Debunking the Sagnac and the Michelson-Morley Experiments

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1. Abstract

There is a lingering (and incorrect) belief that due to the fact that there is a classical (non relativistic) explanation of the Sagnac effect somehow the Sagnac effect disproves STR. The fact that there exists a non-STR explanation for the Sagnac effect in no way disproves STR. The same is also true of the Michelson-Gale experiment which is in effect a cosmic setup of the Sagnac experiment.

2. Elementary Explanation of the Sagnac Experiment

The following is a much simplified and abbreviated explanation that can be found in [1].If two pulses of light are sent in opposite directions around a stationary circular loop of radius R, they will have traveled the same distance at the same speed, so they will arrive at the end point simultaneously. If the loop itself is rotating.we get a simplified form of the Sagnac experiment For any positive value of α, the pulse traveling in the same direction as the rotation of the loop must travel a slightly greater distance than the pulse traveling in the opposite direction. As a result, the counter-rotating pulse arrives at the interference point slightly earlier than the co-rotating pulse. Quantitatively, if we let ω denote the angular speed of the loop, then the circumferential tangent speed of the end point is $v = \omega R$. The respective angles traveled by the two light fronts are:

$$\phi_+=2\pi+\alpha_+=(c/R)t_+ \quad (1)$$

$$\phi_-=2\pi-\alpha_-=(c/R)t_- \quad (2)$$

where:

$$\alpha_+=\omega t_+ \quad (3)$$

$$\alpha_-=\omega t_- \quad (4)$$

Substituting (3) in (1) and (4) in (2) we get:

$$t_+=2\pi R/(c-\omega R) \quad (5)$$

$$t_-=2\pi R/(c+\omega R) \quad (6)$$

where $\omega R=v$

From (5) and (6) it follows that:

$$t_+-t_-=2\pi R*2v/(c^2-v^2)=4\pi R*\frac{\frac{v}{c^2}}{1-\frac{v^2}{c^2}}=4\pi R^2\omega\frac{\frac{1}{c^2}}{1-\frac{v^2}{c^2}}=4A\omega\frac{\frac{1}{c^2}}{1-\frac{v^2}{c^2}} \quad (7)$$

Formula (7) is the exact formula. Most authors[1,3,4] use the fact that v<<c and drop the $1-v^2/c^2$ term. It should be noted that [1] and [4] arrive to the equivalent of (7) before dropping the $1-v^2/c^2$ term. Obtaining an "exact" result that misses the $1-v^2/c^2$ term is a tell-tale sign of an incorrect derivation. We have seen a few such derivations on the GSJ website. Stedman[1] suggests replacing the light interferometry with particle interferometry. By replacing light speed c with particle speed V<<c in (7) we can observe much larger shifts PROVIDED the term $1-v^2/V^2$ is not inadvertently dropped.

From (1) and (2) we obtain:

$$\phi_+-\phi_-= c/R(t_+-t_-)$$

The path length difference is $dL=R(\phi_+-\phi_-)=c(t_+-t_-)$

The shift in the interference fringes is

$$dN=dL/\lambda= (t_+-t_-)c/ \lambda=4A\omega\frac{\frac{1}{c^2}}{1-\frac{v^2}{c^2}}*1/ T \quad (7a)$$

where T is the oscillation period of the light waves. (7a) is the exact formula and it is much less known in literature. Again, at v<<c we obtain the oft cited (albeit incomplete) formula :

$$dN=4A\omega/ c^2T \quad (7b)$$

More recently the Sagnac effect is is being used in industrial applications for its incredible precision in calculating the frequency shift due to Doppler effect: If we consider $f_+=1/t_+$ and $f_-=1/t_-$ with $t_+=P/(c-\omega R)$ and $t_-=P/(c+\omega R)$ (where P is the length of the light path , equal to $2\pi R$ in the case of a circle) we obtain:

$$\delta f=f_- - f_+=2\omega R/P \quad (7c)$$

This analysis is perfectly valid in both the classical and the relativistic contexts, both for phase and for frequency shift.

Interestingly enough, the above reasoning applies to the Michelson Morley experiment. As the light front travels away / towards the incoming interferometer the following equations apply:

$$d_+=l+\delta_+=ct_+ \tag{8}$$

where l is the length of the interferometer arm and δ_+ is the distance traveled by the interferometer in the time t_+ :

$$\delta_+=vt_+ \tag{9}$$

Substituting (9) in (8) we obtain:

$$ct_+=l+vt_+ \tag{10}$$

or:

$$t_+=l/(c-v) \tag{11}$$

In a similar way we get :

$$t_-=l/(c+v) \tag{12}$$

The total time for the light front becomes:

$$t_++t_-=l/(c-v)+l/(c+v) \tag{13}$$

Expression (13) is true regardless of which flavor of relativity we choose. Interestingly enough, several explanations for the Sagnac experiment exist , based on "alternatives" to STR such as the emission theory or a more recent one, called "undulating" theory but none for the Michelson-Morley experiment. This may be due to the fact that the Michelson-Morley experiment is much more difficult to explain correctly, without twisting the facts. We must stress that the expressions "c+v" and "c-v" do not mean in any way that the speed of light can be subjected to Galilean speed transformations. It is clear from the above derivation that these two expressions come about from the fact that the distance l is covered by TWO moving phenomena : the light front and the arm of the interferometer[2,5].

1. G.E.Stedman "Ring-laser tests of fundamental physics and geophysics" http://www.physics.berkeley.edu/research/packard/Competition/Gyros/LaserRingGyro/Steadman/StedmanReview1997.pdf

2. G. Saathoff *et al.*, Phys. Rev. Lett. **91**, 190403 (2003)

3. C.Renshaw, “ Fresnel, Fizeau, Hoek, Michelson-Morley, Michelson-Gale and Sagnac in Aetherless Galilean Space”,
Galilean Electrodynamics, Nov 1996

4. P.Beckmann, “Sagnac and Gravitation”, Galilean Electrodynamics, Feb 1992

5. New Methods for Testing Lorentz Violations in Electrodynamics,

http://arxiv.org/ftp/hep-ph/papers/0408/0408006.pdf