}_y + c_z\mathbf{e}_z}{c\gamma_s(1 - \mathbf{v}_o \cdot \mathbf{c}/c^2)(1 - \mathbf{v}_s \cdot \mathbf{c}/c^2)} \\ \omega' &= \omega_s\gamma_o(1 - \mathbf{v}_o \cdot \mathbf{c}/c^2)/\gamma_s(1 - \mathbf{v}_s \cdot \mathbf{c}/c^2) \end{aligned} \tag{17}$$

The phase and energy velocities relative to the moving observer are again given by Eqs. (14), the velocity of the source not being involved.

For the case of an ether wind, which is appropriate for the Michelson–Morley experiment, the Voigt–Doppler effect from Eqs. (17) and (14), setting $\mathbf{v}_s = \mathbf{v}_o = v\mathbf{e}_x$, may also be shown to yield the Michelson–Morley null result.

4. OBSERVATIONS EXPLAINED BY THE VELOCITY OF ENERGY PROPAGATION

The measurement of the one-way velocity of arrival of light to the earth which does not involve a knowledge of the frequency or wavelength yields necessarily just the velocity of arrival of *energy*, since the other possible wave velocity, the phase velocity, defined as the wavelength times the frequency, is not known. The measurements of Roemer and Bradley, thus, yield the velocity of energy propagation of light c^*.[13] Since the Bradley aberration is the same for all stars independent of their possible absolute velocities, the velocity of energy propagation of light is c relative to absolute space (as assumed by Bradley). The Roemer result is also consistent with the assumption that the velocity of energy propagation of light is c fixed relative to absolute space (as assumed by Roemer). It also demonstrates that the velocity of light is, in fact, fixed in absolute space to within the fractional accuracy $V/c \approx 0.001$, where V is the velocity of the solar system. Assuming that the 2.7°K thermal cosmic background radiation is isotropic, then the velocity of energy propagation of light must be unique as c fixed in absolute space. The earth moving through absolute space receives this one-way thermal energy flux at a rate proportional to $c + v$ in the forward direction and $c - v$ in the rearward direction, where v is the absolute velocity of the earth, which accounts for the anisotropy observed (as assumed by Conklin who discovered the anisotropy).[7]

The Sagnac positive result[8] using moving equipment may be most easily explained in terms of the velocity of energy propagation of light being c fixed in absolute space (as assumed by Sagnac). The ingenious Marinov coupled-mirrors experiment[6] involves the one-way transit time of light in the laboratory. Making the assumption that the velocity of energy propagation of light is fixed in absolute space, Marinov measured the absolute velocity of the solar system in the closed laboratory. His result agrees with that obtained from the 2.7°K cosmic background anisotropy, but his accuracy is greater. He has recently obtained a similar result[14] with two toothed wheels mounted on the ends of a rotating shaft, which involves no mirrors at all.

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