Michelson's Still Illusory Expectation

Eckard Blumschein, 15.01.2013, unfinished

The unexpected null result of the experiment by Michelson and Morley [1] did not disprove absolute space. Michelson's expectation was illusory because of a so far overlooked flaw in his reasoning.

Maxwell imagined light an electromagnetic wave propagating in empty space with constant speed c relative to (abbreviated below as re) this hypothetical medium. Michelson reported in 1881 [2] his attempts to measure the velocity v of earth re space with a detector D of interference (Fig. 1). He arranged a sodium lamp S, a tilted by 45° semi-permeable beam-splitting mirror A and two mirrors B and C, each in equal distance d to A, because he expected that only the length of return path ABA orthogonal to v is not affected by v while the straight return path ACA is obviously longer than 2d by a factor $1/(1-r^2)$ where r stands for the relation v/c.

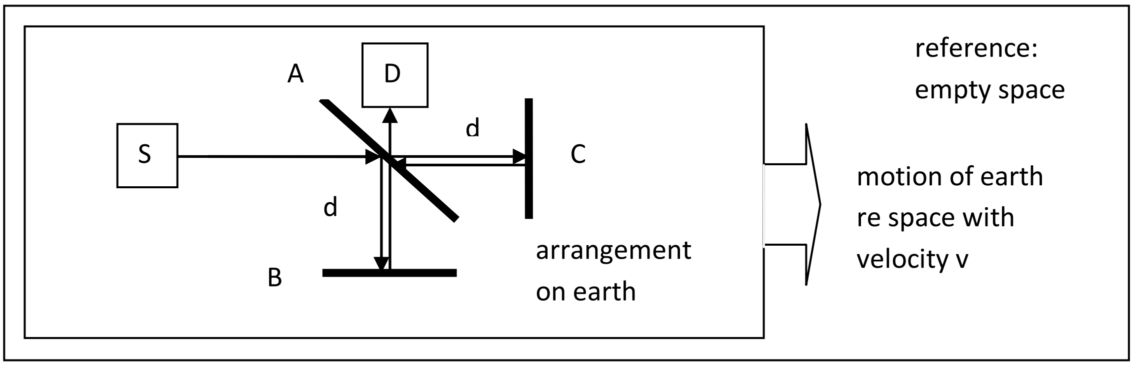

Fig. 1 Michelson's arrangement

Figs. 2 to 4 show the earth-bound arrangement moving with v <<c re space to the right, i.e. in the same direction as the light is emitted from S. The underlying sheet of paper represents the space in which the light is thought to propagate with c. Hence the calculated length of a trace on it corresponds to the time elapsed, and the movement of earth re space implies that any sketched position of the mirrors belongs to just a particular moment. Seen in the perspective of space, the paths AB and BA are tilted and therefore also longer than d.

This flaw in Michelson's expectation was revealed already in winter 1881 in Paris by Alfred Potier. Lorentz [3] and also Michelson and Morley [1] then calculated an enlargement of the return path ABA by the still smaller factor $1/\text{sqrt}(1-r^2)$. While their correction halved the originally expected difference between the two return-paths ABA and ACA, it could still not explain why the experiment [1] and its numerous repetitions failed to measure any significant difference. Michelson had concluded that "the hypothesis of a stationary ether is thus shown to be incorrect". FitzGerald and also Lorentz attributed this "null result" to a hypothetical length contraction affecting the path ACA. Lewis and Tolman [4] acknowledged such shortening as "the only satisfactory explanation of the Michelson-Morley experiment" except if "the velocity of light depends upon the velocity of its source" which has proven untenable. They were wrong.

Figs. 2 and 3 were designed as to illustrate the already shown in the appendix of [1] calculation of the angle of reflection at the moving re space mirror A. For the sake of simplicity, distance d is not measured from the middle between a and b, and non-essential possible influences are omitted, e.g. refraction within mirror A. Fig. 4 then shows the so far overlooked last step.

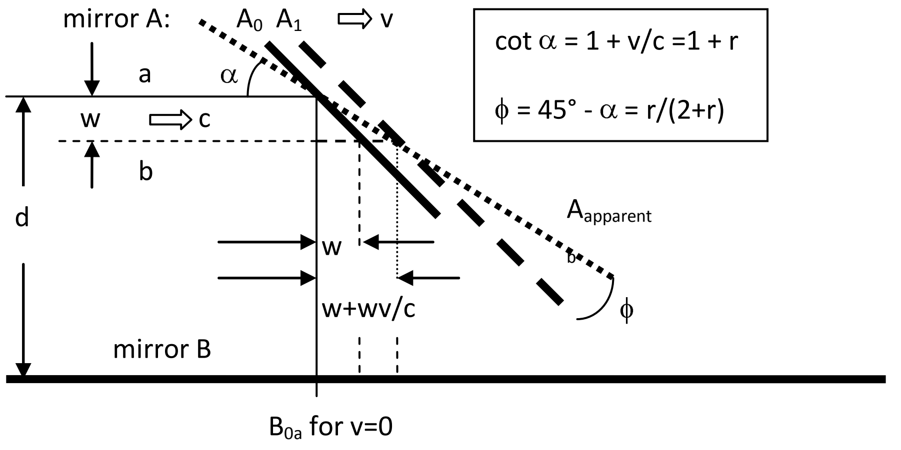

Fig. 2 Two subsequent positions A_0 and A_1 of mirror A and its apparent rotation by the angle ϕ

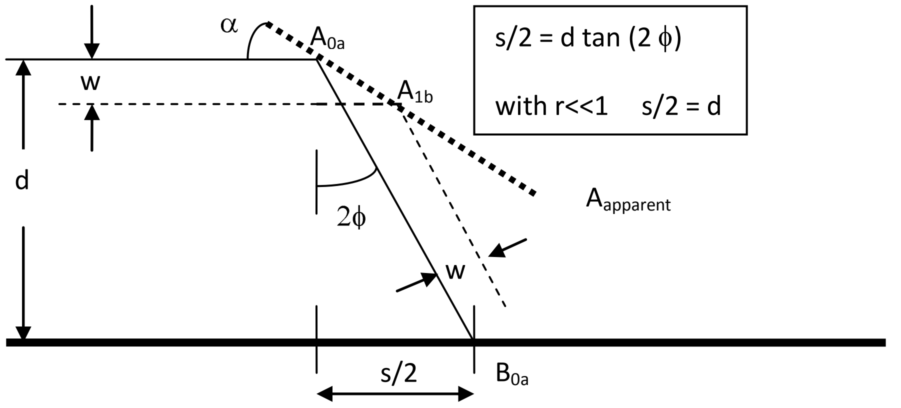

Fig. 3 Reflection at the apparent mirror $A_{apparent}$ and rotation of the lines A_0B_0 by 2ϕ

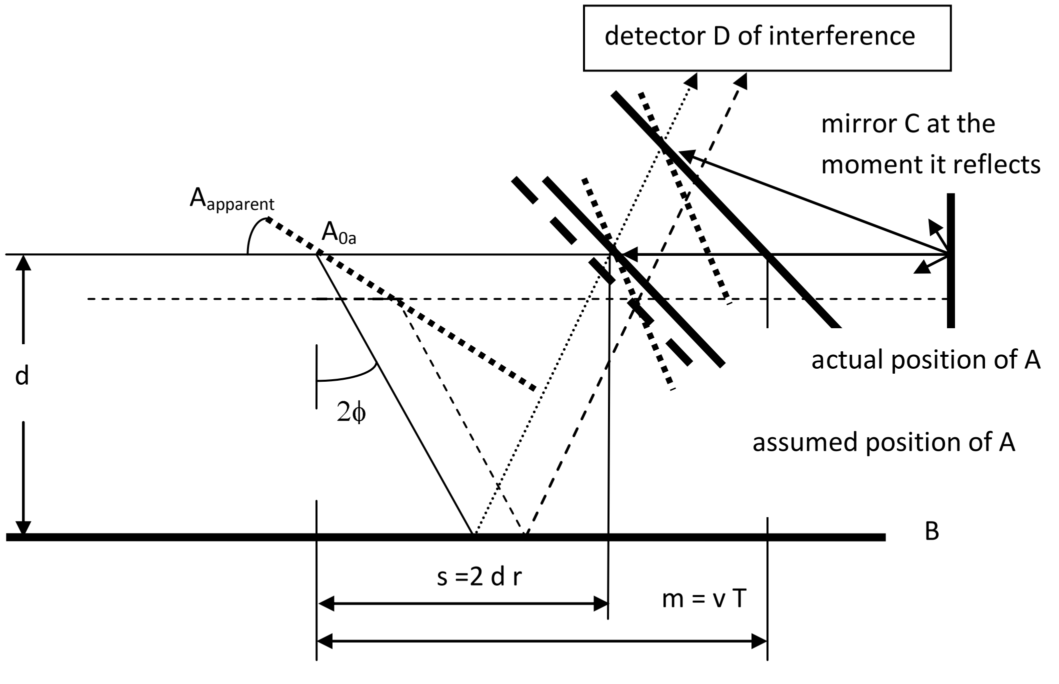

Fig. 4 Actual vs. assumed in [1] position of mirror A at the moment $T = T_{ABA'} = T_{ACA}$

A small re d width w is assumed for the beam incoming from the left of Fig. 2. Given its upper ray (a) hits mirror A in position A_0 at point A_{0a}, then the lower ray (b) hits A in position A_1 at point A_{1b}.

With r=0 the mirrors were at rest re medium. With coinciding positions A_0 and A_1 the wave was reflected exactly downward along the perpendicular distances from A_{0a} to B_{0a} and from A_{0b} to B_{0b}. The front of a reflected wave of width w did then reach the mirror B at the points B_{0a} and B_{0b} simultaneously after t_{AB0}=d/c.

Positive velocity v increases the horizontal length of lower path b by the distance between A_{0b} and A_{1b}. This adds wv/c to w. One can now imagine the beam reflected at an apparent mirror $A_{apparent}$ including the points A_{0a} and A_{1b} which is for positive v anticlockwise rotated re A by a small angle ϕ.

$\phi = \pi/4 - \text{arc cot } (1+r) =$

$= \text{arc tan } 1 - \text{arc tan } (1/(1+r)) = \text{arc tan}\{(1- 1/(1+r))/ (1+(1/(1+r))\} = \text{arc tan } \{r/(2+r)\}$ (1)

With r<<1 ϕ simplifies to r/2.

As shown in Fig. 3, that tilt of the apparent mirror by ϕ corresponds to a tilt by 2ϕ of the reflected beam and results in a shift s/2 of the point B_{0a}. The path from A to B gets accordingly longer:

$\text{sqrt}(d^2+s^2/4)= d \text{ sqrt}(1+r^2) > d$ (2)

and the time t_{AB} increases too:

$t_{AB} = (d/c) \text{ sqrt}(1+r^2).$ (3)

For more than 100 years, it was tacitly assumed that the path from B return to A' is equally long and therewith $t_{ABA'}= (2d/c) \text{ sqrt}(1+r^2)$. This would justify the corrected in 1887 second order effect of r on $2t_{AB}$ being still roughly half as large as on $t_{ACA} = 2d/c(1-r^2)$ which is easily to be seen with expansion in powers of r^2:

With r<<1 $\text{sqrt}(1+r^2)$ for ABA' simplifies to $1+r^2/2$

$1/(1-r^2)$ for ACA simplifies to $1+r^2$

While the usual choice of considering the medium at rest has in principle the advantage to immediately represent the expected trace of motion re medium always with c, it cannot continuously visualize positions of the moving mirrors. The exact position of the reflecting spot on B does not directly matter. However, one has to check whether the shift s of the returned via ABA' beam equals to the actual motion m of the small spot A_{1a} on mirror A during the time $2T_{AB}$ that can be calculated as

$m = v\, 2T_{AB} = 2\, d\, r \text{ sqrt}(1+r^2)$ (4)

The actual motion m of mirror A exceeds s = 2 d r by a factor

$m/s = \text{sqrt}(1 + r^2)$ (5)

Hence, the correction was incorrect. The expected outcome of the experiment by Michelson and Morley was unfounded. The correctness of this stunning revelation is ensured by the agreement of angle ϕ with the value calculated in the appendix of [1] and other papers, e.g [5].

Fig. 4 cannot not well illustrate what Michelson and Morley actually measured because it does roughly correspond to r=0.5 while the velocity v of earth re space is with 30 km/s about 10,000 times smaller than c=300,000 km/s. With r=0.0001, merely the path ABA gets noticeably longer due to the asymmetry by the factor m/s. The path ACA is not noticeably affected by that asymmetry.

With the accordingly corrected correction the difference between

$$t_{ABA} = (2d/c)\ \mathrm{sqrt}(1+r^2)\ \mathrm{sqrt}(1+r^2) = (2d/c)(1+r^2) = K\ (1+r^2) \quad (6)$$

and

$$t_{ACA} = 2d/c(1-r^2) = K/(1-r^2) \quad (7)$$

is too small as to be measured. This can already explain the measured null result. Additional consideration of the tiny effect of increased length BA on the length of ACA may reveal that no discrepancy at all is to be expected.

Fig. 5 a) shows the same as Fig. 4 but from the perspective of the arrangement on earth.

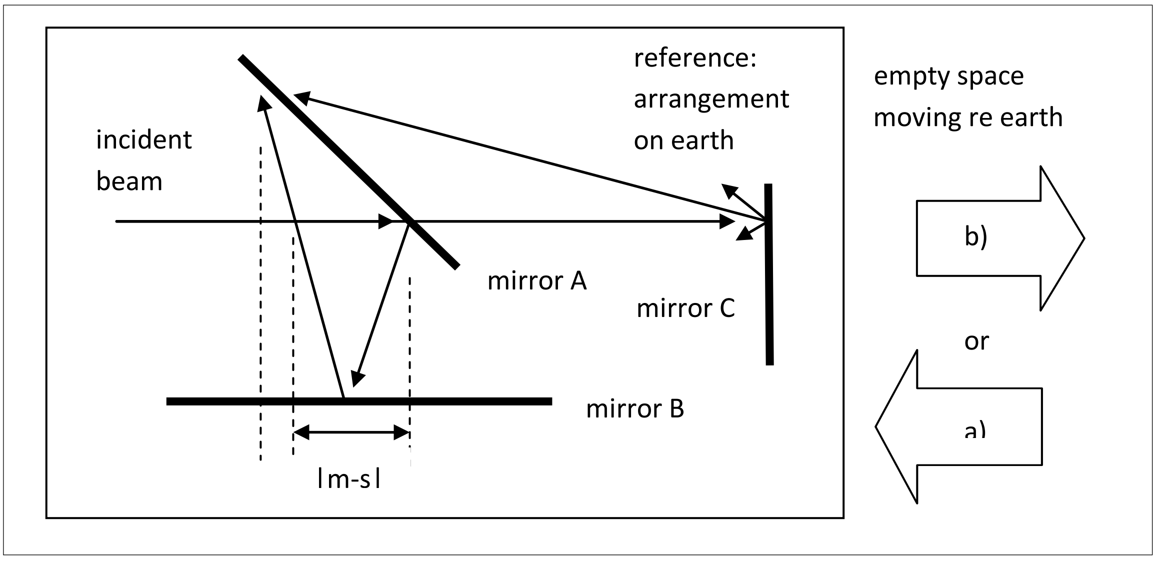

Fig. 5 Reflections re earth at rest with space assumed moving a) to the left and b) to the right

Motion of the earth re space to the right is here seen as motion of space re earth to the left. The path BA is in this case obviously longer than AB. If space is thought to move in the opposite direction (Fig. 5b) then v, r, f, s, and m change their sign, and BA is also longer than AB. The sign of v does not matter.

Already Poincaré [6] and Einstein [7] inferred from unexpected null result of the experiment by Michelson and Morley that one can neither measure nor detect the direction of uniform translatory motion between space and earth. However, they attributed this seemingly strange fact to a hypothetical contraction of the length AC. Above given Figs. and equations provide a plausible alternative. Michelson and Morley were close to that solution when they wrote in [1]: “It may be remarked that the rays ba, and ca, do not meet exactly in the same point a, though the difference is of second order;” They merely added an incorrect guess: “this does not affect the validity of the reasoning.”

Michelson does not deserve being blamed for his imperfect reasoning. He devoted all of his effort to the technical improvement of his impressive experiments. He coped with serious difficulties, e.g. with disturbing vibrations “even at two o’clock in the morning” which caused him to perform early experiments not immediately in Berlin at Helmholtz’s institute but in the quieter nearby Potsdam. Being an experimentalist rather than a theorist, Michelson disliked Einstein’s theory which he considered a monster. Having modified his experiment, he eventually managed to measure [8] the Sagnac effect.

All decisive experts failed to get aware that Michelson’s expectation was illusory from the very beginning. They include von Helmholtz who, by the way, also failed to realize that Ohm was wrong concerning the phenomenon of missing fundamental, Alfred Potier from whom Poincaré learned what is now known as

Einstein synchronization, George Francis FitzGerald who was inspired by Heaviside when he first suggested length contraction and who later hypothesized an effect that was not confirmed by his assistant Trouton, and, of course, Lorentz.

Up to now, many authors of papers and textbooks on physics or its history [9] could not imagine or not accept that Michelson's seemingly plausible expectation may be illusory. Proponents of the special theory of relativity as well as neo-Lorentzian relativists and fans of emission theories do not just celebrate it; they are presenting it to their students in a variety of slightly different representations which indicates that they dealt with it – arguably just superficially.

Those who were unhappy with implications of the unexpected null result hesitated to swallow it. While they did not manage measuring interferences as large as expected by Michelson, they nonetheless noticed smaller one which were ascribed by Cahill [10] to the refractory index of the air. Cahill still supports the length contraction hypothesis as to explain the main discrepancy between Michelson's expectation and the measured data.

Just a few experts didn't question the null result but the Michelson's expectation of the opposite. However, all of them failed so far to plausibly reveal an obvious flaw in his reasoning. The late Marmet claimed in [11] that "two essential fundamental phenomena are missing in the Michelson-Morley demonstration". He obviously ignored the supplement of [1]. Petrov [12] wishfully explained the null result with the old hypothesis of a dragged atmosphere. Shtyrkov [13] suspected a first order effect overriding Michelson's second order effect. While Shukri Klinaku in Prishtina rejected Lorentz transformation also without providing a persuading explanation, Christov [14] meant that "the nil effect of Michelson Morley experiment (MME) is the only possible outcome and cannot be construed as an indication about the existence or nonexistence of an absolute continuum" and "the Lorentz contraction does not need MME anymore in order to survive as the main vehicle of the modern physics of processes at high speeds". He claims having revealed that "an irrelevant to continuum description theoretical formula is derived using the corpuscular concept of light".

It is likewise not easily to be seen how "traegheitsbedingte Vorwaertsstrahlung" [15] (inertia of radiation) explains the null result. Nonetheless Norbert Feist made an acoustic experiment [16] of crucial importance. It shows that acoustic waves exhibit the unexpected for electromagnetic waves behavior too. Acoustic waves are much easier to investigate because they propagate about 1,000,000 times slower. Feist performed a belonging experiment and confirmed that acoustic waves do indeed behave in a manner that is ascribed to length contraction in case of electromagnetic ones. While it is almost impossible to build a tilted by 45° acoustic mirror that doesn't cause turbulence which disturbs the medium air, and Feist did actually not achieve precise results with such tilt, he measured for the shown in Fig. 5 of [17] orthogonal arrangement with r=0.1 a return factor of 1.010,0 with an average error as little as 0.000,5. This corresponds to the factor $1+r^2$, while 0.005 was to be expected with the factor sqrt(1+r2) according to Michelson and Morley.

Feist tried to explain this excellent result by calculating the angle of deflection [13]. As also didn't Marmet, Feist didn't compare his angle quantitatively with the value in the appendix of [1] and e.g. in [14] which is correct but too small as to immediately explain the measured factor.

Fig. 5 of [17] provides a solution to this enigma: The emitter sends a signal with high directivity orthogonal to the reflector. Due to the laminar air flow with velocity v, this signal is conveyed to spot R_1. The exactly reflected from R_1 signal gets lost because it arrives at a location outside the emitter/receiver. Imagine undirected reflections to all sides from R_1 as in case of spotlight to be seen at a cloud. The situation is similar to that in Figs. 4 and 5 were undirected reflections are required at mirror C, and path BA is longer than AB. In Fig. 5 of [17], the path R_2E is longer than the path ER_1. Of course, the signal does not reach the fictitious spot R_2. The emitter E sees the matching wave component as if it came from there.

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