STELLAR ABERRATION

C.K. Thornhill
39, Crofton Road
Orpington
Kent. BR6 8AE
United Kingdom

Abstract

Stokes (1845) supposed that the Earth drags the local ether along with it, forming what is now recognised as a viscous boundary layer, and solved the problem of stellar aberration by determining how a light wave from a star changes as it crosses this ethereal boundary layer. He found that its normal gradually rotates so that, when it reaches the Earth's surface and becomes the direction in which an observer sees the star, it has rotated through precisely the classical angle of aberration.

It has been shown (Thornhill, 2004) that, unless longstanding basic mathematics can be discredited, it must be accepted that the no-ether concept and non-Newtonian relativity are untenable, thus restoring a fluid ether which must have viscosity. Stokes' theory then becomes the first and only viable physical theory of stellar aberration to have emerged. Here a simpler solution is given to the boundary layer problem which reveals the real physical significance of stellar aberration.

The general explanation of the phaenomenon of aberration is so simple and the coincidence of the velocity of light, thence deduced, with that derived from observations of eclipses of Jupiter's satellites, so remarkable as to leave no doubt in the mind as to the truth of that explanation. But when we examine the cause of the phaenomenon more closely it is far from being so simple as it appears at first sight.

Sir George Gabriel Stokes (1819-1903)

1. Introduction

The problem of stellar aberration goes back to James Bradley (1728) who observed that a moving telescope must be inclined to an incoming ray of light so that light corpuscles may travel down the axis of the tube. It was Thomas Young (cf. Whittaker, 1953) who first tried to explain stellar aberration in terms of the wave theory of light, but he believed that the luminiferous ether pervaded all matter without resistance and that, therefore, the ether surrounding the Earth was at rest and not affected by the Earth's motion.

Stokes (1845) supposed that the Earth drags the local ether along with it so that, close to the Earth's surface, the ether moves with the Earth, whilst its velocity changes away from the Earth so that, at some distance away, it is at rest relative to the fixed stars, thus creating a boundary layer around the Earth. He solved the problem of stellar aberration by determining how a light wave is changed as it crosses this ethereal boundary layer to reach the Earth's surface. Many objections to Stokes' theory were raised (cf. Whittaker, 1953). Lorentz, for instance, maintained that the normal component of the ethereal velocity at the Earth's surface would, by itself, completely specify the irrotational motion of an *incompressible* fluid, so that the tangential component could vary and Stokes' conditions would not be satisfied. Attempts were made later to justify Stokes' conditions. Max Planck, for example, suggested that they could be satisfied if the ether were compressible and subject to gravity. Nevertheless, Stokes' theory of stellar aberration was rejected by his contemporaries and has remained unappreciated ever since.

Thornhill (2004) has consistently shown that, unless comparatively simple basic mathematics dating back to Euler and Riemann can be discredited, then it must be accepted that the no-ether concept and non-Newtonian relativity are both mathematically and physically untenable and that, therefore, the ether must be restored. A fluid ether must necessarily have viscosity and so form a viscous boundary layer around the Earth as it moves relative to the fixed stars. Across this boundary layer the relative velocity between the ether and the Earth's surface must tend to zero as the Earth's surface is approached, so accounting for the null observations of Michelson and Morley. It would seem, therefore, that Stokes' theory was the first, and so far only, viable physical theory of stellar aberration to have emerged.

Stokes did not, however, have at his disposal the equation of wave motion in a moving fluid and so he devised an incremental method of determining how the light changes in a moving ether by adding together the separate incremental changes due to radiation in a stationary ether and due to changes in the ethereal motion. He inferred that, when the ethereal motion is irrotational, the normal to a wave front gradually rotates as it approaches the Earth through its ethereal boundary layer. When the light wave reaches a terrestrial observer, where the ether is relatively at rest, the normal to the wave front has rotated through precisely the classical angle of aberration and has become the direction in which the observer sees the star.

Here, Stokes' solution is derived more simply, in the rest-frame of a moving observer, using the equation of wave-motion in a uniform fluid in steady flow. It is shown that, when the ethereal flow is irrotational and the boundary layer therefore laminar, the rays are unaltered behind a wave front as it crosses the boundary layer. The normal to a wave front, however, gradually rotates and, as Stokes found, when it reaches a terrestrial observer, it has rotated through the classical angle of aberration. The ether is then at rest relative to the observer and so the normal to the wave front is then the direction in which he sees the star. It is also found to be the direction in which the star lay when the incoming light waves set out from it. Moreover, it is shown that the incoming wave front is exactly the same, as it arrives at the Earth, as if it had travelled all the way from the star through a stationary ether. Thus the real physical significance of stellar aberration appears to be that all observers, stationary or moving, see a star where it was when the incoming light waves set out from it.

2. Wave propagation in a moving medium

In the general three-dimensional unsteady flow of a general fluid, the wave-hypersurfaces through any point, at any time, have an envelope, the local wave-hyperconoid, given by the differential equation

$$(dx-u_1dt)^2+(dy-u_2dt)^2+(dz-u_3dt)^2 = c^2(dt)^2$$

where c is the local thermodynamic wave-speed and also, in the case of a fluid ether, the local electromagnetic wave-speed (cf. Thornhill, 1985, 1993).

Thus, in general, if a light wave sets out from the origin at time t_1 in a fluid ether moving with constant velocity (u_1, u_2, u_3), the wave front at time t_2 will be the sphere of radius $c(t_2-t_1)$ about the point $[u_1 (t_2-t_1), u_2(t_2-t_1), u_3(t_2-t_1)]$.

In the three-dimensional Figure 1, a light wave sets out, at time $t=0$, from a star at the origin O which is travelling with the local ether at a velocity (u_1, o, o). Then, at time t_1, the wave front will be the sphere of radius ct_1, about the point A, (u_1t_1, o, o). P is a point on this sphere and OP is the ray from O through P.

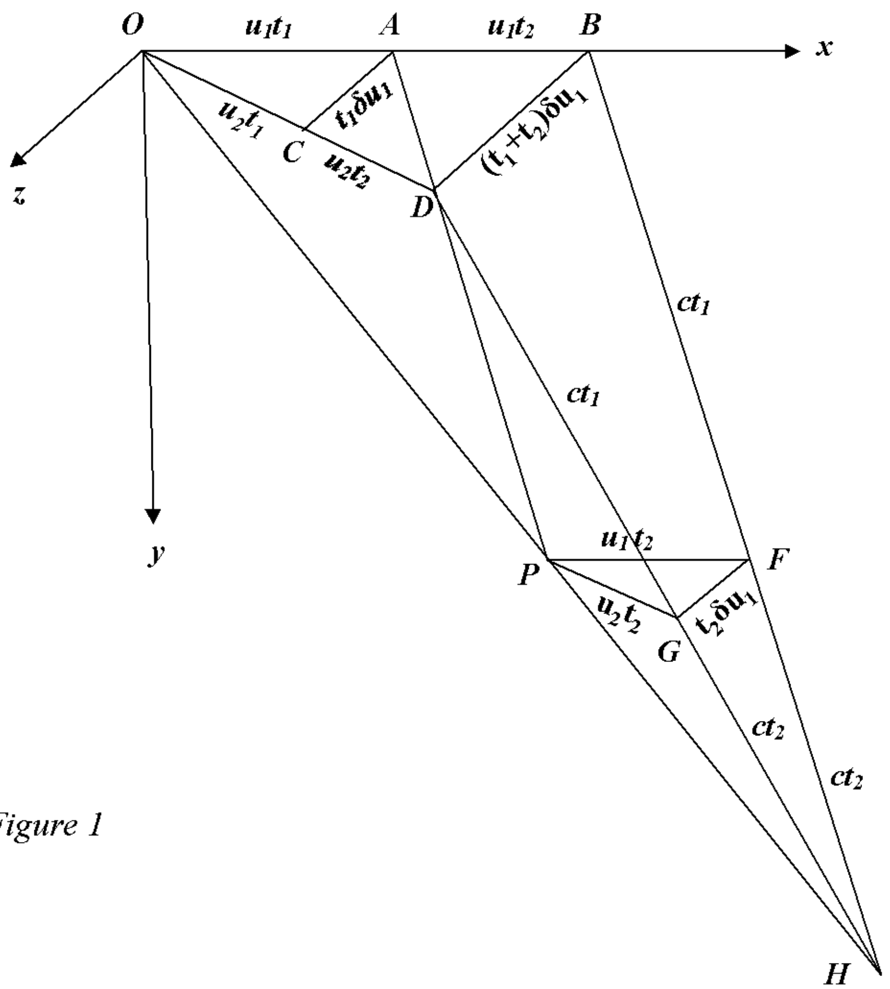

Figure 1

Suppose now that P is a point on some three-dimensional surface PQR across which there is a small incremental change in the ethereal velocity, of magnitude δu_1 in any direction, so that it now becomes u_2 in the direction PG. Then at time (t_1+t_2), the wavelet which sets out from P at time t_1 will be the sphere of radius ct_2 about the point G, where $PG = u_2t_2$. H is the point on this sphere which lies on the ray OP, so that $GH = ct_2$.

Now, if $u_1/c << 1$ and $\delta u_1/u_1 <<1$, it follows that $\delta u_1/c$ is of the second order of small quantities and so, in Figure 1, $GH = FH = ct_2$ to the first order; and then, by similar triangles, $DH = BH = c(t_1+t_2)$, where $OB = u_1(t_1+t_2)$ and $OD= u_2(t_1+t_2)$. Thus, at time (t_1+t_2) the normal at H to the wavelet from P passes through D. If Q is any other point on the surface PQR, across which the incremental change in the ethereal velocity occurs, the same result will hold for Q with times t_3 and t_4, say, instead of t_1 and t_2. When, however, $t_3+t_4 = t_1+t_2$, then the wavelet from Q will also have a normal, at some point J, which passes through D, and where $JD =c(t_1+t_2)$. It follows then that, at time (t_1+t_2), the wavelets from all points on the surface PQR will have an envelope, the sphere of radius $c(t_1+t_2)$, about the point D. Thus, since $OD = u_2(t_1+t_2)$, the wave front, at time (t_1+t_2), will be the sphere of radius $c(t_1+t_2)$ about D, just as if it had propagated all the way from O in an ether moving with speed u_2 in the direction OD. Since, also, H lies on OP, it follows that the rays from O are unaffected by the change in the ethereal velocity across the surface PQR.

3. The moving observer

The three-dimensional Figure 2 concerns an observer O who is moving with velocity $(-u, o ,o)$ relative to a fixed star S and its surrounding ether *at the precise moment of observation*. The figure, however, shows the relative positions of the star and the terrestrial observer, at precisely the time O observes the star, in the frame of reference in which the observer O is at rest and the star and its surrounding ether are moving with velocity (u, o, o). In this frame of reference the star is at S_1 at time $t = o$ and, at the moment of observation, it is at S_2, so that $S_1S_2 = ut$.

Now, the time t taken for a light wave to travel to the Earth from a fixed star is of the order of years, whereas the time taken for it finally to cross the Earth's boundary layer is, in comparison, exceedingly small, so that, practically $S_2O=ct$.

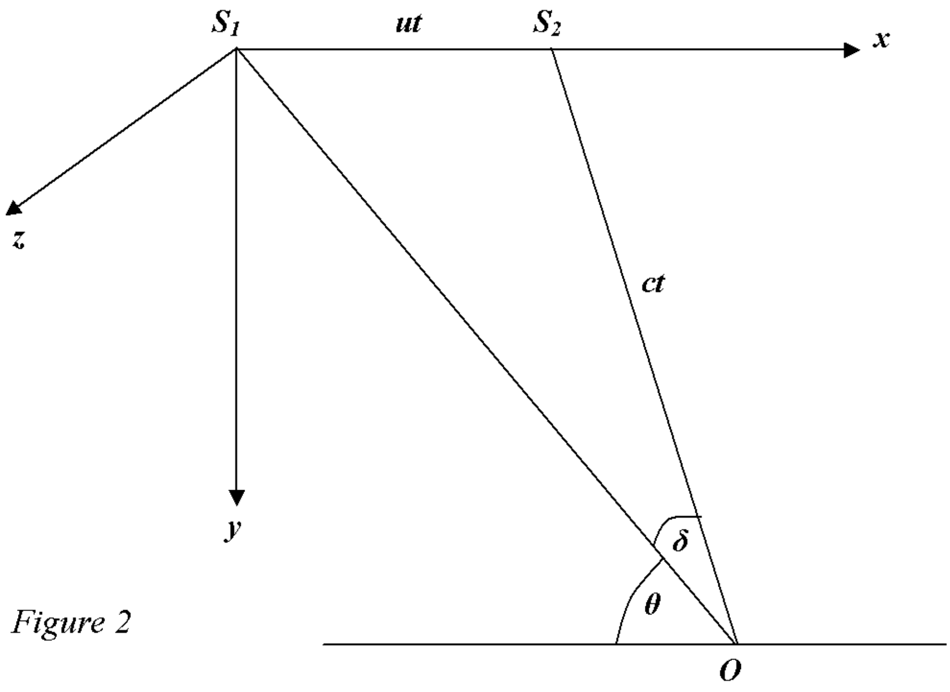

Figure 2

It is now necessary, however, to consider what happens to the wave front, which is practically the sphere of radius *ct* about S_2, as it enters and crosses the Earth's boundary layer in the close vicinity of O. If the flow in the boundary layer is irrotational, then the boundary layer will be laminar, i.e. it can be divided into laminae of incremental thickness across each of which there is an incremental decrease in the ethereal velocity. The results obtained in the previous section then show that as each laminar is crossed and the ethereal velocity is reduced, the point from which the wave will appear to have propagated will move in incremental steps from S_2 towards S_1, along a three-dimensional path. When the wave front finally arrives at O the ethereal velocity there will be zero and the wave front will be a sphere of radius S_1O about S_1 and will thus appear to the stationary observer at O to have propagated all the way from S_1 in a stationary ether. Thus, to the observer O, the star will appear to be at S_1.

The angle $S_1 OS_2$ is given by $u/\sin\delta = c/\sin\theta$ where θ is the angle of elevation of the observed start at S_1, so that δ is the classical angle of aberration.

The real physical significance of stellar aberration appears to be, then, that all observers, stationary or moving, see a star where it was when the incoming light waves set out from it.

Stokes' remarkable achievement in 1845 was thus not only to anticipate the viscous boundary layer some 60 years before Ludwig Prandtl but also to provide the only viable explanation of the phenomenon of stellar aberration some 160 years before the solution given here reveals its true significance.

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