On the Transverse Emission and Propagation of Light from Moving Sources

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In a work presented to the Royal Society more than a decade before Einstein's 1905 publication introducing his theory of special relativity, Sir Oliver Lodge offered some intriguing insights on the subject of stellar aberration. Lodge's explanation differs from the conventional analysis in special relativity theory, but now appears to have been quite right from the beginning.

Introduction

In [1], Sir Oliver Lodge offered some intriguing insights on the propagation and measurement of light in inertial systems in relative motion. Lodge's explanations remain current in many respects. On one particular point, however, his analysis conflicts head-on with corresponding explanations and diagrams in widespread use in today's literature of special relativity theory (SRT). That point is transverse propagation, which is central to the phenomenon of stellar aberration. Transverse propagation is examined in this paper. It is my intention to take a closer look at Lodge's explanations, and to compare them with corresponding arguments in SRT. I will show that Lodge's intuitions and logic are not only in conformity with the basic theoretical tenets of SRT, but that as regards transverse emission, his reasoning avoids an inconsistency of logic that has persisted in mainstream texts to this day. I will show that Lodge's version of transverse emission from a moving source has also been confirmed empirically by anisotropy experiments conducted more than a half-century after Einstein's 1905 publication of SRT. I will also show that Lodge's reasoning eliminates the SRT 'paradox' of stellar source aberration, and opens the way for new avenues of investigation into the use of light as the ultimate measuring tool.

Transverse Radiation in Galilean/Newtonian Relativity

In his 1893 paper Lodge used a diagram to show how rays of light propagate from a source in motion relative to a stationary/moving target (or telescope). The light rays in Lodge's diagram (Fig. 1), travel on a path perpendicular to the motion of the source *S*. The telescope (YZ) can be seen as either moving or stationary. Lodge's caption accurately described stellar aberration from the local observer's point of view. A photon released by a stationary source at **1** would traverse the centerline of the telescope to **Y**, whereas a moving telescope (same direction as source) would require a compensating tilt to avoid causing the photon to follow the **Z** path. Lodge extended this reasoning to include light emitted from a revolving source (which, for purposes of this discussion, will be considered an inertial source for movement over short increments of distance or time): "Hence waves emitted by a revolving source", he said, "advance just as they would if it were stationary; any peculiarity on the surface, say a Sun spot, is depicted in a precisely radial direction, and there will be no displacement of the Sun's center. So also with light from a flying star: the star will be seen in its position at time of emission, just as it is seen in the physical state corresponding to that instant, not to the instant of vision." [1]

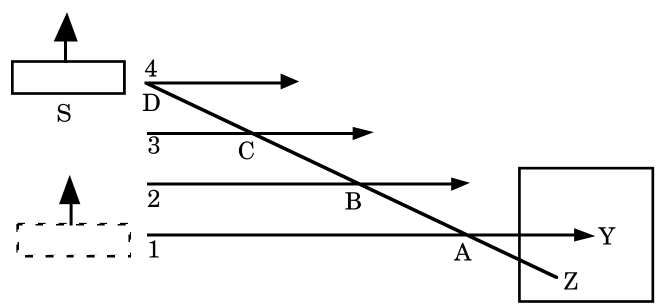

Figure 1. Reconstruction of Lodge's Figure from [1] illustrating the effect of relative motion. His caption: "Diagram of disturbances or waves emitted without momentum from a moving source; leaving target or telescope, at Y if stationary, at Z if moving. The line ABCD is the locus of successive disturbances, but is not the ray or real path. The diagram may also be taken to represent the effect of a cross stream of medium, with source stationary."

Lodge's insistence that, for both inertial and rotational sources, light must follow the orthogonal/radial path even when emitted from a moving source is in clear contrast to the way transverse emission is presented throughout today's literature of SRT. Before examining this reasoning in greater detail, then, I will briefly summarize the concept of transverse emission as it is currently presented in both popular and textbook versions of SRT.

Transverse Emission in Special Relativity

A common illustration incorporated in SRT and found in almost any modern physics text will show that what to observers at rest in the moving frame seems to be perpendicular propagation must appear as angular propagation to an external or stationary observer. Figure 2 is a simplified version of this so-called 'clock' gedanken and is based on the illustration used by A. Wheeler in [2]. In situation (a), observer X is at rest relative to the reference frame A/B; in situation (b), the same reference frame is now in motion relative to observer X. Thus, in (a) an object such as a ball or a photon of light bounces back and forth between observers A and B; in (b) the object still appears to A and B to follow the perpendicular route A/B, but to observer X it now follows the angular route A/B'.

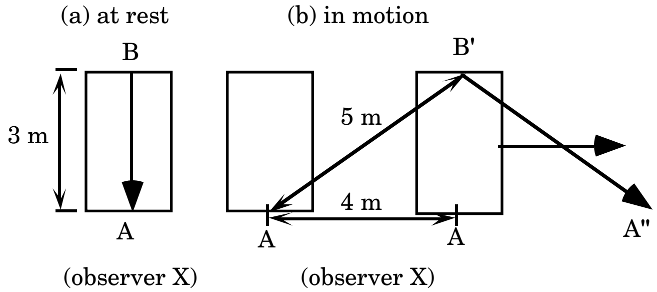

Figure 2. Simplified version of Wheeler's Figure illustrating effect of transverse motion.

Lodge and Special Relativity

In comparing Lodge's observations with illustrations such as the one in Fig. 2, it becomes clear that we have conflicting views as to what actually happens when light is emitted transversely from a moving source. However, if we take a closer look at Lodge's descriptions of transverse radiation, we find that his theory actually conforms in crucial areas to the postulates of SRT.

Momentum

In SRT, for example, the velocity of light is a constant, c, independent of source velocity. Stating Einstein's second postulate in terms of momentum, it can be argued from SRT itself that light receives no inertial or momentum contribution from a moving source. That is to say, light emitted in the same direction as the movement of the source travels at the same velocity as light emitted in the opposite direction from the same moving source, regardless of whether these velocities are measured from the reference frame of the source or from that of a stationary receiver. In the same situation, particles of any significant mass would have different velocities, depending on whether they are emitted forward or backward relative to the motion of the source. But this combining of velocities does not hold for electromagnetic propagation, and it is clear that the difference has to do with whether or not the momentum of the source has any effect on the emitted light. On this point, then, Lodge is very much in keeping with SRT when he captions his own illustration "Diagram of disturbances or waves emitted without momentum from a moving source." [1] It is clear that since Lodge is illustrating orthogonal emission, however, he means explicitly to deny that the momentum of the source could create lateral drift, as it would do with a massive particle.

If Lodge's argument is correct, it seems plausible that the roles of the observers in Fig. 2 should actually be reversed. That is, the photon of light continues on the perpendicular path as the frame moves to the right, and observers A/B now perceive it as following an angular route. In this new scenario, however, the photon appears to observers A/B to angle back toward the trailing end of the frame instead of forward with the motion of the frame. To observer X, it now remains true to the perpendicular.

The plausibility of this argument can be strengthened by reconstructing this oscillating 'clock', exercising more precise control in our descriptions of what is actually happening. For example, it would be entirely in keeping with the original experiment if we now let observer X fire a photon perpendicular to the direction of the moving frame. This photon, moreover, can cross the origin of the coordinate system of the moving frame at precisely the instant that the original photon is emitted from that same origin (point A). Now we have two photons, both leaving $x = 0$ at the same moment, both ostensibly emitted on a perpendicular to the line of travel. It is clear enough in this case that the photon fired by observer X will continue on the perpendicular; the real problem is to find any reason at all why the other photon would *not* follow precisely the same path!

A second proof or reconstruction would be to attach a laser (ideally one with ultrashort pulse capability) rigidly to point A and aimed at point B while the frame AB is at rest relative to X. We fire the laser to test its aim. It strikes point B on the opposite side of the frame, establishing the perpendicular. Now we allow the same reference frame to be put into uniform motion and to pass from left to right in front of X. The rigidly attached laser is again fired when A reaches the origin of the coordinate system. The photon (or laser burst) could only arrive at some future location of B (indicated by B') if the laser has been repositioned to aim for that future location.

Time

Another way of understanding Lodge's take on this mysterious event, the emission of radiation, is to describe it as a function of time. If the source or emitter acts on the photon (or wave front) over a finite time as it is being emitted, then it could be argued that the emission forward would have a different velocity component than the emission backward relative to the source. In other words, these two different emissions would somehow have to incorporate the idea that the source (together with the object being emitted) have moved a finite distance *during* the emission process. In terms of massive particles, it is easy to see how this happens. A slingshot fired from a moving train is ejecting an object—a shot— that already possesses velocity equal to that of the train. Over a finite time (the time taken by the taut elastic bands as they snap to relaxation) a new velocity vector is added to the shot's existing 'train' velocity. The difference, for objects of mass, shows up in different velocities according as to whether the projectile is fired with, against, or transverse to the movement of the train. In SRT, the resultant speeds must, for light, remain the same, no matter the direction of emission. One way to physically account for this peculiar non-addition of velocities is to say that the source does not act upon the emission process (or event) over a finite time. The emission of basic quanta of light should thus probably be considered instantaneous. At one moment the light does not exist (as perceptible light), and in the very next moment it does exist and is moving at the only speed that light can move — c.

Thomas G. Lang's proposed unified field theory [3] would tend to support this 'instantaneous emission' concept. Lang sees matter (at the electron /positron level) as consisting of light confined to an orbital state *even while maintaining its c velocity*. Thus, in the transition from 'electron' to 'photon' there would be no transition of speed – no 'getting up to speed'. The constant c is preserved even at the sub-atomic level.

Again, we come back to Lodge's remarkable insight into the nature of light: "No aberrational effect can be produced by any cause which does not act on a wave front for a finite time." [1] Thus, a telescope 'acts' on an incoming photon over a finite time, the time required by the photon to travel from objective to eyepiece, and therefore we experience aberration. But a star, like any other light source, emits light as discrete and instantaneous photons. It should be pointed out again that in this sense Lodge's version of the emission event is more consistent with SRT than current textbook illustrations; this is so because, in Lodge's version, light is not permitted to go through a 'start-up' process. In other words, light always travels at c. A quantum of light emitted perpendicular to the motion of the source cannot receive a lateral or angular component (and thus cause aberration) because it is not being acted on by the source over a finite period of time. To the extent that a moving source *does* act on light over time, it is simply acting on a *series* of photons emitted instantaneously but at successive intervals: successive action will create a Doppler effect proportionate to its velocity relative to observers in other frames. A similar confirmation of Lodge's insight can be found in the assumption (not exclusive to SRT) that light bouncing back and forth between front-surfaced mirrors loses no time during the reflection process (*i.e.*, absorption and re-emission process).

Distance

Finally, Lodge presented a third perspective on the emission process. He said, "Hence waves emitted by a revolving source advance just as they would if it were stationary. . . ." [1] Lodge was speaking here of rotating or non-inertial systems, but his point is valid for either case. The moving source should be considered *frozen in time* with respect to the emission of a given photon. In terms of SRT, we can again reasonably argue that one way to account for the non-addition of velocities (in parallel emissions) is to say that the emission event involves zero time, and therefore the moving source, with respect to the emission event, has simply ***not moved at all***, and therefore it doesn't matter whether the photon is emitted forward or backward. The source cannot impart momentum to light because as far as the light is concerned, the source is absolutely still. Precisely the same logic should then apply to transverse emissions.

Lodge thus gives us three overlapping perspectives on the mystery of electromagnetic emission. He describes the same event in terms of momentum, of time, and of distance. All three involve zero magnitude, and all three are consistent with accepted understanding of parallel emission. All three should probably be considered valid for transverse emissions as well.

Empirical Confirmations

Lodge's painstaking analysis of electromagnetic propagation is clearly driven by the earlier failure of the Michelson/Morley attempts to detect an ether drift. Even after Einstein's celebrated sidestepping of the null results of the Michelson/Morley experiment, and his derivation of SRT, attempts to refine our measurement capabilities and thereby detect an ether wind have continued in earnest. Einstein may have eliminated the luminiferous ether, but with every incremental advance in our ability to measure light, new experiments to test for spatial anisotropy have surfaced. Of particular significance in this quest has been the effort to go beyond the second-order constraint of the Michelson/Morley interferometer experiment.

One effort to conduct first-order measurement for anisotropy resulted from the discovery of the molecular beam maser. In the experiments of J.P. Cedarholm and C.H. Townes [4,6], a new level of precision using ammonia maser oscillators is indicated:

> "An upper limit of $^1/_{400}$ of $\frac{1}{2}v^2 / c^2$ has been set by the very careful experiments of Joos with a Michelson interferometer. However, since this term is second order in v, the upper limit given for the ether drift velocity is one-twentieth of the orbital velocity of the Earth, or 1.5 km/s. The present experiments have the advantage that the expected effect is linear in v, and also that two clocks can now be compared with much greater precision than can two distances. This experiment, involving a comparison of two maser oscillators to an accuracy of one part in 10^{12}, may perhaps represent the most precise experiment so far reported." [4]

In the Cedarholm experiments radiation from two molecular beams, flowing in parallel but opposite directions in a resonant cavity, is supposed (due to movement of the Earth through the ether at 30K/sec) to produce a beat frequency when the maser outputs are mixed. The null results of these experiments were seen by some as a severe blow to the ether theory. In reviewing the Cedarholm experiments, however, an intriguing possibility arises that these experiments inadvertently offer corroboration of the idea that orthogonal emission and propagation take place without any source-motion (or lateral) effect.

In [5] A.P. French offered these comments on the Cedarholm experiments:

> "Now if the cavity is at rest in the ether, the pulses of radiation travel exactly perpendicular to the direction of molecular motion"….If, however, the apparatus has a velocity $\mathbf{v}$, parallel to the molecular beam, through the ether, then the radiation, to stay with the cavity, as it were, must be emitted at an angle $\pi/2 - \theta$ with respect to the molecular beam ….The size of the angle θ is v / c. This same picture applies to the light emitted along the transverse arm of the Michelson interferometer, if we view things from the ether frame rather than from the laboratory." [5]

Analyzing the experimental setup, there are three or possibly four local inertial frames to consider, depending on whether or not there is an effective ether. These frames are:

1) the resonant cavity (and the Earth upon which it is at rest)
2) the NH_3 beam flowing to the right while emitting
3) the NH_3 beam flowing to the left while emitting
4) the ether itself

If the ether exists, then the Earth (and maser cavity) move through it at one velocity, and the NH_3 beams move at different velocities relative to the Earth, to the ether, and to each other, respectively . The experiment concludes that no ether wind can be detected greater than what would be consistent with an orbital velocity of just 1/1000 of Earth's known velocity. It is different from the Michelson/Morley experiment in that the apparatus and the emitter are (in Michelson/Morley) at rest relative to each other; whereas in Cedarholm, the emitter (NH_3) has significant velocity (0.6 K/sec) relative to the apparatus.

But as French points out, if the apparatus in the Cedarholm experiments is at rest relative to the ether, then the radiation is emitted perpendicular to the molecular beam. Since the experiment produced a null result, we can conclude that either the ether does not exist (in the form anticipated, I hasten to add), or that the Earth, defying all odds, is in fact at rest relative to the ether – that in effect they form one inertial frame. In *either* case, French is clearly saying that the radiation must be traveling exactly perpendicular to the flow of the molecules, and without angular drift, in order to have obtained the null result. The authors of the experiment confirm this interpretation: "The shift may be simply discussed by assuming that, if v is zero, radiation is emitted perpendicularly to the molecular velocity so that there is no Doppler shift." [6]

Thus, the two NH_3 sources flowing in parallel but opposite directions not only fail to produce a significant beat frequency, but instead produce frequencies that are identical to each other and to what would be expected from any excited NH_3 source collectively at rest relative to the laboratory or cavity frame.

In other words, it is not the motion of the source that would cause the radiation to angle off to the right or left, but rather the resistance of the ether if the Earth were speeding through it. Without this ether resistance, the frequencies of the two beams correspond to the normal spectra for excited NH_3. It is exactly as if no time transpires during the emission of a photon from a moving source: the moving source, at the moment of emission, can be considered identical to a stationary source at the same location, precisely as Sir Oliver Lodge had conceptualized the situation in his 1893 presentation.

Returning to our SRT 'clock' experiment (Fig. 2), we can compare the NH_3 beam to the moving platform, and the resonating cavity to the ground observer X. Unlike the light flash going from A to primed B on the platform, however, the radiation in the maser experiment remains orthogonal relative to the direction of the moving source. And if two inertial frames passed in front of Observer X going in opposite but parallel directions, photons emitted together at $x = 0$ would travel together on a perpendicular to the motion of the sources. They would not diverge any more than would photons emitted from binary stars and arriving in our telescope from half the Universe away.

Stellar Aberration Theory

In discussions of the Bradley (or stellar) aberration constant, a typical model will, for convenience, depict a stellar source as fixed. An Earth-based telescope tube could point directly at a star and give a true indication of position (by this is meant true position at the time the light was emitted) except for the fact that Earth moves transversely at a significant velocity (30K/sec) through the star's 'downpour' of photons. Since it takes a finite time for the photon to travel through the moving telescope tube, the tube must compensate by tilting in the direction of Earth's motion, thus causing an aberration of the star's true position. In the course of a year, this compensating tilt of the telescope describes a small ellipse in response to Earth's ever-changing direction in its orbit of the sun.

This model seems adequate to account for aberration as long as the 'fixed' source, or star, is not emitting photons with a lateral drift caused by the star's own proper motion. In other words, if emitted perpendicular to the line of motion of the star, the photon must continue on that path. If this were not true, the aberration constant would fail to yield consistent results for stars and other point sources such as far distant galaxies having varying velocity components. Such a situation would create a multitude of 'photon downpours', so to speak, with each source sending its downpour across us with a different slant. Aberration theory would have to account not only for the motion of Earth, as a constant, but also for the variables related to the particular motion of each and every source being observed. This problem of source-related aberration was addressed decades ago by Eisner who referred to it as a paradox. Eisner's reconstruction of the paradox in terms of binary star systems supports the theory that movement of the source does not create a lateral vector for the emitted light:

> Let us put it another way: consider the light rays from each of the sources that will eventually reach a given observer. These two rays pass through a given point in space in the observer's system at the sources, and through another given point at the observer. If the rays are straight, then they must coincide.
>
> Thus, the observer sees the two sources in the same direction, and so this direction does not depend on the velocity of the source relative to the observer. He sees a source of light in the direction of the point in space in his coordinate system that the source occupied when it emitted the light. Of course, the source may no longer be at that point when the light reaches the observer: it may even have disintegrated in the interval. [7]

Decades after Eisner's analysis, however, the paradox of stellar source aberration continues to plague many physicists. In a recent article devoted to the concept of detecting absolute motion, Georges Sardin still finds it necessary to sidestep the stellar aberration source paradox by invoking a 'net aberration' concept. He says, "The absence of aberration from stellar sources does not necessarily imply that light rays do not undergo aberration since if they did there would be however no net effect in view that the source is uniformly emitting light in all directions. Since light rays cannot be differentiated, the net effect is null." [8]

The 'net aberration' hypothesis has been graphically illustrated by Marmet [9], who is cited by Sardin to explain why source motion would not be a factor in the design of a device for the detection of absolute motion. Figure 3 is my own reconstruction of the illustration used by Marmet. He states, "There is no known explanation for the case when the source is moving." [9] He attempts to explain why stellar source aberration has been undetectable by using a diagram like the one shown in Fig. 3. The diagram shows the photons as having dual vector contributions to their motion (*i.e.*, an emission velocity vector and a source velocity vector). By this dynamic, the photon **ä** emitted directly toward Earth would end up on the μ line (missing Earth altogether), and the β photon would end up on the direct line between star and Earth because of the lateral component added by the star's motion. It is clear, however, that if such a combination of velocity vectors were possible, it must necessarily also apply to the two photons emitted on the parallel to the star's motion. One of these photons is emitted toward K, the other directly away from K. Thus one photon would have a $v+u$ velocity, the other a $v-u$ velocity. The result is that in the given proper time interval (represented in the diagram by the radius of the spherical wave front), the two photons would necessarily have traveled different distances from the historical point of origin, contrary to the SRT postulate for the velocity of light.

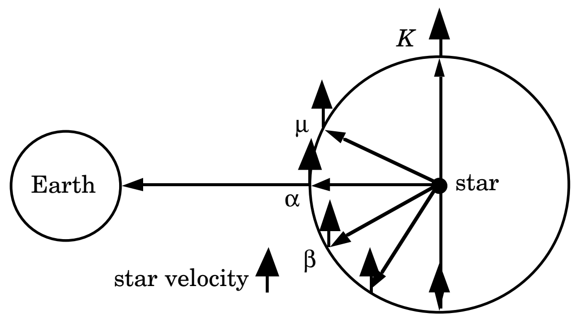

Figure 3. Reconstruction of Marmet's Figure illustrating 'net aberration'.

Conclusions

My purpose in this paper has been to establish that the SRT thought experiment underlying such basic concepts as time dilation and the relativity of motion contains a logical inconsistency. It is not my intention, here, to argue that a reconstructed 'clock' *gedanken* based on insights like those of Sir Oliver Lodge would necessarily undermine SRT. However, it does seem unavoidable that such a reconstruction at least justifies renewed efforts to detect absolute motion, somewhat along the experimental lines suggested by Professor Sardin [8]. That is to say, if a photon does remain 'true' to its direction of emission and does not 'drift' when emitted transversely to the direction of its source, then clearly it should be possible to achieve first-order measurement of one's own motion relative to that preferential frame in which light follows its own rules for velocity and direction. Sardin, for example, envisions a photo-detector [8] which is 'zoomed' outward on a straight line away from a diode laser source. As successive bursts of light are recorded, the increased distance from the laser source means that the moving frame (on Earth, for example) has had a little more time to move during the interval between firing and reception, and therefore each successive impact at the photo-detector should be slightly offset from the previous impact.

Experiments using molecular beam masers, like those of Cedarholm, have confirmed empirically that a source in motion does not 'carry' its orthogonal radiation sidewise. In addition, the physics community has in many other ways acknowledged that SRT, as traditionally presented, has been somewhat misleading. For example, Frank Wilczek of the Institute for Advanced Studies in Princeton, has cast Einstein's celebrated dismissal of the ether in a new light. In the January 1999 issue of *Physics Today*, Wilczek refers to the long discredited ether hypothesis. He says that there is "a myth, repeated in many popular presentations and textbooks, that Albert Einstein swept it into the dustbin of history." [10] He argues that the truth of the matter is more nearly the opposite—that Einstein "first purified, and then enthroned, the ether concept . . .At present, renamed and thinly disguised, it dominates the accepted laws of physics." [10]

Thus, in both the experimental and theoretical arenas, mainstream physics has already implicitly signaled a willingness to depart from strict adherence to traditional SRT. It has been my intention to capitalize on this hard-won ground. I believe that by carefully re-examining one crucial thought experiment underlying SRT theory— the so-called 'clock' *gedanken*— and by reconstructing SRT with a more precise description of transverse emission, the way is opened to some exciting possibilities for both theory and experimentation. Among the possibilities that emerge when it becomes clear that transversely emitted light is free of source-motion, I would suggest the following:

- The absence of stellar source aberration is consistent with SRT postulates and, based on well-established physics, should no longer be considered a paradox.
- The physical description for the velocity of c is uniform for all cases (*i.e.*, for all directions including transverse relative to source, whether moving or not.)
- The detection of absolute motion as suggested by Sardin appears feasible and is an experimental goal worthy of determined pursuit.
- The ether concept should be openly revisited along the lines suggested by Wilczek.

References and Notes

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