Cracking the Enigma of the Sagnac Effect

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Abstract

One of the daunting problems in searching for a correct model of the speed of light is the contradiction between the Michelson-Morley experiment and the Sagnac effect. I have been working on a new theory called Apparent Source Theory (AST), which is based on three assumptions: 1. The effect of absolute motion of an inertial observer is to create an apparent change in the time of light emission. 2. The center of the light wave fronts moves with the same velocity as the absolute velocity of the inertial observer and the velocity of light depends on the mirror velocity relative to the observer 3. Two observers/detectors that happen to be at the same point in space at the same time instant and moving with equal velocities will observe identical physical phenomena (for example, fringe position). The third postulate is used to analyze light speed problems involving accelerating observers/detectors. AST has been successful in providing consistent explanations for many light speed experiments. However, the precise application of AST to the Sagnac effect has been a challenge for AST. In this paper, a new analysis of Sagnac effect based on AST is presented. One of the unexpected findings is that the light beam propagating in the same direction as the observer will take less time to reach the observer than the light beam propagating in the opposite direction. Unconventionally, the fringe shift in the Sagnac effect is not due to a difference in path lengths of the counter-propagating light beams, but due to difference in their velocities according to the ballistic hypothesis. Experimental testing of this claim is proposed.

Introduction

The problem of absolute motion and the speed of light has confounded physicists for centuries and decades. Many experiments have been performed to reveal the fundamental nature of light and the correct model underlying the speed of light, but these have only added more confusions than clarity. All classical and modern theories, including ether theory, emission theory, special relativity, and their variations, have failed to provide a consistent explanation and resolve the contradictions.

The special relativity theory is based on the assumptions of non-existence or non-detectability of absolute motion and constancy of the speed of light. While there are experiments that appear to support these, these assumptions are increasingly being challenged by other experimental evidences. Absolute motion effect has been detected in the Silvertooth, the Marinov and the Roland De Witte experiments. Apparent non-constancy of the speed of light has also been observed in the Venus planet radar ranging experiment and the Lunar Laser Ranging experiment, hinting that mirror velocity adds to the velocity of light.

One of the daunting problems in searching for a correct model of the speed of light is the contradiction between the Michelson-Morley experiment and the Sagnac effect. I have been working on a new theory called Apparent Source Theory (AST) [1][2][3][4][5][6][7],which has been successful in providing consistent explanations for many light speed experiments.

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However, the precise application of AST to the Sagnac effect has been a challenge for AST. In this paper, a new analysis of Sagnac effect based on AST is proposed.

We will first introduce Apparent Source Theory and then apply it to analyze the Sagnac effect.

Apparent Source Theory (AST)

We know that the Silvertooth, the Marinov and the Roland De Witte experiments have shown the existence of absolute motion. The question is: why did the Michelson-Morley experiment give a null result ?

Consider the Michelson-Morley experiment (Fig.1).

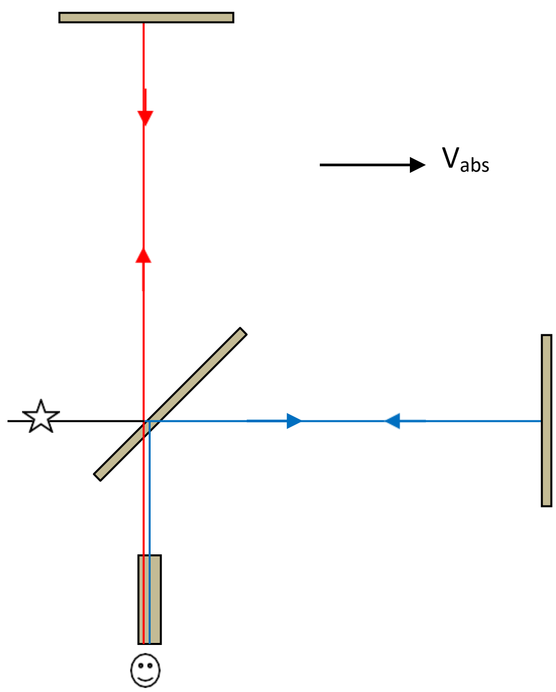


Fig. 1

Let us first see an intuitive explanation of why the Michelson-Morley experiments fail to detect absolute motion. According to AST, the effect of absolute motion of the Michelson-Morley experiment is to cause an apparent *change in the time of emission* of light [7]. The question follows : will change in time of emission of light cause a fringe shift? The answer is obviously: No. This is because both the longitudinal and transverse light beams will be delayed (or advanced) equally, hence no fringe shift occurs. So, relative to the detector of the Michelson-Morley experiment, the effect of absolute motion is only to create an apparent change in the time of light emission. Relative to the co-moving detector, neither the path length nor the speed of light is affected by absolute motion.

Consider a light source and an observer (Fig.2). Assume that the light emits a short light pulse at time t = 0. The observer is passing through point O at t = 0, moving with absolute velocity V_{abs} to the right.

Conventionally, the observer will meet the light pulse at point O'. Distances D' and Δ are determined by the fact that the time it takes the observer to move from O to O' is equal to the time it takes light to move from S to O'

$$\frac{D'}{c} = \frac{\Delta}{V_{abs}} \qquad . . . . \ (1)$$

But,

$$\Delta = D\cos\theta - \sqrt{(D')^2 - (D\sin\theta)^2} \qquad . \ . \ . \ (2)$$

D' and Δ can be determined from the last two equations.

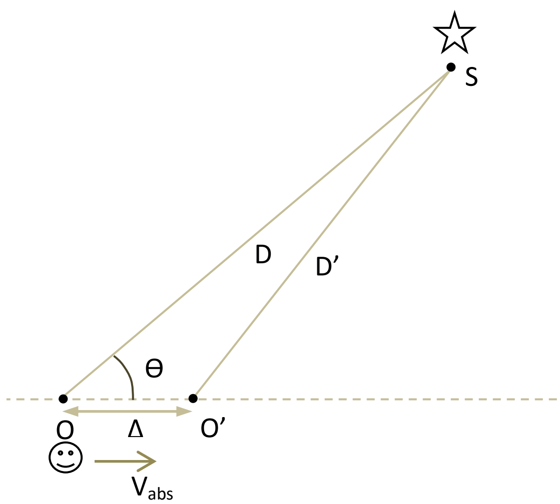


Fig. 2

From the conventional/classical analysis above, we will only adopt the values of Δ and D' in Apparent Source Theory.

We introduce the assumptions of Apparent Source Theory as follows.

1. The effect of absolute motion of an inertial observer is to create an apparent change in the time of light emission.
2. The center of the light wave fronts moves with the same velocity as the absolute velocity of the inertial observer and the speed of light depends on mirror velocity relative to the observer.

3. Two observers/detectors that happen to be at the same point in space at the same time instant and moving with equal velocities will observe identical physical phenomena (for example, fringe position).
The third postulate is used to analyze light speed problems involving accelerating observers/detectors.

Assume that the source emits a light pulse at $t = 0$, *relative to observer's at absolute rest*. Conventionally, the time of light emission is the same for all observers, regardless of their velocities. According to AST, the time instant of light emission depends on the absolute velocity of the observer. The instant of light emission for a moving observer differs from that of an observer at rest. The same event (emission of light) apparently occurs at different time instants depending on the absolute velocity of the observer.

Suppose that the observer is at point O (Fig.3), moving to the right with absolute velocity V_{abs}, at $t = 0$. According to AST, the light *for the moving* observer is not emitted at $t = 0$, but at an *earlier* time $t = - t_1$. Therefore, by the time light is emitted ($t = 0$) *for all observers at rest,* the light emitted for the moving observer will have already travelled distance SP in the moving observer's reference frame.

However, as in classical/conventional thinking, we assume that the moving observer and the observer at rest at point O' will detect the light simultaneously.

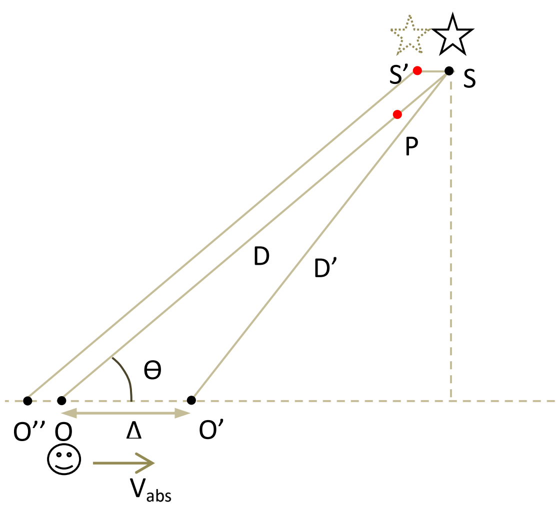


Fig. 3

It follows that, if the light for the moving observer is emitted at an earlier time $t = - t_1$, then the moving observer is at point O'' when light is emitted for the moving observer. Thus, for the moving observer, light is emitted at time $t = -t_1$ and from point S', with the center of the light wave fronts moving with the same velocity as the absolute velocity of the observer (V_{abs} to the right).Since the center of the light wave fronts moves with the same velocity as the velocity of the observer, it follows that the speed of light is equal to c relative to the moving observer, independent of the absolute velocity of the observer.

It follows that, if the moving observer and the stationary observer at point O’ are to detect the light simultaneously, then the distance PO should be equal to the distance SO’.

$$distance\ of\ line\ PO \ = \ distance\ of\ line\ SO'$$

The time of light emission ($-t_1$) is determined as follows.

$$t_1 \ = \ \frac{distance\ SO}{c} \ - \ \frac{distance\ SO'}{c} \ = \ \frac{D}{c} - \frac{D'}{c} \ = \ \frac{distance\ SP}{c} \quad . \ . \ . \quad (3)$$

where *D’* is determined from equations (1) and (2) .

At the instant of light emission for the moving observer *(t* = - t_1) , the (moving) observer is at point O’’ where :

$$distance\ OO'' = \ V_{abs}\ t_1 \quad . \ . \ . \quad (4)$$

Now consider the specific case where the observer is moving directly towards or away from the light source (Fig. 4). Consider an observer moving towards a light source with absolute velocity V_{abs} Suppose that the source emits a short light pulse at *t* = 0, while the moving observer is just passing through point O.

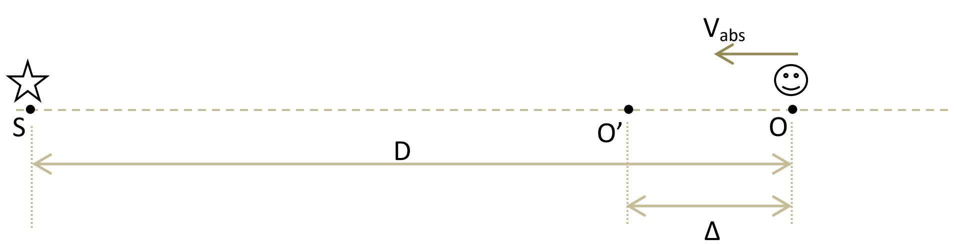


Fig. 4

Classically, we know that the observer meets the light pulse at point O’. To determine Δ, as before, we note that the time taken by the light pulse to move from S to O’ equals the time taken by the observer to move from O to O’, i.e.

$$\frac{D - \Delta}{c} = \frac{\Delta}{V_{abs}} \quad \Longrightarrow \quad \Delta \ = \ D\ \frac{V_{abs}}{c + V_{abs}} \quad . \ . \ . \quad (5)$$

We will use this classically obtained value for Δ in the following formulation of AST.

According to AST, as stated above, the time of emission of light (*t* = 0) applies only for observers at absolute rest. For the moving observer, light is emitted at an *earlier* time ($t = -t_1$),

, just as the observer is passing through point O’’ (Fig. 5), where:

$$distance\ O''O \ = \ V_{abs}\, t_1 \quad . \ . \ . \ (6)$$

And

$$t_1 \ = \ \frac{distance\ SO}{c} - \frac{distance\ SO'}{c} = \frac{D}{c} - \frac{D'}{c} = \frac{x}{V_{abs}} \quad . \ . \ . \ (7)$$

$$\Longrightarrow \ t_1 = \frac{D}{c} - (\frac{D-\Delta}{c}) = \frac{\Delta}{c} = \frac{1}{c}\ D\ \frac{V_{abs}}{c+V_{abs}} \quad . \ . \ . \ (8)$$

From which,

$$x \ = \ V_{abs}\ t_1 = V_{abs}\ \frac{1}{c}\ D\ \frac{V_{abs}}{c+V_{abs}} = \frac{V_{abs}}{c}\ \Delta \quad . \ . \ . \ (9)$$

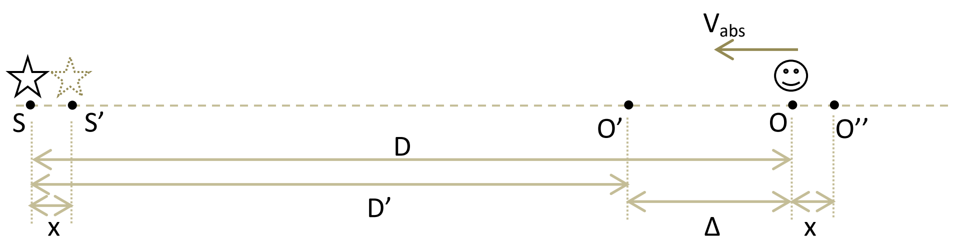


Fig. 5

Now consider the case of an observer moving directly away from a light source with absolute velocity V_{abs} (Fig.6). Suppose that the source emits a short light pulse at t = 0, while the observer is just passing through point O. Classically, we know that the observer meets the light pulse at point O’.

To determine Δ, we note that the time interval taken by the light pulse to move from S to O’ equals the time taken by the observer to move from O to O’, i.e.

$$\frac{D+\Delta}{c} = \frac{\Delta}{V_{abs}} \quad \Longrightarrow \quad \Delta \ = \ D\ \frac{V_{abs}}{c - V_{abs}} \quad . \ . \ . \ (10)$$

As before, we will use this value for Δ in the formulation of AST below.

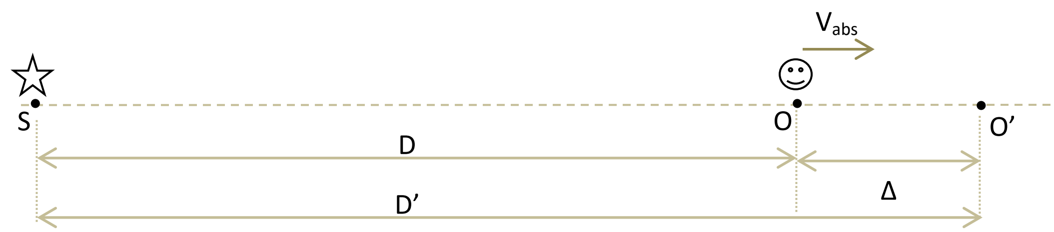


Fig. 6

According to AST, as stated above, the time of emission of light ($t = 0$) applies only for observers at absolute rest. For the moving observer, light is emitted at a *later* time ($t = t_1$),

, just as the observer is passing through point O'' (Fig.7) , where:

$$distance\ OO'' \ = \ V_{abs}\, t_1 \qquad . \ . \ . \ (11)$$

And

$$t_1 \ = \ \frac{distance\ SO'}{c} - \frac{distance\ SO}{c} = \frac{D'}{c} - \frac{D}{c} = \frac{x}{V_{abs}} \qquad . \ . \ . \ (12)$$

$$\Longrightarrow t_1 = \frac{D + \Delta}{c} - \frac{D}{c} = \frac{\Delta}{c} = \frac{1}{c}\ D\ \frac{V_{abs}}{c - V_{abs}} \qquad . \ . \ . \ (13)$$

From which,

$$x = V_{abs}\ t_1 = V_{abs}\ \frac{1}{c}\ D\ \frac{V_{abs}}{c - V_{abs}} = \frac{V_{abs}}{c}\ \Delta \qquad . \ . \ . \ (14)$$

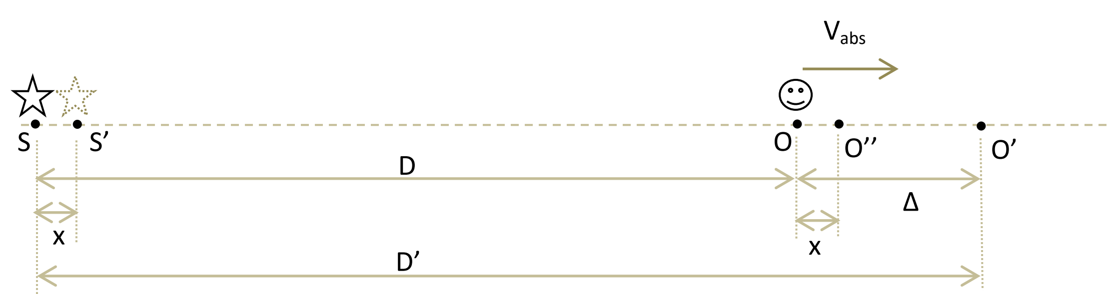


Fig. 7

General formulation of modified Apparent Source Theory

Now we will present the quantitative analysis for the case of an inertial observer moving in an arbitrary direction relative to the light source. We have already seen the qualitative analysis (Fig.3).

Consider a light source and an observer moving with absolute velocity V_{abs} to the right (Fig.8). Let us start with the conventional view again. At the instant of light emission (t = 0) , the distance between the source and the observer is D. However, this statement is based on conventional view because we are assuming that the light is emitted at t = 0 *for all observers*. Conventionally, the instant of emission of a light pulse is the same for all observers, and only the instant of detection of light differs between observers depending on their position and velocity.

According to the new theory proposed in this paper, however, (absolute) motion of an observer not only changes the time of light detection but also the (apparent) *time of light emission*! For observers at different positions and moving with different velocities, the times of emission of the same light pulse are different!

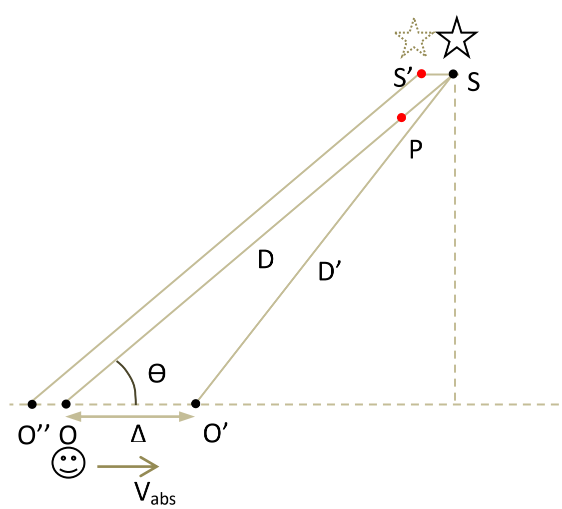


Fig. 8

At t = 0 the source emits a short light pulse (for observers at rest) and the moving observer is just passing through point O. The light for the moving observer is emitted earlier, at $t = - t_1$.
At $t = - t_1$ light is emitted *for the moving observer* from point S', with the center of the wave fronts moving with the same velocity as the velocity of the observer (V_{abs} to the right). At $t = - t_1$ the moving observer is at point O'', where:

$$distance\ O''O = \ V_{abs}\, t_1 = x \qquad . \quad . \quad . \quad (15)$$

Therefore, by the time the observer arrives point O, the light for the moving observer will have travelled a distance SP, in the reference frame of the observer.

$$distance\ SP = c\, t_1 \qquad . \ . \ . \ (16)$$

This means that during the time interval that the observer moves distance O''O , light moves distance SP.

The time of light emission for the moving observer is determined as follows.

$$t_1 = \frac{D}{c} - \frac{D'}{c} \qquad . \ . \ . \ (17)$$

But *D'* and Δ are determined from equations (1) and (2) re-written below.

$$\frac{D'}{c} = \frac{\Delta}{V_{abs}} \qquad . \ . \ . \ (18)$$

and

$$\Delta = D\cos\theta - \sqrt{(D')^2 - (D\sin\theta)^2} \qquad . \ . \ . \ (19)$$

<u>The velocity of light depends on mirror velocity</u>

This is not as such a separate assumption but a consequence of the other assumptions.

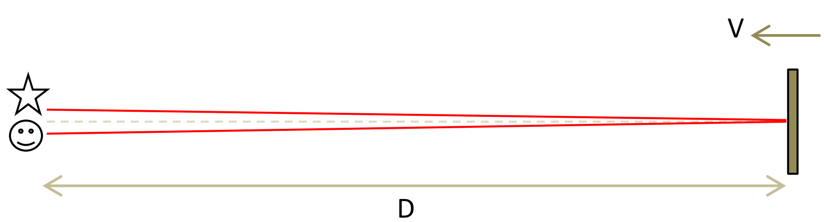


Fig. 9

According to AST, the velocity of light is $c \pm 2V$, where V is a component of the mirror velocity perpendicular to its surface, relative to the observer.

The new model described so far can give a consistent explanation of many light speed experiments such as the Michelson-Morley experiments, stellar aberration, moving source, moving mirror and moving observer experiments, the Sagnac effect, the Silvertooth and the Marinov experiments. Next I will present application of AST to the Sagnac effect, which is the main purpose of this paper.

The Sagnac effect

Although the Sagnac effect involves an accelerating observer/detector, it can be analyzed with sufficient accuracy by assuming an inertial observer/detector as follows.

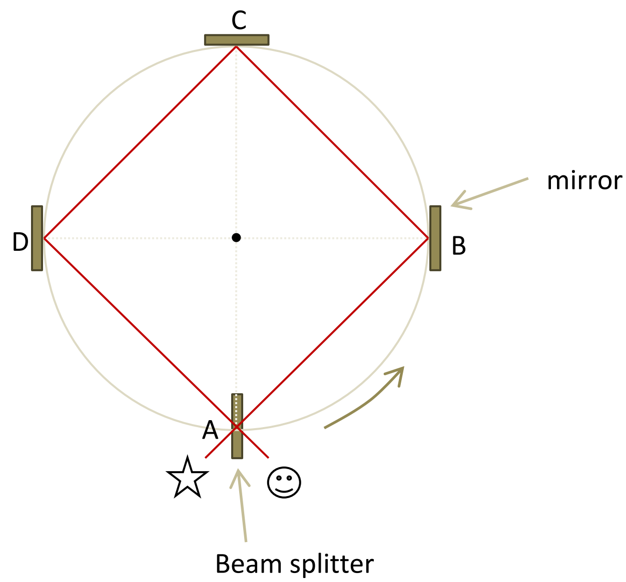


Fig. 10

For simplicity, we assume that the light source and the observer/detector are very close to the point on the mirror where light strikes the mirror. Also we assume that ABCD is a square.

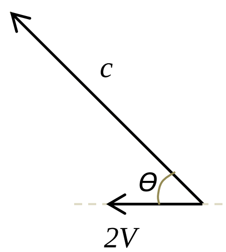
The observer is moving *to the right* with velocity V where:

$$V = \omega R$$

The center of the light wave fronts moves with the same velocity as the observer. This means that the center of the light wave fronts is at a fixed point relative to the observer. *The speed of light is always constant relative to the center of the wave fronts*.

We can assume the observer to be at rest at point A, but the mirrors moving with velocity V *to the left*. Therefore, we also assume that the center of the light wave fronts also is fixed at A.

The counterclockwise light beam moves with velocity from point A to point B. However, after reflection from mirror B, the light acquires the velocity of the mirror, which is V to the left. According to the ballistic hypothesis, the velocity of the reflected light is the vector sum of c and 2V, as shown below.



The resultant velocity of the CCW light reflected from mirror B will be:

$$\sqrt{c^2 + (2V)^2 + \ 2\,c\,(2V\,)\cos\theta} \qquad . \ . \ . \ (20)$$

where Θ is 45^0 in this case.

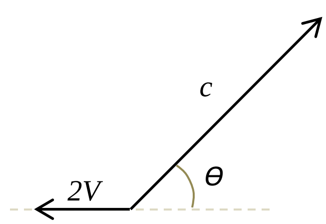
Therefore, the resultant velocity will be:

$$c' = \sqrt{c^2 + (2V)^2 + \ 2\,c\,(2V\,)\cos 45^0} \ = \sqrt{c^2 + (2V)^2 + \ c\,(2V)\sqrt{2}} \qquad . \ . \ . \ (21)$$

The CCW light beam will move with this speed the path BCD (velocity of mirror C will have no effect on the speed of the CW and CCW light beams).

The velocity of the CCW light is affected by the mirror D is moving to the left with velocity *V* and therefore will be equal to *c* after reflection.

The clockwise (CW) propagating light beam will move with velocity *c* between points A and D. However, the velocity of the CW will be affected by the velocity of mirror D, as shown below.



The resultant velocity of CW light reflected from the mirror D will be:

$$\sqrt{c^2 + (2V)^2 + \ 2\,c\,(2V\,)\cos\,(180 - \theta)}$$

$$= \sqrt{c^2 + (2V)^2 - \ 2\,c\,(2V\,)\cos\ \theta}$$

where Θ is 45^0 in this case.

Therefore, the resultant velocity will be:

$$\sqrt{c^2 + (2V)^2 - \ 2\,c\,(2V\,)\cos 45^0} \;=\; \sqrt{c^2 + (2V)^2 - \ c\,(2V)\sqrt{2}} \qquad . \;\; . \;\; . \;\; (22)$$

The CW light beam moves with this velocity along the path DCB. After reflection from mirror B, the velocity of the CW light beam will be equal to *c*.

We can see that both the CW and CCW light beams move with velocity c along the paths AB and AD. The velocities of the two light beams differ along the path BCD, with path length of 2L, and this is what causes the fringe shift of the Sagnac effect.

The difference in arrival times of the CW and CCW light beams at the observer will be:

$$\Delta\tau = \frac{2L}{\sqrt{c^2 + (2V)^2 - c\,(2V)\,\sqrt{2}}} - \frac{2L}{\sqrt{c^2 + (2V)^2 + c\,(2V)\sqrt{2}}} \qquad . \;\; . \;\; . \;\; (23)$$

$$= \frac{\frac{2L}{c}}{\sqrt{1 + \frac{(2V)^2}{c^2} - \sqrt{2}\frac{(2V)}{c}}} - \frac{\frac{2L}{c}}{\sqrt{1 + \frac{(2V)^2}{c^2} + \sqrt{2}\frac{(2V)}{c}}}$$

Using the Taylor series expansion:

$$\frac{1}{\sqrt{1 + x}} = 1 - \frac{x}{2} + \frac{3x^2}{8} - \frac{5x^3}{16} + \;.\;\;.\;\;.$$

$$\Delta\tau \cong \frac{2L}{c}\left(1 + \frac{\sqrt{2}}{2}\;\frac{(2V)}{c} + \frac{3}{8}\;\frac{2(2V)^2}{c^2}\right) - \frac{2L}{c}\left(1 - \frac{\sqrt{2}}{2}\;\frac{(2V)}{c} + \frac{3}{8}\;\frac{2(2V)^2}{c^2}\right)$$

$$\Delta\tau = \frac{4\sqrt{2}\,LV}{c^2} \qquad . \;\; . \;\; . \;\; (24)$$

Let us check this result against the well-known Sagnac effect formula for the time difference between the two counter-propagating light beams.

$$\Delta\tau = \frac{4A\omega}{c^2} \qquad . \;\; . \;\; . \;\; (25)$$

where A is the area of the closed path, which is a square in this case.

$$A = L^2 \quad \text{and} \quad \omega = \frac{V}{R}$$

where R is the radius of the circle.

But

$$R = \frac{L}{\sqrt{2}}$$

Therefore,

$$\omega = \frac{V}{R} = \frac{V}{\frac{L}{\sqrt{2}}} = \sqrt{2}\ \frac{V}{L}$$

Substituting the above values:

$$\Delta\tau = \frac{4A\omega}{c^2} = \frac{4L^2\ \sqrt{2}\ \frac{V}{L}}{c^2} = \frac{4\sqrt{2}\ LV}{c^2} \quad . \ . \ . \ (26)$$

which is the same as equation (24).

In the above analysis of Sagnac effect, we have assumed that the light beams enclose a square area, i.e. $L_1 = L_2 = L$. Next we analyze the general case of rectangular area where $L_1 \neq L_2$ (Fig.11).

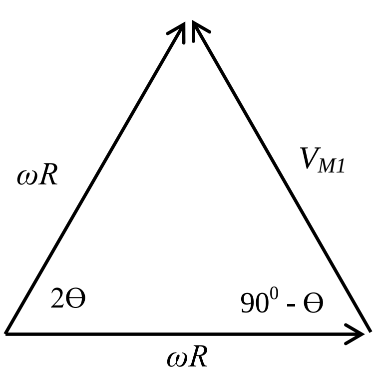
(In this case, we designate the mirrors as M1, M2, M3 , instead of A, B, C, for convenience)

We first determine the velocities of the mirrors relative to the observer.

<u>Relative velocities of the mirrors (that is, velocity of each mirror relative to the observer)</u>

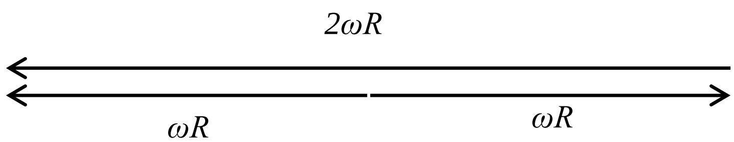
Let the velocity of mirror M1 relative to the observer be V_{M1} , the velocity of M2 relative to the observer be V_{M2} and the velocity of M3 relative to the observer be V_{M3}.

<u>Velocity of mirror M1 relative to the observer</u>



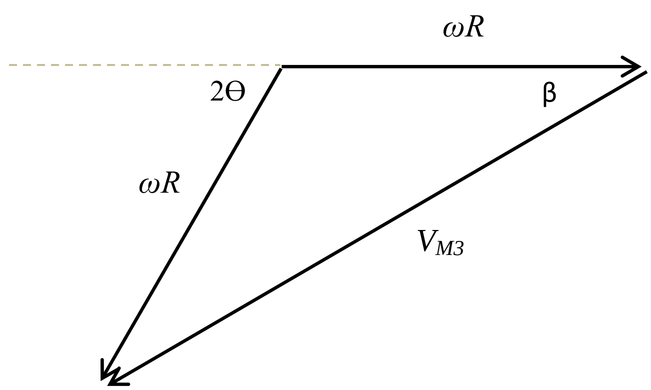
$$V_{M1} = \sqrt{2\omega^2 R^2 \,(1 - \cos 2\theta)}$$

Velocity of mirror M2 relative to the observer



$$V_{M2} = \quad 2\omega R$$

Velocity of mirror M3 relative to the observer



where

$$\frac{\sin \beta}{\omega R} = \frac{\sin(180 - 2\theta)}{V_{M3}}$$

$$V_{M3} = \sqrt{2\omega^2 R^2 \,(1 - \cos(180 - 2\theta))}$$

Next we determine velocities of each light beam (CW and CCW beams) along each segment of their paths. (Fig.11)

Counter Clockwise (CCW) beam

Path O – M1

Velocity of light = *c* (This is because, according to the theory already proposed in this paper, the speed of light is constant relative to the center of the light wave fronts and the center of the light fronts is at rest relative to the observer.)

Path M1-M2

Component of mirror M1 relative velocity (V_{M1}) along perpendicular to mirror (blue line):

$$V_1 = V_{M1} \cos 45^0 = \sqrt{2\omega^2 R^2 \,(\,1 - \cos 2\theta)} \;\cos 45^0$$

Velocity of light along the path M1-M2:

$$V_{12} = \sqrt{c^2 + (2V_1)^2 + 2\,c\,(2V_1)\cos 45^0}$$

The $2V_1$ is because the velocity of light reflected from a moving mirror is $c \pm 2v$, where v is the component of the velocity of the mirror along the perpendicular.

Path M2-M3

Component of mirror M2 relative velocity (V_{M2}) along perpendicular to mirror (blue line):

$$V_2 = V_{M2} \cos(45^0 + \theta) = 2\omega R \cos(45^0 + \theta)$$

Velocity of light along the path M2-M3:

$$V_{23} = \sqrt{{V_{12}}^2 + (2V_2)^2 + 2\,V_{12}\,(2V_2\;)\cos 45^0}$$

Path M3 - O

Component of mirror M3 relative velocity (V_{M3}) along perpendicular to mirror:

$$V_3 = V_{M3} \cos(45^0 - \theta + \beta)$$

$$= \sqrt{2\omega^2 R^2 \,(\,1 - \cos(180 - 2\theta))} \;\cos(45^0 - \theta + \beta)$$

Velocity of light along the path M3 - O:

$$V_{3O} = \sqrt{{V_{23}}^2 + (2V_3)^2 + 2\,V_{23}\,(2V_3\ )\cos 135^0}$$

Clock Wise (CW) beam

Path O – M3

Velocity of light = c

Path M3-M2

Velocity of light along the path M3 – M2:

$$V_{32} = \sqrt{c^2 + (2V_3)^2 + 2\,c\,(2V_3)\cos 135^0}$$

Path M2-M1

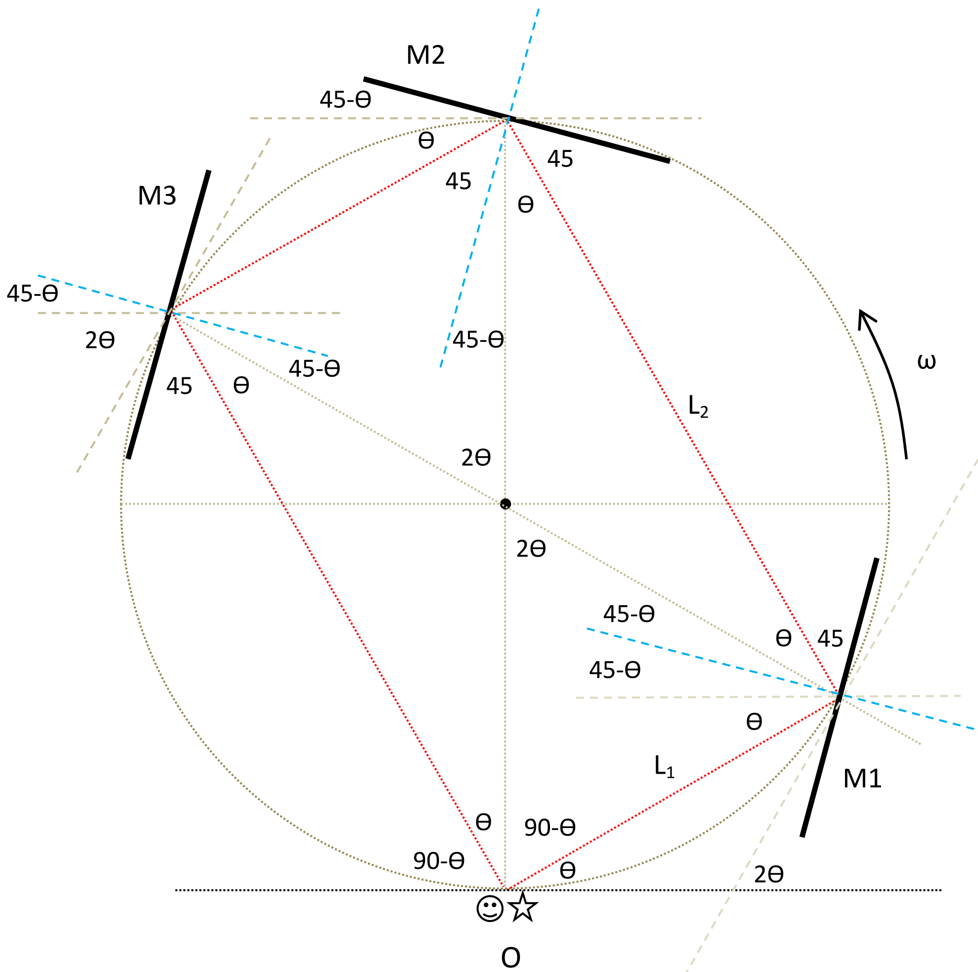
Velocity of light along the path M2 – M1:

$$V_{21} = \sqrt{{V_{32}}^2 + (2V_2)^2 + 2\,V_{32}\,(2V_2\ )\cos 45^0}$$

Path M1-O

Velocity of light along the path M1 – O:

$$V_{1O} = \sqrt{{V_{21}}^2 + (2V_1)^2 + 2\,V_{21}\,(2V_1\ )\cos 45^0}$$


M2
45-Θ
Θ
45
45
Θ
M3
45-Θ
2Θ
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M1
Θ
90-Θ
90-Θ
Θ
2Θ
O

Fig. 11

From the velocities of each beam along the different segments and path lengths, the time difference between the CCW and CW, and therefore the fringe shift, can be calculated. Since analytical analysis of these equations will be more involved, numerical method can be used to compute the fringe shift, and compare the result with the classical result which has been confirmed by experiments.

Using Ms Excel I have confirmed that the prediction of the new theory matches the classical formula of Sagnac effect:

$$\Delta\tau = \frac{4A\omega}{c^2}$$

For

$$\theta = 30^0 \ , \mathrm{R} = 1\mathrm{m}\ , \omega = 0.1\frac{\mathrm{rad}}{\mathrm{s}}, \text{we get:}$$

we get:

$$L1 = 1m \ , \ L2 = \sqrt{3}\, m$$

$$V_{M1} = 1.000000000000E-01$$

$$V_{M2} = 2.000000000000E-01$$

$$V_{M3} = 1.732050807569E-01$$

$$V_1 = 7.071067811865E-02$$

$$V_2 = 5.176380902050E-02$$

$$V_3 = 1.224744871392E-01$$

$$V_{12} = 3.000000001000E+08$$

$$V_{23} = 3.000000001732E+08$$

$$V_{3O} = 3.000000000000E+08$$

$$V_{32} = 2.999999998268E+08$$

$$V_{21} = 2.999999999000E+08$$

$$V_{1O} = 3.000000000000E+08$$

From these values , the times of the counter clockwise beam and the clockwise beam will be:

$$\tau_{ccw} = 1.821367204661E-08$$

$$\tau_{cw} = 1.821367205431E-08$$

The time difference between the counterclockwise and the clockwise beams will be:

$$\Delta t = \tau_{cw} - \tau_{ccw} = 7.698007478214E-18$$

From the classical formula:

$$\Delta\tau = \frac{4A\omega}{c^2}$$

where

$$A = area = L_1 * L_2 = \sqrt{3}$$

Therefore,

$$\Delta\tau = \frac{4A\omega}{c^2} = \frac{4 * \sqrt{3} * 0.1}{(3 * 10^8)^2} = 7.6980036 * 10^{-18}$$

The fringe shift will be:

$$N = \frac{c * \Delta\tau}{\lambda} = \frac{3 * 10^8 * 7.6980036 * 10^{-18}}{600 * 10^{-9}} = 3.849 * 10^{-3}$$

The fringe shift for the new theory will be:

$$N = \frac{c * \Delta\tau}{\lambda} = \frac{3 * 10^8 * 7.698007478214 * 10^{-18}}{600 * 10^{-9}} = 3.849 * 10^{-3}$$

Therefore, the fringe shifts agree to a high degree of precision ! This model should also correctly apply to Sagnac experiments with arbitrary areas enclosed by the light beams.

The Sagnac effect has been an extremely knotty problem and perhaps the single most challenging problem I faced during the years of theoretical research. The reconciliation of the null fringe shift of the Michelson-Morley experiment with the fringe shift in the Sagnac effect has been a daunting problem faced by researchers. The successful analysis of the Sagnac effect presented in this paper can thus be seen as the conclusion of this research.

The question arises: how can the Michelson-Morley experiment and the Sagnac effect be explained with a single model of the speed of light? Why do the Michelson-Morley experiments give null fringe shift? We have already discussed a brief explanation of the Michelson-Morley experiment in this paper. However, a more insightful analysis of the Michelson-Morley experiment is found in the APPENDIX.

Conclusion

The contradiction between the Michelson-Morley experiment and the Sagnac effect is perhaps the most challenging problem of the speed of light. There is no model of the speed of light so far that provides consistent explanations for these experiments. I have been working on a new theory called Apparent Source Theory (AST) for years. Even though I knew from the beginning the potential of AST to explain the Sagnac effect, the actual quantitative analysis which gives the simple Sagnac effect formula we know remained a daunting task. The new analysis presented in this paper is a significant progress in the development of AST. However, there are still a few remaining challenges to be overcome.

Glory be to Almighty God Jesus Christ and His Mother Our Lady Saint Virgin Mary.

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Why Michelson-Morley Experiments Give Null Result

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Abstract

Many researchers and physicists, including renowned scientists, have long questioned the foundations of relativity theory, which are the two postulates: the principle of relativity and the constancy of the speed of light, and their consequences. However, what exactly is wrong with relativity theory has eluded researchers for more than a century. This paper reveals the mystery of why the Michelson-Morley experiments always give null fringe shifts, contrary to other experimental evidences of absolute motion, such as the Silvertooth experiment and the Marinov experiment. A new theory/model of the speed of light is formulated as follows. The effect of absolute motion of the Michelson-Morley device is just to cause *an apparent change in the time of emission of light from the source*. Thus, both the longitudinal and transverse light beams are delayed or advanced equally, *by the same amount*, in which case no fringe shift will occur. The center of the light wave fronts is always the same point *relative to the observer*/detector between the moments of light emission and light detection. The center of the light wave fronts is fixed at the point where the source was *relative to the detector* at the moment of emission and is always fixed in the reference frame of the detector (relative to the detector) and is therefore always co-moving with the observer/detector. The speed of light is constant *c* relative to the center of the light wave fronts, and therefore it is always constant relative to the observer. The mystery behind the Michelson-Morley experiment is that it is impossible to detect absolute motion from the interference pattern formed by light beams originating from a *single* source! Therefore, the key to detect absolute motion by using the Michelson-Morley kind experiments would be by interference of light beams from two *independent* sources. Such hypothetical experiment would give thousands of fringe shifts. However, such experiment is not possible with current technology, because the coherence time/length of light is very short, and because it is nearly impossible to tune the frequencies of two independent laser sources to be equal to within, say, 0.1 to 1 Hz to get any fringe patterns stable enough to see if a fringe shift occurs with change in orientation of the modified MM device in space.

Introduction

The null result of the Michelson-Morley experiments, both the classical and modern, are considered to be the single most important experimental evidence for the principle and theory of relativity. On the other hand, experimental, theoretical and logical counter-evidences against relativity theory are accumulating from time to time [1][2]. The Silvertooth experiment and the Marinov experiment have detected large first order effects of absolute motion. Therefore, the problem of whether absolute motion exists and can be detected is still an unsettled problem nearly one hundred years after the birth of Albert Einstein's relativity theory.

Many researchers and physicists, including renowned scientists, have questioned the foundations of relativity theory, which are the two postulates: the principle of relativity and the constancy of the speed of light, and their consequences such as time dilation and length contraction. Researchers have long known that there is something wrong with relativity theory. However, what exactly is wrong with relativity

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theory has eluded physicists and researchers for more than a century. This paper reveals the mystery of why the Michelson-Morley experiments give null results, despite other experiments that have detected absolute motion.

A new theory of the Michelson-Morley experiment

A new theory of the speed of light is formulated as follows. The effect of absolute motion on the Michelson-Morley device is just to cause *a change in the time delay* of the longitudinal and transverse light beams *by the same amount*, in which case no fringe shift will occur. Both the longitudinal and the transverse light beams are delayed or advanced *equally*, so no fringe shift is expected. The mystery behind the Michelson-Morley experiment is that it is impossible to detect absolute motion from the interference pattern of light beams originating from a *single* source!

Thus, the effect of absolute motion on the Michelson-Morley experiment (MMX) is just to create an additional a time delay (or time advance) of light detection at the observer/detector compared to the time delay when the MM apparatus is at rest. This additional time delay (or time advance) is determined solely by the *direct* distance *D* (Fig.1) between the detector/observer and the light source and angle Θ *at the moment of emission* and the magnitude and direction of absolute velocity.

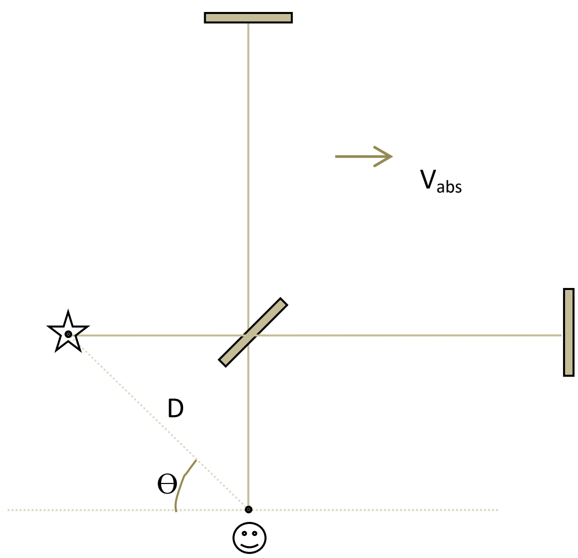

Fig. 1

According to the new theory, the effect of absolute motion of the Michelson-Morley device is to create an additional delay of τ in all the light beams reaching the observer. That is, if the light coming to the detector *directly* from the source undergoes an additional time delay of τ due to absolute motion, then the light beams coming to the detector after reflection from mirrors co-moving with the observer/detector will also be delayed by the same amount τ !

To restate the above clearly, consider three light beams reaching the observer, one coming directly from the source and the other two coming after reflection from mirrors co-moving with the observer. Note that this does not mean that there must be a light beam actually coming to the detector directly from the source necessarily. For example, light directly coming to the observer could be blocked by placing a plate between the source and the observer/detector. *In order to determine how absolute motion affects light coming to the detector after reflecting from the mirror, we determine how absolute motion would affect (delay or advance) light coming to the observer* <u>*directly*</u> *from the source. If the light coming to the detector directly from the source is delayed by τ, then light coming to the observer after reflection from a mirror co-moving with the observer will also be delayed by the same amount τ* !

Absolute motion causes equal delays of all the three light beams reaching the observer/detector. Thus, no fringe shift will occur in the Michelson-Morley experiment because both the longitudinal and transverse light beams will be affected identically/equally by absolute motion of the apparatus. *Both* of the light beams are delayed by τ compared to the case when the MM apparatus is at rest. This is why, according to the new theory, the Michelson-Morley experiment is not capable of detecting absolute motion. This is unlike ether theory which predicts a fringe shift.

To formulate the new theory, consider an observer moving relative to the absolute reference frame, (Fig.2). At first we analyze this experiment classically as follows.

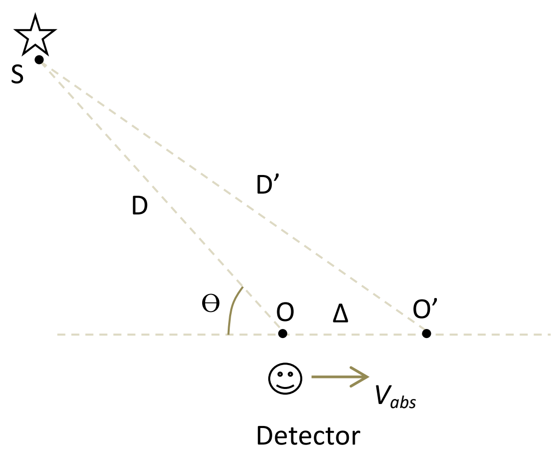

Fig. 2

Let the light source emit a short light pulse at the time instant t = 0. At the moment of emission, the observer is at point O in the absolute reference frame and moving with velocity V_{abs} to the right, as shown. The point of light emission is at distance D and angle Θ relative to the observer/detector, at the moment of emission. Let the observer detect the light pulse at point O'. To determine D' and Δ we proceed classically as follows.

During the time interval that the light moves from point S to point O', the observer moves from point O to point O'. That is:

$$\frac{D'}{c} = \frac{\Delta}{V_{abs}}$$

From the triangle SOO'

$$D' = \sqrt{D^2 + \Delta^2 - 2D\Delta\cos(180^0 - \theta)}$$

Therefore, given *D*, *Θ* and V_{abs}, *D'* and *Δ* can be determined from the last two equations.

Combining the last two equations :

$$D'^2\left(1 - \frac{V_{abs}{}^2}{c^2}\right) - D'\left(2D\,\frac{V_{abs}}{c}\right)cos\theta \,-\, D^2 = 0 \quad . \; . \; . \quad (1)$$

from which *D'*, and then *Δ* are determined.

$$D' = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{\left(2D\,\frac{V_{abs}}{c}\right)cos\theta \;+\; \sqrt{\left(\;\left(2D\,\frac{V_{abs}}{c}\right)cos\theta\;\right)^2 + 4\left(1 - \frac{V_{abs}{}^2}{c^2}\right)D^2}}{2\left(1 - \frac{V_{abs}{}^2}{c^2}\right)}$$

$$\Longrightarrow \quad D' = \frac{\left(D\,\frac{V_{abs}}{c}\right)cos\theta \;+ D\sqrt{1 \,-\, \frac{V_{abs}{}^2}{c^2}\,sin^2\theta}}{\left(1 - \frac{V_{abs}{}^2}{c^2}\right)} \qquad . \; . \; . \; . \quad (2)$$

$$\Longrightarrow \quad D' = D\left(\,1 + \frac{V_{abs}}{c}\,cos\theta\right) \quad , \qquad for \qquad V_{abs} \ll c \quad . \; . \; . \; . \quad (3)$$

Absolute motion of the observer causes an additional time delay of the light, given by:

$$\tau = \frac{D'}{c} - \frac{D}{c} = \frac{D\left(\,1 + \frac{V_{abs}}{c}\,cos\theta\right)}{c} - \frac{D}{c} = \frac{D}{c}\,\frac{V_{abs}}{c}\,cos\theta \quad . \; . \; . \quad (4)$$

A new interpretation

There is nothing new in the classical analysis we have done so far. What is new is the interpretation we are going to give next. Suppose that we add a mirror that is co-moving with the observer to the above experiment (Fig.3). Now we have two light beams reaching the observer/detector: one light beam directly from the source and the other light beam after reflection from the co-moving mirror. We have shown that the light beam coming to the observer/detector directly from the source is additionally delayed by an amount τ given by equation (4) because of observer's motion . The new finding is that, unconventionally, *the light beam reaching the observer after reflecting from the mirror will also be additionally delayed by* *the same amount* τ . This is the century-old mystery behind the null result of the Michelson-Morley experiment. At this point the reader should note the distinction that this is not even in accordance with ether theory. The ether doesn't exist but absolute motion does exist. Not surprisingly, the two have always been (wrongly) considered to be synonymous.

Therefore, in the conventional Michelson-Morley experiment both the longitudinal and transverse light beams are delayed (or advanced) equally/identically due to absolute motion, therefore no fringe shift is expected.

The new theory proposed in this paper is that the effect of absolute motion of the observer is just to create an apparent change in the moment of emission of light. Thus, if the moment of light emission is apparently delayed by τ, then all light beams reaching the observer will be delayed by the same amount, whether it is the light coming to the observer directly from the source or light coming to the observer after reflecting from a co-moving mirror.

The effect of absolute motion of the Michelson-Morley interferometer is just to cause *an apparent change in the time of emission of light from the source*. Thus, both the longitudinal and transverse light beams of the conventional Michelson-Morley experiment are delayed or advanced *by the same amount*, in which case no fringe shift will occur. Both the longitudinal and the transverse light beams are delayed or advanced *equally*, so no fringe shift is expected. The center of the light wave fronts is always at the same point *relative to the observer*/detector between the moments of light emission and light detection. *The center of the light wave fronts is fixed at the point where the source was relative to the detector at the moment of emission and is always fixed in the reference frame of the detector and is therefore always co-moving with the detector*. *The speed of light is constant relative to the center of the light wave fronts, and therefore it is always constant relative to the observer*.

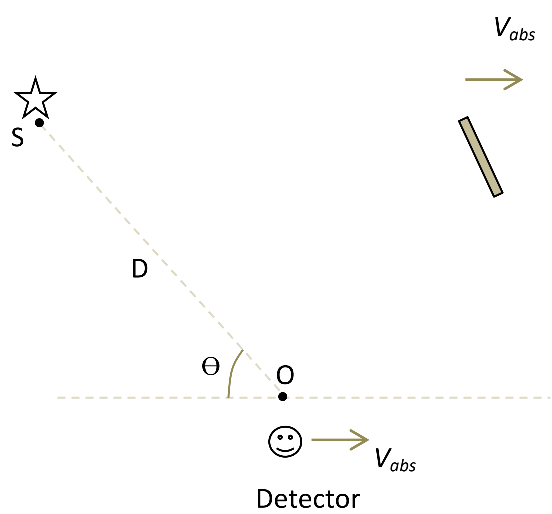

Fig. 3

A hypothetical Michelson-Morley experiment

From the above analysis we have seen that it is impossible to detect absolute motion by using conventional Michelson-Morley kind interferometer experiments. This is because absolute motion of the Michelson-Morley device will not cause any *change in the time difference* of two light rays originating from a *single* source, taking different paths to reach the point of detection. The effect of absolute motion is only to cause *equal time changes* (time delay or time advance) to *both* the light rays, which will not cause any fringe shift.

The key to detect absolute motion by using the Michelson-Morley kind experiments would be by interference of light from two *independent* sources. However, such experiment is not feasible with current technology because the coherence time/length of light is very short and because it is impossible to tune the frequency of two laser sources to be equal to within, say, 0.1Hz to get any 'stable' fringe patterns. In this paper we analyze such experiment and show that it would give thousands of fringe shifts when the orientation of the device in space is changed. Unfortunately, this is only a hypothetical experiment because it is practically impossible to realize. Since rotating the device and observing the fringe positions can take, say, at least 30 seconds, we would need laser sources with coherence time of at least 30 seconds. One might ask: then why analyze an experiment that is known to be practically impossible? We do this to clearly reveal the mystery that has eluded physicists for one century.

We will first consider the effect of absolute motion on the light beam from S2.

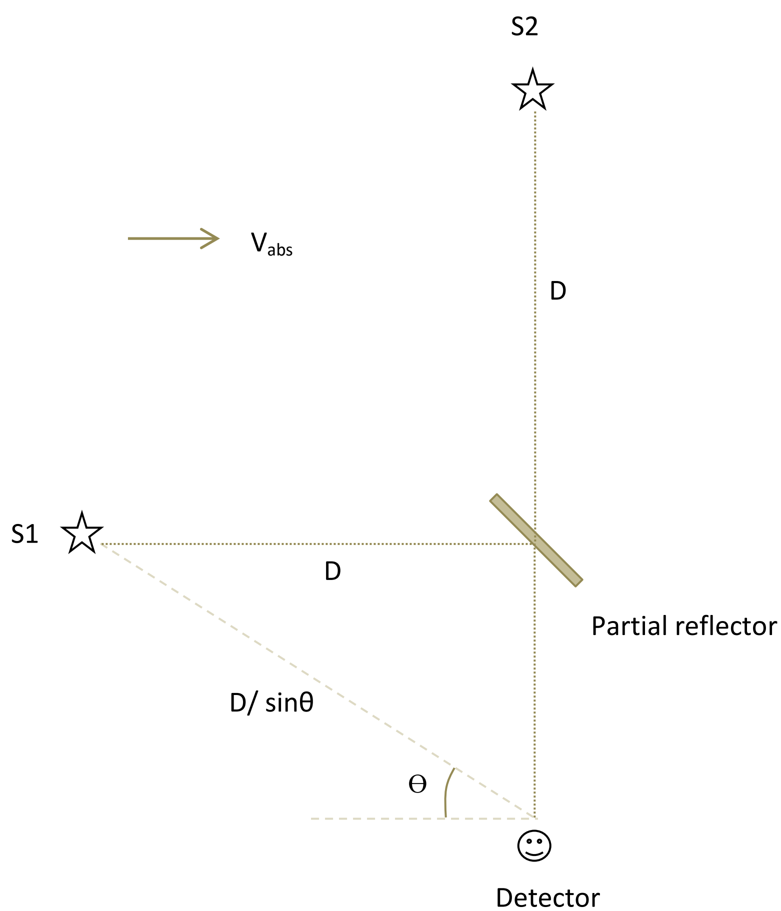

Fig. 4

It can be shown that the effect of absolute motion on the light beam from S2 is negligible because the position of S2 relative to the observer is orthogonal to the direction of absolute velocity. This can be shown by substituting θ = 90^0 in equation (2), which will give:

$$D' = \frac{\left(D\,\frac{V_{abs}}{c}\right)cos\theta \; + D\sqrt{1 - \frac{{V_{abs}}^2}{c^2}\,sin^2\theta}}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)} = \frac{D\sqrt{1 - \frac{{V_{abs}}^2}{c^2}}}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)}$$

Therefore,

$$\tau = \frac{D'}{c} - \frac{D}{c} = \frac{\frac{D\sqrt{1 - \frac{{V_{abs}}^2}{c^2}}}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)}}{c} - \frac{D}{c} = \frac{D}{c}\left(\frac{\sqrt{1 - \frac{{V_{abs}}^2}{c^2}}}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)} - 1\right)$$

$$\Rightarrow \tau \cong \frac{D}{c}\;(1 - 1) \cong 0\;,\; for \quad V_{abs} \ll c$$

Next we consider the effect of absolute motion on the light beam from S1. The additional time delay induced by absolute motion of the light beam reaching the detector after reflecting from the mirror is given by equation (4):

$$\tau = \frac{D}{c}\frac{V_{abs}}{c}\cos\theta \;, \qquad for\; V_{abs} \ll c$$

Therefore, the time difference between the longitudinal and orthogonal light beams will be:

$$\tau = \frac{\frac{D}{\sin\theta}}{c}\frac{V_{abs}}{c}\cos\theta = \frac{D}{c}\frac{V_{abs}}{c}\frac{1}{\tan\theta}$$

For example, if D = 1 m = 0.001 km, $\theta = 30^0$, V_{abs} = 390 km/s , c = 300000 km/s

$$\tau = \frac{D}{c}\frac{V_{abs}}{c}\frac{1}{\tan\theta} = \frac{0.001}{300000}\frac{390}{300000}\frac{1}{\tan 30^0} = 7.5 * 10^{-12}\,s$$

Let the wavelength of the laser light used be 600 nm.

$$the\ fringe\ shift\ caused\ by\ absolute\ motion = \frac{c\,\tau}{wavelength}$$

$$= \frac{3 * 10^8 * 7.5 * 10^{-12}\,s}{600 * 10^{-9}} = 3750\,fringes$$

Contrast this with the almost null result of the Michelson-Morley experiments!

Unfortunately, such experiment is nearly impossible because the coherence length/coherence time of laser sources is too short and it is practically impossible to tune the frequencies of two laser sources to be equal to within, say, 0.1 to 1 Hz, to get any 'stable' and visible interference fringes. Even if it was possible to tune the two laser frequencies to be equal to within, say, 10 Hz the experiment would be feasible. Although the fringes would be moving in this case, this would be a feasible experiment given the large number of fringe shifts predicted when the orientation of the apparatus is changed. As already noted, the coherence time of the light should be at least about 30 seconds, the time needed to rotate the device and observe changes in fringe positions.

Moving source experiments

The new model of (absolute) motion and the speed of light gives a straight forward explanation of moving source experiments. Assume an observer that is at absolute rest. A light source is moving relative to the observer (and therefore relative to the absolute reference frame). According to the new theory, the effect of *absolute motion of the observer* is just to create an apparent change in the time of emission of light from the source. This apparent change in time of emission is determined by the absolute velocity of the observer and the position (distance and direction) of the light source relative to the observer *at the moment of emission*. Since in this case the observer is at rest (zero absolute velocity), with only the source moving, there is no apparent change in the moment of light emission. Therefore, the time delay of light between emission and detection is determined by the distance between the observer and the source *at the moment of emission*.

$$time\ delay\ between\ emission\ and\ detection = \frac{D}{c}$$

Since only the position (distance) of the source from the observer at the moment of emission and the absolute velocity of the observer (in this case zero) determine the time delay, the velocity of the light source is irrelevant, confirming the independence of the speed of light from the velocity of the source.

Moving observer experiments

Imagine a light source at that is at absolute rest. (the motion/velocity of the source is irrelevant, we are assuming it just for clarity). The light source emits a short light pulse at the instant $t = 0$. At the moment of emission, the observer is at distance D from the source and moving with absolute velocity V_{abs} to the right (Fig. 5).

Fig.5

This is the case of Θ = 0 in Fig.2. Therefore, from equation (2):

$$\Rightarrow \quad D' = \frac{\left(D\,\frac{V_{abs}}{c}\right)cos\theta \; + D\sqrt{1 - \frac{{V_{abs}}^2}{c^2}\,sin^2\theta}}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)}$$

$$\Rightarrow \quad D' = \frac{\left(D\,\frac{V_{abs}}{c}\right) + D}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)} = \frac{D\left(1 + \frac{V_{abs}}{c}\right)}{\left(1 - \frac{{V_{abs}}^2}{c^2}\right)} = \frac{D}{1 - \frac{V_{abs}}{c}}$$

The apparent time delay of emission caused by observer's absolute motion is:

$$\tau = \frac{D'}{c} - \frac{D}{c} = \frac{\frac{D}{1 - \frac{V_{abs}}{c}}}{c} - \frac{D}{c} = \frac{D}{c}\left(\frac{1}{1 - \frac{V_{abs}}{c}} - 1\right) = \frac{D}{c}\;\frac{V_{abs}}{c - V_{abs}}$$

In this case, τ is the apparent change (delay) in the time of light emission for the moving observer. Therefore, in order to determine the moment of light detection, we consider this apparent time delay of emission.

$$moment\ of\ light\ detection = \tau + \frac{D}{c} = \frac{D}{c}\;\frac{V_{abs}}{c - V_{abs}} + \frac{D}{c}$$

$$= \frac{D}{c}\left(\frac{V_{abs}}{c - V_{abs}} + 1\right) = \frac{D}{c - V_{abs}}$$

This agrees with moving observer experiments.

Stellar aberration

Suppose that at $t = 0$ the light source emits light from point S in the absolute reference frame. At the moment of emission ($t = 0$) , the observer is at point O, moving with absolute velocity V_{abs} to the right (Fig. 6) .

Let the moving observer detect the light at the point O'. As already described, the position (distance and direction) of the point of light emission (or the center of the wave fronts) *relative to the observer* at the moment of emission (line OS) is the same as position of the point of light emission (the center of the light wave fronts) at the moment of light detection (line O'S').

We can see that the two lines OS and O'S' are parallel and have equal lengths. Therefore, whereas an observer at rest at point O' will see the light as coming from the point S, the moving observer sees the light as coming from S'.

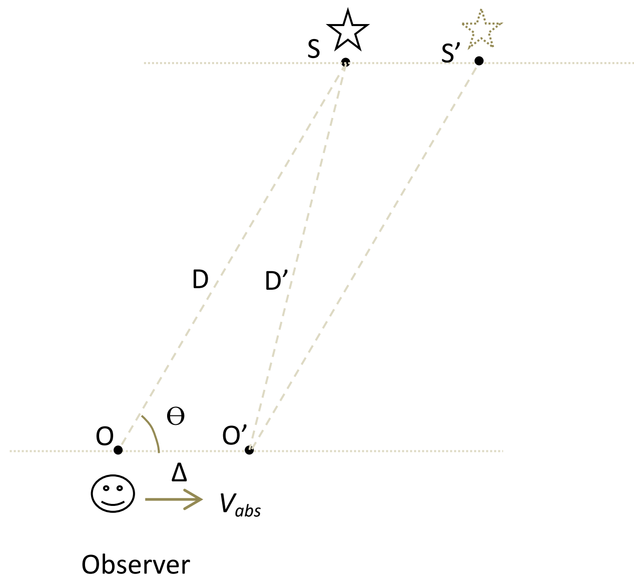

Fig. 6

The Arago and the Airy star light refraction and aberration experiments

The Arago experiment was perhaps the first experiment that encountered the paradoxical nature of the speed of light, which would confound physics for centuries to come. Francois Arago set out to test (actually to 'confirm', as he was an advocate of emission theory) if the speed of light depended on the velocity of the stars. For this, he observed the refraction of light from different stars. He found that the lights from all the stars were refracted by the same amount, in the same way, showing that the speed of light was independent of the velocity of the star. Then, naturally he decided to test if the speed of light depended on the velocity of the observer. For this, he observed the refraction of light from a star at different times of the year, in order to utilize variations in the Earth's orbital velocity. To his surprise, he found no evidence that refraction of light coming from the star varied at different times of the year, showing that the speed of light did not depend on the velocity of the observer either. Thus was born the light speed paradox.

Airy also did an experiment by using water filled telescopes to test if star light aberration angle differed from the aberration angle measured when observed by a telescope filled with air. He did not find any difference in the aberration angles in the two cases.

The new theory in this paper gives a straight forward explanation of the Arago and the Airy star light refraction and aberration experiments. *Light always approaches the observer with a constant velocity c, irrespective of the velocity of the observer and the velocity of the source. The only effect of the (absolute)* *motion of the observer is to create a change in the time of detection of light,* which is irrelevant to the star light refraction and aberration experiments.

Conclusion

Nature has hidden its mystery in a safe place, and that is behind the null result of the Michelson-Morley experiment, derailing mainstream physics and everybody else who tried to find it, for over a century. The null result of the Michelson-Morley (MM) experiment can be considered as the single most important factor in the development and wide acceptance of the Special Relativity theory. For mainstream physics there is no more mystery and the Michelson-Morley experiment null result is just one evidence for the principle of relativity. Other researchers who have at least realized the failures of relativity theory and have been searching for alternative explanations have proposed numerous different ideas on why the MM experiment gave a null result, such as ether drag hypothesis. This paper has finally revealed the mystery of the Michelson-Morley experiment. How can the Michelson-Morley experiment give null result and absolute motion exist at the same time?!

Light is always emitted from its source with the velocity of the center of the light wave fronts equal to the (absolute) velocity of the observer. This means that the center of the wave fronts is always co-moving with the observer and therefore is at rest relative to the observer. The speed of light is constant c relative to the center of the wave fronts and therefore relative to the observer. This theory finally gives the correct explanation of the constancy of the speed of light relative to all observers. Albert Einstein was the first to realize and explicitly state the constancy of the speed of light. However, his interpretation of this principle of constancy of the speed of light, which is the Special Relativity theory, was wrong. This paper has finally revealed the correct interpretation. To account for absolute motion of the observer, light is emitted apparently earlier or later than the conventional time of light emission. This explains why an observer moving away from a light source detects the light later than if they remained at rest. The new theory can explain the Michelson-Morley experiment, moving source and moving observer experiments, stellar aberration and several other light speed experiments.

Glory be to God and His Mother, Our Lady Saint Virgin Mary

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