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BRADLEY ABERRATION PROPOSED TO MEASURE ABSOLUTE VELOCITY OF CLOSED LABORATORY

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Bradley aberration, which uses the yearly angular displacement of starlight to measure the velocity of the Earth about the sun, can be used in the closed laboratory to measure the absolute velocity of the laboratory. Lasers replace starlight. Comparing the aberration for two oppositely directed light beams as a function of direction, the absolute velocity of the laboratory may be deduced. A special "telescope" to be used to detect small angular changes is described.

Key words: measuring absolute velocity, Bradley aberration.

1. INTRODUCTION

Bradley [1] aberration is well known as an astronamical effect where the apparent positions of all stars are found to be a function of the velocity of revolution of the Earth about the sun. Each star traces out a small ellipse each year. Knowing that the oneway velocity of energy propagation of light in free space is c, the velocity of the Earth in its orbit about the sun may be determined using the Bradley aberration [2]. Bradley aberration need not be limited to astronomical observations. The parallel rays of a laser beam in the laboratory can simulate the parallel rays of starlight. A laser source fixed in the laboratory moves with the laboratory; but a distant star also appears to move with the laboratory.

Bradley aberration is readily explained if it is assumed that the oneway velocity of energy propagation of of light **c*** observed by an observer moving with the absolute velocity **v** is

$$\mathbf{c}^* = \mathbf{c} - \mathbf{v}, \tag{1}$$

where **c** is the oneway energy velocity of light in free space with respect to absolute space or the luminiferous ether. The observed velocity **c*** is not a function of the velocity of the source. (Other observations involving the oneway velocity of energy propagation of light **c***, such as those of Roemer [3], Conklin [4], and the two experiments of Marinov [5,6], are also explained using Eq. (1) [7]. The phase velocity of light **c'**, which in general is neither of the same magnitude nor direction as the velocity of energy propagation **c***, is required where interference is involved. It is the phase velocity that explains the null Michelson-Morley result as a Voigt-Doppler effect [8].) A laser source moving with the laboratory cannot, thus, affect the result (1) by virtue of its motion.

Referring to Fig. 1, the aberration angle β of a telescope is the difference between the true direction of a star and the apparent direction, when the absolute velocity of the telescope is **v** making an angle θ with respect to the true direction of the star. From Eq. (1), where the telescope is aligned in the direction of **c*** and the true direction is **c**, it may be readily deduced from the law of sines that

$$\tan\beta = (v/c)\sin\theta/[1 + (v/c)\cos\theta]. \tag{2}$$

Rotating the entire setup including the source through 180° the aberration angle β' becomes

$$\tan\beta' = -(v/c)\sin\theta/[1 - (v/c)\cos\theta]. \tag{3}$$

As far as the apparatus is concerned, it may be noted that β' is negative; as the aberration is in the opposite direction relative to the apparatus after a rotation of 180°. Using Eqs. (2) and (3) for two appropriately chosen values of θ, and knowing the orientation of the telescope with respect to celestial coordinates, the magnitude and direction of the absolute velocity of the laboratory **v** may be readily deduced from the aberration angles β and β'.

It is not possible to determine the absolute velocity of the laboratory by observing stars; because it is not

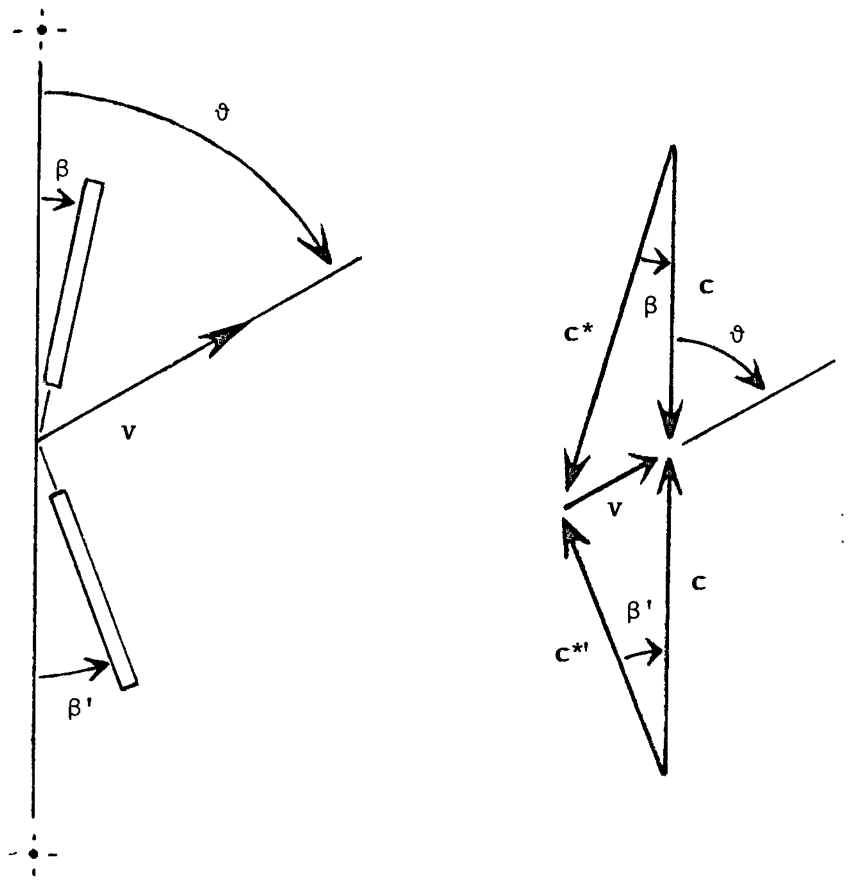

Fig. 1. Bradley aberration angle β when the absolute velocity of the telescope **v** makes an angle θ with respect to the true direction of the star or laser, Eq. (2), and the aberration angle β' when the entire setup including source is rotated through 180°, Eq. (3).

possible to know what star might be really 180° displaced with respect to another star, the entire star field being distorted by Bradley aberration. In contrast, in the laboratory it is quite easy to know when two sources are truly 180° with respect to each other, as they may be rigidly mounted on a turntable and rotated through 180° (See Sec. 2 below for the specific alignments).

2. PROPOSED EXPERIMENTAL SETUP

The idea for the proposed experiment indicated in the previous section may have occurred to someoneelse in the 261 year history of Bradley aberration. Perhaps the experimental difficulties stood in the way of the experiment being actually performed. The angles to be measured are quite small, the maximum aberration angle for an absolute velocity of the solar system of $v/c = 0.001$ is of the order of 0.05 degrees or 3 minutes. To obtain three place accuracy for v then implies angular accuracies of the order of 5×10^{-5} degrees or about 0.2 seconds. Starlight provides an ideal collimated beam; so simulating starlight in the laboratory is extremely difficult. Most beams that can be realized in the laboratory have an angular spread of rays exceeding the 0.2 seconds desired. To get around the problem the star may be simulated by a laser source where the angular spread is very small.

To measure the aberration angles β and β' to the necessary accuracy a "telescope" indicated in Fig. 2 is proposed. (The setup for measuring small angular differences has already been proposed for the case of two independent rotating toothed wheels used to measure the absolute velocity of the solar system [7].) Two identical screens W_1 and W_2, each with two slits, are mounted rigidly on a turntable a distance L apart. Light from laser S_1 is reflected at the semitransparent mirror M_1 to yield a light beam B_1 which passes through one of the slits in screen W_1. After passing through the semitransparent mirror M_2 (which is included merely to make all four beams optically equivalent) and traveling the distance L, beam B_1 passes through the corresponding slit in screen W_2. After passing through the semitransparent mirror M_3, beam B_1 of resultant intensity I_1 is detected by the photodetector P_1. Light from laser S_1 is also transmitted through the semitransparent mirror M_1 and is reflected from the semitransparent mirror M_4 to yield light beam B_2. After passing through the second slit in screen W_1 and traveling the distance L, beam B_2 passes through the corresponding slit in screen W_2. The resultant intensity I_2 of beam B_2 is detected by the photodetector P_2. It may be seen from Fig. 2 that beams B_3 and B_4, arising from laser S_2, also pass exactly through the same slits in screens W_1 and W_2 to yield resultant intensities I_3 and I_4 detected by photodetectors P_3 and P_4.

Beams B_1 and B_2 are passed through the slits in screen W_1 of width b a distance d apart. The distance between beams B_1 and B_2 as they pass through screen W_1 is then b + d from

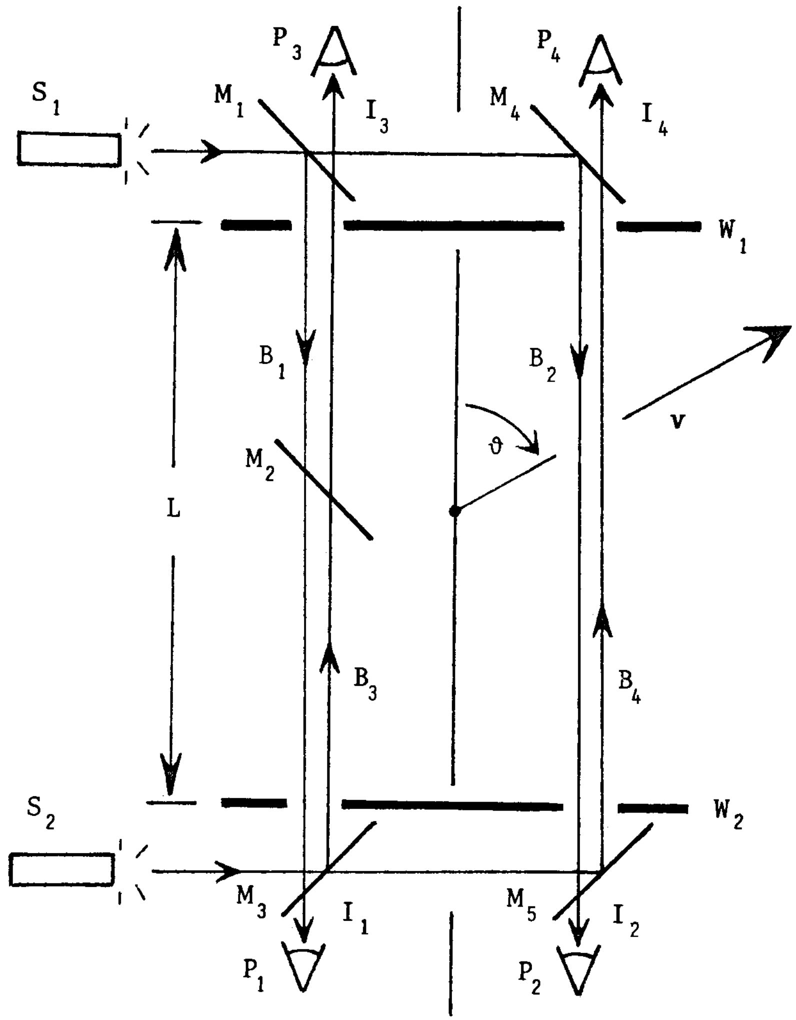

Fig. 2. The "telescope" proposed to measure the small aberration angles β and β', Eqs. (2) and (3), showing the two laser sources, the five semitransparent mirrors, the two screens with two slits each, the four beams, and the four photodetectors.

center to center. The mirrors M_1 and M_4 can be adjusted so that screen W_2 is illuminated by beams B_1 and B_2 closer together by a distance d apart from center to center, as shown in Fig. 3.

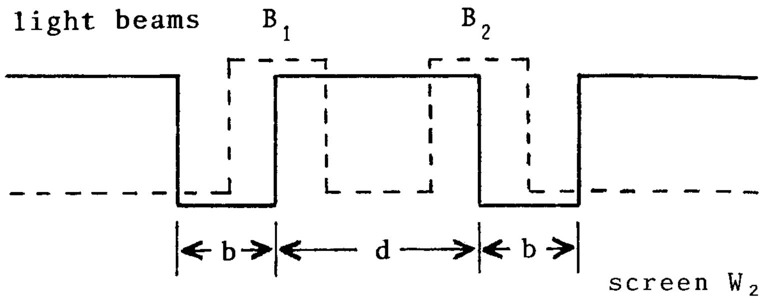

Fig. 3. Diagram of the intensities of light beams B_1 and B_2 from screen W_1 (dashed lines) illuminating the screen W_2 (solid lines) such that beams B_1 and B_2 are a distance d apart rather than b + d as when leaving screen W_1.

3. ABERRATION ANGLES FROM INTENSITIES

Beams B_1 and B_2 (and beams B_3 and B_4) may be adjusted as shown in Fig. 3 when the component of the absolute velocity of the laboratory in the plane of the turntable is in the direction of the telescope ($\theta = 0$ as shown in Fig. 2). If I(max) is the intensity when a beam from screen W_1 fills the slit in screen W_2, the adjustment shown in Fig. 3 is for $I_1 = I_2 = I_0 = I(\max)/2$ for beams B_1 and B_2. For some general direction θ the intensity patterns of beams B_1 and B_2 will be shifted relative to screen W_2 due to Bradley aberration. In particular, in the time Δt that it takes light to travel from screen W_1 to W_2 the apparatus will be displaced in absolute space in the θ direction by the amount $v\Delta t$, where v is the component of the absolute velocity of the laboratory in the plane of the turntable. Light traveling down in the direction shown in Fig. 2 covers the distance $L - v\Delta t\cos\theta$ in the time Δt, where $\Delta t = (L - v\Delta t\cos\theta)/c$; or

$$\Delta t = L/(c + v\cos\theta). \tag{4}$$

The lateral displacement Δx of screen W_2 in the time Δt is $v\sin\theta\,\Delta t$ or

$$\Delta x = (v/c)L\sin\theta/[1 + (v/c)\cos\theta]. \tag{5}$$

Thus, beams B_1 and B_2 are shifted by this amount to the

left relative to screen W_2, as viewed from behind screen W_2 in the position of the photodetectors P_1 and P_2. It may be similarly deduced that beams B_3 and B_4 are shifted by

$$\Delta x' = (v/c)L\sin\theta/[1 - (v/c)\cos\theta], \tag{6}$$

to the right as viewed from behind screen W_1 in the position of the photodetectors P_3 and P_4. Referring to Fig. 1, it may be appreciated that

$$\Delta x/L = \tan\beta \qquad \text{and} \qquad \Delta x'/L = \tan\beta'. \tag{7}$$

It may be seen from Fig. 3 that a shift of the beams to the left relative to screen W_2 by the amount Δx produces an increase in intensity of B_1 given by

$$\Delta I_1/I_0 = 2\Delta x/b, \tag{8}$$

and a decrease in the intensity of B_2 by the amount

$$\Delta I_2/I_0 = 2\Delta x/b. \tag{9}$$

The difference in intensities of I_1 and I_2 can be measured to great accuracy (to a fractional error less than about 10^{-3}) by using an electronic bridge network to balance the outputs of the photodetectors P_1 and P_2. The intensity difference is given by

$$I_1 - I_2 = I_0 + \Delta I_1 - (I_0 - \Delta I_2) = \Delta I_1 + \Delta I_2 = 4I_0\Delta x/b. \tag{10}$$

It may be seen from Fig. 3 that $2I_0 = I(\max) = I_1 + I_2$. The intensity difference given by Eq. (10), using Eq. (5), then yields

$$(v/c)\sin\theta/[1 + (v/c)\cos\theta] = (b/4L)(I_1 - I_2)/(I_1 + I_2). \tag{11}$$

Similarly considering beams B_3 and B_4 one obtains

$$(v/c)\sin\theta/[1 - (v/c)\cos\theta] = (b/4L)(I_3 - I_4)/(I_3 + I_4). \tag{12}$$

Adding the differences, Eqs. (11) and (12), electronically yields

$$\frac{(v/c)\sin\theta}{1 - (v/c)^2\cos^2\theta} = \frac{b}{4L}\left\{\frac{I_1 - I_2}{I_1 + I_2} + \frac{I_3 - I_4}{I_3 + I_4}\right\}. \tag{13}$$

The addition of Eqs. (11) and (12) not only serves to eliminate some possible errors in alignment it also reduces the error in measuring $(v/c)\sin\theta$ if $(v/c)\cos\theta$ is neglected. Thus, the fractional error in Eq. (11) or (12) would be $(v/c)\cos\theta \sim 10^{-3}$; while the fractional error in Eq. (13) is only $(v/c)^2\cos^2\theta \sim 10^{-6}$. Neglecting $(v/c)\cos\theta$, the desired result becomes

$$v\sin\theta = (cb/4L)\left[(I_1-I_2)/(I_1+I_2) + (I_3-I_4)/(I_3+I_4)\right], \quad (14)$$

where v is the component of the absolute velocity of the laboratory projected onto the plane of the turntable.

A further reduction in errors due to misalignment can be obtained by averaging the result (14) with the result obtained when the entire setup together with the sources is rotated through 180°. The detectors change their roles as follows: $P_1 \to P_4$, $P_2 \to P_3$, $P_3 \to P_2$, and $P_4 \to P_1$. Before turning $I_1 > I_2$ and $I_3 > I_4$; but after turning the new intensities I_1', I_2', I_3', and I_4' are such that $I_2' > I_1'$ and $I_4' > I_3'$. The velocity of the laboratory is then given by

$$v\sin\theta = -(cb/4L)\left[(I_1'-I_2')/(I_1'+I_2') + (I_3'-I_4')/(I_3'+I_4')\right]. \quad (15)$$

Any large difference between these two results (14) and (15) would imply a need to readjust the alignments.

The magnitude of the component of the absolute velocity of the laboratory in the plane of the turntable is obtained by rotating the turntable until $v\sin\theta$, as given by the average of Eqs. (14) and (15), is a maximum. The value obtained is v. The direction of the component of the absolute velocity of the laboratory in the plane of the turntable is obtained by rotating the turntable until $v\sin\theta = 0$. The direction is then along the axis of the "telescope". The sense of the velocity along this direction may be obtained by rotating through 90° and noting the sign of $I_1 - I_2$ (or $I_3 - I_4$). If positive then the situation shown in Fig. 2 prevails. If negative the sense is opposite.

4. ERRORS

The experimental setup and the procedure outlined above provides essentially an 8-way average to obtain Bradley's aberration angle, four light beams in opposite directions each. This goes a long way toward eliminating any possible alignment errors. The electronic balancing technique, whereby an electronic bridge is used to measure output differences between photodetectors reduces the error in measuring small angular differences by at least a factor of 10^{-3}. The effect of diffraction will be quite small; as the slits used can be relatively large, of the order of a millimeter. Since the angles of interest are small; $\Delta x/b$ is small; so a change in intensity ΔI as a function of Δx may be assumed to be linear; thus,

$$\Delta I = K\Delta x, \quad (16)$$

where K is a constant. Since ratios of intensities are to be used, $\Delta I/I$; the constant K cancels out and need not be known. In this way the small effect of diffraction is largely eliminated.

The experimental error may be obtained from the reproducibility of results when the four mirrors are readjusted, the two lasers replaced or interchanged, and the four photodetectors replaced or interchanged.

5. ABSOLUTE VELOCITY FROM THE TURNTABLE COMPONENTS

In order to include the component of the absolute velocity of the laboratory due to the tangential velocity of the Earth's rotation it is recommended that the "telescope" indicated in Fig. 2 be free to rotate to all possible three dimensional directions. In this way the "telescope" can sample all directions rapidly. The turntable component of the velocity will be a maximum when the plane of the turntable is perpendicular to **v**. The orientation of the normal to the turntable defines the direction of **v**. The magnitude for this orientation is then given by the average of Eqs. (14) and (15). Referring to Fig. 2, the sense of **v** along the normal to the turntable is provided by the sign of $I_1 - I_2$ (or $I_3 - I_4$).

If the effect of the tangential velocity of rotation of the Earth's surface is not of interest, it being only about 1.5×10^{-3} of the velocity of the solar system, then the turntable can remain in the plane of the Earth's surface. Because the direction of the normal to the turntable changes over 24 hours; the absolute velocity of the Earth may be deduced. Considering three rectangular coordinate directions fixed to the Earth's surface at a latitude δ_0, where one is directed east with a unit vector $\mathbf{e}_1$, one is directed north with a unit vector $\mathbf{e}_2$, and one is directed upward with the unit vector $\mathbf{e}_3$, the absolute velocity of the Earth **v** is given by

$$\mathbf{v}/v = -\mathbf{e}_1 \sin(\omega t - \alpha)\cos\delta + \mathbf{e}_2[-\cos(\omega t - \alpha)\cos\delta\sin\delta_0 + \sin\delta\cos\delta_0] + \mathbf{e}_3[\cos(\omega t - \alpha)\cos\delta\cos\delta_0 + \sin\delta\sin\delta_0], \quad (17)$$

where ω is the angular velocity of rotation of the Earth, α and δ are the right ascension and declination of the velocity of the Earth $\mathbf{v}$, and t is the time of day from $t = 0$ at the vernal equinox. When the east component in the laboratory is found to be zero, then $\omega t = \alpha$ or $\alpha + \pi$. When $\omega t = \alpha$ the absolute velocity of the Earth is given by

$$\mathbf{v}/v = \mathbf{e}_2 \sin(\delta - \delta_0) + \mathbf{e}_3 \cos(\delta - \delta_0). \quad (18)$$

And when $\omega t = \alpha + \pi$,

$$\mathbf{v}/v = \mathbf{e}_2 \sin(\delta + \delta_0) - \mathbf{e}_3 \cos(\delta + \delta_0). \quad (19)$$

Thus from the measured north components when the east component is zero,

$$v_{21} = v\sin(\delta - \delta_0) \quad \text{and} \quad v_{22} = v\sin(\delta + \delta_0), \quad (20)$$

the declination of the absolute velocity of the Earth is

$$\tan\delta = \tan\delta_0 (v_{22} + v_{21})/(v_{22} - v_{21}); \quad (22)$$

and the magnitude is given by

$$v = \left[v_{21}^2 + v_{22}^2 - 2v_{21}v_{22}\cos(2\delta_0)\right]^{1/2}/\sin(2\delta_0). \quad (22)$$

The right ascension α for $\mathbf{v}$ is given by the angle $\alpha = \omega t$ or $\omega t - \pi$ when the east component of $\mathbf{v}$ is zero. The sense of $\mathbf{v}$ along α, δ is determined by the sign of ΔI_1 (See Sec. 2).

REFERENCES

1. J. Bradley, *Lond. Phil. Trans.* **35**, No. 406 (1728).
2. L. Motz and A. Duveen, *Essentials of Astronomy* (Wadsworth, Belmont, California, 1966), pp. 68-70.
3. O. Roemer, *Phil. Trans.* **12**, 893 (1677).
4. E. K. Conklin, *Nature* **222**, 971 (1969).
5. S. Marinov, *Gen. Rel. Grav.* **12**, 57 (1980).
6. S. Marinov, *Thorny Way of Truth, Part II* (East-West, Graz, Austria, 1984), pp. 68-81.
7. J. P. Wesley, *Phys. Essays*, December 1989.
8. J. P. Wesley, *Found. Phys.* **16**, 817 (1986).