How Michelson's 1881 miscalculation of the expected fringe shift helped in the demise of the ether

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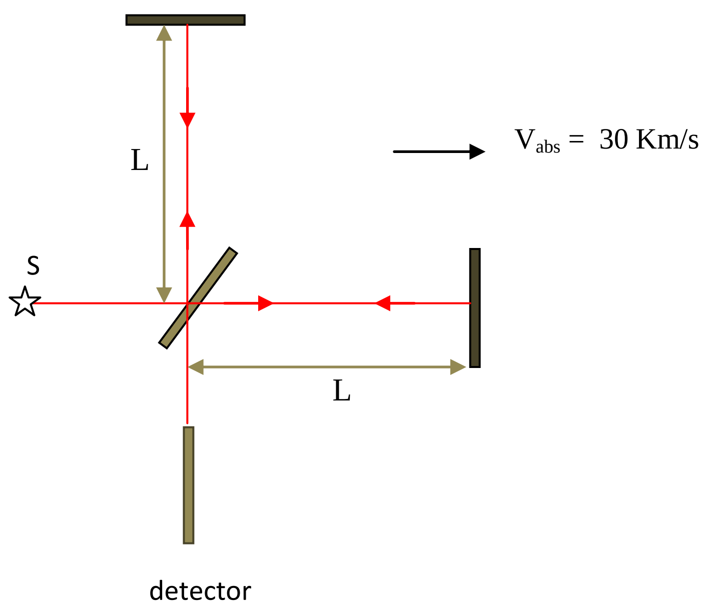
Abstract

We will see how Michelson's original error in calculation of the expected fringe shift in the 1881 experiment and its subsequent correction by Potier and Lorentz led to hastening of the abandonment of the ether. In an effort to increase the sensitivity of the experiment, Michelson and Morley considerably increased the arm length of light in the 1887 experiment, and by doing so, they ended up in building an instrument that ruled out the ether even more decisively than the 1881 Michelson experiment. All their efforts to detect the ether unexpectedly played out against the ether, not in favor of it. The reason why the 1887 experiment was much less sensitive than the 1881 experiment, despite the fact that the 1887 experiment used a considerably longer arm length, has always remained a mystery that no one has ever viewed it as such. By continuously increasing the arm length in subsequent experiments, physicists unknowingly ended up in setting up and repeating experiments that were much less sensitive to absolute motion than the 1881 Michelson experiment.

Introduction

In 1881, Michelson set out to measure the velocity of the Earth relative to the hypothetical ether. His apparatus was an interferometer with two orthogonal arms of each 1.2 m length. According to ether theory, the round trip times of the longitudinal and transverse light beams would be affected slightly differently due to motion of the apparatus relative to the ether, resulting in a fringe shift.



Michelson obtained[1] the expression for round trip time of the longitudinal beam to be:

$$T_l = \frac{2L}{c} \frac{1}{1 - \frac{V^2}{c^2}} \cong \frac{2L}{c} \left(1 + \frac{V^2}{c^2} \right)$$

For the round trip time of the transverse beam he obtained the expression:

$$T_t = \frac{2L}{c}$$

from which he calculated the expected fringe shift to be 0.04 fringes, corresponding to Earth's orbital velocity of 30 Km/s and arm lengths of L = 1.2 m .

However, the maximum fringe shift he observed in the experiment was only about 0.018 fringes. This result was unexpected and would be disappointing for him. He concluded that the stationary ether hypothesis was wrong and that the experimental result supported Stoke's complete ether drag hypothesis.

Corrections by Alfred Potier and Lorentz

However, Alfred Potier in 1882 and Lorentz in 1886 pointed out an error in Michelson's calculation of the expected fringe shift. They pointed out that Michelson's expression for the round trip time of the transverse light should have been:

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

from which the expected fringe shift would have been 0.02 fringes.

This value was close to the fringe shift of 0.018 fringes observed by Michelson. However, by the time this error was reported, Michelson had lost his enthusiasm to detect the ether, perhaps because his original disappointment with the experimental result had deeply affected him. Normally, with the errors now known, one would expect Michelson to proclaim that he had detected the ether. However, the modern interpretation is that Michelson's apparatus was not sensitive enough to detect the expected fringe shift accurately, and that this required a much more "sensitive" experiment (the 1887 Michelson-Morley experiment).

The 1887 Michelson-Morley experiment

Michelson's failure to detect the expected fringe shift in his 1881 experiment and the subsequent proposals of Alfred Potier and Lorentz prompted Michelson and Morley in 1887 to devise a much more "sensitive" and accurate interferometer, with arm lengths almost ten times the 1881 experiment (L = 11m). Michelson and Morley increased the arm lengths almost tenfold, by using folded light beams by multiple reflections from mirrors, because they thought this would reveal the ether velocity.

As it turned out, however, increasing the arm lengths of the apparatus played out against the ether, not in favor of it. The experimental result was 'worse' than the 1881 experiment because the ratio of the expected fringe shift to the observed fringe shift was about 1 in the 1881 experiment and was about 40 in the 1887 experiment!

Influence of Michelson's original miscalculation and subsequent corrections by Alfred Potier and Lorentz

One can imagine Michelson's enthusiasm to detect the ether and his disappointment when he failed to observe the fringe shift he expected. His miscalculation of the expected fringe shift created a large mismatch with the observed fringe shift, which then led to Michelson's great disappointment. This disappointment, together with Alfred Potier's and Lorentz's later corrections, prompted Michelson to repeat the experiment with much greater care and thought, after several years, which resulted in the 1887 experiment. However, all the efforts of Michelson and Morley to make the design of the instrument to be much in favor of the ether, unexpectedly, turned out to play out against the ether. The increase in arm length made the apparatus even less sensitive[3].

One wonders what would happen if Michelson correctly calculated the expected fringe shift in his 1881 experiment. If Michelson correctly calculated the expected fringe shift of 0.02 fringes, which was close to the observed fringe shift of 0.018, he might conclude that he had detected the ether. However, on the other hand, this result would also be inconclusive because the time and orientation of the instrument when this maximum fringe occurred may be (was) different from the time and orientation for the maximum fringe shift expected. In any case, Michelson's disappointment would not have been as great.

Considering the great uncertainty about the outcome of the experiment and its interpretation, the main influence of Michelson's original error was that it prompted Michelson and Morley to undertake the construction of a much more "sensitive" instrument. I guess that if Michelson correctly calculated the fringe shift in his 1881 experiment, there would be less disappointment and less motivation to build an apparatus with increased arm length, which in turn resulted in, unexpectedly, the 1887 experiment that was much "worse" than the 1881 experiment. Michelson and Morley would more likely repeat the 1881 experiment, or would consider other ideas than increasing the arm length of light, which would be considered positive or inconclusive and would delay the abandonment of the ether by years, if not decades.

The corrections made by Alfred Potier and Lorentz prompted Michelson to repeat the experiment, with arm length much longer than the 1881 experiment. Loyd S. Swenson Jr. had somehow described this in his 1987 article in Physics Today as: " The influences of Potier and Lorentz is here evident" [2].

Inverse relation between light arm length and sensitivity of the Michelson-Morley interferometer - Apparent Source Theory

According to the new theory, known as Apparent Source Theory, I already proposed [3], the expected fringe shift in the 1881 experiment should be of the order of 0.02 fringes and the expected fringe shift in the 1887 experiment should be of the order of 0.0014 fringes. *Apparent Source Theory predicts that the fringe shift decreases with increase in the arm length of the instrument, which is completely unexpected !* This was in fact what was observed when the 1887 experiment is compared with the 1881 experiment!

Proposed experiment to test absolute motion and Apparent Source Theory

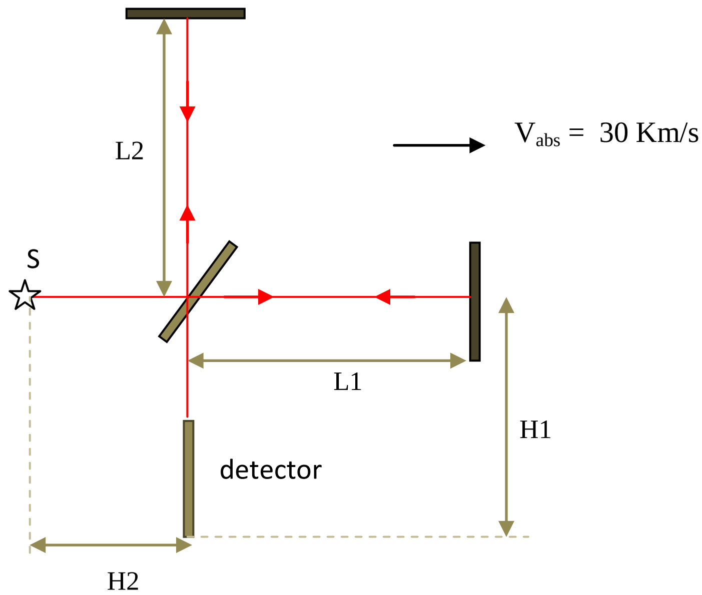
Since the sensitivity of the apparatus has inverse relation to the arm lengths L1 and L2 (see next figure), the logical idea is to use an apparatus with a shorter arm length. However, in [3] it has been revealed that dimensions H1 and H2 also play a key role in the determination of the fringe shift[3].

For:

$$V_{abs} = 390\frac{Km}{s} \;\; , \;\; H1 = 1m \;\; , \qquad H2 = 1m \;\; , \qquad D \; = \; \sqrt{H1^2 + \; H2^2} \; = 1m \, ,$$

$$\Delta = D \; \frac{V_{abs}}{c} = 0.0013m \, , \quad L1 = 10 \; cm \;\; , \qquad L2 = 10 \; cm$$

The resulting path difference will be 210.78 nm , and the corresponding fringe shift for λ = 575 nm is 0.366572 fringes !



Conclusion

In this paper, we have seen how Michelson's original error in the expected fringe shift and the large discrepancy between the expected and observed fringe shifts disappointed him. This disappointment, together with the subsequent correction of Michelson's original error by Alfred Potier and Lorentz, prompted Michelson (and Morley) to undertake the construction of a much more accurate, stable and "sensitive" experiment by, among other features of the instrument, increasing the arm length of the interferometer by almost ten times. However, by the increasing the arm length ten times, they made an apparatus that will disprove the ether hypothesis even more decisively than the 1881 experiment because the ratio of expected fringe shift to the observed fringe shift of the 1881 experiment was about 1, where as the ratio for the 1887 experiment was about 40 ! By continuously increasing the arm length in subsequent experiments, physicists unknowingly ended up in experiments which were much less sensitive than the original 1881 Michelson experiment. The mystery of why the 1887 experiment disproved the ether even more decisively than the 1881 experiment has been revealed by Apparent Source Theory: as the arm length of the apparatus is increased, the instrument becomes less and less sensitive !

Thanks to God and the Mother of God, Our Lady Saint Virgin Mary

References

1. Michelson-Morley experiment, Wikipedia

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