One-way speed of light

I found the article in *Journal of Creation* **37**(2) 2023 by Clifford Denton interesting and stimulating. I offer some more points for careful consideration.

For a rigorous proof that the two-way speed of light is constant we should also consider what happens when the apparatus moves at right-angles to the motion of light within it.

As seen in the absolute frame of reference of figure 1, the light in the apparatus will take a diagonal path of length L_1 as it takes a time t for the downward journey.

The Lorentz transformation does not change L.

By Pythagoras,

$$L_1^2 = L^2 + (v\,t)^2$$

So $(c\,t)^2 = c^2\,t^2 = L^2 + v^2\,t^2$

So $t^2 = L^2/(c^2 - v^2)$

$$(2\,t)^2 = 4\,L^2/(c^2 - v^2)$$

As the total time $t_1 = 2\,t$,

$$t_1^2 = 4\,L^2/(c^2 - v^2)$$

The time t_2 measured by the clock moving with the apparatus is $\gamma\,t_1$.

$$\begin{aligned} t_2^2 &= \gamma^2\,t_1^2 \\ &= 4\,L^2\,(1 - v^2/c^2)/(c^2 - v^2) \\ &= 4\,L^2\,(c^2 - v^2)\,/\,c^2\,(c^2 - v^2) \\ &= 4\,L^2\,/\,c^2. \\ t_2 &= 2\,L\,/\,c \end{aligned}$$

Average speed apparent to the observer moving with the apparatus: total distance / total time, is

$$2\,L\,/\,(2\,L\,/\,c) = c.$$

This shows that the same average speed will be obtained whether the motion is parallel or perpendicular to the direction of the light, and also that in the latter case it is the same as the one-way speed. This is very satisfactory.

It is true that all the precise measurements of the speed of light have been two-way averages. However there are two groups of astronomical measurements, initially made about three hundred years ago, which are difficult to interpret as two-way averages. Neither of them was planned to be a measurement of its speed.

Ole Roemer

The first came from the very practical difficulty in the 17th century of determining longitude. Galileo had suggested that the eclipses of Jupiter's innermost satellite (which he had discovered, now called Io) could be used as a clock. Giovanni Cassini in Paris employed Ole Roemer to make accurate observations so that tables could be produced for this purpose. Roemer found that the timing of the eclipses varied with the distance of Jupiter from the earth, and eventually concluded that this was due to the time taken for the light to cross the orbit of the earth about the sun. There are times when the eclipses cannot be observed, such as when Jupiter appears close to the sun, and Roemer correctly predicted that after one such period in 1676 the eclipse would be seen some 11 minutes later than expected.

Roemer's conclusion was highly controversial in the 17th century. The eminent philosopher Descartes held that light travelled instantly, but Isaac Newton, Edmund Halley and Christiaan Huygens supported Roemer. Cassini remained sceptical but did include Romer's adjustments in his tables as an empirical correction. With continual observations, they improved in accuracy (and user-friendliness). In an edition c. 1730 the amplitude of Romer's adjustment is 7 min (figure 2).[1]

A sinusoidal adjustment implies that the speed of light is constant as it crosses the orbit of the earth.

These tables were accurate enough to be useful for surveying land. For example two observations made in 1730 in Beijing gave its longitude as 116° 13' and 116° 23' East of London. The accurate longitude is 116° 24' giving errors in position of only 10 miles and 1 mile respectively.

Sadly, this method failed for ocean navigation. It proved impossible to keep a 12-foot-long telescope (length recommended by Edmund Halley) steady enough on a ship to observe the eclipses.

James Bradley

In the 1720s James Bradley was hoping to observe stellar parallax: an annual variation in the position of a star as it is viewed from the earth in different seasons. The angle (figure 3)

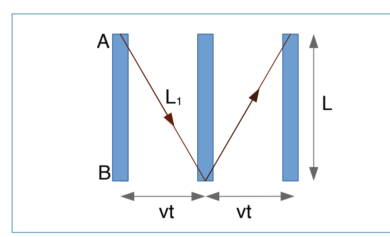

Figure 1. Apparatus AB moving at right angles to the light.

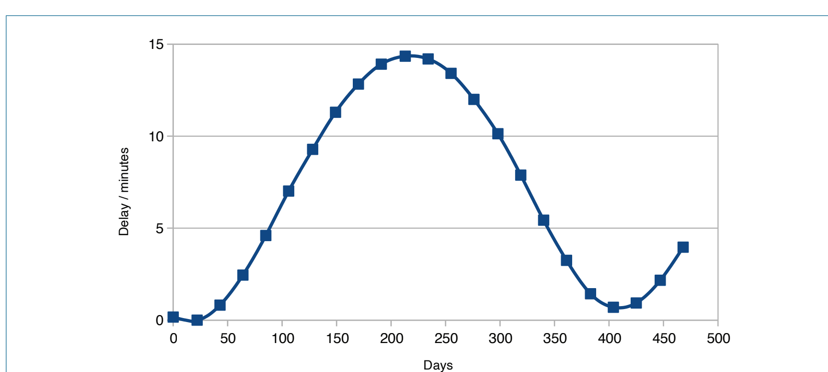

Figure 2. Roemer's adjustment included in Cassini's tables c.1730

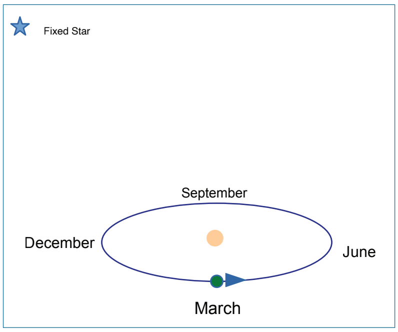

Figure 3. Orbit of the earth around the sun

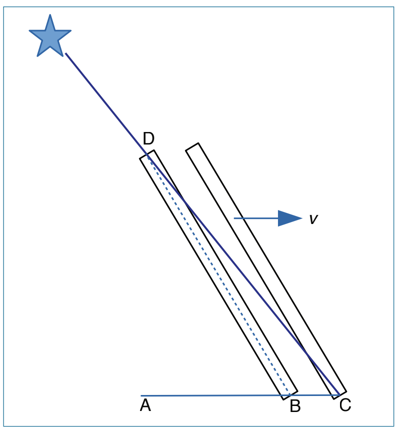

Figure 4. Bradley's explanation of stellar aberration observed through a telescope BD.

between the fixed star (which should be 1,000's of times further away) and the plane of the orbit of the earth should be largest in December and smallest in June.

What Bradley actually saw was that the angle was largest in March and smallest in September, three months later than expected. This was a great puzzle. Eventually he realised that the angle was greatest when the earth was moving fastest to the right, and smallest when moving fastest to the left.

Bradley explained that this 'stellar aberration' in March was due to the movement of his telescope from B to C (figure 4) in the time t it took the particle of light to travel from D to C. The telescope needed to be tilted at a steeper angle than the ray for the light to travel centrally down it.

v = speed of the Earth.

BC = $v\,t$, DC = $c\,t$.

Let x = angle BDC, y = angle ABD.

By the sine rule:

DC/sin(DBC) = BC/sin(x)

Since sin(DBC) = sin(ABD) = sin(y)

$c\,t$ / sin(y) = $v\,t$ / sin(x)

c = v sin(y) / sin(x)

Over the course of two or three years, around 1727, Bradley observed the aberration of many stars. He found that the ratio sin(y):sin(x) was 10210:1 for all of them. At c = 10210 × the speed of the earth, light could travel the circumference of its orbit in 1/10210 of a year, and its radius in 1/2π × 10210 of a year which is 8 min 12 sec.[2] This was close enough to Roemer's 7 min for light from the sun to reach the earth.

Bradley concluded that:

- Light comes at the same speed from stars in different positions in the heavens.
- Light comes at the same speed from bright stars and dim stars, which may be further away.
- Light from the sun, and light reflected (from Io) travel at the same speed.
- Copernicus was right to assert that the earth moved round the sun.
- The fixed stars are much further away than had been thought.[3]

Personally, I do not consider Post-Modernism to be a logical consequence of physical relativity. One could just as well say that a universal speed of light for all observers fits a universal standard of morality for all people.

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References

1. Ward, W., The description and use of a new astronomical instrument, for taking altitudes of the sun and stars at sea without an horizon: together with an easy and sure method of observing the eclipses of Jupiter's satellites, or any other phoenomenon of the kind, on ship-board : in order to determine the difference of meridians at sea: to which are added, tables for computing the times when the eclipses of the first satellite of Jupiter happen under the meridian of London, The George Peabody Library, The Johns Hopkins University Sheridan Libraries, jstor.org.
2. The modern value is 8 min 20 sec, only 1.3% different.
3. Bradley, J., Rev., On the motion of the fixed stars, *The Monist* **22**, reprinted from the Philosophical Transactions of 1727.

» Clifford Denton replies:

I thank Richard Ward for his response to my article. He is correct that we need to deal with a system travelling at right angles to the emitted light if we are to consider the passage of light emitted at any and every angle to the direction of motion of the apparatus. This has a bearing, too, on the interpretation of the Michelson/Morley experiment, in which light was split into two directions at right angles.

It is most satisfying, as he says, how the results can be derived quite simply. Once one can adjust one's mindset confidently back to absolute measurements, one makes progress. It is all too easy for one's mind to be caught up in the fog that relativity theory has brought. That is why it was so pleasing to read Ward's derivation of the parallel result, quite lucid and fog-free. It is my hope and prayer that others, more up to date with physics, will find this lucidity and take the work forward, especially where time dilation and length contraction can be investigated more fully.

We must continue to be rigorous with our work. It is all too easy to make logical errors, even though the mathematics is quite straightforward. In his own proof, Ward quotes the Lorentz transformation regarding length contraction. I would prefer to simply refer to length contraction and time dilation independent of Lorentz, because of the way time is tied up in the Lorentz equations as a variable. We can appreciate the work of others from the past, but seek right answers for right reasons rather than right answers for wrong reasons. We all depend on those who went before and enter the dialogue with humility, ever seeking to correct error.

Thanks also to Ward for the reminder of Roemer and Bradley. There is surely much that can continue to be investigated on the one-way passage of light.

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