Anisotropy of Light Speed Due to Earth's Own Rotation

by

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Abstract

The Sagnac effect demonstrates an anisotropy of light speed as a first-order effect on the scale of Earth's rotation, but not for higher velocities such as Earth's orbital speed or its speed relative to the CMB. Following logic reason, experiments investigating the second-order effect should also exhibit this deviation due to Earth's own rotation, but not for higher velocities. Specifically, interferometer experiments with optical resonators would be capable of verifying this matter. This paper shows that none of the existing experiments provide a statement on this issue. The detection of such a second-order effect from Earth's own rotation would provide clues to new physics.

1. Introduction

An analysis of relevant interferometer experiments, especially those using optical resonators, yields two important results: First, the test theories used disregard Earth's own rotation from the outset, so only the influence of orbital speed and higher velocities can be ruled out with increasing precision. Second, various effects are excluded or averaged out from the measurement results. These include supposed imbalances of the rotating measurement apparatus or unspecified "spurious signals". A re-analysis of the raw data of the experiments is suggested, provided they exist in unprocessed form. Moreover, it would be sensible to conduct an experiment with optical resonators that focuses solely on the anisotropy on the scale of Earth's own rotation. The following examines existing experiments regarding these aspects.

2. Classical Interferometer Experiments, i.e., Apparatus of the Michelson-Morley Type

At an Earth's rotational speed of about 464 m/s, a shift of the interference fringes of the experiment in the order of v^2/c^2 would be expected. Assuming a light speed of 2.998×10^8, this corresponds to a squared anisotropy of about 2.4×10^{-12} m/s. Considering the light wavelength and the arm length of 2m in the Michelson-Morley apparatus, this corresponds to a shift of the interference fringes by an order of 10^{-5} fringes. Even a hundredfold increase in arm length would not yield a measurable result. All classical interferometer experiments are therefore unsuitable for demonstrating the second-order effect due to Earth's own rotation.

3. Interferometer Experiments Using Optical Resonators

Only experimental setups that are rotatably mounted, analogous to the classical apparatus, are considered, as the shift of an interference or the measurement of the beats of the resonators' frequency deviations requires that the direction of the resonators can be changed relative to the velocity vector of Earth's own rotation. Experiments that do not meet this condition are therefore not considered. The only three dealing with a rotatable apparatus are:

3.1 Brillet and Hall, 1978

The paper by Brillet and Hall points to a spurious signal, quote: *"—and a spurious nearly sinusoidal frequency shift at the table rotation rate f."* Since this is a signal of the simple rotational frequency, but we are looking for a signal of the double frequency due to squaring, this signal should not be relevant. However, the paper further states: *"we find that taking data in blocks of N table rotations (N ≈ 8-50) is helpful in minimizing the cross coupling of these noise sources into the interesting Fourier bin at 2 cycles per table revolution."* Thus, a first averaging of the data over 8 to 50 rotations is already taking place, which should have eliminated a large part of our sought signal. It is further described: *"To discriminate between this spurious signal and any genuine ether effect, we made measurements for 12 or 24 sidereal hours"* and *"Averaging after this rotation leads, as shown in Fig. 2, to a typical 1-day result below 1 +/- 1 Hz."* At this point, it becomes clear that a rotation-dependent signal is not being sought at all but completely averaged out, and the search is exclusively for a diurnal signal. The signal that would result from a rotation of the apparatus is therefore not further recorded. The published result data of the experiment are thus completely inconclusive for our sought signal. If raw data still exist for this experiment, it would be interesting to know the uninterpreted magnitude of the signals in connection with the double rotation frequency of the apparatus.

3.2 Eisele et al, 2008

Within the paper by Eisele et al, divergent data are averaged beforehand, the cause of which is attributed to an unavoidable tilt of the apparatus: *"Sensitivities of the beat to tilts were determined at the beginning of each run."* and *"The means of the amplitudes of the tilt modulations at 2ω were less than 0.2 µrad, leading to an effect on the means of the coefficients of B, C of less than 5 x 10^{-17}."* Despite averaging, there is a phase shift of 0.2 µrad here, which is already a multiple (10^{-8}) of our sought signal (order of 10^{-12}). The evaluation of the measurement results is then done using the Robertson-Mansouri-Sexl (RMS) test theory. The paper states: *"The RMS test theory (with the effects of Earth's rotational velocity neglected) leads to expressions for B(t), C(t) with similar structure."* In further analysis, the data are then interpreted only with regard to B(t) and C(t), neglecting Earth's own rotation. The published result data of the experiment are thus inconclusive for our sought signal for both reasons mentioned above. Here too, the raw data would be highly interesting and should be interpreted without applying the test theory.

3.3 Herrmann et al, 2018

In this experiment as well, the sought signals are suppressed from the outset. An initial analysis of the paper by Herrmann et al deals with the error signals, particularly those at double the rotational frequency of the apparatus: *"For example, gravitational or centrifugal forces that act on the resonators may get modulated with the turntable rotation and therefore modulate the length of the resonators. However, most of these affects lead to a modulation at a rate of ωtt = 2π/Ttt so that they are in principle distinguishable from the anisotropy signal searched for at 2ωtt. Moreover, if the data spans more than one day, systematic effects with a fixed phase in the laboratory average out in the analysis for an anisotropy of c that is fixed relative to a sidereal frame."* Apparently, the slight errors at double the rotational frequency can only be attributed to a variety of causes, so the strategy is chosen to investigate a daily modulation: *"This daily modulation is essential to discriminate an anisotropy signal from constant or slowly varying systematic effects caused by active rotation as described in Section I. Only systematic effects subjected themselves to a 23.93 h modulation would mimic such a sidereal anisotropy signal."* By no means can our sought signal be found within a diurnal averaging. Furthermore, it specifically states: *"These samples extend over 450 s each such that we may neglect a* *possible modulation due to Earth's rotation within each sample."* Furthermore, the RMS test theory again is applied, which disregards Earth's own rotation from the outset.

4. Conclusion

All experiments that could provide information about a second-order anisotropy of light speed concerning Earth's own rotation have been interpreted in a way that a signal at double the rotational frequency of the apparatus and in the sought magnitude is either (partly together) suppressed in the error analysis, averaged out through long-term investigation, or eliminated by the applied test theory. If the raw data of even one of the experiments were evaluated such that such a signal emerged, it would indicate new physics.

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