The Michelson-Morley Experiment in Ontic and Epistemic Space

by A. F. Kracklauer

Abstract

The Michelson-Morley experiment is reanalyzed from the view point of an interpretation of Special Relativity based on the supposition that the space of existence is Euclidean with absolute time, whereas the space of *perception* has the usual Minkowski structure. The final viability of this approach is supported by this analysis to the extent that the results calculated from these experiments using this view point do not lead to a fatal contradiction with empirical data.

1 Relativity, and a fundamental obscurity

As best is known, there could be only four means to observe the material world, i.e., by exploiting one of the interactions: strong, weak, gravity and electromagnetic. Obviously, so far only the last is practical and employed. This implies, that there are at least two events crucial to each and every electromagnetic interaction between observer and observed object: the one at the object when an electromagnetic signal (ray, pulse) departs, and a second one when the signal arrives at the observer. Now, clearly, observed objects exist, better said: "are located," in a 3-dimensional space of extension (plus one more for time: a complication ignored for the moment); but, an observer receives the signal with an eye equipped only with a 2-dimensional retina. Consequently, perception must be analyzed in terms of a process of geometrical projection of the "real" 3-dimensional world (or ontic space) onto a 2-dimensional retina (or epistemic space). Moreover, light signals arriving at the eye of an observer at any given instant originated at various times depending on their separation. All this is trivial nowadays.

Nevertheless, trivial though it be, with respect to coordinate systems it was not explicitly discussed in Einstein's fundamental papers on relativity, nor in virtually all text books on the subject thereafter. (Ultimately, reality invaded the matter, however, and eventually authors were forced to deal somehow or other with these aspects, but seemingly never systematically.) This has led to confusion at a deep level within the discipline of physics, one consequence of which is that the theories of relativity are the subject of endless polemics by sceptics, critics and doubters in spite of their evident success for applications of at least portions of these theories. Naturally therefore, a central question is then: is there a missing key notion, which if added to these theories would obviate this obscurity?

It is the point herein to investigate just such a proposition.[1] Whatever novelty is introduced herein is based on the observation, that the statement that all distance on the light cone vanishes, should be interpreted to mean that for an *observer* all signals arriving at his eye at any given instant are such that, he, the observer, cannot resolve them, i.e., he cannot determine how far away and when they originated but is limited to registering their incoming azimuth and elevation (and instant of arrival). Thus, the fact that such vectors on a light cone have "zero length" in Minkowski space says nothing at all about the sources of the signals, or about the nature of space between sources and observers, but expresses only the fact that these signals arrived at an observer's eye at the same instant.

Now, it is a directly derivable fact from Lie group theory, that those transformations which leave a null vector in Minkowski space invariant, are the Lorentz transformations.[1] In other words, what the Lorentz transformations do, according to this view point, is to transform these vectors such that they always pertain to signals arriving simultaneously at his observer's eye, which can, as a physical fact, be sensible only if the transformations have no physical effect at all on the source of the signals, or on the intervening space and media it might contain. Whatever change they describe must pertain exclusively to the geometry induced by of the process of receiving these signals — eventual modifications, therefore, will be the result of motion of the observer's eye through the point of perception at the instant of arrival of these signals, all of which may be captured by saying that Lorentz transformations describe the totality of Bradley aberration and Doppler shifts. These two effects obviously do not arise from any modifications of sources of signals.

1. The structure has been developed in purely mathematical terms, where, however, its relevance only for the observer was unrecognized.[2, 3]

The advantage offered by this interpretation is, that then those Lorentz effects which are considered nowadays as preternatural: Lorentz-Fitzgerald contraction and time dilation, are also just "optical" effects "in the eye of the beholder." They arise then strictly as a consequence of the geometrical consequences of projecting the "ontic world" using light rays onto the retina or "epistemic world" of an observer. The natural question here is, then, what is the innate geometrical nature of the "real world" before it is subjected to aberration by projection? To this question, we submit, that the logic of the situation seems to say that it is just what prerelativistic kinematics and mechanics induced one to believe it to be, namely the Cartesian product of a Euclidean 3-space of extension with a 1-dimensional space of absolute time. The nowadays favored view consisting of a melding of these two into space-time, and the coincidental complexification of simultaneity[2], on the other hand, seem to be features of the induced hyperbolic space "in the eye of the beholder." It is the process of projection by means of light rays that generates Minkowski space, but then not as an "ontic" space, but as the "epistemic" space in the observer's eye. This imaginary "Minkowski" world, in turn, in the brain of an observer is mapped or "deprojected" onto the ontic world automatically to enable this observer to accurately interact with it. Perhaps, since this whole process transpires unconsciously, it it taken for granted and overlooked in analysis of physical-mechanical processes.

At this moment in history, a revision of a fundamental physics theory can be seen as intemperate speculation. Nevertheless, until such a proposal can be rejected on the basis that it leads to conflicts with empirical facts, it deserves consideration. In that spirit this writer has undertaken to formulate, on the basis of this hypothetical paradigm, the reanalysis of the foundation experiments supporting relativity. In the following, the Michelson-Morley experiment shall be analyzed. It will be shown that a calculated displacement of the fringe pattern expected for this experiment on the basis of this view point is such, while novel in details, does not require that the view point espoused herein be rejected.

2 Geometry of the Michelson-Morley experiment in absolute space and time

The basic conception of 3-dimensional extension space is founded on the observation that events, i.e., a location $\otimes$ time, can be taken as absolute. That is, a position in 3-space in the sense of "coordinate free" mathematics is unique in so far as a location is at a specific somewhere and nowhere else; i.e., while it can be parametrized in terms of an infinite number of coordinate origins and axes orientations, in fact the physical point is always the same. As a consequence of the fact that for raw events no metrical relationship is presumed between space and time, time too is in the same sense, "absolute" (absolute means that no matter what it influence it exercises, it is itself uninfluenced). The nature of light rays, ultimately for service as projection rays, is brought to this structure now with the assumption that every event, i.e., point in 3-space at an instant, can be taken as a source for a Green's function pulse (i.e., a Dirac delta source) resulting in a spherical shell or shock wave pulse propagating away from it at the speed of light. Clearly, in this formulation, two events are "simultaneous" if their spherical Green's shock wave shells are equal in size. In summary, we see this this imagery as the realization of the otherwise well known assertion regarding the universal constancy of the speed of light; it is an alternate formulation of this principle, which, hopefully, will turn out to be equivalent in effect but more intuitively comprehensible.

Given the above, the analysis of a particular experiment is carried out in part by computation of the optical path length from source events through the optical chain to the detector. At the detector, alternate optical routes are compared and converted to differences which are manifest by shifts of interference patterns. In addition, the geometry of perception, as encoded in the Lorentz transformations, is to be taken into account at at each optical element (mirror, detector, etc.) to determine the aberration and Doppler shift occurring there.

2. In any case, even in orthodox relativity theory a more specific differentiation should be made between "time dilation" and "clock retardation." Obviously, pendulums swing slower on a mountain top, but this has nothing to do with time *per se*.

Fig. 1 shows a schematic of the optical paths for both the case when the apparatus is at rest and in motion.

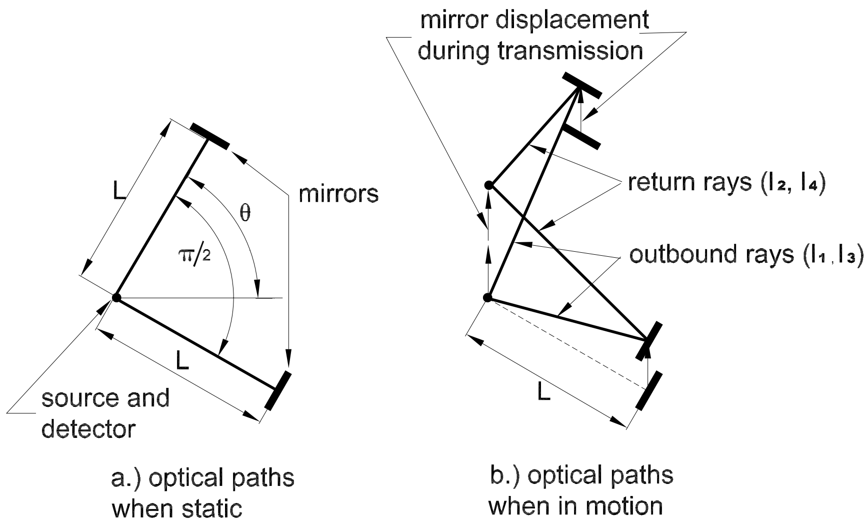

Figure 1. The geometry of the setup of the Michelson-Morley experiment. Subfig. a. depicts the geometry of the two arms, each of length L at rest and oriented, arbitrarily, at an angle of θ to the projection of the velocity vector of the laboratory onto the plane of the experiment. In this circumstance, the two paths are equal and given no shift in the interference pattern. Subfig. b. depicts the same setup when the whole apparatus is moving with velocity v in the vertical direction. The result of this motion is, that, during the time the ray propagates from the source, the mirrors move up by an amount vt, but such that the optical path from source to mirror satisfies the equation $l = ct$. Likewise, the reflected ray encounters the detector at a position with approximately twice the displacement of the mirror. The true path length must be determined self consistently again so as to satisfy the equation $l' = ct$. Clearly, the optical path lengths are equal and symmetric only when the angle $\theta = \pi/4$; in all other cases there must be a fringe shift.

From the geometry on Subfig. 1b, it can be seen that the path length for the outbound ray on the upper leg of the apparatus in motion must satisfy the Pythagorean equation:

$$l_1 = \sqrt{(L\cos(\theta))^2 + (L\sin(\theta) + vt)^2}, \tag{1}$$

where l_1 denotes the path length of the outbound ray. The term "vt" can be replaced by $v\,l_1/c$, to get:

$$l_1 = \sqrt{(L\cos(\theta))^2 + (L\sin(\theta) + vl_1/c)^2}. \tag{2}$$

Likewise, for the return ray, the path length must satisfy:

$$l_2 = \sqrt{(L\cos(\theta))^2 + (L\sin(\theta) - vl_2/c)^2}, \tag{3}$$

where the second term is formulated to take into account both the displacement of the mirror to a new source-like position and then the additional displacement of the detector. Upon careful examination, one can see that the return ray's path is just a parallel displacement to the path that the outbound ray would have taken were the displacement velocity in the opposite direction, hence to get the total path length equation, it is sufficient to change the sign of the velocity term.

With analogous reasoning, the equations for the orthogonal or lower leg in Fig. 1 are found to be:

$$\begin{aligned} l_3 &= \sqrt{(L\cos(\theta-\pi/2))^2 + (L\cos(\theta-\pi/2) - v\,l_3/c)^2}, \\ l_4 &= \sqrt{(L\cos(\theta-\pi/2))^2 + (L\sin(\theta-\pi/2) + vl_4/c)^2}. \end{aligned} \tag{4}$$

From these individual path length expressions, the total difference giving the interference displacement is:

$$\Delta(\theta, v, L) = (l_1 + l_2) - (l_3 + l_4). \tag{5}$$

3 Analysis of a Michelson-Morley experiment

Nowadays it is taken that the velocity of the Earth, the location of any laboratory in which a Michelson-Morley experiment is carried out, is moving on the order of 365 kilometers meters per second with respect to the cosmic microwave background (CMB). In addition there are smaller contributions due to rotation of the earth and orbital motion about the sun. Here a recent repeat of the Michelson-Morley experiment by Munera shall be used as illustration.[4, 5] In that experiment, the individual legs were 2.044 meters long, and the signal had a wave length of 5320 Å. To secure stability, the table was immobile, and so not rotated, but allowed to move with the Earth, effectively rotating once a day.

To compute the self consistent solutions for the outbound and inbound legs when the apparatus is in motion, we use Maxima to do the calculation numerically and avoid making any approximations intended to give tractable expressions.

```
(%i1) fpprec:32$ L:2.044$ c:3*10^8$
(%i4) l[1](theta,v):=(find_root(l1^2 - (L*cos(theta))^2 + (L*sin(theta)
      + v*l[1](theta,v)/c)^2)^(1/2),l1,.8*L,1.2*L);
      l[2](theta,v):=(find_root(l2^2 - (L*cos(theta))^2 + (L*sin(theta)
      - v*l[2](theta,v)/c)^2)^(1/2),l2,.8*L,1.2*L);
      l[3](theta,v):=(find_root(l3^2 - (L*cos(theta - %pi/2))^2 + (L*sin(theta - %pi/2)
      - v*l[3](theta,v)/c)^2)^(1/2),l3,.8*L,1.2*L);
      l[4](theta,v):=(find_root(l4^2 - (L*cos(theta - %pi/2))^2 + (L*sin(theta - %pi/2)
      - v*l[4](theta,v)/c)^2)^(1/2),l4,.8*L,1.2*L);
      delta(theta,v):=(l[1](theta,v) + l[2](theta,v)
      - l[3](theta,v) - l[4](theta,v))/(lambda/2)
```

(%o4) $$l_1(\vartheta,v) := \left(\mathrm{find\_root}\left(l1^2 - (L\cos(\vartheta))^2 + \left(L\sin(\vartheta) + \frac{v\, l_1(\vartheta,v)}{c}\right)^2\right)^{\frac{1}{2}}, l1, 0.8\,L, 1.2\,L\right)$$

(%o5) $$l_2(\vartheta,v) := \left(\mathrm{find\_root}\left(l2^2 - (L\cos(\vartheta))^2 + \left(L\sin(\vartheta) - \frac{v\, l_2(\vartheta,v)}{c}\right)^2\right)^{\frac{1}{2}}, l2, 0.8\,L, 1.2\,L\right)$$

(%o6) $$l_3(\vartheta,v) := \left(\mathrm{find\_root}\left(l3^2 - \left(L\cos\left(\vartheta - \frac{\pi}{2}\right)\right)^2 + \left(L\sin\left(\vartheta - \frac{\pi}{2}\right) - \frac{v\, l_3(\vartheta,v)}{c}\right)^2\right)^{\frac{1}{2}}, l3, 0.8\,L, 1.2\,L\right)$$

(%o7) $$l_4(\vartheta,v) := \left(\mathrm{find\_root}\left(l4^2 - \left(L\cos\left(\vartheta - \frac{\pi}{2}\right)\right)^2 + \left(L\sin\left(\vartheta - \frac{\pi}{2}\right) - \frac{v\, l_4(\vartheta,v)}{c}\right)^2\right)^{\frac{1}{2}}, l4, 0.8\,L, 1.2\,L\right)$$

(%o8) $$\delta(\vartheta,v) := \frac{l_1(\vartheta,v) + l_2(\vartheta,v) - l_3(\vartheta,v) - l_4(\vartheta,v)}{\frac{\lambda}{2}}$$

Here $\delta = \Delta/(\lambda/2)$ is the number of fringe shifts, given a signal with wave length λ.

The results of these calculations are presented in the following figures. Fig. 2 shows the variation of the number of fringe shifts as the whole apparatus is rotated from perfect alignment along the velocity vector of the laboratory with respect to the absolute 3-dimension position space. For immediate purposes it was taken that the absolute space frame is identified as the frame in which the cosmic microwave background is isotropic. Indications are the the Earth is moving through this background with a velocity of about 365 kilometers per second. Further, to take account of the possibility that both the orbital motion of the earth about the sun and the rotation of the earth about its axis is parallel with this velocity, a total velocity of 400 kilometer per sec. was assumed.

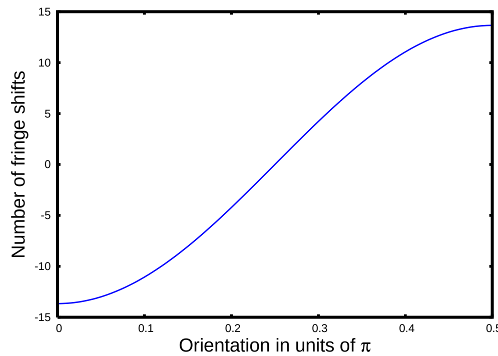

Figure 2.

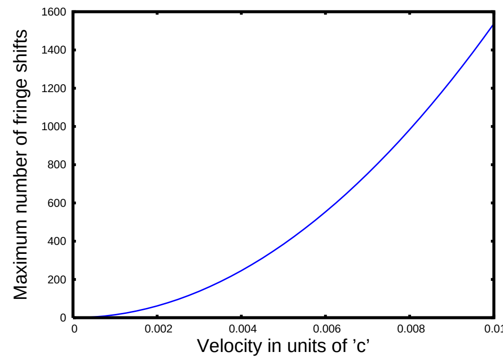

Figure 3.

Figure 2. shows that in the extreme case in which a rotation of $\pi/2$ exchanges the arms parallel to the velocity of the apparatus with respect to the absolute frame of location, the number of fringe shifts would be about 28.

Figure 3. presents the variation of the maximum number of fringes to be expected for various velocities with respect to the absolute frame.

4 Geometrical factors

In realistic experiments, the number of maximum fringe shifts would be reached only when the experiment is so aligned that the velocity of the laboratory with respect to the absolute space frame lies in the plane of the experiment. Further, rotation is typically done very slowly in order not to introduce vibration etc. destroying the fringe pattern, and this can have the effect of variably damaging alignment with the velocity. To get reasonable estimates of the number of fringe shifts to expect, according to the paradigm proposed herein, it is necessary to take these factors into account, which requires precise knowledge of the universal ephemerides of the laboratory at the time of the experiment.

Here we assume that the absolute space frame is that in which the Cosmic Microwave Background (CMB) is isotropic. It has been determined that the solar system is effectively in motion with a velocity of about 365 kilometers per second in a direction with galactic ecliptic coordinates of (260, 60). This is the velocity of the solar system taking into account that the galactic center has a velocity of about 600 km/sec but that the solar system's galactic rotation velocity of about 250 km/sec is opposed, giving a net velocity of the solar system of about 380 km/sec.

The most important feature of the geometrical orientation of the solar velocity with respect to the CMB is its declination, which effectively orients its direction so that rotations about an axis on an Earth-radius emerging close to the equator of the Earth do not exchange alignment of the arms of a Michelson-Morley experiment; the velocity of the earth through the CMB, and therefore through the absolute space frame, does not lie in the plane of the experiment.

A crude formula for calculating the projection of the absolute velocity onto the plane of the experiment is:

$$v_{\text{eff.}} = 380\sin((2\pi/360)\times(50^\circ + 23^\circ\sin(2\pi\,\text{days}/365))\times\sin((2\pi/360)\times\text{latitude}\,^\circ). \tag{6}$$

This formula takes the declination of solar ecliptic with respect to the galactic ecliptic (50°), then the declination of the earth with respect to its ecliptic, (23°) and finally the latitude of the laboratory into account. The consequences of this estimate for the projection of the absolute velocity onto the plane of the experiment on the surface of the earth for both the experiments done by Munera and Michelson-Morley are presented in Fig. 4. Then, Fig. 5 shows the expected number of phase shifts.

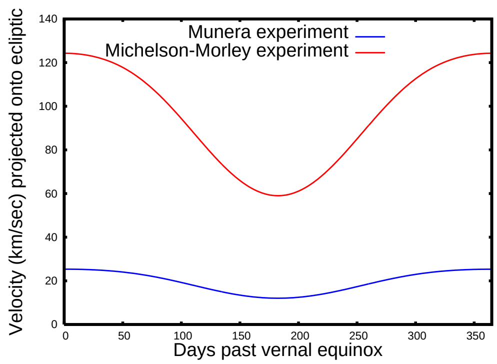

Figure 4.

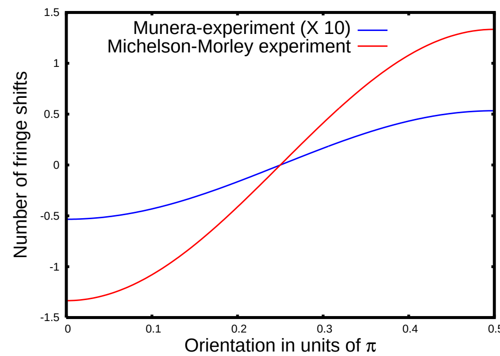

Figure 5.

The relatively small number of fringe shifts seems to accord well with the data taken in these experiments. The accuracy of these calculations is restricted by the fact that, in order to stabilize the experimental apparatus, rotations were executed slowly. In turn, this means that in the course of taking measurements the orientation of the plane of the experiments changed, which must be known accurately for precise calculations of the expected number of fringe shifts. This information is unavailable.

From this observations, nevertheless, it can be concluded that historically taken data in these experiments does not render the proposed paradigm unlikely.

5 Comments and analysis

According to the view point taken herein, objects "exist" in an absolute 3-dimensional space and age with respect to an absolute time scale. An observer of "objects" does not see these facts directly, rather they are projected onto his retina by light rays originating in these absolute spaces, but terminating on his 2-dimensional retina after a time sufficient for the ray to propagate from its absolute position to the absolute position of the observer's retina. Clearly, if two rays lying on a radius from the observer's eye are such that a pulse from a distant source and one from a closer source arrive together, then the observer cannot resolve them; it can be taken that for him the modulus of their vector difference is zero.

This is a statement about the physical state of the two signals arriving at the observer, but it does not pertain to the sources. Indeed, for other observers these same two events are not on their light cones. Because the signals were emitted at an earlier time, the principle of causality forecloses any possibility that the observer can somehow alter the situation; there is no action he can take after emission at the point of reception to resolve the signals. Nevertheless, it is likewise a known physical fact that motion of an observer induces *perceived* alterations of incoming signals, i.e., aberration and Doppler shifts. The effect then of instantaneous motion through the point of observation must conform to the requirement of preserving the null length of those vectors on the light cone centered at the point of observation. The transformations known to leave the light cone invariant are the Lorentz transformations. Thus, the Minkowski space structure is that which describes the *perceived* signals at the observer's eye, not the ontological facts pertaining to the sources. It can be said, that it describes space-time perspective as induced by observing with light.

The advantage of this view-point, if it can be maintained for all relativistic situations, would be that it offers a straight forward resolution of the perplexities afflicting Special Relativity in connection with Lorentz-Fitzgerald contraction and time dilation. These effects pertain to the *perceived* signal, not the source. At the same time, these effects are not physiological effects for an observer, they are rather geometrical consequences of interaction by means of light, and, as such, also affect passive material optical elements modifying light signals, for example mirrors and prisms.

Above the Michelson-Morley experimental setup was analyzed from this view point, but only to the extent of computing the phase shift as a consequence of alterations of the optical path length variation resulting from motion of the apparatus. No account was taken of aberration or Doppler shift at the mirrors or detector. These latter effects should produce changes in frequency, so that modulation of the interference pattern should appear. However, the size of this effect is certainly beyond the experimental limits at this time.

Clearly, the effect of latitude of the laboratory on the quantity of the fringe shifts seems to imply that locating the laboratory nearer to a pole would render the effect more visible. Were this to be observed, it would enhance the likelihood that the paradigm discussed herein is viable.

The central theme of this paper is *not* a criticism of Special Relativity, rather an endorsement of a particular, but nowadays uncommon, interpretation of it. The full structure of Minkowski space is retained, but restricted to the space of events comprising the receptions of light rays effectively projecting the Euclidean 3-space with absolute time of ontic significance onto the Minkowski space-time of epistemological significance. The advantage won is a simple resolution of many paradoxical claims (often essentially empirically unsubstantiated anyway) and antinomies

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