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PROPOSAL TO MEASURE TERRESTRIAL BRADLEY ABERRATION

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Because parallax exactly masks Bradley aberration when ordinary terrestrial sources are used; it is proposed to measure the angle of parallax, and thus, the angle of aberration, by observing telescopically the appearance of a three dimensional object used as a source. For a setup rigidly fixed to the Earth's surface at a northern latitude the variation of the appearance of the object as a function of the time of day can then yield the magnitude and direction of the absolute velocity of the Earth.

Key words: Bradley aberration terrestrial, absolute velocity measurement.

As discussed in a prior paper [1], light from ordinary terrestrial sources, radiating equally in all directions, cannot be collimated such as to yield a beam unidirectional with respect to absolute space (such as provided by starlight). Parallax for such an ordinary source exactly equals and masks aberration. It is, therefore, proposed that a small three dimensional object be used as a source, such as a small sphere, white on one side and black on the other. Such an object may be taken as simply a small thin rectangular white card making an angle ϕ with respect to the viewing direction, as shown in Fig. 1.

The telescopes shown are focused on the small white card, the background being black. The amount of light admitted into a telescope is proportional to the projection

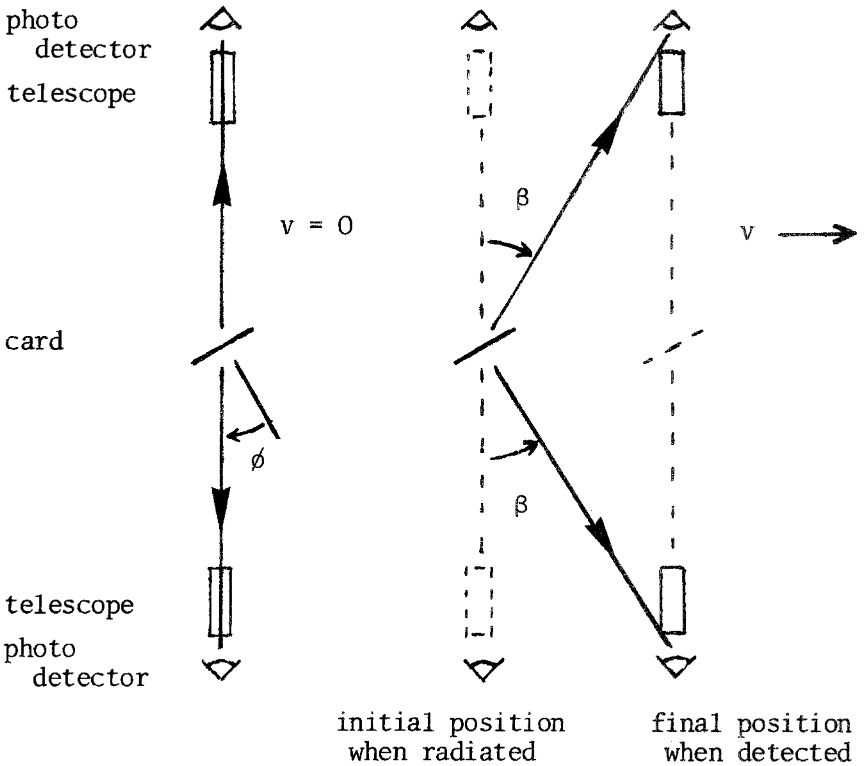

Fig. 1. Diagram showing how the appearance of a small white card, as measured by the amount of light received by two telescopes, can be used to measure the angle of Bradley aberration β, when the laboratory moves with the velocity v in the plane of the figure as shown.

of the surface area of the card normal to the line of sight; thus,

$$\begin{aligned} I_+ &= K\cos(\phi - \beta) \approx K'(1 + \beta\tan\phi), \\ I_- &= K\cos(\phi + \beta) \approx K'(1 - \beta\tan\phi), \end{aligned} \tag{1}$$

where K and K' are constants. ϕ is the angle between the normal to the card and the initial line of sight for v = 0, β is the aberration angle, I_+ is the light intensity seen by the lower telescope, and I_- is the light intensity seen by the upper telescope as shown in Fig. 1. The approximate equalities in Eq. (1) are for small values of the aberration angle β.

As already known the absolute velocity of the Earth (or solar system) has a magnitude of about $v = 300$ km/sec; so the aberration angle, as given by $\sin\beta = v/c \approx \beta$, can be no greater than the order of 0.001 radians or 3.4 minutes. Consequently the second terms in the brackets on the right of Eqs. (1) will be small. The appropriate strategy is to use photoelectric detectors to detect the amount of light I_+ and I_- and to measure the difference using a bridge network. The difference may be accurately determined yielding for the situation indicated in Fig. 1 the result

$$\beta = \cot\phi\,(I_+ - I_-)/(I_+ + I_-) = v/c. \tag{2}$$

The idealized situation presented in Fig. 1, lying entirely in a plane, which illustrates the principles involved, cannot be readily realized in the laboratory. It is, thus, necessary to consider the more realistic and more complicated three dimensional geometry actually involved. The amount of light received by a telescope is proportional to the projection of the area of the card normal to the line of sight; thus,

$$I = K\mathbf{n}\cdot\mathbf{L}/L, \tag{3}$$

where K is a constant, $\mathbf{n}$ is the unit normal to the card, and $\mathbf{L} = \mathbf{r} - \mathbf{r}_0$ is the vector distance from the card at $\mathbf{r}_0$ to the point of observation at $\mathbf{r}$. When the setup is translated with the absolute velocity $\mathbf{v}$, the light that arrives at the detector must travel along the vector $\mathbf{L}'$ given by

$$\mathbf{L}' = \mathbf{r} + \mathbf{v}\Delta t - \mathbf{r}_0 = \mathbf{L} + \mathbf{v}\Delta t, \tag{4}$$

where the end point $\mathbf{r}$ has moved a distance $\mathbf{v}\Delta t$ in the time Δt necessary for light to travel the distance L'. Substituting $\Delta t = L'/c$ in Eq. (4), squaring both sides, and solving for L' yields

$$\begin{aligned} L' &= L\left[\mathbf{L}\cdot\mathbf{v}/Lc + \sqrt{1 - v^2/c^2 + (\mathbf{L}\cdot\mathbf{v}/Lc)^2}\,\right]/(1 - v^2/c^2) \\ &\approx L(1 + \mathbf{L}\cdot\mathbf{v}/Lc), \end{aligned} \tag{5}$$

where the approximate equality means terms varying as $v^2/c^2 \sim 10^{-6}$ have been neglected compared with unity.

Combining Eq. (3), replacing $\mathbf{L}$ by $\mathbf{L}'$, with Eqs. (4) and (5), the amount of light received by the telescope when the Earth moves with the absolute velocity $\mathbf{v}$ is given by

$$I = K\left[\mathbf{n}\cdot\mathbf{L}/L + \mathbf{n}\cdot\mathbf{v}/c - (\mathbf{n}\cdot\mathbf{L})(\mathbf{L}\cdot\mathbf{v})/L^2c\right], \tag{6}$$

where terms varying as v^2/c^2 have been neglected. Employing the strategy of using two colinear telescopes, as indicated in Fig. 1, the amount of light received by the second (or upper) telescope is given by Eq. (6) by replacing $\mathbf{n}$ by $(-\mathbf{n})$ and $\mathbf{L}$ by $(-\mathbf{L})$. The fractional difference which can be accurately measured is then given by

$$Y = (I_+ - I_-)/(I_+ + I_-) = (\sec\phi\,\mathbf{n} - \mathbf{L}/L)\cdot(\mathbf{v}/c), \tag{7}$$

where the fact that $\mathbf{n}\cdot\mathbf{L}/L = \cos\phi$ has been used. Measuring Y for different choices of the laboratory parameter $\mathbf{s} = \sec\phi\,\mathbf{n} - \mathbf{L}/L$, which lies in the $\mathbf{n},\mathbf{L}$ plane and is perpendicular to $\mathbf{L}$, can yield the magnitude and direction of the absolute velocity $\mathbf{v}$ of the Earth.

There are many ways that one might proceed to find $\mathbf{v}$. One particular method is presented here. Let $\mathbf{L}$ be rigidly fixed to the surface of the Earth lying in the north-south direction with the telescope placed south of the card. Introducing cartesian coordinates fixed to the Earth with a right-hand triad of unit vectors directed east $\mathbf{e}_E$, north $\mathbf{e}_N$, and up $\mathbf{e}_U$, the vectors $\mathbf{L}$ and $\mathbf{n}$ are given by

$$\begin{aligned} \mathbf{L} &= -L\,\mathbf{e}_N \\ \mathbf{n} &= \sin\phi\cos\gamma\,\mathbf{e}_E - \sin\phi\sin\gamma\,\mathbf{e}_N - \cos\phi\,\mathbf{e}_U, \end{aligned} \tag{8}$$

where γ is the angle through which the card (or whole setup) can be rotated about the axis through the telescope, counted as positive when $\mathbf{n}$ moves downward, and ϕ is kept fixed.

It is convenient to introduce cartesian coordinates fixed with respect to the celestial sphere (or absolute space) with the unit vector $\mathbf{e}_x$ in the direction of the vernal equinox, the unit vector $\mathbf{e}_z$ in the direction of the celestial north (or the Earth's axis), and the unit vector $\mathbf{e}_y = \mathbf{e}_z \times \mathbf{e}_x$. The triad fixed to the Earth's surface in terms of the celestial directions are then given by

$$\begin{aligned} \mathbf{e}_E &= -\sin\alpha'\,\mathbf{e}_x + \cos\alpha'\,\mathbf{e}_y, \\ \mathbf{e}_N &= -\cos\alpha'\cos\delta'\,\mathbf{e}_x - \sin\alpha'\cos\delta'\,\mathbf{e}_y + \sin\delta'\,\mathbf{e}_z, \\ \mathbf{e}_U &= \cos\alpha'\sin\delta'\,\mathbf{e}_x + \sin\alpha'\sin\delta'\,\mathbf{e}_y + \cos\delta'\,\mathbf{e}_z, \end{aligned} \tag{9}$$

where α' is the right ascension and δ' is the declination (or colatitude) of the laboratory. Substituting Eqs. (9) into (8) the three directions of interest, $\mathbf{v}$, $\mathbf{L}$, and $\mathbf{n}$ become

$$\mathbf{v}/v = \cos\alpha \sin\delta\, \mathbf{e}_x + \sin\alpha \sin\delta\, \mathbf{e}_y + \cos\delta\, \mathbf{e}_z,$$

$$\mathbf{L}/L = \cos\alpha' \cos\delta'\, \mathbf{e}_x + \sin\alpha' \cos\delta'\, \mathbf{e}_y - \sin\delta'\, \mathbf{e}_z,$$

$$\begin{aligned} n_x &= -\sin\phi \cos\gamma \sin\alpha' - \sin\phi \sin\gamma \cos\alpha' \sin\delta' \\ &\qquad + \cos\phi \cos\alpha' \cos\delta', \\ n_y &= \sin\phi \cos\gamma \cos\alpha' - \sin\phi \sin\gamma \sin\alpha' \sin\delta' \\ &\qquad + \cos\phi \sin\alpha' \cos\delta', \\ n_z &= -\sin\phi \sin\gamma \cos\delta' - \cos\phi \sin\delta'. \end{aligned} \tag{10}$$

It is now of interest to consider the fractional differences in light received Y, as given by Eqs. (7) and (10), for the special cases when $\alpha' = \alpha$ and for 6 hours later when $\alpha' = \alpha + \pi/2$; thus,

$$\begin{aligned} Y(\alpha) &= -(v/c) \tan\phi \sin\gamma \cos(\delta - \delta'), \\ Y(\alpha + \pi/2) &= -(v/c) \tan\phi\, (\cos\gamma \sin\delta + \sin\gamma \cos\delta' \cos\delta). \end{aligned} \tag{11}$$

These results (11) suggest the following experimental procedure: First, the angle γ is chosen as zero ($\gamma = 0$, as shown in Fig. 1). Then when the right ascension of the laboratory α' equals the right ascension of the absolute velocity of the Earth α, Y will be zero, as given by the first of Eqs. (11); thus,

$$Y_1 = 0 \quad \text{when} \quad \gamma = 0, \quad \alpha' = \alpha. \tag{12}$$

Second, the fractional difference is observed 6 hours later while γ is still zero when $\alpha' = \alpha + \pi/2$. From the second of Eqs. (11) this yields

$$Y_2 = -(v/c) \tan\phi \sin\delta \quad \text{when} \quad \gamma = 0, \quad \alpha' = \alpha + \pi/2. \tag{13}$$

Third, the setup is rotated about the axis of the telescopes by 90° (so that $\mathbf{n}$ moves downward) so $\gamma = \pi/2$. In this case the second of Eqs. (11) gives

$$\begin{aligned} Y_3 &= -(v/c) \tan\phi \cos\delta' \cos\delta \\ &\text{when} \quad \gamma = \pi/2, \quad \alpha' = \alpha + \pi/2. \end{aligned} \tag{14}$$

From Eqs. (12), (13), and (14) the desired absolute velocity of the Earth $\mathbf{v}$ in direction and magnitude is given by

$$\alpha = \alpha' \qquad \text{when } \gamma = 0 \text{ and } Y_1 = 0,$$
$$\delta = \tan^{-1}(\cos\delta' \, Y_2/Y_3), \tag{15}$$
$$v = c \cot \phi \sqrt{Y_2^2 + \sec^2\delta' \, Y_3^2} \, .$$

Professor Edward Hale of the University of Missouri-Rolla hopes to perform this experiment in the near future.

REFERENCES

1. J. P. Wesley, *Found. Phys. Lett.* **3**, 395 (1990).