Michelson-Gale-Pearson Experiment – the Factual Analysis

Gocho V. Sharlanov[1, 2]
1 Independent Researcher 2 Stara Zagora, Bulgaria

Abstract. The article starts with a general introduction to the problem in modern physics about the constancy of the speed of light for all frames of reference. In the "General Introduction", besides presenting the used terms and definitions, the fundament of a real solution about all "unexpected" and "inexplicable" results of the experiments related to the measurement of the velocity of light in the time-spatial region "on the Earth surface" is given.

The factual analysis of the "Michelson-Gale-Pearson" experiment shows that the equation that Michelson proves by means of this experiment (which, in the words of Michelson, is "deduced on the hypothesis of a fixed ether"), has actually been deduced on the basis of the classical mechanics and the Galilean relativity, which are indisputably valid and legitimate in our local time-spatial domain "on the Earth's surface". The speed of light in vacuum (in relation to the stationary space) depends on the intensity of the gravitational field. The speed of light in vacuum is constant in the time-spatial region "on the Earth's surface" due to the uniform and constant intensity of the gravitational field in this region, which is determined (dominated) by the mass of the celestial body (the Earth).

It is clear, however, that the experiment proves that the measured velocity of light in the frame of reference related to the Earth's surface is different at different latitudes of the Earth surface and that in the "East-to-West" direction is higher, and in the direction "West-to-East" is lower than the speed of the light in vacuum. The difference is equal to the linear velocity of the Earth's surface (the speed of motion of a point on the Earth's surface in the stationary space for the respective latitude) where the northern and southern pipes are located.

The question remains - why did not Michelson wish to make this conclusion... Probably because the experiment actually proves that the measured speed of light is not the same for all inertial frames of reference, which is the fundament of the special theory of relativity. That is why, probably, Michelson did not make this conclusion because at this time the special theory of relativity was already accepted as a true theory by contemporary physics and Michelson was awarded as Nobel laureate….

KEY WORDS: special theory of relativity; speed of light postulate; Michelson-Gale-Pearson experiment; speed of light invariance.

1 General Introduction – Used Terms and Definitions

1.1 Concerning the used frames of reference and the speed of light

1.1.1 Frames of reference

The reference system (frame of reference) is a concept in physics (usually associated with the movement) to denote the point of view of the observer.

When we talk about a frame of reference (reference system), we usually imagine it as a coordinate system and we talk about an observer or an experimenter attached to it. When an observer is attached to a frame of reference, this frame is stationary for the observer.

Coordinate systems.

The reference frames used in dynamics are known as coordinate systems. The most widely used is the Cartesian coordinate system which consists of an origin and three axes. The axes are fixed lines, sized/dimensioned with numbers, corresponding to the same unit of length, perpendicular to one another and with direction for each axis. The common point where the axes cross is known as the origin of the coordinate system.

Using the Cartesian coordinate system, in a time-spatial region with constant measurement units (a region with a uniform intensity of the gravitational field), the location of any point in the space can be described, as well as the change into the time of the location of any point.

As a consequence, in the experiment, we distinguish two main frames of reference:

1) Reference system related to the Earth's surface. This is the frame of reference we usually use. In this frame of reference (for an observer, positioned at a point on the Earth's surface) – any object immovably fixed on the Earth's surface is stationary. This frame of reference is fixed to the moving surface of the Earth and it is moving in the stationary space due to the rotating of Earth around its axis in the stationary space.

2) Stationary reference system. Celestial bodies and space. Everything in the Universe possessing mass moves. The gravitation is the driving force. It is caused by the masses of celestial bodies and it sets them into motion. Therefore, a stationary reference system cannot actually exist because we cannot actually connect the "origin" of a stationary coordinate system to a stationary material point. Also, we cannot give exact directions to the axes because we cannot orient them to theoretically non-existing stationary points. However, for most of the cases under consideration, we can use the following approximately stationary frames of reference:

• *"Earth-centered inertial (ECI) coordinate system"* which can be considered in our time-spatial region as a stationary coordinate system in relation to the stationary space.

The origin of this coordinate system is at the center of the Earth (which is not stationary) and its *axes* are approximately stationary in the space (aimed at very distant astronomical objects).

In other words, we can say that the "Earth-centered inertial (ECI) coordinate system" is related to the space itself where the Earth rotates…, where the photons are born and propagate. If an observer is positioned at a point in this coordinate system, he/she will be stationary in relation to the space near the Earth's surface and will see that the Earth's surface moves (as a result of the Earth's rotation around its axis) in the stationary space with a certain linear velocity (the velocity of a point of the Earth's surface in the stationary space, at the respective latitude). Every point of the Earth's surface always moves in the eastern direction. The magnitude of the linear velocity (i.e., the speed) of a particular point of the Earth's surface, depends on the latitude and is the speed at which the point is moving along its path in the stationary space. It is approximately 0.46 km/s for any point on the equatorial line and is zero at the points of intersection of the axis of rotation of the Earth with the Earth's surface, which points coincide with the north and south poles.

Therefore, when we are located in our local region "near the Earth's surface" and talk about the speed of light "in vacuum" or "in the empty space" – this will mean that the speed of light is measured in relation to the "Earth-centered inertial (ECI) coordinate system".

• *"Heliocentric Inertial (HCI) coordinate system"* also can be considered in certain cases as stationary in relation to the space. *The origin* of this coordinate system is at the center of the Sun (which is not stationary) and its *axes* are approximately stationary in the space (aimed at very distant astronomical objects). An observer positioned stationary in the HCI frame will see how the planets orbit around the Sun (the Earth moves in its orbit around the Sun at approximately 30 km/s); how the plasma of the Sun rotates (at the equator the solar plasma rotation period is about 24.5 days and is almost 38 days at the poles).

> *Note: In this paper, the designation "frame of reference related to the space itself" is used as a generalized designation of "stationary in relation to the space coordinate system". For the sake of precision, the term "velocity" is used when referring to the vector $\vec{V}$ (with its magnitude and direction); and the term "speed" is used when referring to only the scalar magnitude $\left|\vec{V}\right|$ of the vector.*

Difference between the mechanical and the optical experiments carried out on the surface of the Earth

• In the mechanical experiments, due to the force of gravity, the material bodies in the atmosphere are involved in the rotation of the Earth around its axis.

• In the optical experiments, however, the photons are not involved in the Earth's rotation around its axis because they do not have a mass and the gravitational force of attraction for the photons is equal to zero – (see Newton's law of universal gravitation). Therefore, the speed of the photons is constant in empty space (in vacuum, in the frame of reference related to the space itself /in the ECI frame of reference). The measured speed of light in the reference system related to the moving surface of the Earth in the stationary space, however, is not equal to the speed of light in the empty space and this was proven by the experiments. The stationary space is actually the medium of the electromagnetic and gravitational fields.

1.1.2 On the speed of light in different frames of reference

The two major frames of reference, where we will consider the measurement of the speed of light (of the electromagnetic radiation), are "the frame of reference related to the Earth's surface" and the "Earth-centered inertial (ECI) frame of reference" – the system that, in the considered case, is stationary relative to the space itself.

> *For the contemporary physics, there is no difference between "the speed of light in the frame of reference related to the Earth's surface" and "the speed of light in the Earth-centered inertial (ECI) frame of reference, which is the speed of light in vacuum". This is because the modern physics wrongly has accepted that the speed of light is the same in all inertial frames of reference. The factual analysis of all experiments will convince anyone that this claim is a big blunder.*

Anyone would ascertain the following fact – that all experiments undoubtedly prove that there is a difference between the measured velocity of light in the "frame of reference related to the Earth's surface" and the speed of light "in the empty space" (in the "Earth-centered inertial (ECI) frame of reference"). The only exception is the conceptually incorrectly designed Michelson-Morley experiment, in which, due to the inappropriate idea (the two-way measurement of the speed of light), used in the Michelson's interferometer, this difference is completely compensated, which fact is presented in a separate manuscript.

1.1.3 Two important statements as a consequence of Newton's law of universal gravitation

The electromagnetic field exists on the space. The hypothetical "luminiferous aether" (the medium for the propagation of the electromagnetic radiation) turns out to be the warped space-time by the celestial bodies themselves.

Newton's law of universal gravitation states that in the Universe any particle or body with a mass m_1 attracts any other particle or body (with a mass m_2) with a force that is directly proportional to the product of their masses (m_1 and m_2), and inversely proportional to the square of the distance between their centers (r), where G is the gravitational constant:

$$F = G\frac{m_1 m_2}{r^2} \qquad\qquad (1)$$

We have to be aware that space cannot be affected by the gravitational forces (cannot be attracted) because space has no mass. Therefore, Newton's law of universal gravitation has another important meaning:

First statement:

From this law, it becomes clear that the space is stationary – that means "the vacuum is stationary". This is undeniable, because space has no mass, and the gravitational forces do not attract it (the space does not rotate along with the Earth, but only the material bodies and the molecules in the atmosphere).

Second Statement:

The gravitational force affects the space by contracting it.

Experiments show that the propagation of the electromagnetic radiation and the electromagnetic properties of the atoms depend on the intensity of the gravitational field (on the density of this medium/on the contraction of the space/).

• In the regions with weaker gravitation, the energy density of the medium of the propagation of the photons (the vacuum) is lower. This means that the wavelength and frequency of any electromagnetic radiation are higher (photons will jump easier – farther and faster). This means that the "meter" becomes longer, and the "second" is shortened. Therefore, the speed of propagation of the photons (of the electromagnetic quanta) is higher $(c=\lambda v)$. And vice-versa:

• In the regions with stronger gravitation, the energy density of the medium of the propagation of the photons (the vacuum) is higher. This means that the wavelength and frequency of any electromagnetic radiation are lower (which means that the "meter" becomes shorter, and the "second" becomes longer). Therefore, the speed of propagation of the photons (of the electromagnetic quanta) is lower $(c=\lambda v)$.

In his article *"On the Influence of Gravitation on the Propagation of Light"* (see the reference number [1]), Einstein discussed the change of the speed of light in vacuum (proposing a formula without deriving it), when the light enters the regions with a different gravitational potential which actually are regions with different intensity of the gravitational field:

"If we call the speed of light at the origin of co-ordinates co, then the speed of light c at a place with the gravitation potential Φ will be given by the relation:

$$c = c_0\left(1 + \frac{\Phi}{c^2}\right) \qquad\qquad (2)$$

The principle of the constancy of the speed of light holds good according to this theory in a different form from the one that usually underlies the ordinary theory of relativity." [1]

In the same article Einstein also points out that the frequency of any electromagnetic radiation changes depending on the gravitational potential:

$$v = v_0\left(1 + \frac{\Phi}{c^2}\right) \qquad\qquad (3)$$

This equation, however, was deduced on the basis of the acceptance that the photons (quanta) have mass and consequently the conclusions are wrong. For example, if the photon is losing energy when overcoming the star's gravity (as Einstein "proves"), then the photon will lose a different amount of energy depending on the mass of the star – i. e. the "redshift" will be different and the spectral series of the emission spectrum of the hydrogen atom will be shifted depending on the mass of the star! But there is no such dependence… and no astronomer has observed it!

The frequency of certain electromagnetic radiation defines the base unit of time "second". Therefore, the base unit of time "second" also changes in places with different gravitation potential (with different intensity of the gravitational field) because the duration of the same number 9,192,631,770 time-periods of the used particular electromagnetic radiation will change (see the definition of the "second" since 1967, Ref. [2]). This means that in regions with weaker gravitation (where the frequency increases) the base unit of time "second" becomes shorter (with shorter duration). In this paper, Einstein does not discuss the change in the wavelength of electromagnetic radiation. However, in other articles related to the general theory of relativity it is discussed that in regions with higher gravitation the base unit of length "metre" is contracted (the wavelength of any electromagnetic radiation is shortened) – see the definition of the "metre" in SI accepted in 1960, Ref. [3].

It is clear, however, that the space is stationary but the contraction of the space (changed density of the medium of propagation of the electromagnetic radiation) is moving along with the celestial bodies. All celestial bodies (as well as the Earth) are traveling through the space-time of the Universe along with the distortion (contraction) of the contiguous, warped by the bodies themselves (and belonging to them) time-spatial domains, which we can name *"near the surface of the celestial bodies"*.

The misunderstanding of the dominant part of the physical society consists in the fact that the contraction of space moves along with the celestial bodies, but the space remains stationary!

The intensity of the gravitational field *"near the surface of the celestial body"* remains practically the same during the travel of the celestial body through the space because the intensity of the gravitational field is determined (dominated) by the mass of the celestial body. The speed of light in vacuum (in the stationary empty space), in any particular time-spatial domain, corresponds to the intensity of the gravitational field in this time-spatial domain.

Therefore, during the travel of the celestial body through the space the constant intensity of the gravitational field "near the surface of the celestial body" determines the constant "speed of light in vacuum" there.

Therefore, that is the reason why there is no variation in "the speed of light in vacuum" when the Earth moves in its orbit around the Sun and together with the Solar System in the Galaxy.
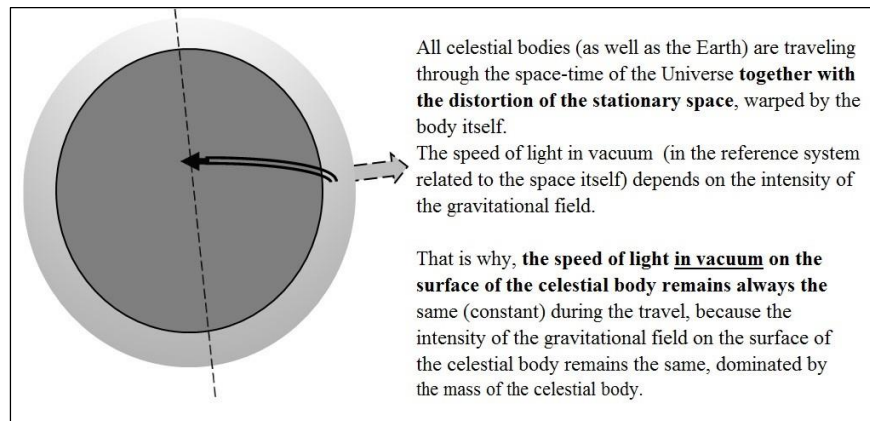

All celestial bodies (as well as the Earth) are traveling through the space-time of the Universe **together with the distortion of the stationary space**, warped by the body itself.
The speed of light in vacuum (in the reference system related to the space itself) depends on the intensity of the gravitational field.

That is why, **the speed of light in vacuum on the surface of the celestial body remains always the** same (constant) during the travel, because the intensity of the gravitational field on the surface of the celestial body remains the same, dominated by the mass of the celestial body.

Figure 1. Movement of the celestial bodies together with the distortion of their "own time-spatial domain"

As a consequence, we have to be aware that the behavior of the electromagnetic radiation in vacuum must be considered in two aspects:

• in regions with different intensity of the gravitational field.

• in regions (local time-spatial domains) with a uniform intensity of the gravitational field;

The local physical reality is a "local time-spatial domain". It is any time-spatial domain with a practically uniform (the same) intensity of the gravitational field in the vicinity of any celestial body which remains constant in the general motion of the celestial bodies in the Universe and where the base units of time and of space (length) can be considered to be constant. Our local physical reality can be named "near the Earth's surface".

1.2 The speed of light in regions with different intensity of the gravitational field

The speed of light in vacuum depends on the intensity of the gravitational field. In regions with different intensity of the gravitational field, the speed of light in vacuum (in relation to the stationary space) is different and this has been proven by experiments:

1) The speed of light in vacuum is higher in regions with weaker gravitation.

In the regions with a weaker intensity of the gravitational field, the electromagnetic waves will not be so suppressed by the gravity – they will oscillate more freely (easier). This means that they will oscillate with a higher frequency v – the "time period" of the electromagnetic oscillations will be of shorter duration. This means that the "spatial period" (the wavelength λ) of the electromagnetic oscillations will also be greater (they will "jump" with larger wavelength). Therefore, the increased frequency and the increased wavelength of each electromagnetic radiation determine not only the shortening of the "second" and the lengthening of the "meter" but also increase in the speed of light in vacuum ($c=v\lambda$). That was proven by the registered anomalies in the accelerations of the space-probes "Pioneer 10", "Pioneer 11", "Galileo", "Ulysses" …

> *"The expected travel time of the communicational electromagnetic signals (based on the constancy of the speed of electromagnetic radiation) between the spacecraft and the Earth turns out to be much more than the real travel time. So we register backward attraction (acceleration) of the ship to the Sun."* [4].

The new higher speed will be valid again for the entire electromagnetic spectrum – it will be again a local physical constant. This logic coincides with the idea of the general theory of relativity.

2) The speed of light in vacuum is lower in regions with stronger gravitation.

Experimentally, using the units of measurement defined on the Earth's surface, a slower speed of radar electromagnetic signals has been experimentally measured in the region with strong gravitation (near the Sun) by the American astrophysicist Dr. Irwin I. Shapiro (Shapiro time delay effect), reported in 1964 (see Ref. [5]). The result of this experiment was confirmed later much

more precisely using controlled transponders aboard the "Mariner-6" and "Mariner-7" spacecrafts as they orbited the planet Mars.

1.3 The speed of light in regions with a uniform intensity of the gravitational field

In regions with a uniform intensity of the gravitational field, the speed of light in vacuum (in relation to the stationary space) is a local constant in any local time-spatial domain with a uniform intensity of the gravitational field, and this concerns the whole spectrum of electromagnetic radiation.

> *"The "speed of light in empty space" is the correlation between the frequency and the wavelength for the whole electromagnetic spectrum, which is a local constant for our and for any other local time-spatial domain, where the intensity of the gravitational field is uniform."* [**6**].

However, in regions with a uniform intensity of the gravitational field (as in the region "near the Earth' surface"), the experiments register different velocity of light in relation to the moving frames of reference in the stationary space. This reality is confirmed by:

• the experiments "One-way measurement of the speed of light", (see Ref. [**7**] and Ref. [**8**]);
• the "Sagnac experiment" (Ref. [**9**];
• the experiment "Michelson-Gale-Pearson" (Ref. [**10**, **11**].

All of the experiments related to the speed of light measurement have their real explanation (see Ref. [**12**]) in accordance with the classical mechanics and the Galilean relativity (which are indisputably valid and lawful in our local time-spatial domain "on the Earth's surface").

The exception is only the Michelson-Morley experiment… The analysis of the Michelson-Morley experiment shows (see Ref. [**12**]) that the inappropriate conceptual design, used in the construction of the Michelson interferometer (the advanced version of which is used in the famous Michelson-Morley experiment, held in 1887), is actually the primary root cause for the great delusion that "the speed of light is the same in all inertial frames of reference", which is the core of the special theory of relativity. The difference in the velocity of light (in the frame of reference related to the moving Earth's surface in the stationary space) between the two light beams, traveling in two opposite directions on the same arm, is completely compensated if the "two-way light beam interferometer" is used.

> *"Actually, if even the "ether wind" exists (caused by the Earth's motion through the stationary luminiferous ether) – the difference in the speed of light between the two light beams, traveling in two opposite directions on the same arm, is completely compensated. It is true for any arm in any direction! In other words, if the projection of the velocity of the "ether wind" on the direction of one of the light beams is (+V), then the projection of the velocity of the "ether wind" on the direction of the reflected light beam (traveling in opposite), will be exactly (-V)."* [**6**].

The "unexplained anisotropy of the light velocity", depending on the direction of the light beam in the "one-way measurement of the speed of light" experiments performed using the GPS system, has its explanation that corresponds to the physical reality. The results of the experiments "One-way measurement of the speed of light", of the "Sagnac experiment", of the "Michelson-Gale-Pearson experiment", of the "Michelson-Morley experiment" and of the Fizeau experiment are analyzed in detail in the monograph [Ref. **12**]. Moreover, the essence of the so-called "fundamental tests of the special theory of relativity", which have been considered as three major types, are revealed there. This monograph includes the analysis of the article *"On the Electrodynamics of Moving Bodies"* (see Ref. [**13**]) presenting the special theory of relativity and **shows exactly where and how** the claim *"the speed of light is the same in all inertial frames of reference"* was applied. It is also presented in *"Thesis on the behavior of the electromagnetic radiation in the gravitational field of the Universe"* (in 10 Statements), which actually rejects the postulate of the constancy of the speed of light for all frames of reference and shows a solution of other big problems in physics today, such as: *"the accelerated expansion of the Universe"* and *"the dark matter and the dark energy in the Universe"*.

2 Analysis of the "Michelson-Gale-Pearson Experiment"

2.1. Initial conditions for the experiments.

1) The experiments are carried out in our local physical reality – i.e. in the time-spatial region "in the vicinity of the Earth's surface", where the intensity of the gravitational field is uniform (the same), and where our primary physical constants – the base units for measurement of time and length are constant.

2) The two frames of reference for examining the experiments are:

• The "frame of reference related to the Earth's surface". In this frame of reference (for the observer, located in this frame of reference), the Earth's surface is stationary;

• The "Earth-centered inertial (ECI) coordinate system", which in most of the considered cases is actually a "frame of reference related to the stationary space itself".

3) In the local time-spatial region *"near the Earth's surface"*, the electromagnetic radiation propagates in vacuum at a constant speed equal to c. This means that in the "Earth-centered inertial (ECI) coordinate system", the speed of light in vacuum is constant and equals to 299,792,458 m/s. This numeric value was accepted by the General Conference on Weights and Measures (Resolution 2 of the 15th CGPM, 1975 – Ref. [**14**]).

The expectation of the influence of Earth's revolution around the Sun on the velocity of light is based on the *hypothesis of a stationary ether*. According to this hypothesis, there is an invisible substance filling the space that was believed to be the necessary medium for the propagation of electromagnetic radiation (of the light). Initially, the hypothesis of the stationary ether was tested about the expected change in the speed of light when the Earth moves in its orbit around the Sun. With the experiments of Michelson in the 1881 year [**15**] and later with the experiment "Michelson-Morley" [**16**], no such

change in the speed of light was registered. Then the conclusion of Michelson was:

> *"The interpretation of these results is that there is no displacement of the interference bands… The result of the hypothesis of a stationary ether is thus shown to be incorrect, and the necessary conclusion follows that the hypothesis is erroneous."* [**15**]

One of the main conclusions in the monograph [**12**], is that the "hypothetical ether" (the medium of propagation of the electromagnetic radiation) is actually the space itself. The speed of light propagation in the "empty space" depends on "the density of this ether (space)" and this density depends on the intensity of the gravitational field.

Not only in the 19th century, but in the 21st century, this is still not realized that **the Earth does not move so simply through the space**.

All celestial bodies (as well as the Earth), are traveling through the space-time of the Universe together with the distortion (contraction) of the stationary space, warped by the body itself.

This means that the intensity of the gravitational field on the surface of the celestial body, which is determined by the mass of the celestial body itself (e.g. Earth), is always constant. This means that *the speed of electromagnetic radiation in vacuum* that depends on the intensity of the gravitational field, *is always constant*.

In a local time-spatial region with a uniform intensity of the gravitational field, however, the measured velocity of light in the different reference systems is different and obeys (it is subject to) the classical mechanics and Galilean relativity. The experiment "Michelson-Gale-Pearson" was carried out in the local time-spatial region "*near the surface of the Earth*", in the frame of reference related to the moving Earth's surface. The experiment was designed to test *whether the speed of light is influenced by the Earth's rotation around its axis*.

In this article, it will ascertain that the result of the presented theoretical explanation of the experiment "Michelson-Gale-Pearson", **based on the classical mechanics and Galilean relativity, completely coincides with the experimental result reported by Michelson and Gale.**

The idea for this test was originally given by Michelson [**17**]. According to Michelson, the experiment was undertaken at the urgent instance of Dr. L. Silberstein. In the first part of the article *"The Effect of the Earth's Rotation on the Velocity of Light, I.",* we can read:

> *"In the Philosophical Magazine, (6) 8, 716, 1904, a plan was proposed for testing the effect of the earth's rotation on the velocity of light."* [**10**].

2.2. Description of the used "ring-interferometer". Results presented to the scientific community.

Description of the experiment. The "Michelson-Gale-Pearson experiment" (see below *Figure 2*) uses a very large rectangular ring interferometer (a perimeter of 1.9 kilometer – 612.648m x 339.24m).

The experiment was carried out in the northern hemisphere at a latitude (41° 46').
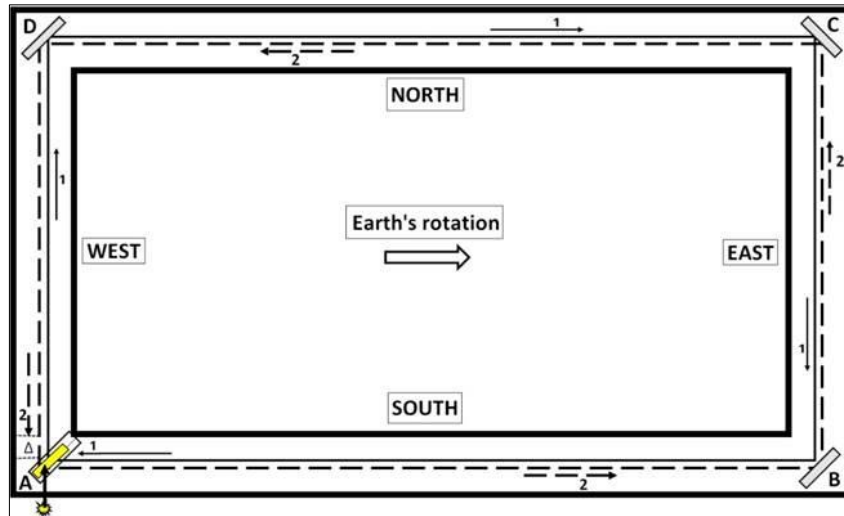

Figure 2. Scheme of the Michelson-Gale-Pearson experiment

A beam of light was split in half and the two beams were sent in opposite directions in an evacuated tube (vacuum conditions). Mirrors located in each corner of the rectangular were reflecting the two beams. When the two beams were reunited, they were out of phase. This means that the two beams did not arrive at the same time – although they passed exactly the same path in the frame of reference related to the Earth's surface. Therefore, the light beams are travelled at different speeds in the frame of reference related to the Earth's surface, and as we will see – the interference fringe displacement corresponds to the calculated theoretical value depending on the linear velocity of the Earth's surface at the latitude of the northern and southern sides of the rectangular contour... i.e., **this corresponds to the theoretical value calculated according to the classical mechanics and the Galilean relativity**.

The theoretical rationale and the description of the experiment were presented by Michelson and Gale in two articles "*The Effect of the Earth's Rotation on the Velocity of Light*" (part I and part II), published in 1925 in *Astrophysical Journal* – see Ref. [**10**] and Ref. [**11**].

> *"The expression for the difference in path between two interfering pencils, one of which travels in a clockwise, and other in a counterclockwise direction, **may be deduced on the hypothesis of a fixed ether as follows**: If l_1 is the length of path at latitude Φ_1 and l_2 that at latitude Φ_2, v_1 and v_2 the corresponding linear velocities of the earth's rotation, and V the velocity of light, the difference in time required for the two pencils to return to the starting-point will be:*

$$T = \frac{2l_2 v_2}{V^2 - v_2^2} - \frac{2l_1 v_1}{V^2 - v_1^2} \qquad (4), \quad \text{Ref. [10]}$$

In the same article, from equation (4), Michelson deduced the formula (5) for the difference in phase of the two light beams, when returning to the starting point:

$$\Delta = \frac{4lh}{V\lambda}\, \omega\, sin\, \phi \qquad (5), \qquad \text{Ref. [10]}$$

The task that Michelson actually defines, is experimentally to verify the validity of formula (5), where Δ is the displacement of the fringes; lh is the area of the rectangular around which the light travels; ω is the Earth's angular velocity; λ the effective wavelength of the light employed; and V is the speed of light in vacuum.

The results of the experiment. As reported by Michelson:

"Air was exhausted from a twelve-inch pipe line laid on the surface of the ground in the form of a rectangle 2010x1113 feet. Light from a carbon arc was divided at one corner by a thinly coated mirror into direct and reflected beams, which were reflected around the rectangle by mirrors and corners. The two beams returning to the original mirror produced interference fringes." [11].

The experiment is similar to that of Georges Sagnac. The difference is that the moving frame of reference (the spinning disk in the stationary space, with all the apparatus of the ring interferometer), in this case, is the moving Earth's surface in the stationary space. The source of light, the detector, and the mirrors move eastward in the stationary space with the linear velocity at the respective local latitudes for the northern and southern sides of the rectangular contour.

The "Michelson-Gale-Pearson experiment" was carried out accurately – the precision of the experiment is undeniable:

"The displacement of the fringes due to the earth's rotation was measured on many different days, with complete readjustments of the mirrors, with the reflected image sometimes on the right and sometimes on the left of the transmitted image, and by different observers." [11].

The experiment, as reported by Michelson in the second part of the article, is successful – the obtained formula (6) as a result of the experiment coincides with the theoretically deduced formula (5) in the first part of the article:

> *"The calculated value of the displacement on the assumption of a stationary ether, as well as in accordance with relativity (actually Galilean) is:*

$$\Delta = \frac{4lh}{V\lambda}\omega \sin \phi \qquad (6), \quad [11].$$

The immediate result of the experiment is that the effect of the Earth's rotation around its axis on the velocity of light was confirmed!

We can see that the reported conclusion – that the established by the experiment "calculated value" is in accordance with *"the displacement on the assumption of a stationary ether"*. However, this does not correspond to the conclusion of Michelson in 1881 (45 years earlier), that *"the result of the hypothesis of a stationary ether is thus shown to be incorrect".*

As we know, in 1881 and in 1887, Michelson attempted to determine the change in the speed of light due to the motion of the Earth in its orbit around the Sun through the "stationary ether". These experiments are considered in detail in the monograph [12], where the reason for this conclusion by Michelson in 1881 was presented. The explanation of all "unexpected" and "inexplicable" results of the most famous experiments related to the behavior and measurement of the speed of light is based on the classical mechanics, the Galilean relativity and on the presented *"Model of the physical reality in the Universe"* in part II of the same monograph [12].

But now let us consider the explanation of the "Michelson-Gale-Pearson experiment", which corresponds to the physical reality.

2.3. Explanation of the results of the experiment in conformity with the classical mechanics and the Galilean relativity.

This subsection presents a theoretical explanation of the experimental results in accordance with the classical mechanics and Galilean relativity, which are in force, (valid) in the *time-spatial domain* with a uniform intensity of the gravitational field ("on the surface of the Earth").

Let us examine in detail the movement of the two light beams *(Figure 2)*, taking into account that the two sides of the rectangular ring interferometer (AB and CD) are parallel to the equator. All the parts of the pipeline (with the mirrors) are moving with the linear velocities at the latitudes (southern and northern), respective to their location. Since the experiment was carried out in the Northern hemisphere, then *the linear velocity in the stationary space* of the mirrors A and B (located at the Southern side of the rectangle) is greater than *the linear velocity in the stationary space* of the mirrors C and D (located at the Northern side).

We will examine the experiment with respect to the two reference systems: in the reference system related to the space itself *(Earth-centered inertial (ECI) coordinate system)* and in *the reference system related to the Earth's surface*. As was shown in *Figure 2*, beam "1" travels in a clockwise direction, and beam "2" travels in a counter-clockwise direction.

2.3.1. Examination of the experiment in the reference system related to the stationary space (in the stationary "Earth-centered inertial system").

For an observer, positioned in the stationary space (in the "Earth-centered inertial (ECI) frame of reference"), each point on the Earth's surface moves with a linear velocity respective to the latitude, where the point is located (for a point closer to the equator, its linear velocity is higher). In "ECI-frame of reference", the speed of light is equal to the *"speed of light in the vacuum"* and therefore, is a constant because the intensity of the gravitational field in the local region "in the vicinity of the Earth's surface" is constant. However, in this frame of reference, the path that the two beams pass (in the stationary space) is different. This is due to the different speeds of movement of the mirrors located in the southern and northern pipes. Therefore, the path in the stationary space that the two rays pass between the mirrors will be different because the mirror to which the respective beam travels will move away (or approach) differently over the time when the light beams move.

As was mentioned, the *linear velocity* of the mirrors A and B in the southern pipe (closer to the equator), is greater than the *linear velocity* of the mirrors C and D in the northern pipe. It means that the path in the stationary space of the light beam 2, propagating to the East in the southern pipe, will be longer than the path of the light beam 1, propagating to the East in the northern pipe (the mirror B moves faster than the mirror C). Respectively, the path of the light beam 1, propagating to the West in the southern pipe will be shorter than the path of the light beam 2 propagating to the West in the northern pipe (the mirror A moves/ approaches faster than the mirror D).

Let us denote the path lengths of the beam paths "1" and "2" in the stationary space (in the ECI-frame of reference). According to *Figure 2*, the path lengths of the beams "1" and "2" on the side AB will be respectively $|BA|_1$ and $|AB|_2$; and the path lengths of the beams "1" and "2" on the side CD – respectively as $|DC|_1$ and $|CD|_2$. Therefore, due to the difference in latitude of the sides AB and CD (the linear velocity of mirror A and mirror B located on the south side is higher than the linear speed of mirror C and mirror D located on the north side), for the path of the two light beams in the stationary space (in the ECI-frame of reference) in direction West to East, we can write:

$$|AB|_2 > |DC|_1 \qquad\qquad (7)$$

, and for the westward travel-path of the light beams, we can write:

$$|BA|_1 < |CD|_2 \qquad\qquad (8)$$

Therefore, the path traveled in the stationary space by the light beam "2" (which travels in a counter-clockwise direction) is longer than the path traveled covered by the light beam "1" (which travels in a clockwise direction):

$$(|AB|_2 + |CD|_2) > (|BA|_1 + |DC|_1) \qquad\qquad (9)$$

As a result, the two light beams are out of phase when they return to point A. The resulting difference in phase will be higher, not only when the sides AB and CD are longer. When the sides AD and BC are longer, the difference between the linear speeds is higher due to the higher latitude difference. Therefore, the phase difference will be higher when the area of the rectangle is greater (like in the Sagnac's ring interferometer).

2.3.2. Examination of the experiment in the frame of reference related to the Earth's surface that moves/rotates in the surrounding stationary space.

Michelson (the observer/ experimenter), actually made his measurement in the frame of reference related to the Earth's surface. The two light beams are moving in opposite directions but they travel the same total travel-path in this frame of reference. This is because the pipelines and the mirrors are stationary in this frame of reference (they are fixed on the Earth's surface) – therefore, the distances between them do not change.

However, if the observer measures the speed of light in the frame of reference related to the Earth's surface, they will register different speeds of the light beams in the directions "from East to West" and "from West to East" (as at the experiments *"One-way measurement of the speed of light"*). Moreover, the difference in the speeds of the light beams will be higher on the southern side in comparison with this difference on the northern side, due to the higher linear velocity of the Earth's surface at the southern side. As a result, the two light beams are out of phase when they return to point A.

Let us, according to the above-mentioned reflections, make a calculation (*according to classical mechanics*) for the difference between the travel time of the two beams *in the reference system related to the surface of the Earth*:

If c is the *speed of light in vacuum* (the local physical constant in our local time-spatial domain); l1 is the northern pipeline length (latitude Ø1), where the linear velocity of the Earth's surface is v1 ; and l2 is the southern pipeline length (latitude Ø2), where the linear velocity of the Earth's surface is v_2, then, *in the frame of reference related to Earth's surface*:

1) according to the Galilean relativity: the measured speed of light in the northern pipe, in the direction "East to West", will be $(c+v_1)$, and in the direction "West to East", will be $(c-v_1)$;

2) according to the Galilean relativity: the measured speed of light in the southern pipe in the direction "East to West" will actually be $(c+v_2)$, and in the direction "West to East" will be $(c-v_2)$;

Therefore, the time necessary for the light beam "1" (moving in the clockwise direction), to travel on the northern pipe is $l_1/(c-v_1)$; on the southern side is $l_2/(c+v_2)$, and the total time for the two sides is:

$$T_1 = \frac{l_1}{c - v_1} + \frac{l_2}{c + v_2} \qquad (10)$$

The time necessary for the light beam "2" (moving in the counterclockwise direction), to travel on the northern pipe is $l_1/(c+v_1)$; on the southern pipe is $l_2/(c-v_2)$, and the total time for the two sides is:

$$T_2 = \frac{l_2}{c - v_2} + \frac{l_1}{c + v_1} \qquad (11)$$

If we ignore the small difference between the travel-time of the two beams on side BC and on side AD (in the directions "South to Nord" and "Nord to South"), the total time-difference of the two light beams will be:

$$T_2 - T_1 = \frac{2l_2 v_2}{c^2 - v_2^2} - \frac{2l_1 v_1}{c^2 - v_1^2} \qquad\qquad (12)$$

… i.e., in the frame of reference related to the Earth's surface (where the experiment was carried out):

The equation (12), obtained from the given real explanation of the experiment (based on the classical mechanics and the relativity of Galileo), is the same as the equation (4) from the article of Michelson, which, according to him is "deduced on the hypothesis of a fixed ether", [**10**].

3. Conclusion

We can conclude on the equation (4), mentioned in the first Michelson's article (Michelson, 1925), which, according to his words, is "deduced on the hypothesis of a fixed ether":

• that the equation (4) was derived on the base of the classical mechanics and Galilean Relativity.

• that the equation (4) is *derived in the frame of reference related to the Earth's surface* (where the experimenter was located and the experiment was carried out);

• that the fact that in our time-spatial region of constant gravity, *"the speed of the light is constant **in vacuum**"* is used, which is actually the speed of the light in the reference system related to the stationary space (in this case – the *"Earth-centered inertial (ECI) coordinate system"*).

Let us track the chronology:

1) In his first article *"The Effect of the Earth's Rotation on the Velocity of Light, I"* [**10**], Michelson shows that equation (5) follows directly from equation (4). However, Michelson did not show that the equation (4) is deduced on the base of the classical mechanics and the Galilean relativity. He only mentions *that "the expression for the difference in path between two interfering pencils"*, which is the equation (4), *"may be deduced on the hypothesis of a fixed ether"*.

2) In the second article, it is reported that the equation (6) is confirmed by the experiment [**11**]. This means that the theoretically derived equation (5) is confirmed, because it is actually the same as the equation (6).

3) **The equation** (12) that was derived in the analysis, is the time difference for reaching the starting point of the two light beams (the difference between equation (10) and equation (11)). We have seen that the equation (12), which is derived in the previous subsection, based on the classical mechanics and Galilean relativity, **is exactly the same as the equation** (4), whose derivation Michelson does not show but mentions that *"may be deduced on the hypothesis of a fixed ether"*.

Therefore, the "Michelson-Gale-Pearson experiment" proves the validity of our theoretical explanation, given in subsection 2.3, which was done on the basis of the classical mechanics and Galilean relativity!

In fact, if we look at the formulas (10) and (11) – they show that in the frame of reference related to the Earth's surface, ***the speed of light in different directions is different*** (as in the experiments *"one-way determination of the speed of light"*). Therefore, the question can be asked:

> *Why did Michelson not mention that when deriving the theoretical formulas (4) and (5), he used the fact that in relation to the Earth's surface (in the reference system related to the Earth's surface) – the velocity of light in "West to East" direction is (V-v), and in "East to West" direction is (V+v), where V is the **speed of light in vacuum**, and **v** is the **linear velocity of the Earth's surface**? **This would mean that**:*

The speed of light is not the same for all inertial frames of reference!

In fact, the result of the *"Michelson-Gale-Pearson experiment"* undeniably proves this fact!

The reason for this "failure to mention" by Michelson in 1925, is (perhaps) that he did not want to enter into conflict with the proponents of the special theory of relativity and because:

The Nobel Prize in Physics 1907 was awarded to Albert A. Michelson

> *"for his optical precision instruments and the spectroscopic and metrological investigations carried out with their aid". (Nobelprize.org)*

In fact, Michelson has earned this award for his great contribution to science. Actually, it is not his conclusion that "the speed of light is the same in all inertial frames of reference*"* ...

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