Understanding of the late Michelson's experiments that confirmed the aether existence

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This paper contains a brief discussion of results of two experiments made by Albert Michelson in the years of 1923-1925. According to the paper written by the Nobel Prize winner the aether dragging should exist.

1 Introduction

The first trials of computation of the terrestrial rotation with using an interferometer, which were made in the years 1893 and 1897 by Sir O. Lodge are mentioned by Anderson et al. (1994) in the common paper. Similar idea had later been developed by G. Sagnac and published in 1913 in French scientific magazine have called *Comptes rendus* (Sagnac, 1913).

An expected displacement of interference fringes was also later successfully confirmed by Albert Michelson who used not rotating version of interferometer, resting in terrestrial frame of coordinates. In the year 1925, *The Astrophysical Journal* published two-piece paper written by Michelson (1925) and by Michelson & Gale (1925), taking into account an influence of the terrestrial rotational movement on the velocity of light. It was connected with possibility of detection of cosmic aether with the use of light dragging by rotating Earth. The existence of such aether was earlier excluded for orbital movement of the Earth around Sun.

The Fizeau experiment connected with light dragging by flowing water, that was conducted in mid of 19th century, is currently consistent with the formalism of later created Special Theory of Relativity. An additional influence of this idea on Michelson's thinking had been possible.

2 The experimental set

The first experimental set was located on Mount Wilson. The closed system of pipes having approximately one mile of length was the route of light beam. This device had not been isolated from weather conditions and the experiment with use of this version of interferometer was conducted by Michelson in 1923. Latter this construction has been improved. The way of light was increased to about 2 km and such version of the interferometer was transported to Clearing in Illinois state.

After reduction of pressure inside the pipe, the interference fringes became sharp and stationary. Zero order fringe was created inside a shorter system, that was too small to form measurable displacement. The measurements had been made with the use of lighting of 20-ampere alternating-current arc, what allowed Michelson to reach measurable shift of interference fringes. The wavelength of sodium light derived on the base of measurements was equal to about 570 nm.

The second Michelson's paper contains description of experimental set and final results found with the use of improved version of the interferometer.

3 The Michelson's theory

The beams moving along the parallel of latitude on rotating surface of the Earth should produce a difference of detection time described by the formula:

$$T = 2{\cdot}\nu_2{\cdot}l_2/(V^2 - (\nu_2)^2) - 2{\cdot}\nu_1{\cdot}l_1/(V^2 - (\nu_1)^2),$$

where ν_1 and ν_2 are linear velocities of terrestrial surface on geographical latitudes ϕ_1 and ϕ_2; l_1 and l_2 are light ray lengths on each of these latitudes. The light speed is marked by V, $l_1 = l_0{\cdot}cos(\phi_1)$, $l_2 = l_0{\cdot}cos(\phi_2)$, $\nu_1 = \nu_0{\cdot}cos(\phi_1)$, $\nu_2 = \nu_0{\cdot}cos(\phi_2)$ and $\phi_1 - \phi_2 = h/R$; R is the radius of the planet. This formula was later simplified by Michelson.

As a result, the difference between position of two fringes should be equal to

$$\varDelta = 4{\cdot}l{\cdot}h/(V{\cdot}\lambda){\cdot}\omega{\cdot}sin\phi = 4{\cdot}A/(V{\cdot}\lambda){\cdot}\omega{\cdot}sin\phi$$

where: ω is angular velocity of the Earth rotation, λ is the length of light wave, and ϕ is geographical latitude of the observation point located on the terrestrial surface. The product "lh" is tantamount to the detector surface (A).

The earlier paper with discussion of the phenomenon was edited in *Philosophical Magazine* by Michelson (1904), therefore a year before edition of Einstein's *Zur Elektrodynamik bewegter Körper* and nine years earlier than Sagnac article was published. This text was based on the assumption, that the total speed could be higher than the velocity of light in vacuum, similarly as in case of 1887 paper written commonly with Morley (Michelson & Morley, 1887).

The formula introduced by Michelson in 1904 year contains an assumption, that the time delay should be increased by rays being perpendicular to the direction of Earth's rotational movement. In this way he found relationship between geographical latitude and the value of this time-shift. The time delay in his paper was derived from initial expression: $T = 2{\cdot}v_0/V^2 \int(cos\phi - \frac{y}{R}sin\phi)dx$, where x denotes distances in east/west directions, y - distances in south/north directions, v_0 - rotational velocity of the terrestrial surface, V - speed of light and R is terrestrial radius.

Similar formula was also constructed by Silberstein (1921), and the author of this paper, according to Michelson's, was most interested in conducting of this interferometer experiment and made the direct pressure on Michelson to do it. The Silberstein's computations had been made with an assumption about quite different shapes of light rays, that should propagate in opposite directions. This explanation does not involve the earlier adopted assumption connected with adding of the aether dragging to the light speed, however could be tantamount to it. His idea was based on refraction and supposition that velocity higher than the speed of light should create a similar phenomenon with rays refracted in quite different direction.

In Silberstein's formula the geographical latitude of place, where these measurements were done, has no influence on the final result.

4 The geographical latitude approximation

The final Michelson's expression can be find with using the following relation:

$$cos^2(\alpha) - cos^2(\beta) = sin^2(\beta) - sin^2(\alpha) = \frac{h}{R} \cdot (sin\alpha + sin\beta),$$

making approximation, in which $sin(\beta) - sin(\alpha) = \beta - \alpha$. But in case of geographical latitude equal to 41° $46'$, where his interferometer was located, the value of this function is more than 62 times smaller than the value of this angle. Aditionally an applied condition that $\phi_1 - \phi_2 = h/R$ appears to be too much simplified and should be replaced by $sin(\phi_1) - sin(\phi_2) = (h_1 - h_2)/R$, where h, h_1 and h_2 are connected with geometrical definition of sinus function for particular latitude. As a result, the expected value of displacement should also be much smaller than described by Michelson's formula.

This transformation allowed him to introduce the sinus function of medium angle. The possible errors made by this replacement of both latitudes by their medium values had not been later discussed in his paper.

5 The description of Michelson's result

As a result of several series of measurements, that had been conducted in 1925 year, the medium value of fringes displacement equaled to 0,230 was derived. This value is different by 0,006 from the one calculated with the use of the original formula presented above. But the shift, being the difference between different optical ways, was in fact equal to 130 nm and was divided by the length of wave to produce this result. A non zero displacement of fringes was measured by Michelson, Gale and Pearson and light dragging could be an explanation of this phenomenon. However, when to divide the result by 62, therefore by the factor omitted by Michelson, the final value, equaled 0,0039, falls in the range of measurement error (0.016). So the light dragging could be explanation, but in case of much smaller shift of fringes than registered.

Nonexistence of cosmic aether was in 1887 confirmed by Michelson with Morley in case of velocities smaller than 5 km s^{-1}. The introduction of the aether to existing theory made in 1925 was done without contradiction to conclusions found during famous experiment made before, because the linear velocity of rotation on terrestrial equator is ten times smaller than boundary of error in case of the 19th century experiment.

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