

Aberration and Light Paths in the Planetary System and Universe

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Abstract

In space navigation, optics, and light paths, the real nature of space is essential. Bradley discovered the stellar aberration of light. It is a small deviation of the propagation of light from a star to Earth, and it is described by an aberration angle α . In fact, on that path, the light path is influenced by the motion of Earth around the Sun. This phenomenon is very interesting and progressive, as it cannot be fully explained by the present - day relativity theory. Therefore, the solution of this problem provides new, innovative, essential, and fundamental physics beyond the capability of present - day relativity theory. This problem is solved here. Thereby, for each star, the light path from the star to Earth is derived. Moreover, for each star and point of observation, the aberration angle α is derived. Furthermore, this solution of the above aberration problem of relativity theory is related to a more general theory, that provides a unification of relativity, gravity and quantum physics, as well as solutions of other essential problems of physics.

Keywords: Stellar Aberration, Light Path, Relativity, Adequate Coordinate System, Space Navigation, Planets, Universe

Introduction

Bradley discovered the very interesting and foundational phenomenon of stellar aberration, alias annual aberration, see [1]. In that phenomenon, the light emitted by a star is observed at Earth as follows: The direction vector $\vec{v}_{light,star}(t)$ of the arriving light is a function of time, and it has an averaged, different, direction vector $\vec{v}_{light,star}$. The angle $\alpha(t)$ between these two vectors is called aberration angle, see Figure. (1). This angle varies periodically, and it has the periodic time of one year, $T_\alpha = 1a$. The aberration angle α is the difference of the varied angle φ and the averaged angle ϑ , see Figure. (1):

$$\alpha = \varphi - \vartheta \quad (1)$$

In particular, for the case $\vartheta = 90^\circ$, the aberration can be described as follows, see [2], p. 912, third equation, and a derivation is presented in section (7):

$$\cos \varphi = -\frac{v}{c} \quad (2)$$

As a mathematical fact, $\cos \varphi = \sin(90^\circ - \varphi)$. In the considered case, that difference $90^\circ - \varphi$ is equal to the difference $\vartheta - \varphi$, and this is equal to $-\alpha$, see Eq. (1). Therefore, the aberration can be described as follows Eq. (2):

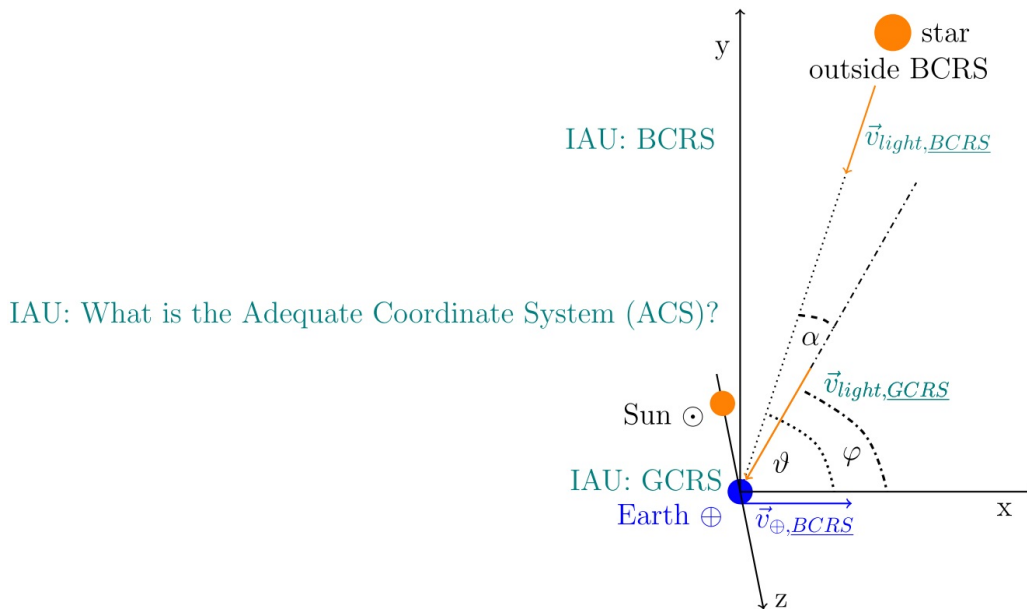


Figure 1: Bradley Discovered the Stellar Aberration, Alias Annual Aberration

He observed the angle α of aberration [1]. For this, he observed light that was emitted by the star and that arrived at Earth. That light has a light path that can be observed via a real image, see [3]. The tangent vector to that light path, with length c and in the direction of light propagation, is a (classical) light velocity vector $\vec{v}_{light}$. In particular, in the BCRS, that vector has an averaged value $\vec{v}_{light,BCRS}$. Similarly, in the GCRS, that vector is $\vec{v}_{light,GCRS}$. The varied angle φ minus the averaged angle ϑ is called angle of aberration $\alpha = \varphi - \vartheta$. The ACS has been derived by different mutually independent methods in [4,5,3,6]. The angle between Earth's velocity $\vec{v}_{\oplus,BCRS}$ relative to the BCRS and $\vec{v}_{light,BCRS}$ is named ϑ . The angle between Earth's velocity $\vec{v}_{\oplus,BCRS}$ and $\vec{v}_{light,GCRS}$ is named φ . In this paper, a second subscript with an underline describes the used object of reference or frame of reference, and $-v_{x,\oplus,BCRS}$ is named v .

$$\sin(-\alpha) = -\frac{v}{c} \quad \text{or} \quad \sin(\alpha) = \frac{v}{c} \quad (3)$$

For the considered case, the observed angle of aberration is as follows, see [7]:

$$|\alpha| = 20.5'' = 20.5 \text{ arcseconds.} \quad (4)$$

Therefore, in a very good approximation, the aberration angle in Eq. (3) can be described as follows:

$$\alpha = \frac{v}{c} \quad (5)$$

For the considered case, this formula is also presented in [7], Eq. (2.30). Thereby, $|v|$ is the speed of Earth relative to the Sun, see Figure. (1). Consequently, this formula is in accordance with observation for the case that v is the speed of Earth relative to the Sun. The value of $v = |\vec{v}_{\oplus,\odot}|$ is as follows, see [7]:

$$|v| = |\vec{v}_{\oplus,\odot}| = \frac{2\pi \cdot \text{AU}}{1 \text{ year}} = 29\,866 \frac{\text{m}}{\text{s}} \quad (6)$$

Thereby, 1 AU is one astronomical unit, see [7]. Hereby, the ellipticity of Earth's orbit causes very small variations. These are neglected here, as an approximation. As an additional test, Earth's velocity relative to the Sun in Eq. (6) is inserted in Eq. (5):

$$|\alpha| = \frac{29\,866 \frac{\text{m}}{\text{s}}}{3 \cdot 10^8 \frac{\text{m}}{\text{s}}} = 20.5'' \quad (7)$$

This is in full accordance with the observation, Eq. (4), [7].

However, Einstein provides the same formula Eq. (2), but Einstein states that the speed v in that formula would be the speed between the observer and the source, that is the star [2], page 911, lines 16-18 and page 912 line 13, that is the third formula on that page. This false statement by Einstein is in accordance with Einstein's principle of relativity, but it is not in accordance with observation. This falsity is the aberration problem of relativity theory.

In contrast, the result derived here and observed in astronomy and presented in Eq. (7) shows that there is an influence of the Sun's velocity relative to Earth upon the light that propagates from the star to Earth. This observed and derived influence is clearly beyond the capability of Einstein's principle of relativity.

The aberration problem of relativity theory is solved here as follows: The International Astronomical Union proclaimed the problem to find an Adequate Coordinate System (ACS), which is appropriate for space navigation, see [8]. The solution of this ACS problem, see [4,9,5,6] is used. In each ACS, the light path is at rest, see [3]. Moreover, for each point P in the universe, the ACS and its uniquely determined velocity have been derived, see [9,10,6] Therefrom, the light path from a star to Earth is derived in general. Moreover, the aberration angle is derived for each star and for each point of observation, see Figure. (4).

Celestial Reference Systems

The International Astronomical Union (IAU) proposed to use the Geocentric Celestial Reference System (GCRS) for space navigation near Earth, and the IAU proposed to use the Barycentric Celestial Reference System (BCRS) (nearly heliocentric) for space navigation in our solar system, more generally, the IAU proclaimed the problem to find the Adequate Coordinate System (ACS), see [8]. In general, when light propagates from one Celestial Reference System (CRS) to another CRS, the direction of propagation changes, see Figure. (1).

Use of Light Paths

In general, the propagation of light from a star to an observer can be described with help of a light path, see [3]. In this investigation, the light paths, that occur in stellar aberration, are used as a tool of the analysis, see Figures. (1) and (2).

Firstly, the light paths are used in order to define the light velocity vector, see Figure. (1).

Secondly, the light path is at rest in the ACS, see [3]. Therefore, the light velocity vector $\vec{v}_{light,ACS}$ relative to the ACS is fundamental for the light path in aberration.

Thirdly, for each point P in the universe and for each time since the Big Bang, there is an ACS, with a uniquely determined velocity $\vec{v}_{ACS,BCRS}$, see [4,5,3,6]. Therefore, for each point P, the light velocity vector $\vec{v}_{light,BCRS}$, relative to the BCRS, can be transformed to the light velocity vector $\vec{v}_{light,ACS}$, relative to the ACS.

Fourthly, this is achieved with help of the relativistic addition of the velocities (see section 5) $\vec{v}_{light,BCRS}$ and $-\vec{v}_{ACS,BCRS}$, see Figure. (3):

$$\vec{v}_{light,ACS} = \vec{v}_{light,BCRS} \text{ rel. add. with } -\vec{v}_{ACS,BCRS} \quad (8)$$

The result of the relativistic addition is derived next. Thereby, the vectors are described in full generality. Moreover, for each point P, the ACS is derived, and the aberration angle is deduced.

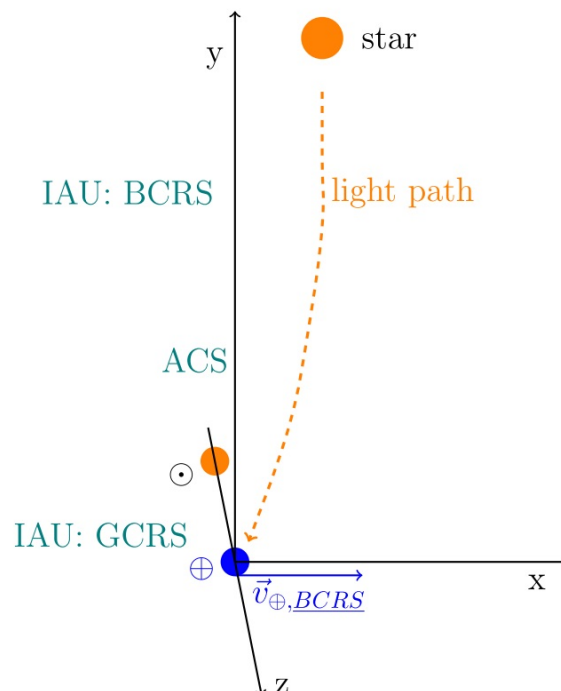


Figure 2: Stellar Aberration: As an Illustration, the Case $\vartheta = 90^\circ$ is Shown: in Stellar Aberration, the Light Path Gradually Changes its Direction, when it Propagates from the BCRS to the Geocentric Celestial Reference System GCRS

Use of the Lorentz Transformation

In general, the Lorentz transformation describes a transformation of physical quantities of an object that moves with a velocity v relative to an ACS [3,6]. Thereby, without loss of generality, the velocity is parallel to an x axis. The reason is that the coordinate system can be chosen freely, and three Lorentz transformations, one for each velocity component, can be concatenated. Hereby, a change in the ACS is described by the following increments:

$$\begin{pmatrix} dt \\ dx \\ dy \\ dz \end{pmatrix} \quad (9)$$

Thereby, in the ACS, without loss of generality, a pilot's system moves with a velocity v to the right. The respective increments are named as follows:

$$\begin{pmatrix} dt_p \\ dx_p \\ dy_p \\ dz_p \end{pmatrix} \quad (10)$$

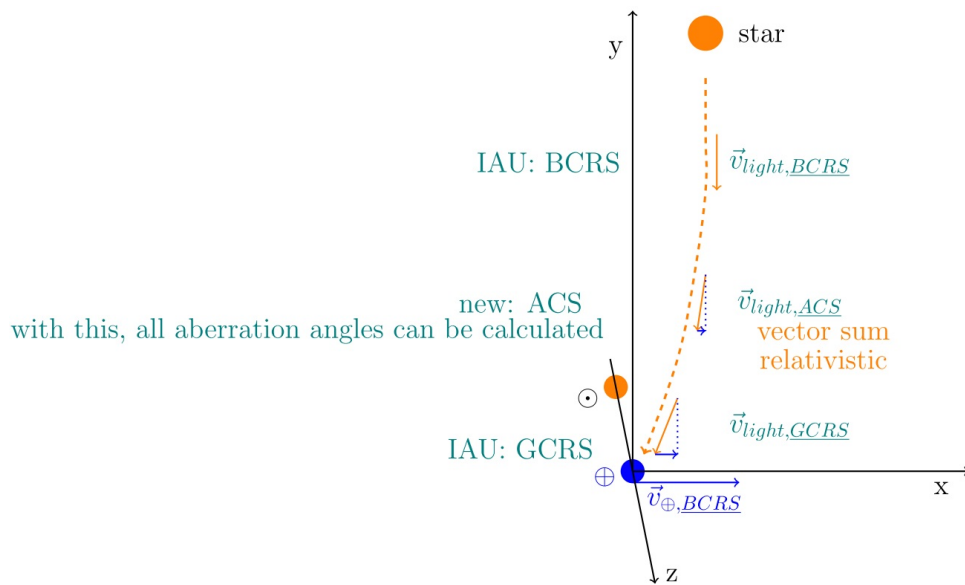


Figure 3: Stellar Aberration: as an Illustration, the Case $\vartheta = 90^\circ$ is shown: Various Light Velocity Vectors

$\vec{v}_{light,BCRS}$, $\vec{v}_{light,ACS}$ and $\vec{v}_{light,GCRS}$ are shown (orange). These are derived with help of the velocity vectors $\vec{v}_{ACS,BCRS}$ (blue) of the ACS, relative to the BCRS. Therefrom, the angles of aberration α are obtained. Thereby, the light velocity vector $\vec{v}_{light,ACS}$ is the vector sum of $\vec{v}_{light,BCRS}$ and $-\vec{v}_{ACS,BCRS}$, whereby the relativistic addition of velocities is used, see sections (4) and (5).

The equations of the Lorentz transformation can be derived without analysis of the ACS. The respective equations can be described as follows, see [11].

$$\begin{pmatrix} dt_p \\ dx_p \\ dy_p \\ dz_p \end{pmatrix} = \begin{pmatrix} \gamma \cdot (dt - \frac{v}{c^2} dx) \\ \gamma \cdot (dx - v \cdot dt) \\ dy \\ dz \end{pmatrix} \quad \text{with } \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (11)$$

Therefrom, the equations of the inverse Lorentz transformation can be obtained by replacing v by $-v$, see [11]:

$$\begin{pmatrix} dt \\ dx \\ dy \\ dz \end{pmatrix} = \begin{pmatrix} \gamma \cdot (dt_p + \frac{v}{c^2} dx_p) \\ \gamma \cdot (dx_p + v \cdot dt_p) \\ dy_p \\ dz_p \end{pmatrix} \quad (12)$$

Relativistic Addition of Velocities

In the addition of velocities, the following situation is considered: At an arbitrary point P , there is an ACS. In the ACS, a pilot moves with a velocity v in the positive x direction. Additionally, there moves an object A. It has a velocity $\vec{u}$, relative to the ACS. As a consequence, A has the following velocity $\vec{u}_p$, relative to the pilot:

$$\begin{pmatrix} u_{x,p} \\ u_{y,p} \\ u_{z,p} \end{pmatrix} = \frac{1}{1 - \frac{v}{c^2} \cdot u_x} \cdot \begin{pmatrix} u_x - v \\ u_y \cdot \sqrt{1 - \frac{v^2}{c^2}} \\ u_z \cdot \sqrt{1 - \frac{v^2}{c^2}} \end{pmatrix} \quad \text{with } u_x = \frac{dx}{dt} \text{ and } u_{x,p} = \frac{dx_p}{dt_p}$$

(13)

similarly, $u_y = \frac{dy}{dt}$ and $u_{y,p} = \frac{dy_p}{dt_p}$ and $u_z = \frac{dz}{dt}$ and $u_{z,p} = \frac{dz_p}{dt_p}$

On the basis of the equations of the Lorentz transformation in section (4), the above equations can be derived, see [11]. The inverse equations can be obtained by replacing v by $-v$.

$$\begin{pmatrix} u_x \\ u_y \\ u_z \end{pmatrix} = \frac{1}{1 + \frac{v}{c^2} \cdot u_{x,p}} \cdot \begin{pmatrix} u_{x,p} + v \\ u_{y,p} \cdot \sqrt{1 - \frac{v^2}{c^2}} \\ u_{z,p} \cdot \sqrt{1 - \frac{v^2}{c^2}} \end{pmatrix} \quad (14)$$

Velocity of the ACS

In this section, for each point P , the velocity of the ACS is derived, see [6], Eqs. (42) and (43), or [10].

$$\vec{v}_{p, \underline{UCS}} = \frac{\sum_{i=1}^{i=N} G_i^* \cdot \vec{v}_{\vec{G}_i^*, \underline{UCS}}}{\sum_{i=1}^{i=N} G_i^*} = \langle \vec{v}_{\vec{G}_i^*, \underline{UCS}} \rangle \quad (15)$$

Thereby, the UCS is an Unspecific Coordinate System. In contrast, the ACS is specific, and in the ACS, time dilation is described correctly, and the light path is at rest in the ACS. Hereby, $\vec{v}_{p, \underline{UCS}} = \vec{v}_{\underline{ACS}, \underline{UCS}}$. Thence, in Eq. (15), $\vec{v}_{p, \underline{UCS}}$ is the velocity of the ACS:

$$\vec{v}_{\underline{ACS}, \underline{UCS}} = \langle \vec{v}_{\vec{G}_i^*, \underline{UCS}} \rangle \quad (16)$$

In the case of stellar aberration, the UCS is the BCRS, see Figure. (1):

$$\vec{v}_{\underline{ACS}, \underline{BCRS}} = \langle \vec{v}_{\vec{G}_i^*, \underline{BCRS}} \rangle \quad (17)$$

Angle of Aberration Derived for Each Point

In this section, for each point P , the angle α of aberration is derived: For each point P , the ACS velocity $\vec{v}_{\underline{ACS}, \underline{BCRS}}$ is derived in Eqs. (16) and (17). The averaged light velocity vector $\vec{v}_{light, \underline{BCRS}}$ from the star to the observer is usually observed and known, see Figure. (1). These two vectors are combined. For this, the relativistic addition of velocities in Eq. (14) is applied to the case of aberration in Eq. (8)

$$\vec{v}_{light, \underline{ACS}} = \vec{v}_{light, \underline{BCRS}} \text{ relativistically summed with } -\vec{v}_{\underline{ACS}, \underline{BCRS}}. \quad (18)$$

Therefore, the relativistic sum in Eq. (14) is used with the following velocities: The light moves through the BCRS, before it moves through the GCRS. Therefore, the light's velocity is first analyzed in the BCRS:

$$\vec{u} = \vec{v}_{light, \underline{BCRS}} \quad (19)$$

Then the light's velocity is analyzed in the ACS:

$$\vec{u}_p = \vec{v}_{light, \underline{ACS}} \quad (20)$$

As a consequence, the velocity v , that has to be summed relativistically, is $-v_{x, \underline{ACS}, \underline{BCRS}}$, see Figure. (3):

$$v = v_{x, \underline{BCRS}, \underline{ACS}} = -v_{x, \underline{ACS}, \underline{BCRS}} \quad (21)$$

Consequently, the tangent of φ is the ratio of $u_{y,p}$ and $u_{x,p}$, see Figure. (1):

$$\tan \varphi = \frac{u_{y,p}}{u_{x,p}} \quad (22)$$

Eq. (13) is applied to the above equation. As a consequence, $\tan \varphi$ is

$$\tan \varphi = \frac{u_y}{\gamma \cdot (u_x - v)} \quad (23)$$

Next, $u_x = c \cos \vartheta$ and $u_y = c \sin \vartheta$ are used, see Figure. (1):

$$\tan \varphi = \frac{\sin \theta}{\gamma \cdot (\cos \vartheta - v/c)} \quad (24)$$

In the above Eq., $\tan \varphi = \sin \varphi / \cos \varphi$ is inserted, and the Eq. is solved for $\cos \varphi$:

$$\cos \varphi = \sin \varphi \cdot \gamma \cdot (\cos \vartheta - v/c) \cdot \frac{1}{\sin \vartheta} \quad (25)$$

In the above Eq., $\sin \vartheta = u_y/c$ and $\sin \varphi = u_{y,p}/c$ are used:

$$\cos \varphi = \gamma \cdot (\cos \vartheta - v/c) \cdot \frac{u_{y,p}}{u_y} \quad (26)$$

Eq. (13) is applied to the above equation:

$$\cos \varphi = \gamma \cdot (\cos \vartheta - v/c) \cdot \frac{1}{\gamma(1 - u_x v/c^2)} \quad (27)$$

Next, $u_x = c \cos \vartheta$ is used:

$$\cos \varphi = \frac{\cos \vartheta - v/c}{1 - \cos \vartheta \cdot v/c} \quad (28)$$

This equation is identified with the second equation in [2], p. 912. However, remind that Einstein proposed that v would be the velocity of Earth relative to the star, but, this is falsified. This equation describes aberration in our planetary system in a general manner, and v is the velocity of the BCRS relative to the ACS, see Eq. (21). More generally, this equation describes aberration in each planetary system of the universe in a general manner, and v is the velocity of the respective star of the respective planetary system relative to the ACS.

In particular, for the case $\vartheta = 90^\circ$, the above equation is as follows:

$$\cos \varphi = -\frac{v}{c} \quad (29)$$

This Eq. is identified with the third equation in [2], p. 912, and with Eq. (2). However, remind that Einstein proposed that v would be the velocity of Earth relative to the star, but, this is false.

Derived Light Path in Stellar Aberration

In general, each light path can be obtained by concatenating the light velocity vectors $\vec{v}_{light,ACS}(P)$. The reason is that the light path is at rest in the ACS, and that $\vec{v}_{light,ACS}(P)$ is the vector at P , which has the length c , and which is tangential at the light path. An example is shown in Figure. (5). In this manner, the present derivation provides the full light path from the star to the observer.

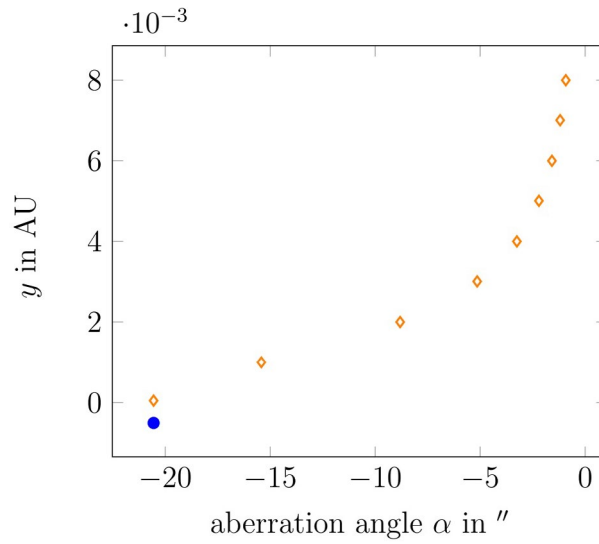


Figure 4: Stellar aberration: As an Illustration, the Case $\vartheta = 90^\circ$ is Shown: The Angle α of Stellar Aberration (Orange) is Shown as a Function of the Distance y from Earth (Blue Circle). The Absolute Value $|\alpha|$ Increases, when the Light Approaches Earth. There, it Achieves the Value $\alpha = -20.5''$ Observed at Earth

Aberration Angles for the Case $\vartheta = 90^\circ$

In this section, as an example, for the case $\vartheta = 90^\circ$, the angles of aberration are derived, calculated and presented graphically, see Figure. (4). At a coordinate z , the field caused by Earth is

$$G_{\oplus}^* = \frac{G \cdot M_{\oplus}}{z^2}, \quad (30)$$

and the field caused by Sun is

$$G_{\odot}^* = \frac{G \cdot M_{\odot}}{AU^2 + z^2}. \quad (31)$$

As the Sun is at rest in the BCRS, the respective field has the velocity zero, relative to the BCRS:

$$\vec{v}_{\vec{G}_{\odot}^*, \underline{BCRS}} = 0. \quad (32)$$

As the Earth has the speed $29866 \frac{\text{m}}{\text{s}}$ in the BCRS, , see [7], the respective field has that velocity, relative to the BCRS:

$$\vec{v}_{\vec{G}_{\oplus}^*, \underline{BCRS}} = 29866.298 \frac{\text{m}}{\text{s}} \quad (33)$$

As a consequence, the expectation value of the gravitational fields and the velocity of the ACS are as follows:

$$\langle \vec{v}_{\vec{G}_i^*, \underline{BCRS}} \rangle = \frac{G_{\oplus}^* \cdot \vec{v}_{\vec{G}_{\oplus}^*, \underline{BCRS}}}{G_{\odot}^* + G_{\oplus}^*} = \vec{v}_{\underline{ACS}, \underline{BCRS}} \quad (34)$$

The x-axis has been chosen parallel to this vector, see Figure. (1). Consequently, the velocity $|\nu|$ in Eq. (5) is as follows:

$$|\vec{v}_{\underline{ACS}, \underline{BCRS}}| = |\nu| \quad (35)$$

Therefore, the absolute value of the aberration angle is as follows, see Eq. (5):

$$|\alpha| = \frac{|\vec{v}_{\underline{ACS}, \underline{BCRS}}|}{c} \quad (36)$$

With help of this equation, the aberration equations have been calculated as a function of the coordinate y , see Figure. (4).

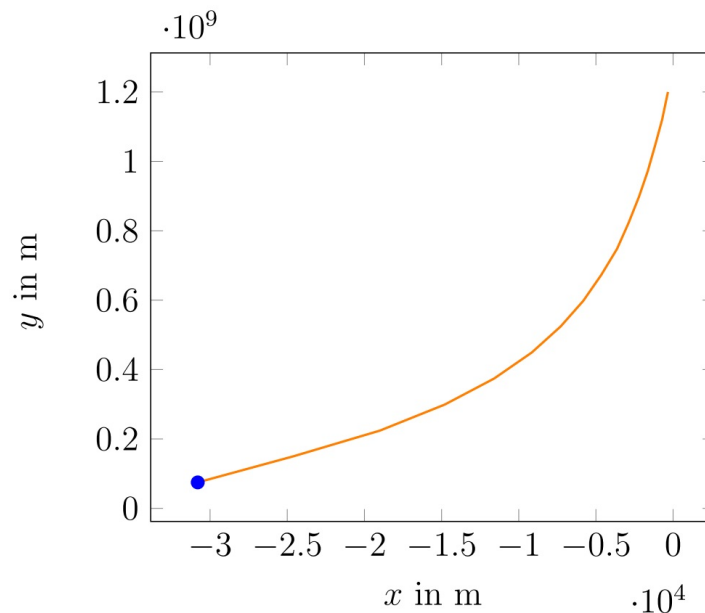


Figure 5: Stellar Aberration: As an Illustration, the Case $\vartheta = 90^\circ$ is Shown: The Deviation in x Direction is Shown as a Function of y. Earth is Marked by a Blue Circle

Discussion

Bradley discovered the phenomenon of stellar aberration, see Figure. (1) and [1]. Einstein tried to explain it, he derived the adequate Equation (28), but he proposed that the velocity in that equation would be the velocity of Earth relative to the star, see [2]. However, it is the velocity of Earth relative to the Sun. Einstein's false velocity is an example of the missing Adequate Coordinate System (ACS) in present - day relativity theory. Therefore, present - day relativity theory is an idealization, see [9].

The ACS problem has been solved, see [4,5,3,6]. In this paper, that solution is used in order to derive the correct aberration angle for each point in the planetary system, and for each point in the universe, see Figure. (4). Similarly, the light path of aberration is derived for each point in the planetary system, and for each point in the universe, see Figure. (5). For these predictions, an innovative and new theory of space is used: Space is a stochastic average of indivisible volume portions [12,13,14], [9,10,6,15]. This theory provides a founded and derived unification of relativity, gravity, and quantum physics, and it solves many problems of physics. This unification is used here in the expectation value in Eqs. (15, 16 and 17) with moving gravitational fields of celestial bodies everywhere in the planetary system and in the universe. This includes the full light path and the various nearby celestial bodies, from the emission to the observer.

It is proposed, that the predicted angles and light paths of aberration are investigated experimentally in future space missions.

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