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Retrospective Analysis of the Well-Known Experiments

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ABSTRACT

We analyze ray path in the Sagnac and Michelson-Gale experimental setups and in the Michelson interferometer. Work of rotating interferometers is proved to be in full agreement with the concept of static ether. A theory of Michelson-interferometer work in vacuum and in a gas is developed. Three second-order small factors pointed out in papers by Demjanov and Shamir-Fox are taken into account. The new results are considerably different from conclusions of the mentioned papers. An absolute laboratory velocity of 10 km/s found by Miller is reevaluated to become 236 km/s according to the new formulas. A new theory of the Michelson interferometer fully agrees with the concept of the static ether. It is predicted that in the well-known OPERA experiment, the diurnal plot of the neutrino velocity should have one maximum and one minimum separated by a time interval of 12 hours.

Keywords: Ether, Michelson interferometer, Fresnel effect

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INTRODUCTION

The concept of static ether attracted minds of physicists for over a century. The ether was given the key role in dynamical processes of mechanics, as well as in electrodynamics and optics. Meanwhile in 1881, Michelson (Albert A Michelson, 1881) attempted to determine the velocity of the laboratory on the Earth relative to the static ether. Since the expected effect has not been observed, he claimed that the static-ether hypothesis is wrong. After that the physical nature of inertial frames and the principle of relativity became unclear. It became also unclear whether the validity of the relativity principle is limited and what are in general light and electromagnetic waves. Later on, Michelson-Morley, Morley-Miller, and Miller experiments were carried out, in which the Michelson-interferometer sensitivity was improved and the rigidity of its rotatable platform was increased. Miller found that an interference-fringe shift repeating each half of rotation of the platform is observed in all experiments with the Michelson interferometer. However, this effect was over an order of magnitude less than the theoretical prediction. It turned out that the velocity of motion of the Earth through the ether is several times less than the orbital velocity of the Earth. It was almost impossible to understand and accept this result. Hence, a conclusion started to strengthen that Miller observed the effect of some disturbances instead of the real effect. This conclusion was inconsistent.

Indeed, no disturbances of any origin could repeat with a periodicity equal to one half of the time of one rotation of the platform. Nevertheless, doubts on conclusions by Miller strengthened and became more and more widespread. In 1913, Sagnac (1913b) carried out the experiment with a rotating interferometer. His experiment appeared to be in full agreement with the concept of static ether. In 1925, Albert A Michelson and Gale (1925) carried out an experiment with a huge interferometer rotating together with the Earth. No disagreements with the hypothesis of static ether were found. However, positions of ether opponents have significantly strengthened during two decades, while supporters of the ether concept turned out to be in minority and isolation. Nowadays, “ether battles” have already hidden in the smoke of the last century, so that we are able to objectively analyze these historical experiments. Our task is eased since we are aware of new papers by Demjanov, Shamir-Fox, and Shtyrkov. Note that it is not necessary to consider the historical experiments in chronological order, so we intend to analyze these experiments in the order facilitating clarity of fairly complicated physical processes.

SAGNAC AND MICHELSON-GALE EXPERIMENTS

The design of the Sagnac experimental setup is shown in Fig1. The mirrors M_1, M_2, M_3, and M_4, as well as other optical elements are rigidly mounted on a horizontal rigid disk of 50 cm in diameter. The disk is driven into rotation by the roller D. A small incandescent lamp O played the role of the light source.

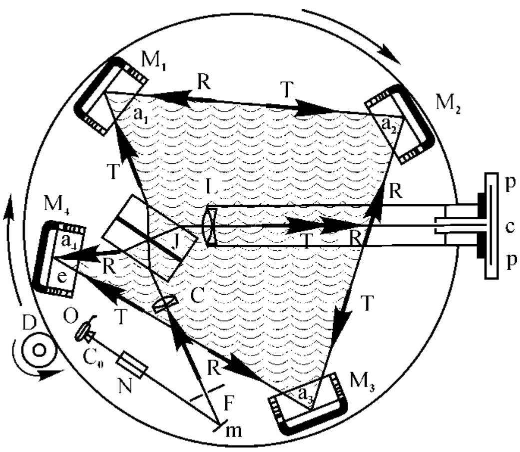

Fig 1. Design of the Sagnac setup

The microscope objective C_0 formed the image of the lamp filament. Upon passing the Nicol prism N, this image was set to the slit F using the small mirror m. A beam of parallel polarized rays is incident through the objective C on the device J used to split and join rays. Here, the ray beam splits into reflected and transmitted rays. Figure 1 shows the paths of transmitted ray T and reflected ray R. Upon passing these paths in opposite directions, both rays join in the device J and propagate in the same direction through the lens L.

The resulting interference fringes are registered by the photographic plate p. The angular velocity of the setup was not greater than three rotations per second to reduce deformations of the mirrors M_1, M_2, M_3, and M_4 and to avoid adverse air circulation. Two photos of interference fringes were made corresponding to cases of rotation with the same angular velocity but in opposite directions. The dimensionless shift Δ of the central interference fringe relative to its neutral position corresponding to $\omega = 0$, where ω is the angular velocity of the experimental setup, depend on the area S, bordered by the optical contour rather than on the optical-contour shape. This area is marked with dark background in Fig 1 (Sagnac, 1913a, 1913b).

$$\Delta = \frac{4\omega S}{c\lambda} \qquad (1)$$

Here, c is the speed of light in the static ether and λ is the wavelength of the light. The factor 4 should be replaced by 8 in Eq (1) if Δ is the relative fringe shift corresponding to alternation of the direction of rotation. If the angular velocity was equal to 143 rpm and the area $S = 866\ cm^2$, the expected and observed values of Δ were 0.079 and 0.077, respectively, for the wavelength $\lambda = 4360$ Angstrom. The difference of these values of Δ was in accord with the accuracy of the experiment. Sagnac was an advocate of the static-ether concept. His experiment confirmed the reliability of experimental determination of the angular velocity relative to the ether. However, two issues remained unclear after this experiment: (i) whether the ether is dragged by large bodies and (ii) whether the effect of the ether is screened by metal surfaces. The Michelson-Gale experiment (Albert Abraham Michelson, 1925; Albert A Michelson & Gale, 1925) answered these questions with exhausted clarity. The design of the corresponding experimental setup is shown in Fig 2.

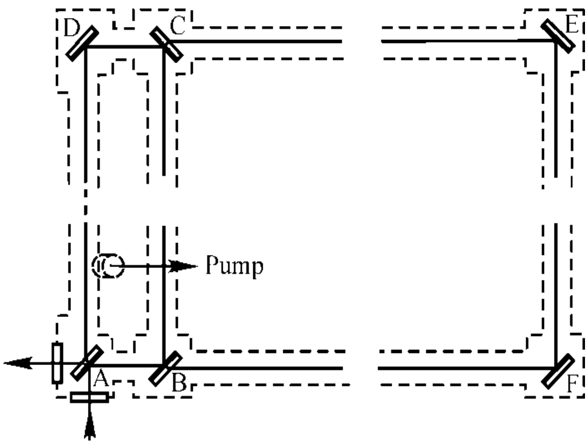

Fig 2. Light channels in the Michelson-Gale experiment. AF = 620m, AD = 340m.

In contrast to the Sagnac setup in which light beams propagated immediately in the atmospheric air, counter propagating rays in the Michelson-Gale setup passed along a closed contour mounted on the ground and made of iron pipes of about 30 cm in diameter. The perimeter of the large contour AFED was almost two kilometers. The small contour ABCD was necessary to determine the neutral position of the interference fringe, which corresponded to zero value of ω. Continuous 3-hour work of a powerful pump reduced the pressure inside pipes to 1 cm Hg. According to the concept of static ether, the dimensionless shift Δ of the central interference fringe at the geographic latitude φ should be determined by the formula (Albert A Michelson & Gale, 1925),

$$\Delta = \frac{4S\omega Sin\varphi}{c\lambda} \qquad (2)$$

If $\varphi = 90°$, the light-contour plane is orthogonal to the axis of Earth rotation, so that Eq (2) is identical to Eq (1). The Michelson-Gale experiment was carried out at the latitude 41°46′. The value of Δ calculated using Eq (2) amounted to 0.236 while $\Delta = 0.230$ was found experimentally (Albert A

Michelson & Gale, 1925). This difference was in accord with the accuracy of the experiment. Thus, the Michelson-Gale experiment proved that, firstly, the ether penetrates freely through metal envelopes and affects processes inside as if these envelopes were absent and, secondly, the ether is static and is not dragged by the motion of bodies even as large as the Earth.

ANALYSIS OF RAY PATHS IN A ROTATING LIGHT CHANNEL

To generalize the Sagnac and Michelson-Gale experiments, we consider the following imaginary though undoubted experiment. First, assume that the Michelson-Gale experiment is carried out at the North Pole. Second, assume that the area of the main contour is the same, S = 0.208 km^2, but has the shape of a hollow torus in which many mirrors with input and output of interfering rays similar to Sagnac design are mounted on chords. Let R be the toroidal contour radius. Then, by writing its area S as 0.208×10^6 m^2 we find

$$R = \sqrt{\frac{0{,}208}{3{,}14}} \times 10^3 m = 257m$$

As a result, the diameter of our toroidal channel is slightly larger than one half of a kilometer. Light rays inside it propagate along the perimeter of a regular polygon which is maximally close to a circle. Let us transform Eq (2) by putting $S = \pi R^2$, $\omega = v/R$, and $\varphi = 90°$ in it. As a result,

$$\Delta = \frac{4\pi R v}{c\lambda} \tag{3}$$

Then the circular velocity v of the ring channel is found as

$$v = c\frac{\lambda\Delta}{4\pi R}. \tag{4}$$

Of course, the velocity v under conditions of experiment on the Earth can be found without our interferometer. However, the most significant in this case consists in the fact that this velocity given by Eq (4) does not depend on the translational velocity of the Earth relative to the ether. The reason for this is clear. Imagine that the toroidal channel is crossed by an orthogonal plane passing through the translational-velocity vector originating from the toroid center. The translational velocity makes the same angles with the tangent line to the ring channel at the points of the channel which are symmetric with respect to the constructed plane. Therefore, two counter propagating rays passing the same parts of the channel in opposite directions and in reverse order retain nothing of the translational velocity at the moment of their joining. This means that the Sagnac and Michelson-Gale experiments would go on in the same way also in the case where the rotation axis of the Earth was at rest relative to the ether. Now we can consider our imaginary experiment in space in such a way that the rotation axis of the toroidal channel is at rest relative to the ether while its circular velocity v has nothing to do with diurnal rotation of the Earth. First of all, consider ray paths in the absolute frame related to the static ether. Let the ray propagating in the direction opposite to the toroidal channel be denoted by subscript 1 and the ray co-propagating the toroidal channel, by subscript 2. Let σ_1 and σ_2, respectively, be the paths passed by these rays from splitting points to joining points. Let t_1 and t_2, respectively, be the times of propagation along the paths σ_1 and σ_2. Then

$$\sigma_1 = ct_1, \quad \sigma_2 = ct_2 \tag{5}$$

since each ray moves in the ether with the same velocity c.

As long as the first ray passes along the toroidal channel, the channel itself shifts the distance vt_1 toward the ray, whereas the path of the second ray increases by vt_2. Thus, the following equalities are valid.

$$\sigma_1 = 2\pi R - vt_1 \ , \quad \sigma_2 = 2\pi R + vt_2 \tag{6}$$

From Eqs (5) and (6) we find

$$t_1 = \frac{2\pi R}{c+v}, \quad t_2 = \frac{2\pi R}{c-v}, \quad \sigma_1 = \frac{2\pi R}{1+v/c}, \quad \sigma_2 = \frac{2\pi R}{1-v/c}$$

The considered variants of the Sagnac and Michelson-Gale experiments, in which effects of the order of *v/c* are registered, cannot be significantly affected by terms of the order of v^2/c^2, so that

$$\Delta\sigma = \sigma_2 - \sigma_1 = \frac{4\pi R}{1 - v^2/c^2} \times \frac{v}{c} \approx 4\pi R\frac{v}{c}$$

Dividing $\Delta\sigma$ by the wavelength λ, we find the relative spatial delay of the first ray from the second one in units of the wavelength. The resulting quantity is equal to the relative interference-fringe shift Δ given by Eq (3). Thus, the result given by Eq (3) and confirmed by the Sagnac and Michelson-Gale experiments is obtained assuming that light is waves propagating in the static ether with the velocity "c". This means that the mentioned experiments prove that the static ether is real. Note that the rays whose paths are considered pass the splitting point at different instants of time, the corresponding difference being $\Delta t = t_2 - t_1$. Let us now analyze the ray path in the reference frame of the rotating toroidal channel. In this case, each ray passes the same distance $2\pi R$ but the velocities of the rays turn out to be different. If, as before, ray 1 propagates opposite to the direction of the translational velocity v of the toroidal channel and ray 2 propagates in the direction of this velocity, we find that the velocity of the first ray in the rotating frame is equal to,

$$c + v, \tag{7}$$

while the velocity of the second ray is

$$c - v \tag{8}$$

Here, as before, c is the absolute speed of light in the static ether. As a result, the first and second rays make the complete passes around the toroidal channel during the times t_1 and t_2, respectively, where

$$t_1 = \frac{2\pi R}{c+v}, \quad t_2 = \frac{2\pi R}{c-v}$$

Let $\Delta t = t_2 - t_1$ be the time interval from the moment of splitting of the first ray from the non-splitted light beam to the moment of splitting of the second ray,

$$\Delta t = 2\pi R\left(\frac{1}{c-v} - \frac{1}{c+v}\right) = \frac{4\pi R v}{c^2(1 - v^2/c^2)} \approx \frac{4\pi R v}{c^2}$$

Note that in the case of ray-path analysis in the static ether, there is both spatial and temporal coherence of rays. In the rotating frame, however, waves in ray 1 are shorter than in ray 2, so that only temporal coherence takes place. The ratio c/λ specifies the number of waves per unit time. Thus, multiplying Δt by the ratio c/λ yields the difference in the fraction of wave which occurred up to the moment of joining of rays. Note that this quantity is equal to the relative interference-fringe shift, i.e.,

$$\Delta = \frac{4\pi R v}{c\lambda}$$

We arrive at the same result (3) that was obtained by analyzing ray paths in the static ether, i.e., in the absolute frame. This proves that the relative velocity of a light ray in any moving frame is equal to the vector difference between the absolute speed of light **c** in the static ether and the translational velocity **v** of the moving frame. Figure 3 shows the fragments of two counterpropagating rays between two neighboring reflecting mirrors. The local direction of the translational velocity **v** of the toroidal channel is also shown here. It is quite important that light rays 1 and 2 are not dragged into the rotational motion of the toroidal channel in the sense that the directions of these rays in the static ether remain the same. This makes it possible to introduce the *local* inertial frame moving with the velocity **v** (Fig 3). The velocities of rays 1 and 2 in this frame are given by Eqs (7) and (8), respectively.

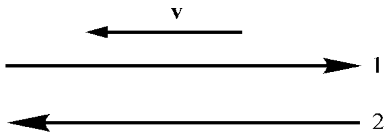

Fig 3. Counterpropagating rays 1 and 2 in the frame moving with the velocity **v**.

It is absolutely insignificant in this example whether rays 1 and 2 in Fig. 3 are fragments of counterpropagating rays in a toroidal channel or they arrived from distant stars to an observer on the Earth if **v** is the observer velocity relative to the ether.

EXPERIMENTS USING THE MICHELSON INTERFEROMETER

The first Michelson interferometer for detecting the translational velocity of a laboratory on the Earth relative to the static ether has been created in 1881 and used for experiments in the Potsdam Astrophysical Observatory (Albert A Michelson, 1881). The scheme of this interferometer is shown in Fig. 4. A monochromatic light beam A is incident onto a glass plate P_1 at an angle of 45°. The rear side of the plate is coated with a thin silver layer. As a result, the beam A splits in two orthogonal rays r_1 and r_2. Upon reflecting from mirrors M_1 and M_2, both layers come back, are incident onto the screen on which an eye is shown, and interfere. A transparent plate P_2 making an angle of 45° with ray r_2 is necessary to equalize the distances passed by rays r_1 and r_2 in glass. Let *l* be the distance between the point on plate P_1, at which the rays split and join, and mirrors M_1 and M_2. Let **v** be the velocity of motion of the laboratory through the ether, which is strictly parallel to ray r_1 and is directed from P_1 to M_1 at the considered instant of time, and c is the speed of light in the static ether. Then, according to the initial idea by Michelson (Albert A Michelson, 1881), propagation of light from P_1 to M_1 and back takes the time t_1 given by

$$t_1 = \frac{l}{c-v} + \frac{l}{c+v} = \frac{2l}{c}\cdot\frac{1}{1-v^2/c^2} \qquad (9)$$

whereas ray 2 reaches the splitting point at the time

$$t_2 = \frac{2l}{c}$$

Using these formulas, Michelson found that

$$\Delta t = t_1 - t_2 = \frac{2l}{c}\left(\frac{1}{1-v^2/c^2} - 1\right) \approx \frac{2l}{c}\cdot\frac{v^2}{c^2} \qquad (10)$$

This value of Δt has been predicted by Michelson. However, H.Lorentz, pointed out an error in this consideration. Consider the essence of this error. The left part of Fig. 5 shows the path of ray r_2 in the laboratory frame and the right part of this figure, the trace of the same ray in the static ether. Michelson was wrong assuming that the velocity of ray r_2 in the laboratory frame is equal to *c*. In fact, *c* is the speed of light in the static ether, i.e., in the case corresponding to the right part of Fig 5.

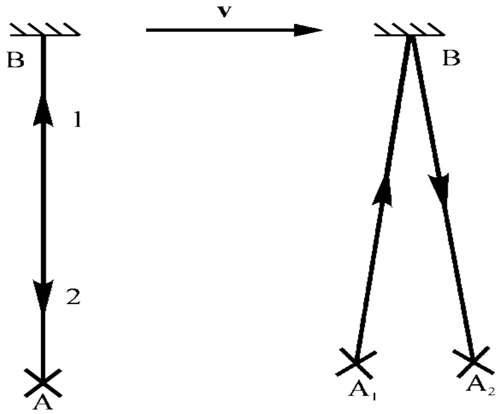

Fig 5. Path of ray r_2 in the laboratory (left) and absolute (right) frames.

Meanwhile, the velocity of ray r_2 in the laboratory is equal to ccosα, where α is one half of the angle A_1BA_2. Thus, the total time of motion of ray r_2 is

$$t_2 = \frac{2l}{c\cos\alpha} = \frac{2l}{c\sqrt{1-v^2/c^2}}. \qquad (11)$$

Therefore, instead of Eq (10) we obtain the following more correct expression for Δt:

$$\Delta t = \frac{2l}{c}\left(\frac{1}{1-v^2/c^2} - \frac{1}{\sqrt{1-v^2/c^2}}\right) \approx \frac{l}{c}\cdot\frac{v^2}{c^2} \qquad (12)$$

Thus, in comparison to the more correct value given by Eq (12), Michelson expected to get a factor of 2 greater delay of ray r_1 from ray r_2 when these rays reach the screen in his experimental setup. This first Michelson interferometer was too sensitive to disturbances. Even in the case where the interferometer has been mounted at the basement level of the Potsdam Observatory, steps on the sidewalk at a distance of hundred meters from the observatory gave rise to such disturbances that the interference pattern disappeared completely. Multiplying the ratio c/λ by Δt given by Eq (12) yields the relative shift Δ_0 of the central interference fringe from its neutral position:

$$\Delta_0 = \frac{l}{\lambda} \cdot \frac{v^2}{c^2} \quad (13)$$

However, this result corresponds to the configuration of interferometer arms shown in Fig. 5. If the platform is turned by an angle of 90° around the vertical axis, the interference pattern is shifted from the neutral position in the opposite direction. As before, the value of Δ_0 is given by Eq (13). The relative shift Δ of the central interference fringe between these two extreme positions of the platform, i.e., the value of $\Delta=2\Delta_0$ is registered in the Michelson interferometer. Therefore,

$$\Delta = \frac{2l}{c} \cdot \frac{v^2}{c^2} \quad (14)$$

This formula yields the following expression for the translational velocity v of motion of the laboratory through the static ether:

$$v = c\sqrt{\frac{\lambda\Delta}{2l}} \quad (15)$$

When carrying out the Potsdam experiment, Michelson was motivated by quite reasonable idea that the translational velocity of the laboratory should be no less than the orbital velocity of the Earth equal to 30 km/s. Based on this estimate for v, he calculated the expected value of Δ. However, the result was overvalued by a factor of two because of the error in Eq (10) for Δt. No regular shifts of the interference pattern, which depend on the platform orientation, were observed since such shifts were over an order of magnitude less than expected and were completely lost because of disturbances. As a result, Michelson published a conclusion that the hypothesis of static ether is wrong (Michelson, 1881). In 1887, Michelson and Morley carried out a new experiment using a significantly improved interferometer (Albert A Michelson & Morley, 1887). The platform was made of solid stone. Its thickness was 30 cm, the size in plane, 1.5 × 1.5 m, and the weight, over 1.5 tons. The platform rested upon a ring-shaped buoy floating in mercury. The mercury vessel was made of cast iron. The path length of each ray was increased up to 11 m using multiple reflections from additional mirrors. A deep concrete substructure reaching the primary rock was made for the experimental setup. Adjustment of this expensive device took a few months, but the observations were carried out during only six hours including one hour per day at noon on July 8, 9, and 11 and one hour per day in the evening on July 8, 9, and 12 (Miller, 1933). The experiment was carried out at Cleveland (42° N). It was expected to observe a fringe shift of 0.4 of the fringe width. Instead, only shifts not exceeding 0.01 of the width of one fringe were observed (Albert A Michelson & Morley, 1887). It is surprising that in this experiment which became the most famous one, only the same two points on the diurnal plot of the temporal dependence of the relative fringe shift were tested thrice by the researchers. To estimate the probability of observing the maximal effect for such a schedule of the experiment, we consider the case where the diurnal plot of the relative fringe shift Δ is known. The plot has one maximum and one minimum. Let somebody cover the curve by a paper sheet and asks you to select two points on the time axis. The plot is uncovered as soon as you do this. What is the probability that one of the selected points corresponds to the maximum? The maximal effect in the Michelson-Morley experiment could be observed with the same probability. A new and the most advanced stage of improving the Michelson interferometer is related to the name of Miller (Kennedy, 1926; Miller, 1933). In 1902-1905, this prominent searcher for scientific verity worked in collaboration with Morley. Then Morley retired and Miller continued working alone. Only the cast-iron vessel for mercury from the Michelson setup was used in the new interferometer. The solid-stone platform was replaced by a steel cross whose rigidity was an order of magnitude higher. The sensitivity of the new setup increased fourfold. Miller and Morley carried out their experiments at Cleveland, i.e., at the same place where Michelson and Morley have done their observations. A regular effect repeating twice per complete revolution of the setup was observed. Based on Eq (15), this effect implied that the regular velocity of the laboratory was equal to 3 km/s. After 1905, Miller carried out his experiments mainly near the Mount Wilson Observatory (34° N). As a result, he found that the velocity v given by Eq (15) is approximately equal to 10 km/s (Kennedy, 1926; Miller, 1933). No explanations for almost threefold increase in translational velocity (15) at Mount Wilson in comparison with Cleveland can be found in (Miller, 1933) and (Kennedy, 1926). Miller had nothing to do with doubtful assertions that this effect could increase with the altitude above the sea level. Moreover, S. Vavilov in (Vavilov, 1928) cited the following words by Miller: “New data show that the ether wind at Mount Wilson does not significantly differ from this wind at Cleveland.” One should not be confused by the term “ether wind” used by Miller. Based on the absence of noticeable relation between the direction of orbital velocity of the Earth and the effect registered on the interferometer screen, he understood that in fact, the velocity of motion of the Sun through the ether exceeds 200 km/s(Miller, 1933). Similar to all contemporaries, he did not guess that Eq (15) is wrong and tended to the model of gas-like ether. Miller carried out hundreds and thousands observations at different times of a day. He understood how to properly clean the registered effects from numerous disturbances of various nature and putted statistical procession of experimental data into practice. It is absolutely clear from the analysis of his extended paper (Miller, 1933) that, while searching for verity, Miller was free of preconceived notions and, moreover, intentions to justify some a priori accepted idea by all means. He searched for verity and abandoned any working hypotheses contradicting the experiments. Determination of the spatial orientation of the line along which the absolute velocity of the Sun and the solar system as a whole are directed is one of the most important scientific discoveries by Miller. This line turned out to be almost orthogonal to the ecliptic plane and pointed to the star ζ Dra. This is a circumpolar star of the northern hemisphere. The azimuth of ζ Dra at the latitude of Mount Wilson is 8 degrees less than that at Cleveland. Since the arms of the Michelson interferometer with the vertical axis of rotation were always directed to the horizon line, it is obvious that in accord with a latitude difference of 8 degrees, the effect observed at Mount Wilson should be greater than that at Cleveland.

In 1926, (Kennedy (1926)) carried out new experiments using an upgraded Michelson interferometer. As was clearly pointed out at the beginning of (Kennedy, 1926), these experiments were mainly aimed at verifying the conclusions by Miller. We do not mention all the new elements used in the Kennedy setup and point out only those which gave rise to doubts in the validity of Miller scientific results. Kennedy made the paths of the light rays by a factor of 16 shorter and covered the setup with a jacket filled with helium at the atmospheric pressure. It was noted by Kennedy in (Kennedy, 1926) that the difference n-1, where n is the refractive index of the medium, for helium is 10 times less than for the atmospheric air. In what follows, we find that the fringe shift should decrease by an order of magnitude because of this factor alone. Hence, Kennedy did not observe noticeable fringe shifts related to turns of his setup. He reported that the Miller effect was not confirmed rather than noted the relation of the registered effect to the refractive index of the medium. In 1927, Illingworth (1927) carried out experiments with an improved Kennedy setup. As before, helium was used as the working medium. A small regular effect was observed. The translational velocity of the observatory was estimated to amount to 1 km/s using Eq (15) (Kennedy, 1926).

In 1929, Michelson, Pease, and Pearson carried out new observations using large interferometer. Solid cast-iron bedding taken from a polishing machine for 100-inch telescope mirror was used as the platform. The platform weighted over 3 tons. It was based on a ring-shaped metal cavity floating in mercury. The optical-path length was equal to 26 meters, i.e., a factor of 2.4 greater than in the Michelson-Morley experiment (A. Michelson, Pease, & Pearson, 1929). A regular effect repeating each half of the complete rotation of the platform was observed. According to Eq (15), the maximal effect corresponded to a velocity of 6 km/s. The azimuth of the Miller north point (ζ Dra) was confirmed in the presence of a staff member of the Mount Wilson Observatory.

WORK OF THE MICHELSON INTERFEROMETER IN VACUUM

The following understandable question arises upon getting informed on experiments with the Michelson interferometer after studying the Sagnac and Michelson-Gale experiments. Why the ray paths in rotating interferometers fully agree with the static-ether concept while experiments with the Michelson interferometer yield absolutely unexpected and inexplicable results?

When analyzing this question we notice that in the case of rotating interferometers, each ray passes the light-channel contour in certain direction and these directions are opposite. As a result, the temporal ray-path difference turns out to be proportional to the ratio v/c, where v is the linear velocity of the rotating channel. In the case of Michelson interferometers, each of two orthogonal rays returns along the same path onto which it was sent. This stipulates the temporal ray-path difference of the order of v^2/c^2, i.e., the quantity of second-order smallness. We explain the strange results obtained in experiments with the Michelson interferometer in the following way. We think that these experiments are accompanied by some adverse effects of the order of v^2/c^2 that were not taken into account. Note that such effects are negligible in experiments with rotating interferometers in which they amount to thousandths of the observed effect. The first such effect can be pointed out immediately. It is the Fitzgerald effect. O. Lodge (Reprinted on 1909 (2003)) reported in the issue of Nature published on June 16, 1892 that he got to know from Fitzgerald how the negative result of the Michelson experiment could be explained. According to the idea by Fitzgerald, the length of a body moving through the ether is slightly contracted along the direction of its absolute velocity. Consider the results following from this hypothesis. Figure 6 which corresponds to the laboratory frame shows the paths of direct ray 1 collinear to the vector **v** and reverse ray 2. Suppose that the distance AB becomes *kl* instead of l, where *k* is the Fitzgerald-contraction coefficient to be determined. Then, instead of Eq (9), the following expression holds for t_1,

$$t_1 = \frac{2l}{c} \cdot \frac{k}{1-v^2/c^2} \qquad (16)$$

It is seen that this expression becomes equal to t_2 given by Eq (11) if and only if the coefficient k is equal to

$$k = \sqrt{1 - v^2/c^2}$$

This means that if the length of a rod orthogonal to its absolute velocity **v** is equal to l, then the length l_1 of the same rod aligned with the velocity **v** is determined by the expression

$$l_1 = l\sqrt{1 - v^2/c^2} \qquad (17)$$

Fitzgerald formula (17) is absolute and valid in any reference frame. With allowance for the obtained value of k, the time intervals t_1 and t_2 given by Eqs (16) and (11), respectively, become equal,

$$t_1 = t_2 = \frac{2l}{c} \cdot \frac{1}{\sqrt{1-v^2/c^2}}, \quad \Delta t = t_1 - t_2 = 0 \qquad (18)$$

The second equality in Eq (18) means that the interference fringes on the interferometer screen do not shift upon rotation of the platform by the right angle. Consider the ray paths in the static ether. In Fig. 7, the interval A_1B is the path of ray 1 in the direction of the velocity **v** and the interval BA_2 is the path of reverse ray 2. The following formulas hold for these intervals:

$$A_1B = l\sqrt{1 - \frac{v^2}{c^2}} + v\tau_1, BA_2 = l\sqrt{1 - v^2/c^2} - v\tau_2 \quad (19)$$

Here, τ_1 and τ_2 are the time intervals necessary to pass the distances A_1B and BA_2. Since the speed of light in ether is always constant and equal to c, the following evident equalities hold,

$$A_1B = c\tau_1, \quad BA_2 = c\tau_2 \qquad (20)$$

From Eqs (19) and (20) we find

$$\tau_1 = \frac{l\sqrt{1 - v^2/c^2}}{c - v} \quad , \quad \tau_2 = \frac{l\sqrt{1 - v^2/c^2}}{c + v}$$

Summation of τ_1 and τ_2, yields the total time of propagation of ray r_1 (Fig 4),

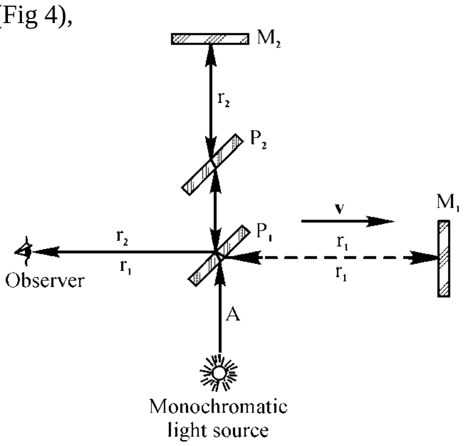

Fig 4. Scheme of the Michelson interferometer.

$$t_1 = \frac{2l}{c} \cdot \frac{1}{\sqrt{1-v^2/c^2}} \qquad (21)$$

Consider now the right part of Fig 5 showing the path of ray r_2 (Fig 4) in the ether. Let t_2 be the time of propagation of the ray along the sides of the angle A_1BA_2. Since the interval A_1A_2 is equal to the distance passed by the laboratory during the time t_2, the total path of ray r_2 is determined by the expression

$$2\sqrt{l^2 + (vt_2/2)^2} \qquad (22)$$

At the same time, this path in the ether is equal to ct_2. Putting the last quantity equal to that given by Eq (22), we find

$$t_2 = \frac{2l}{c} \cdot \frac{1}{\sqrt{1-v^2/c^2}} \qquad (23)$$

Since the quantities determined by Eqs. (21) and (23) are equal, we obtain $\Delta t = 0$ and conclude again that Fitzgerald formula (17) really explains the absence of any effect in the experiments with the vacuumized Michelson interferometer. This conclusion is confirmed by experiments (V. V. Demjanov, 2010). Both Michelson and Miller supposed that if real, the Fitzgerald contraction should depend on the elastic properties of a substance. Miller attempted to verify this idea experimentally by mounting mirrors M_1 and M_2 and plates P_1 and P_2 (Fig. 4) on bars made of various materials. No difference was observed and this is a natural result. It is wrong to think that the ether contracts a body which resists this contraction. In fact, the sizes of a body are determined by intermolecular and interatomic distances in it. These distances are completely determined and controlled by the ether. If a body moves through the ether, the ether properties inside this body vary along the direction of motion. This affects sizes of any bodies in the same way. The result does not depend on the elastic properties of a body since these properties are also stipulated by the ether. Let us draw attention to something very significant. We analyzed ray paths both in the laboratory frame and in the absolute frame related to the ether and obtained completely identical results. Meanwhile, considering the ether with allowance to the hypothesis that the speed of light is constant, we would arrive at the Lorentz transformations treated in the absolute sense. This approach would be disproved by contradiction of the results of analysis of the ray paths in different frames. This means that analysis of ray paths in the Michelson interferometer should necessarily be carried out both in the laboratory and in the absolute frame. This helps to reject false models of physical processes.

WORK OF THE MICHELSON INTERFEROMETER IN A GAS

The time of propagation of two orthogonal rays r_1 and r_2 in Fig. 4 become equal due to the Fitzgerald effect only under vacuum conditions. However, the Michelson, Michelson-Morley, Miller, and Michelson-Pease-Pearson experiments were carried out in the atmospheric air. As a result, regular fringe shifts dependent on the spatial position of the platform were observed. V. Demjanov was the first who understood this. This occurred in 1968. However, Academy of Sciences of the USSR blocked publication of papers contradicting the treatment of the Michelson-Morley experiment as definitely negative. This was the reason of the great delay of publication of the sound ideas by (V. Demjanov, 2009; V. V. Demjanov, 2010). First of all, consider the influence of decrease of the speed of light in a gas on the effects registered by the Michelson interferometer. Let us analyze the ray paths in a medium in the absolute frame. Consider Fig 7 in which the paths of direct ray r_1 (Fig 4) and reverse ray are shown. Since expressions (19) for the distances A_1B and BA_2 remain valid, the following equalities take place,

$$\tau_1 = \frac{l\sqrt{1-v^2/c^2} + v\tau_1}{c/n} \quad , \quad \tau_2 = \frac{l\sqrt{1-v^2/c^2} - v\tau_2}{c/n} \qquad (24)$$

where n is the refractive index of the medium and τ_1 and τ_2 have the same meanings as before. Using Eq(24), we obtain the following new expressions for τ_1 and τ_2 ,

$$\tau_1 = \frac{nl}{c} \cdot \frac{\sqrt{1-v^2/c^2}}{1-nv/c}, \quad \tau_2 = \frac{nl}{c} \cdot \frac{\sqrt{1-v^2/c^2}}{1+nv/c}$$

Summation of τ_1 and τ_2 yields the new total time t_1 of propagation of ray r_1 (Fig 4).

$$t_1 = \frac{nl}{c} \cdot \sqrt{1-\frac{v^2}{c^2}}\left(\frac{1}{1-\frac{nv}{c}} + \frac{1}{1+\frac{nv}{c}}\right) = \frac{2nl}{c} \cdot \frac{\sqrt{1-\frac{v^2}{c^2}}}{1-\frac{n^2v^2}{c^2}} \approx$$
$$\approx \frac{2nl}{c}\left(1-\frac{v^2}{2c^2}\right)\left(1+\frac{n^2v^2}{c^2}\right) \approx \frac{2nl}{c}\left(1+\frac{n^2v^2}{c^2}-\frac{v^2}{2c^2}\right) \qquad (25)$$

The path of ray r_2 (Fig 4) in the ether along the sides of the angle A_1BA_2 (Fig 5), is given by Eq (22) in which the speed of light is now equal to *c/n*. This makes the new time t_2 different,

$$t_2 = \frac{2\sqrt{l^2 + (vt_2/2)^2}}{c/n}$$

so that

$$t_2 = \frac{2nl}{c} \cdot \frac{1}{\sqrt{1-(nv/c)^2}} \approx \frac{2nl}{c}\left(1+\frac{n^2v^2}{2c^2}\right) \qquad (26)$$

Subtraction of t_1 given by Eq(25) from t_2 given by Eq (26) yields the time difference of paths of rays r_1 and r_2 (Fig 4),

$$\Delta t = \frac{n(n^2-1)l}{c} \cdot \frac{v^2}{c^2}$$

Multiplying Δt by the frequency which is always equal to the ratio c/λ, where λ is the wavelength in vacuum, we find the fraction of wavelength by which rays r_1 and r_2 shift upon reaching the screen. As was already mentioned above, this quantity is equal to the dimensionless shift Δ_0 of the central fringe relative to its neutral position:

$$\Delta_0 = n(n^2-1)\frac{l}{\lambda} \cdot \frac{v^2}{c^2}$$

Multiplying this result by a factor of 2, we find the maximal relative shift Δ of the central fringe repeating each half of the complete rotation of the platform:

$$\Delta = N_0 \frac{2l}{\lambda} \cdot \frac{v^2}{c^2}, \quad N_0 = n(n^2-1) \qquad (27)$$

This yields the following new expression for the translational velocity of the laboratory,

$$v = c\sqrt{\frac{\lambda\Delta}{2lN_0}} \qquad (28)$$

The following parameters were used in the Michelson-Morley experiment (Michelson & Morley, 1887),

$$l = 11\,m\ , \quad \lambda = 0.55 \cdot 10^{-6}\,m\ , \quad \Delta = 0.01 \qquad (29)$$

In the case of atmospheric air, n = 1.0003, so that

$$N_0 = 6 \cdot 10^{-4}, \quad v = 194\,km/s \qquad (30)$$

However, this result does not take the Fresnel effect into account. This effect confirmed by the Fizeau experiment consists in drag of light waves by a medium moving through the ether.

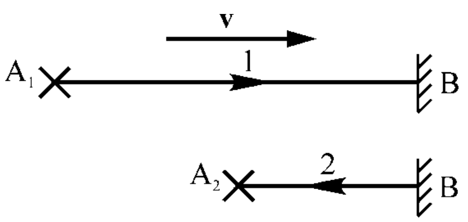

Fig7. Paths of direct 1 and reverse 2 fragments of ray r_1 in the absolute frame.

If c_1 and c_2, respectively, are the velocities of direct and reverse rays in Fig 7, then these velocities in a medium with the refractive index n are given by the Fresnel formulas

$$c_1 = \frac{c}{n}\left[1 + \left(n - \frac{1}{n}\right)\frac{v}{c}\right] \ , c_2 = \frac{c}{n}\left[1 - \left(n - \frac{1}{n}\right)\frac{v}{c}\right] \qquad (31)$$

With allowance for these formulas, expressions in Eq (24) become,

$$\tau_1 = \frac{nl\sqrt{1 - v^2/c^2} + nv\tau_1}{c\left[1 + \left(n - \frac{1}{n}\right)\frac{v}{c}\right]}, \quad \tau_2 = \frac{nl\sqrt{1 - v^2/c^2} - nv\tau_2}{c\left[1 - \left(n - \frac{1}{n}\right)\frac{v}{c}\right]}.$$

This yields

$$\tau_1 = \frac{nl\sqrt{1 - v^2/c^2}}{c(1 - v/nc)} \quad , \quad \tau_2 = \frac{nl\sqrt{1 - v^2/c^2}}{c(1 + v/nc)} \qquad (32)$$

The sum of τ_1 and τ_2 is the total time t_1 of motion of ray r_1 (Fig 4) to mirror M_1 and back

$$t_1 = \frac{nl}{c}\sqrt{1 - \frac{v^2}{c^2}}\left\{\frac{1}{1 - v/nc} + \frac{1}{1 + v/nc}\right\} =$$

$$= \frac{2nl}{c}\frac{\sqrt{1 - v^2/c^2}}{1 - v^2/n^2c^2} \approx \frac{2nl}{c}\left(1 + \frac{v^2}{n^2c^2} - \frac{v^2}{2c^2}\right) \qquad (33)$$

Formula (26) for the total time t_2 of motion of the second ray r_2 (Fig 4) remains intact. We do not agree with the viewpoint (Shamir & Fox, 1969) that this ray should be dragged in the perpendicular direction and this should affect the time t_2. Indeed, the time t_2 equals 2l divided by the velocity of motion of the ray along the normal to the vector **v** and this velocity does not depend on the Fresnel effect. Since now t_1 given by Eq (33) is less than t_2 given by Eq (26), we define the time difference Δt of ray paths as $t_2 - t_1$ (the sign alternation of Δt has no effect on work of the Michelson interferometer),

$$\Delta t = \frac{nl}{c}\left(1 + n^2 - \frac{2}{n^2}\right)$$

Now, in the same way as before, we arrive at the following new formulas instead of Eq (27),

$$\Delta = N\frac{2l}{\lambda} \cdot \frac{v^2}{c^2} \quad , \quad N = 1 + n^2 - \frac{2}{n^2} \qquad (34)$$

Using data (29) and n = 1.0003, we arrive at the following values for N and v different from Eq (30),

$$N = 18 \cdot 10^{-4}\ , \quad v = 112\ km/s \qquad (35)$$

The value of v given by Eq (35) is undoubtedly more accurate than that given by Eq (30). However, Fresnel formulas (31) were never verified with accuracy of the order of v^2/c^2 necessary to analyze the Michelson-interferometer work. This means that formulas (34) and result (35) should be considered approximate. In addition, we do not claim that formulas (34) are applicable for liquid and solid media. In Shamir and Fox experiment (Shamir & Fox, 1969), light propagated through organic glass, but expected results were not obtained. V. Demjanov (Demjanov, 2010) proves that in the experiment (Shamir & Fox, 1969), interference took place for rays passed along short paths in air to polished ends of organic glass and back. It follows from the first formula in Eq (34) that

$$v = c\sqrt{\frac{\lambda\Delta}{2lN}} \qquad (36)$$

Comparison of expressions (15) and (36) shows that the following equality is valid:

$$v = v_m/\sqrt{N} \qquad (37)$$

where v_m is the value of the translational velocity found from the wrong formula (15) which was used by Michelson, Morley, and Miller. If Eq(37) with allowance for the obtained value of N given by Eq(35) is used, the Miller velocity v_m = *10 km/s* is reevaluated to much greater velocity,

$$v = 236\ km/s \qquad (38)$$

In (V. Demjanov, 2009; V. V. Demjanov, 2010; Shamir & Fox, 1969), ray paths in the Michelson interferometer were analyzed taking into account three factors considered. However, our results (34), (36), and (37), as well as intermediate considerations, differ from both Demjanov's papers (V. Demjanov, 2009; V. V. Demjanov, 2010) and data of (Shamir & Fox, 1969). New formula (34) for Δ allows one to understand why Kennedy (Kennedy, 1926) failed to observe the Miller effect. Kennedy made his experimental setup a factor of 160 less sensitive by decreasing the path length l of each ray by a factor of 16 and the function N by a factor of 10 because of using helium instead of the atmospheric air. This experiment (Kennedy, 1926) is useful only as a demonstration of the dependence of the observed effect on the refractive index of the medium. However, being interpreted in the wrong way, it played the negative role in the history of physics. Let us now confirm that analysis of ray paths in the laboratory frame yields the same results. Consider Fig 6 in which rays 1 and 2 pass the same distance $l\sqrt{1-v^2/c^2}$ with different velocities.

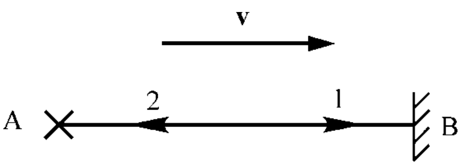

Fig 6. Paths of direct 1 and reverse 2 fragments of ray r_1 in the laboratory frame.

Now the velocity of direct ray 1 is equal to $c_1 - v$ and the velocity of the second ray is equal to $c_1 + v$, where c_1 and c_2 are the velocities of these rays in the static ether (see Eq (31)). The time intervals τ_1 and τ_2 during which rays 1 and 2 pass the specified distance are now given by the following formulas:

$$\tau_1 = \frac{l\sqrt{1-v^2/c^2}}{\frac{c}{n}\left[1+\left(n-\frac{1}{n}\right)\frac{v}{c}\right]-v} = \frac{nl}{c}\cdot\frac{\sqrt{1-v^2/c^2}}{1-v/nc},$$

$$\tau_2 = \frac{l\sqrt{1-v^2/c^2}}{\frac{c}{n}\left[1-\left(n-\frac{1}{n}\right)\frac{v}{c}\right]+v} = \frac{nl}{c}\cdot\frac{\sqrt{1-v^2/c^2}}{1+v/nc}$$

These formulas are identical to previous ones given by Eq (32). Hence, the sum t_1 of the above quantities (see Eq (33)) does not change. Expression (26) for the total time t_2 of propagation of ray r_2 (Fig 4) from A to B and back (Fig 5) also remains intact since this time is equal to the distance 2l divided by the velocity of ray r_2 in the direction orthogonal to the vector **v**. This is exactly the time t_2 calculated in the laboratory frame.

ABSOLUTE AND EARTH-AVERAGE SPEED OF LIGHT

The quantity which we denoted c is the speed of light in the static ether or the absolute speed of light, whereas the symbol c_m denotes the quantity conventionally called the speed of light in vacuum. The subscript m refers to the name of Michelson who significantly improved the accuracy of c_m. According to the last data,

$$c_m = (299792458 \pm 1.2)\ \text{m/s} \qquad (39)$$

Let us explain why c_m has the meaning of the Earth-average speed of light. Indeed, Michelson sent a light ray from the Mount Wilson Observatory to a mirror on San Antonio Mountain at a distance of 35 km. Then a path of 70 km propagated by the light ray "back and forth" over the same path was divided by the total time of propagation of the ray. The resulting speed c_m is some average speed of light in the laboratory on the Earth. In contrast to the actual speed of light ray relative to the Earth, this speed is highly stable. Consider the origin of this stability. Rays r_1 and r_2 in Fig 4 correspond to two extreme cases which should give rise to the maximum spread, if any, of the values of c_m. However, according to Eq (21) for t_1 and Eq (23) for t_2, both rays pass the distance 2l during the same time. As for the Fitzgerald contraction of the path of ray r_1 (Fig 4), the procedure of measuring the Earth-average speed of light c_m implies that the distance l is measured once and then is considered independent of the orientation of the line along which the light ray passes back and forth. This means that the Earth-average speed of light c_m is stable since this quantity is determined as follows,

$$c_m = \frac{2l}{t_1} = \frac{2l}{t_2} = c\sqrt{1-\frac{v^2}{c^2}} \approx c - \frac{v^2}{2c} \qquad (40)$$

If the absolute velocity of the Sun given by Eq (38) is rounded off to 250 km/s and the orbital velocity of the Earth is accepted equal to 30 km/s, then the squared absolute velocity of the Earth is estimated as follows,

$$v^2 = (250^2 + 30^2)\ km^2/s^2 = 634 \cdot 10^8 m^2/s^2$$

Since, according to Miller, the absolute velocity of the Sun is almost orthogonal to the orbital velocity of the Earth. Hence,

$$\frac{v^2}{2c^2} \approx \frac{634\cdot 10^8}{2\cdot 3\cdot 10^8} \approx 106\ \text{m/s} \qquad (41)$$

Thus, we arrive at the conclusion that any stable speed of light measured in a laboratory on the Earth is the Earth-average speed c_m given by Eq (39). According to Eqs (40) and (41), this speed is about 106 m/s less than the absolute speed of light in the static ether. Meanwhile, the actual speed of light ray under Earth conditions depends on its direction and can vary in the approximate range $c_m \pm 250\ km/s$. The stability of c_m lays in the basis of the accuracy of radar methods for distance measurements since the radar electromagnetic signal returns over the same path along which it was sent.

POSSIBILITY OF EXPERIMENTAL TESTING OF NEW RESULTS

Fitzgerald formula (17) implies that it is impossible for a body to move in the ether with the speed of light and, moreover, with a superluminal velocity. However, the velocity of an elementary particle in the laboratory frame can exceed the speed of light in the ether. Velocities of elementary particles under Earth conditions can indeed reach (299792 + 200) km/s. The well-known OPERA experiment is recalled is this respect. This experiment makes it possible to measure velocities in the neutrino fluxes which are generated in CERN (Geneva) and then through underground layers are directed to Gran Sasso Laboratory near Rome. Neutrinos pass a distance of 732 km. The time of motion is determined using an atomic clock. With allowance for the geographic locations of Geneva and Rome, there is the time of a day in any season when the Geneva-Rome direction makes an angle of about 20° with the vector of relative velocity of the ether. The neutrino velocity should be maximal at this time and minimal 12 hours later. Note that it does not matter whether the maximal velocities of neutrinos are superluminal since this depends on the energy at which the neutrino flux is generated. However, if the collider energy is the same, then the diurnal plot of the neutrino velocity should have one maximum and one minimum. Confirmation of this forecast would make undoubted the reality of the ether and the validity of Miller discoveries.

MAIN RESULTS AND CONCLUSIONS

1. Analysis of ray paths in rotating interferometers in which the light contour is passed by two counterpropagating rays without alternation of the direction of pass of each ray (Sagnac and Michelson-Gale experiments) fully agree with the concept of the static ether.

2. The Michelson-Gale experiment proved that, firstly, even such a massive body as the planet Earth does not drag the ether into rotational motion and, secondly, metal pipes do not screen the ether whose properties remain fully intact inside pipes.

3. Experiments with the Michelson interferometer, aimed at determination of the velocity of motion of a laboratory through the ether by detecting small effects of the second order of magnitude, were explained erroneously and resulted in denial of the ether. This error is mainly caused by the fact that the theoretical estimate of the expected effect was underestimated by a factor of 20-40 because three factors of the same order of magnitude as the expected effect were not taken into account. The first factor is the Fitzgerald effect consisting in contraction of the size of a body in the direction of the velocity of its motion through the ether. The second factor is a decrease of the speed of light in a medium, e.g., in the atmospheric air. The third factor is the Fresnel effect according to which light waves are partially dragged by a moving medium.

4. Analysis of ray paths in the Michelson interferometer with allowance of three above-mentioned factors results in fairly good agreement between theoretical predictions and experiments. In this case, the concept of the static ether is confirmed.

5. Among a variety of experiments with various modifications of the Michelson interferometer, the most valuable scientific results were obtained by Miller (Miller, 1926, 1933). He determined the direction of the velocity of motion of the Sun through the ether even more accurately that could be expected when using such a disturbance-sensitive device as the Michelson interferometer. This velocity is directed approximately to the star ζ Dra (the Miller point). The absolute velocity of the Sun estimated by Miller as 10 km/s because of using commonly accepted but wrong formula (15) is reevaluated in a velocity of 236 km/s based on formulas (36) and (37).

6. Widespread opinion that allegedly improved experiment by Kennedy (Kennedy, 1926) argues against the conclusions by Miller is groundless and caused by misunderstanding of actual consequences of novelties by Kennedy. Helium was used in his setup and the length of optical paths was reduced by a factor of 16. As a result, the interferometer sensitivity was reduced by a factor of 160, so that the interference-fringe shift was completely absent.

7. Analysis of ray paths in the frame of moving interferometer yields the same result as in the absolute frame of the static ether only if the relative speed of light is found as the vector subtraction of the translational velocity of the interferometer from the absolute speed of light in the ether. Variability of the speed of light in moving frames was confirmed in the experiment by E. Shtyrkov (Shtyrkov, 2005) aimed at controlling aberration of electromagnetic radiation emitted from a geostationary satellite.

8. The Fitzgerald effect, the location of the Miller point near the northern pole of the ecliptic, and the conclusion that the speed of light is not constant for an observer on the Earth hint the idea of modernization of the well-known OPERA experiment. The diurnal plot of the neutrino velocity should have one maximum and one minimum separated by a time interval of 12 hours. The maximal neutrino velocity can exceed the speed of light by not more than 200 km/s depending on the energy of neutrino-generation processes.

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