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Aberration of Light from a Terrestrial Source

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Abstract: The possibility of observing the aberration of light from terrestrial sources is investigated. The effect of the curvature of the wave fronts of the light flux of a terrestrial source on the observability of its light aberration is analyzed. The influence of the curvature of its wave fronts on the compensation of the light aberration of the ground motionless source relative to the observer source is studied. An analysis of the light aberration of the source in the Jung's interferometer specifies on influence of curvature of wave fronts of light stream on his cracks on displacement of interference picture depending on speed of interferometer. The schemes of experiments of observing the current aberration of the light aberration of the ground stationary source relative to the observer and displacements of interference picture in the Jung's interferometer, which allow the observer to measure the speed in the system *ICRF*.

Keywords: Ground Source, Light Aberration, Wave Front Curvature, Jung's Interferometer, In the System *ICRF*

1. Introduction

Star aberration was discovered at attempts to find the parallax of stars. In search of their parallax the row of supervisions of rejections of stars with a year period was conducted (1671 - Picard, 1674 - Guk, 1698 - Flamsteed, 1725 - S. Molene with D. Bredley) [1-3]. Bredley, conducting more exact observing during 1726-1728, explained them by the finiteness of the light speed, by motion of the Earth around the Sun and actually derived the formula of star aberration.

For the first time the question of observing the aberration of light from terrestrial sources apparently was touched by Boshkovich. He considered it's possible to observe it with increasing (according to Newton) of the light speed in the medium [2].

The aberration of light from terrestrial sources was briefly mentioned by G. Lorenz [4].

Having considered the Stokes' and Fresnel's theories of the light propagation in moving bodies (plane waves in optically isotropic bodies) and on the basis of the last one, he made two conclusions. "First, we have an aberration of light ... and in the apparent directions of the rays coming from the star ... the astronomer ... can predict using the usual laws of optics and not paying attention to the motion of the Earth, all the results of any experiments ... that can be conducted with these rays. Finally, all optical phenomena that can be reproduced with the help of terrestrial light sources are absolutely independent of the motion of the Earth. If we turn the whole device, including the light source, we'll change the direction of the rays relatively to the direction of the translational motion of the Earth, and then we will never notice any changes"."The explanation of the fact that the motion of the Earth has no effect on any optical phenomena produced terrestrial sources of light is so simple that it can be expressed in a few words. It suffices to note that in the experiments on interference, the phase differences remain unchanged."

This conclusion was made when Lorentz accepted the condition "A section of a wave of this size can be taken as a plane" [4].

Einstein also at consideration of the theory of aberration accepts "Let in the system K very far from the beginning of coordinates there is some source of electrodynamics' waves", i.e. flat waves are examined. Further, in the works related to aberration, he does not return to this question [5].

The aberration of the light from a terrestrial source was not considered in detail later [3, 6, 8].

Zommerfeld does not focus on the terrestrial source of the light flux in the Michelson's experiment. However, he unambiguously points to the aberration of the light flux on a moving mirror, ensuring the encounter of transverse and longitudinal rays on the shifted relative to the transverse beam mirror and its entry into the observer's tube. "On the contrary, the angle $\propto$ differs in the primed system by a small amount of the first order (we can call it the aberration angle);" p.104 "The fact that light exactly falls into the observer's B moving telescope is provided by changing the law of reflection in reflection from a moving mirror H in its position H$''$" p. 108 [6].

The study of the informative parameters of Michelson interferometers with the aberration accounting proves the feasibility of using them for the observer's speed measuring in the JCRF system [7].

B.N. Himmelfarb just mentions about it. "Thus, in the inertial reference system, aberration does not exist by itself. It manifests itself only in relation to other similar systems. ... From the classical point of view, the aberration would have to be detected for terrestrial bodies. "[9].

However, aberration exists by itself without any other similar systems, for example, the age-old one. It only manifests itself (becomes observable) upon transition to another inertial system with this method of telescope observation. Measurement of the aberration when the telescope is filled with a uniaxial anisotropic environment is possible without transition into another inertial system [10].

Later S.B. Lukyanov and G.M. Idlis investigated the aberration of light from a terrestrial source [11, 12]. As a result of the analysis, S.B. Lukyanov on the basis of erroneous premises concludes, "due to the superposition of the effects of aberration, the lag of light and the intrinsic motion of the source in terrestrial conditions, the source is always visible where it is at the time of observation, and not at the moment of radiation. And in this case the angle of aberration $\propto$ is not zero. The zero is equal to the difference $\propto -\gamma$, which is the measurable quantity [11].

In the opinion of G.M. Idlis the aberration of light from a terrestrial source is absent as a result of the equality of the speeds of the terrestrial source and the observer.

"However, the situation is much simpler here. The position of terrestrial light sources is fixed in the coordinate system associated with the Earth, relatively to which the observer is stationary. Consequently, $\nu = 0$ (concerning what here and in the aberration formula - daily, yearly, age-old) and there's no aberration ($\propto = 0$), i.e. the observer sees the terrestrial source exactly where the flash occurred. If the light source is stationary on the surface of the Earth, it will be there at the moment of observation, but this is completely irrelevant: at the moment of observation, the light source may no longer exist at all. "[12].

It should be noted here that among the set of stars it is possible to find stars having at the given time a speed equal to the speed of the observer. At this time, the star and the observer represent an inertial system with fixed sources in it and an observer analogous to the observer system with a ground source. The aberration of the light flux of such stars does not depend on this for the observer, which is confirmed by the finiteness and independence of the light speed from the speed of its source and observer [2,3].

However, the aberration of light from terrestrial sources is not observed while star aberration is observed independently of the motion of the stars.

Lukyanov S.B. and Idlis G.M. did not take into account the curvature of the light wave fronts from the ground source and the independence of the light speed from the source velocity.

Interest in the aberration of light from a terrestrial source increased in connection with observations of artificial earth satellites and the resulting anomalies in the measurement results [13-20].

They also do not consider the influence of the curvature of the wave fronts of the light source, but attract concepts from "your - alien" light source to partial medium entrainment near the source [17].

Research of the possibility of observing the aberration of light from a terrestrial source is the goal of the work.

2. Analysis of Light Aberration of a Terrestrial Stationary Source Relatively to an Observer with an Account the Curvature of Its Wave Fronts

Let analyze the light aberration from a terrestrial source, taking into account the curvature of its wave fronts, first from the classical point of view, and then take into account, if necessary, relativistic effects in the moving system.

Let the device of supervision B of length l is at the beginning of coordinates $k(x, y, z)$ (Figure 1) of the inertial system axis oriented z ⍰. The point source of light S is located in the distance L on the axis z ⍰ from it, but star S_0 is located in the distance L_0 on the axis z ⍰ from it. System $k(x, y, z)$ with the observer, the observation device B, the light source S and the star S_0 moves in the coordinate system $ICRF$ in the direction of the apex of the star S_0 with speed $v_z = v_a$. The axis Z of the system K is directed in the apex of its movement with speed $v_z = v_a = v_{max}$ in the coordinate system $ICRF$.

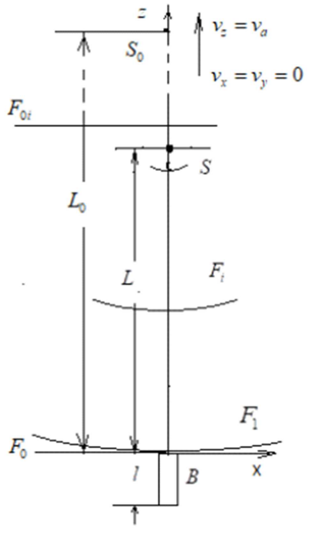

Figure 1. *System $k(x, y, z)$ oriented with respect to the apex in the coordinate system $ICRF$.*

Thus, along the axes x, y, the system k does not move $v_x = v_y = 0$. When observing a star S_0 and a source S there is no aberration since plane wave fronts F_{0i}, F_0 star S_0 and spherical wave fronts F_i , F_1 the sources S propagate in the system k along the axis z and axis of the observation device B without displacement along the axes x, y.

Now, let (Figure 2) the inertial system $k(x, y, z)$, containing the star S_0, the same point source of light S and the observation device B of the length l, oriented along the axis x, move in the coordinate system $ICRF$ in the direction of the axis x at a constant speed v. This means that the star S_0, the light source S, the observation device B and the observer move with speed v. The light fluxes of the star S_0, the source S in the system k, because of the independence of the speed of light c from the speed v of motion of the star S_0, the source S do not participate in this movement and lag behind the light source S, the observation device B and the observer.

The wave front F_1 in the system k enters the entrance of the observation device pipe after time $t_{F1} = \frac{S_1 B_2}{c}$ after the radiation moment t_1 of the light sources S, when it and the observation device B were in position S_1 and B_1.

The observation device B and the light sources S will shift in parallel in the coordinate system $ICRF$ to the direction of the axis x in time t_{F1} by a distance $\Delta = t_{F1} v$ relative to the position when upon emission the incoming wave front F_1 enters into the observation device at a distance of $\Delta = t_{F1} v$ and will be in the position S_2 and B_2.

In the system k, the wave front F_1 at the instant of time t_{F1} will be displaced relative devices input B of the observation along the axis $-x$ by a distance $\Delta = t_{F1} v$. But the vector of the phase velocity of a divergent *spherical* wave is oriented radially from the source.

All its points for equal time t_L are equidistant by the distance $S_1 B_2$ from the point source S and oscillate in the same phase. As a result, the observation device B axis of the length l should be located exactly along the radius $S_1 B_2$ of the wave front F_1 of the light source S for its observation.

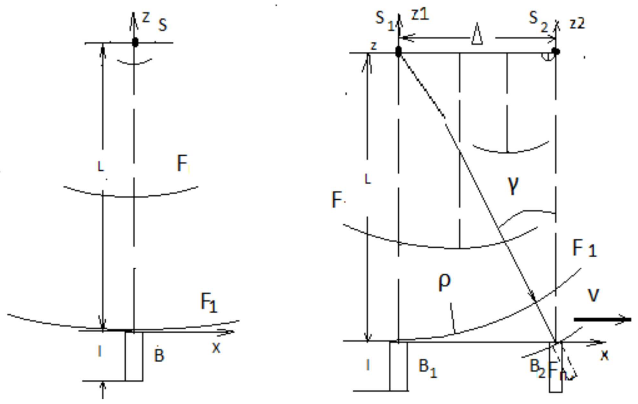

Figure 2. *System K moving at the speed V and oriented along the X axis.*

All the spherical wave fronts F_i radiated at intermediate points of time t_i from t_{F1} by a point light source S propagate in the system k along the axis z with displacements along the axis x in the negative direction $(-x)$, proportional to the intermediate instants of time t_i from t_{F1}, because $v_x = v$, $v_z = 0$, $v_y = 0$. Because of the displacement along the axis x of the wave front F_1 by the distance $-\Delta = t_{F1} v$ with respect to the observation device B and the curvature $\rho = \frac{1}{S_1 B_2}$ of the spherical wave front F_1, its part, extracted by the input window of the observation device's tube in position B_2 entrances for its radius $B_2 - S_1$ at an angle $\gamma = S_1 - B_2 - S_2$ (Figure 2) to the axis of the observation device of length l. So far as $t_{F1} = \frac{S_1 B_2}{c}$, $\Delta = S_1 S_2$, $\Delta = t_{F1} v$, $\gamma_B = arcsin \frac{(S_1 S_2)}{(S_1 B_2)}$,

Then

$$\gamma_B = arcsin \frac{v}{c} \tag{1}$$

Because of crookedness $\rho = \frac{1}{S_1 B_2}$ of the spherical wave fronts F_i the observer, in the time of observation of the source S, will have to unfold the observation device in position B_2 along its radius $B_2 - S_1$ against the direction of the velocity vector v.

The angle γ of rotation of the observation device, so that the wave front F_1 , after passing the distance l of the observation device, formed the image of the light source in the eyepiece crosshairs, should be γ_B.

However, because of the motion in the observation system $ICRF$ relative of the spherical wave front F_1 with the speed v an aberration occurs, the angle α_B in the direction of the speed v is equal to [3]

$$\alpha_B = arcsin \frac{v}{c} \qquad (2).$$

Because the angles γ and α are both equal and oppositely directed $\gamma_B + \alpha_B = 0$, so the direction of the observation device B to the sourse S remains unchanged $B_2 S_2$.

In the general case, when the speed v of the system's k motion makes an angle ψ with direction of the wave front propagation at the observation device input, angles (1, 2) will be equal to:

$$\gamma_B = arcsin \frac{v}{c} sin\psi \tag{3}$$

$$\alpha_B = arcsin \frac{v}{c} sin\psi \tag{4}$$

The sum of angles will be $\gamma_B + \alpha_B = 0$, the image of the light source remains as in the eyepiece crosshair and the observation device remains directed at the light source as in the case figure 1.

The aberration of light from a terrestrial source is compensated by the curvature $\rho = \frac{1}{S_1 B_2}$ of the wave front F_1 of the light flux of closely located source and therefore is not observable.

For the wave front of a star $\rho_{S0} = 0$. The compensation of the stars aberration is absence and $\gamma_{S0} = 0$.

Thus, the wave fronts curvature of ground-based sources closely spaced to the observer, taking into account, in accordance with, the independence of their propagation from the source and observer movements significantly affects the results of observations, in accordance with [5].

The partial compensation of the aberration is of practical interest. It is springing up for an intervening value of the curvature ρ_A of the observation object wave front (for example, space vehicle).

Taking into account Lorentz's comment on aberration in interference experiments we consider the effect of aberration in a Jung interferometer with a ground source.

3. Aberration of Light From a Terrestrial Source in a Jung's Interferometer

Let consider the aberration of light from a terrestrial source in an interferometer by the method of dividing the wave front according to Jung's scheme, where the phenomena of interference and diffraction are particularly pronounced.

Figure 3 shows the light fluxes propagation diagram to the slits in the inertial coordinate system $k(x, y, z)$. The axis Z of the system K is directed in the direction of the apex of its motion at the system $ICRF$ with velocity $v_z = v_a = v_{max}$. Thus, the system k for apex x, y is not moving $v_x = v_y = 0$.

The system $k(x, y, z)$ contains a light source S_0, in the form of a brightly illuminated narrow slit parallel to the axis y (perpendicular to the plane of the drawing), the screen E_1 in the plane x , y with narrow slits A, C parallel to the axis y. The screen E_1 is set at the distance L_1 on axis z from the light source S_0, and the slits A, C are parallel and symmetrical to the axis y at distances b along the axis x. Thus, the slits are illuminated by different sections of the same cylinder wave front. Light rays are diffracted on narrow slits A, C, expand after the screen, partially overlap and interfere.

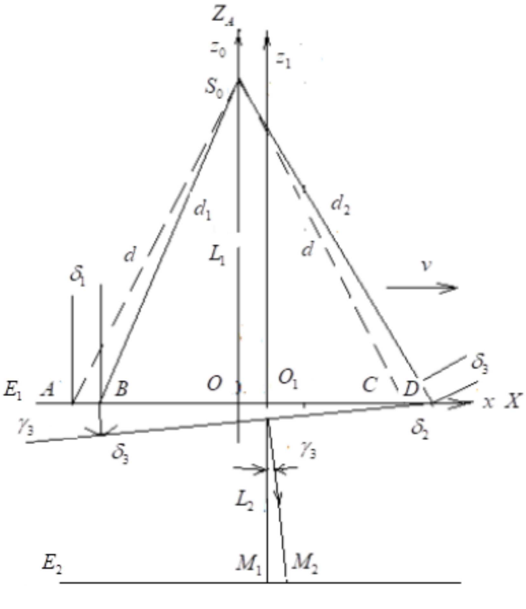

Figure 3. *Propagation of fronts to slits.*

The interference pattern is observed on the screen E_2 at a distance L_2 from the screen E_1 without offset from the direction S_0O.

At the moment of time t_0 the system $k(x, y, z)$ is immovable along the axes x , y in the $ICRF$ coordinate system, and moves along the axis z with speed v_A.

The wave front of the source S_0 gets at the same time on the slits A, C after the time $t_{01} = t_{02} = \frac{d}{c}$, where d is the distance from the source to the slots (Figure.3).

Equality of times is provided by the symmetrical arrangement of the slits relatively to the beginning of coordinates $AO = OC = b$ and by the equality of the slit's displacements for the times of passage of the parts of the wave front caused by the motion of the system $k(x, y, z)$ in the coordinate system $ICRF$ along the axis Z with speed v_A. The difference in the path of the rays diffracting on the slits A, C is absent $S_0A = S_0C = d$. The wave surfaces arising in accordance with the Huygens-Fresnel principle from the separated by the slits A, C parts of the wave front after the screen E_1 will propagate along the axes Z, z_0 , remaining parallel to the screen.

Let the system $k(x, y, z)$ moves in the coordinate system $ICRF$ along the axis x with speed v. The cylinder wave front of the source S_0 will now reach the screen E_1 in positions of the slits B, D at different times and will spill apart other parts of the source's S_0 wave front.

Indeed, the wave front F_i will fall into the slit in position B after time $t_1 = \frac{d_1}{c}$. Due to the independence of the luminous flux propagation from its source speed to the slit in position B, D, will be included other its segment, displaced, for the slit B on δ_1 and for the slit D on δ_2, along the axis x. If before getting into a slot in a position B the wave front passes the way d_1, then it will pass the way d_2 before getting into a slot in a position D . While the wave front passes the way difference $S_0D - S_0B = d_2 - d_1 = \delta_3$, the wave front with radius δ_3 will form as a result of diffraction from the selected slot in the position B of the wave front after the screen E_1 (Figure 3). Due to the difference δ_3, the interference field will be deflected by an angle $\gamma_3 = arcsin\frac{\delta_3}{BD}$ from the direction S_1O_2.

In this way

$$\gamma_3 = arcsin\frac{\delta_3}{2b} \tag{5}$$

Dependence δ_3 and γ_3 on the speed of the system is easily determined from Figure.3.

Really $d_2^2 = L_1^2 + (b + \delta_2)^2$; $d_1^2 = L_1^2 + (b - \delta_1)^2$. Considering that $\delta_2 = d_2\frac{v}{c}$; $\delta_1 = d_1\frac{v}{c}$;

and $\delta_2^2 - \delta_1^2 = (d_2^2 - d_1^2)\frac{v^2}{c^2}$ the magnitude of the second order in $\frac{v}{c}$,

$$d_2^2 - d_1^2 = (b + \delta_2)^2 - (b - \delta_1)^2 = 2b(\delta_2 + \delta_1); d_2^2 - d_1^2 = 2b\frac{v}{c}(d_2 + d_1); d_2 - d_1 = 2b\frac{v}{c} = \delta_3;$$

$$\delta_3 = 2b\frac{v}{c} \tag{6}$$

and from (5) it follows

$$\gamma_3 = arcsin\frac{v}{c} \tag{7}$$

Now (Figure 3) it can be seen that the offset of the interference pattern M_1M_2 with respect to the direction O_1M_1 is proportional to the distance L_2 between the screen E_1 with the slits and the observation screen E_2.

This shift could be observed $M_1M_2 = L_2\frac{v}{c}$.

However, during the passage of the interfering light fluxes to the observation screen, it will also shift to a distance

$$\Delta_2 = -L_2\frac{v}{c} \tag{8}$$

The resulting shift will be zero. That is, as in the Michelson interferometer, the interference pattern in the Young interferometer is absent.

4. Possibilities of Using the Influence of the Curvature of the Wave Fronts of Terrestrial Sources

Let us consider some possibilities of using this influence to determine the speed of the observer relatively to the light flux of the source in the coordinate system $ICRF$.

Let us establish in the system k (Figure 2) collimator C of a source's light flux S, which ensures the output of a light flux with a parallel plane x, y by a plane wave front, covering the input of the observation device pipe B taking into account its displacement Δ (Figure 4).

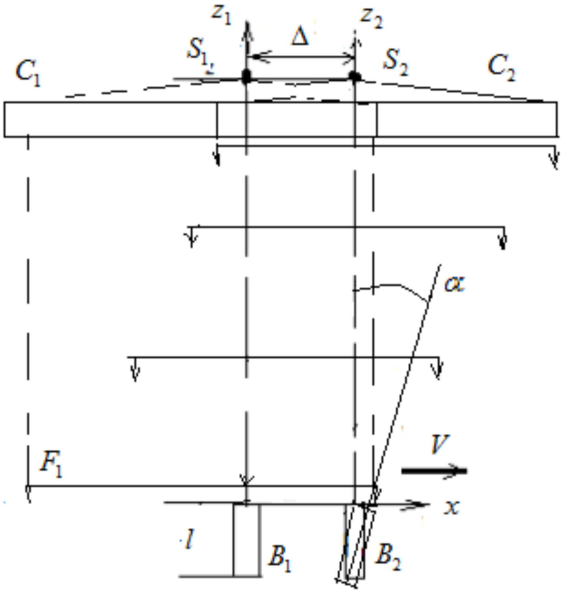

Figure 4. *Terrestrial source with flat wave front.*

Now the displacement Δ of the observation device relatively to the wave front in time of its receipt on its input does not cause the need for a rotation of the observation device by an angle $\gamma_B = arcsin\frac{v}{c}sin\psi$ (3) because of the identity of the flat wave front for the positions of the observation device B_1, B_2. In view of the movement of the observation device relatively flat wave front, it must be deflected, as when observing a star, in the direction of the motion velocity v in the coordinate system $ICRF$ by the aberration angle $\alpha_B = arcsin\frac{v}{c}sin\psi$ (4).

There is the possibility of measuring the observer's speed. We perform the calibration of the installation (Figure 2) fixing the position of the observation device with images of the source S in the crosshairs of its eyepiece. Without changing the relative location of the observation device B and the source S, we establish a collimator C of the light flux in accordance with figure 4. By measuring the deviation Δ of the source image S, we determine in accordance with (4) the angle of aberration and the speed vector $vsin\psi$ along it, taking into account the orientation of the field of view of the observation device's eyepiece. At low speed v, it is equal to

$$v = \frac{\Delta}{Lsin\psi}c \tag{9}$$

To determine the velocity in the coordinate system $ICRF$ using a Young interferometer, we will perform its calibration, fixing the position of the interference pattern on the observation screen E_2 (Figure 3).

Then let install the light flux C_0 collimator of the source S_0 in the interferometer (Figure 5). The collimator provides at the output receiving of a light flux with a flat wave front, which parallel plane x, y screen of the slits E_1. This flat wave front cover slits A, C into account its displacement. DELENE--When using the slits A, C (Fig. 7).

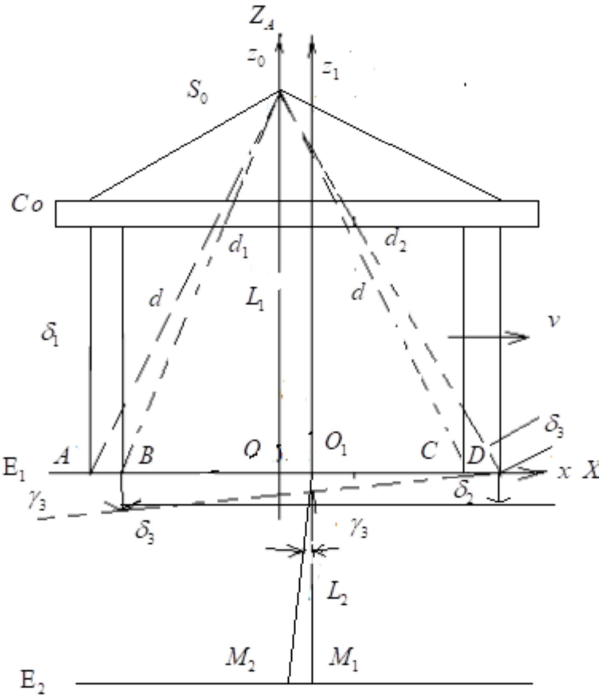

Figure 5. *Propagation of plane wave fronts to the slits of the interferometer.*

Now, when the slits A, C are displaced to the position B, D due to the movement of the device with the speed v, the wave front simultaneously passes the slits B, D. The difference in the course of the rays diffracting on the slits B, D is absent.

Interference pattern on the observation screen E_2 will shift (8) on $\Delta_2 = -L_2\frac{v}{c}$ in the opposite direction of the speed v

side. After measuring the shift Δ_2 , determine the speed in the $ICRF$ coordinate system $v = \frac{\Delta_2}{L_2 sin\psi} c$

In all the results of the analysis obtained values of the first order $\frac{v}{c}$. The influence of motion (second order values) determined by the Lorentz transformations can be ignored here when measuring order values. The effect of motion ($\Delta t, \Delta r$ - second order values $\frac{v^2}{c^2}$) determined by the Lorentz transformations may not be taken into account here when measuring order values $\frac{v}{c}$.

5. Conclusions

1. Based on the Einstein principle of the light speed constancy, regardless of the source speed and the observation device, the analysis of the influence on the aberration of the wave fronts curvature of the ground source and stars proves the absence of an aberration when observing the ground source due to the curvature of its wave fronts in contrast to the planar wave fronts.
2. The aberration of light from a closely located point-based ground stationary relative to the observer source is compensated by the curvature of its wave fronts (3), (4).
3. The interference pattern in the Young interferometer does not change as it moves due to the displacement of the observation screen during the passage of light fluxes from the slits to the observation screen compensating for the deviation of the interference pattern.
4. The aberration of light from a terrestrial source should be observed while providing a flat wave front of its light flux.
5. A change in the interference pattern in a Young interferometer as it moves should be observed when the interferometer slits are illuminated by a light flux with a plane wave front.
6. Observing the aberration of light from a ground-based source with a flat wave front of the light flux and changing the interference pattern in a Young interferometer makes it possible to measure the speed of an observer in the $ICRF$ coordinate system without changing the direction of the observer motion.

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