Universal Invariance: A Novel View of Relativistic Physics

T. E. Phipps, Jr.
908 S. Busey Avenue
Urbana, IL 61801
Email: tephipps@sbcglobal.net

A test theory is described for special relativity theory, based on universal invariance rather than universal covariance. A feature of the theory is its use of "collective time," similar to that told by GPS clocks, from which all environmental effects are compensated out. A second-order crucial experiment employing the VLBI system is proposed, involving the precise measurement of stellar aberration.

Keywords: Invariance, collective time, GPS timekeeping, stellar aberration, VLBI system.

1. Introduction

Special relativity theory (SRT) relies upon two types of form preservation, *invariance* (as of proper time and proper space intervals) and *covariance* (as of electromagnetic field quantities). Since both types are considered to apply to observable quantities under physical inertial transformations, questions naturally arise as to which type is more fundamental and whether an alternative theory could exist employing only one. That is, are both necessary to physical theory or is one dispensable? In this paper I shall present the case for indispensability of invariance and dispensability of covariance. Although the resulting alternative physical theory agrees with established SRT in most of its predictions, certain differences will emerge that entitle it to compete as a "test theory."

Invariance, the preservation of mathematical form without redefinition of symbols, has a long and honorable history in both physics and mathematics. Little need be said about it. Covariance, the more relaxed preservation of form *with allowed redefinition of symbols* (*e.g.*, via linear combinations of symbols), is of more recent origin. Probing the history, we find in physics (or mathematics) no instance of covariance prior to the advent of Maxwell's equations describing the electromagnetic field. It was their failure of Galilean invariance that encouraged the relaxation. Maxwell's equations are especially noteworthy for two formal features, (1) their covariance under Lorentz transformations, (2) their exclusive use of partial derivatives for both space and time variables. The latter mathematical feature leads to the physical inference of *spacetime symmetry*. Since covariance holds under the Lorentz transformation rather than the Galilean transformation, this led historically to the abandonment – without further evidence – of the latter for the description of physical inertial transformations.

It is generally supposed that no invariant description of the electromagnetic field exists. However, Heinrich Hertz in his book [1] *Electric Waves* (last chapter) exhibited a Galilean-invariant form of Maxwell's equations. He achieved this through an altered treatment of the time variable, asymmetrical with space variables, so that spacetime symmetry was broken. His trick was to replace the partial time derivative, $\partial / \partial t$, wherever it appeared in Maxwell's equations, with a total time derivative,

$$\frac{\mathrm{d}}{\mathrm{d}t} = \frac{\partial}{\partial t} + \left(\mathbf{v}_d \cdot \nabla\right), \tag{1}$$

where $\mathbf{v}_d$ is a new velocity-dimensioned parameter requiring physical interpretation. Hertz unfortunately chose an ether interpretation, which subsequently led to disagreement with observation [2] and to immediate discrediting of his formalism. Thus the basis was established for today's widely-held (but mistaken) conviction that only covariance can serve the mathematical purpose of describing electromagnetic phenomena.

It is readily shown [3] that a better interpretation of Hertz's velocity parameter $\mathbf{v}_d$ – providing an improved operational definition appropriate to field theory – is *velocity of the field detector* relative to the observer's inertial frame (or field point fixed in it). Here the field detector is conceived as a localized object possessed of a classical trajectory, thus suited to idealization as a Newtonian point mass or point charge that passes at velocity $\mathbf{v}_d$ through the field point at the instant of detection or "measurement." [As is immediately apparent from Eq. (1), Maxwell's is a *covered theory* corresponding to $\mathbf{v}_d = 0$, the special case in which the field detector is stationary at the field point.] This alternative interpretation of $\mathbf{v}_d$ is not in conflict with observation, as it predicts none of the counterfactual magnetic effects associated with moving dielectrics that followed from the ether interpretation [2]. The injection into the field equations of a parameter *descriptive of sink velocity* – a parameter $\mathbf{v}_d$ recognizable physically as the same as the "$\mathbf{v}$" featured in the Lorentz force law (there designated "test charge" velocity) – may be expected to eliminate the need for a separate Lorentz force postulate. Indeed, this is readily shown [3] to be the case, with resulting postulational simplification of field theory. (See Appendix A.) The upshot is that *only* the field equations need be postulated, the Lorentz force law being a deduced consequence. Although spacetime symmetry is thus sacrificed by substituting invariance for covariance, the compensating reward is a streamlining of field theory at the postulational level.

At first glance it appears a fatal objection that the "discredited" Galilean transformation (GT) is restored as the descriptor of physical inertial motion – since "everyone knows" that the Lorentz transformation (LT) is the proper descriptor. But on rare occasions what everyone knows is precisely what is impeding progress. Let us look into this. The choice of the LT as descriptor of inertial motion was a forced move, once the path of covariance had been chosen. Theorists accepted it without question, and there was no rush of experimentalists into their laboratories to test it. (All experiments proving spatial isotropy have been billed as proofs of the LT. They are, of course, equally proofs of the GT.) The LT in its simplest form asserts that

$$x' = \frac{x - vt}{\sqrt{1 - (v/c)^2}}, \tag{2a}$$

$$y' = y, \quad z' = z, \tag{2b,c}$$

$$t' = \frac{t - vx/c^2}{\sqrt{1 - (v/c)^2}}. \tag{2d}$$

Consider (2d) at first order in $\beta = v/c$. First-order considerations being physically dominant, it is always essential to get the first-order physics right. At that order (2d) reduces to

$$t' = t - \beta x / c, \tag{2e}$$

whereas the GT asserts that $t' = t$. There is thus a strong qualitative difference – and a failure of the LT to reduce to the GT, so that covariant theories are *not* covering theories of classical (invariant) Newtonian or Galilean ones. The paths of invariance and covariance diverge at the earliest possible moment.

The first-order LT-GT time transformation discrepancy $\beta x/c$ affects the running rates of clocks throughout space, hence the phases of all observable oscillatory phenomena, such as electromagnetic waves. It should seemingly affect astronomical observations [3] at large *x*, as the earth changes its inertial system (β-value) on an annual basis. No such periodic phase variations (or accompanying frequency variations) have been reported. The observations appear consistent with $t' = t$ for all *x*. The topic is never addressed in textbooks.

The rejection or "breaking" of spacetime symmetry inherent in the substitution of invariance for covariance demands a total reappraisal of the mensuration properties of space. No longer can it be automatically assumed, as demanded by the LT, that a Lorentz contraction of extended structures occurs physically (or an "appearance" of such). Once spacetime symmetry is broken, the numerous "experimental proofs" of the Lorentz contraction (such as Michelson-Morley) are nullified (see [3]). We shall hence exploit here the simplest option, to postulate *length* as a physical invariant,

$$\mathrm{d}r^2 = \mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2 = \text{invariant}, \tag{3}$$

and identify $\mathrm{d}\mathbf{r}$ as the spacelike interval between two events. Empirically, it is one of the minor embarrassments of SRT that all experimental attempts to verify the Lorentz contraction *by direct measurement* have failed. More generally, there is no empirical support for the claimed invariance of the spacelike interval $\mathrm{d}\sigma = ic\mathrm{d}\tau$. All empirical evidence for the special theory confirms only the invariance of

$$\mathrm{d}\tau^2 = \mathrm{d}t^2 - \mathrm{d}r^2/c^2 = \text{invariant} \tag{4a}$$

or

$$\mathrm{d}\tau = \mathrm{d}t\sqrt{1-(v/c)^2} = \text{invariant}\,, \tag{4b}$$

the timelike interval between two events on a particle trajectory. Here t is the "frame time" of an inertial frame and τ is the (invariant) proper time of a particle moving in that frame. If r in (4a) refers to the position of the field detector, then v in (4b) is the magnitude of $\mathbf{v}_d$ in (1). Invariance, reflecting the objective existence of something "out there" in nature, implies the possibility of operational definitions, meaning the existence of suitable measuring instruments (pocket watch of the co-moving observer for $\mathrm{d}\tau$, meter stick for dr). There exist no such instruments capable of measuring $\mathrm{d}\sigma$. The abundance of experiments confirming $\mathrm{d}\tau$ invariance hides the paucity of evidence for $\mathrm{d}\sigma$ invariance. This is another well-kept secret not to be found in textbooks.

With this introduction, we can move on to a reappraisal of one of Einstein's most influential epiphanies – concerning the nature of time.

2. Two Views of "Time"

Einstein rejected the conception of time as an idealized abstraction (the Newtonian approach) and insisted that time was what clocks measured when left to run naturally. It was his remarkable discovery that such natural clock-running – the measure of "proper time" – was invariant in the sense that all observers would agree on it, but was affected by environmental changes. Specifically, clock rate, hence proper time, was not invariant under changes of gravity potential or state of motion. The rapidly moving clock was slowed, as was the clock more deeply immersed in a gravity field. Einstein discovered the specific laws of slowing, so these effects could be quantified. They have been amply verified empirically. The motion effect, to which attention is confined here, is quantified by Eq. (4b).

Einstein's approach appears to embody the essence of operationalism or instrumentalism, in that emphasis on what a clock reads ("measures") seems to equate to a healthy eradication of metaphysics. "Time" is made concrete. What could accord better with the spirit that banished from physics the intangible ether? Unfortunately, things are not quite that simple. If we are to trust instruments, we must make sure of their trustworthiness. Classical thermodynamics became a quantitative science precisely because we did not trust the readings of thermometers, but insisted – whenever we discovered an environmental effect that affected their readings – on *correcting out* that environmental effect, so that "temperature" became an idealized abstraction rather loosely related to the actual readings of thermometers. Thus only compensated thermometers, not "naturally running" ones, proved useful in the classical science of heat and work. I emphasize that by this rival approach *all* environmental effects are to be compensated, without exception; if a new one were to be discovered in the laboratory tomorrow, it would not be seen as revealing the hidden physics of "temperature," but would be compensated out. Does this mean thermodynamics contains elements of metaphysics? By the Einstein philosophy the answer must be *yes*.

Actually, that philosophy is nowhere consistently applied. In the case of clocks, selected environmental effects, such as magnetic fields, friction, etc., are compensated out. They are not considered to affect time's flow-rate, nor to afford any insight into the physics or philosophy of "time." But we are eclectic. Motion and gravity are accorded special status. We know the correction laws for them, but do not apply the corrections. Why is this? What meat have these elected effects fed on, that they define *time*, the very fabric of the universe?

And if they do, how do we know it? We behave as if we know it, so we must know it.

In fact we do not know it, because what is involved is arbitrary choices on our part – choices of what to compensate about clock-running and what not to compensate. When such choices go unchallenged, as has been the case historically, they are not backed by any knowledge at all – since knowledge can come only from a patient study of alternatives. Suppose, then, that we apply the policy that gave us classical thermodynamics and compensate out *all* environmental effects on clock rate. This is easily done because we know the laws of nature required for the compensations. What is the result? In a word, the result is the Global Positioning System (GPS).

Yes, that's right. The foregoing has already been done, long since – and by engineers at that! In the GPS both gravity and motion effects on atomic clocks located in earth satellites, as well as other environmental effects, are compensated to remove them entirely, so that all clocks of the system, however and wherever moving, run at exactly the same rate. This rate is different from the clocks' proper-time rates, which vary with their individual states of motion and locations in the earth's gravity field. How can such a thing be? It will help to digress briefly into the mathematical subject of differentials.

Differentials are exact or inexact. It happens that in Eq. (4b) the frame-time differential dt is exact, whereas the proper-time differential $\mathrm{d}\tau$ is inexact. Thus

$$\mathrm{d}t = \frac{\mathrm{d}\tau}{\sqrt{1-\left(v/c\right)^2}} = \gamma\,\mathrm{d}\tau = \text{exact} \tag{5}$$

will be recognized as a Pfaffian form [4], wherein the factor γ serves as an "integrating factor" to render $\mathrm{d}t$ exact. Exact differentials have vitally important advantages. Not only do they define quantities suited to serve as geometrical "coordinates," but they foster integrability, hence collective descriptions, as of the many-body problem. In contrast, imagine trying to describe GPS kinematics in terms of the mutually-inconsistent, non-integrable proper times of the uncompensated individual satellite clocks. The GPS motional compensations amount to applying the integrating factor γ appropriate to each individual clock, so as to bring them all into step together. Equally well-known corrections for changes of gravity are introduced, but (for simplicity) will not be considered here.

Specifically, how are the integrating factors γ applied in the GPS? The "natural running" of the clocks is not tampered with. Instead, the number of natural atomic oscillations *counted* as defining a "second" of time is altered (reduced) by the factor $\gamma > 1$ while the clock is still on the ground. In anticipation of objective physical clock-slowing due to motion in orbit, the clock is thus compensated before launch to run correspondingly *fast* (*i.e.*, to measure an increased number of "seconds" between any two events). This means it ceases to be an Einstein clock. If it were used to measure light speed in the earthly laboratory, it would measure not *c*, but c/γ. Such clocks cannot be called "clocks" – they do not exist – in the Einstein-Minkowski *world*, wherein all "clocks" by postulate measure light-speed *c* exactly (per Maxwell's equations) in all circumstances. When placed in orbit the fast-running (compensated) clock ceases to run fast. Its atomic oscillations are physically slowed due to the imparted motion, and it must consequently run (measure seconds) at the same rate as its mate at rest on earth. This agrees with GPS observations and shows that clock-slowing due to motion in orbit is an objective fact, not an "appearance." Such slowing applies alike to compensated GPS time and to uncompensated proper time (since the two differ only in the defined number of oscillations per "second" of the same cloud of atoms). Note that the resulting objective physical *asymmetry* of proper-time running rates of clocks in relative motion (due to the objective slowing of the atomic oscillations produced by the orbital motion) disagrees with the mathematical *symmetry* attributed to clock rates by the Lorentz transformation. The physicists' claim that GPS evidence confirms SRT is typical public relations hype of people constitutionally incapable of doubting their own premises, hence of perceiving anything whatever as disconfirming those premises. The public is currently subjected to the same thing by *climate scientists* in respect to "global warming."

Oddly enough, the GPS approach to timekeeping – based on compensating all environmental effects so that all clocks of an arbitrarily-moving swarm run always exactly in step, regardless of individual motions, locations, or environmental conditions – brings us full-circle back to essentially the Newtonian idealized (or Platonic) notion of "time." In this scheme there may be considered to be a Master Clock at rest in an inertial system, in a zero or constant gravity field, corresponding in the GPS either to an actual clock at rest on the earth's surface or to a notional (more truly inertial) clock at rest on the axis of a hypothetical non-rotating earth … or to some other still more truly inertial counterpart, acting as a *fiducial reference*. All clocks then are compensated to run in step with the Master Clock. It is assumed that, as time passes, whatever further compensations are needed to maintain rate synchrony are continuously made in conformity with the motions of each individual clock. If the clock trajectories are known (*e.g.*, by solving the many-body mechanical problem) then, the laws of compensation being also known, such continual rate synchronization is in principle always feasible. The motions thus become describable as a function of frame time t of the Master Clock, in terms of which those motions are integrable – because of the exactness of $\mathrm{d}t$ – and the many trajectories can be graphed by use of a single coordinate t. Thus analysis of the many-body problem is itself vastly simplified, as compared with any attempt to deal directly with uncompensated (path-dependent) proper times.

Elsewhere [3] this type of frame time associated with an inertial Master Clock has been called "collective time" and designated t_0. That terminology will be retained here. In special relativity any kind of frame time is recognized as *non-invariant* under inertial transformations. Since invariance is usually considered requisite to "relativity," it might be expected that the present alternative theory would be incompatible with the Relativity Principle. There are a number of forms of that principle, with some of which it may indeed be incompatible. However, it is compatible with the "canonical" form, *viz.*,

Relativity Principle*: The laws of physics are invariant under changes of inertial system.*

We verify this compatibility at once by noting that the collective time rates of clocks of swarm A associated with Master Clock A and of swarm B associated with Master Clock B are necessarily in some fixed ratio α dependent solely on the relative motion and environmental conditions of the two inertial Master Clocks. The latter could be brought into agreement (rate synchrony) through a further compensation by the factor α, or they could be allowed to differ physically and the *unit of time* (the "second") could be redefined for one swarm or the other by the same factor. Alternatively, Newton's Principle of Similitude tells us that the *laws of physics* (at least for mechanical physics) are not affected by the choice of mensuration units for any of the symbols employed in physical description. In consequence, the *numerical* "flow rate" ascribed to time does not influence any observable aspect of nature. In effect, such a flow rate has no objective existence, apart from numerical convention, since we can make it anything we like by choice of units. The implication is that the laws of physics are indeed invariant under arbitrary changes of Master Clocks or their inertial frames. So, a Relativity Principle holds. It is not true that introduction of the Master Clock concept, or of the collective time idea, implies the necessary existence in nature of a fundamental system or ether. Collective time is in fact neutral (agnostic) on that subject.

Concerning the important topic of *inertiality*, as we know, the laws of both mechanics and electromagnetism mysteriously simplify in inertial systems. Einstein's generally covariant description of non-inertiality via his theory of curved space only confirms this, since the resulting four-index tensor formulation of the laws of nature manifestly complicates them. As for the physics of inertiality, that is presumably Machian, and lies beyond the scope of the present investigation. We shall take it on faith here and offer no apology for fitting "time" and timekeeping to it by referring our Master Clocks always to inertial systems. If apology is nevertheless required, the over-riding goal of the physicist (as distinguished from the mathematician) may be asserted to be *simplicity* of description. I make this claim in full recognition that a century of evolution has taken physics in the opposite direction.

In summary, we have presented two conflicting views of "time," the Einstein view that clocks (whose mensuration properties are assumed to define time) must in general be allowed to run at their undisturbed natural rates, so that certain elected environmentally-induced rate variations can reveal profound physical properties of time itself; and the Newtonian or Platonic idealized view, that clocks must be compensated to eliminate *all* environmentally-induced rate variations, so that "time" is left with no physical properties whatsoever, and is just a mathematical parameter best chosen for the simplest possible description of nature.

3. The Manifestation of Universal Invariance in Mechanics

Covariance, born of Maxwell's equations, quickly communicated itself to mechanics and became *universal covariance*. Let us verify that invariance is suited to exhibit a similar ideological aggrandizement by encompassing mechanics. Three short steps will take us to this goal:

Step 1. Newton's second law is taken as valid at first order in (v/c):

$$\mathbf{F}_{\mathrm{lab}}^{(\mathrm{Newton})} = \frac{\mathrm{d}}{\mathrm{d}t} m\mathbf{v} = \frac{\mathrm{d}}{\mathrm{d}t} m \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{r}, \tag{6}$$

the force being measured in the laboratory inertial frame.

Step 2. For higher-order theory (required to be a formal covering theory of the first-order theory), invariant replacements are made in (6), invariant force for lab-measured force, invariant rest mass m_0 for m, and τ for t:

$$\mathbf{F}_{\mathrm{inv}}^{(\mathrm{timelike})} = \frac{\mathrm{d}}{\mathrm{d}\tau} m_0 \frac{\mathrm{d}}{\mathrm{d}\tau}\mathbf{r} = \gamma \frac{\mathrm{d}}{\mathrm{d}t} m_0 \gamma \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{r}, \tag{7}$$

where use has been made of

$$\frac{\mathrm{d}}{\mathrm{d}\tau} = \frac{\mathrm{d}t}{\mathrm{d}\tau}\frac{\mathrm{d}}{\mathrm{d}t} = \gamma \frac{\mathrm{d}}{\mathrm{d}t}, \tag{8}$$

which follows from (5). Reintroduction in (7) of the laboratory frame time t is necessitated by the general impracticality of measuring time by swarms of proper-time clocks associated with swarms of particles.

(Although proper time is operationally definable, the operations are not in general easily reduced to practice, nor are the results compatible with simple analysis, except for single bodies.)

Step 3. In Eq. (7) the force is referred to as *timelike* because it is a time derivative of (time-dependent) momentum. For forces of this nature it is found [3] in complete generality that their invariant forms are related to force measured in the laboratory by

$$\mathbf{F}_{\mathrm{inv}}^{(\mathrm{timelike})} = \gamma\,\mathbf{F}_{\mathrm{lab}}^{(\mathrm{timelike})}. \tag{9a}$$

Eq. (9a) applies to all forces of timelike character. Note the formal analogy to Eq. (8), by which the factor γ^{-1} converts an invariant quantity into a frame-observable quantity. In contrast to (9a), all forces of spacelike character (for example, those described as minus the spatial gradient of a scalar potential function) obey a different rule [one of invariance, reflecting spacelike interval invariance, Eq. (3)], *viz.*,

$$\mathbf{F}_{\mathrm{inv}}^{(\mathrm{spacelike})} = \mathbf{F}_{\mathrm{lab}}^{(\mathrm{spacelike})}. \tag{9b}$$

The distinction between these two rules, (9a) and (9b), highlights in terms of "force" the non-existence of spacetime symmetry. Applying (9a) to (7), we obtain the well-known result

$$\mathbf{F}_{\mathrm{lab}} = \mathbf{F}_{\mathrm{lab}}^{(\mathrm{timelike})} = \gamma^{-1}\mathbf{F}_{\mathrm{inv}}^{(\mathrm{timelike})} = \frac{\mathrm{d}}{\mathrm{d}t} m_0 \gamma \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{r} = \frac{\mathrm{d}}{\mathrm{d}t}\gamma\, m_0 \mathbf{v}, \tag{10}$$

which is probably the most amply-confirmed prediction of SRT. Complete accord with SRT throughout the range of mechanical experimentation can be anticipated in consequence.

In obtaining here a higher-order modification of Newtonian mechanics in agreement with observation, no use has been made of SRT's alleged $\mathrm{d}\sigma$ invariance, only of $\mathrm{d}\tau$ invariance. From the foregoing there is no reason to doubt that invariance is perfectly capable of bearing the full load of "universality" (covering all physics) traditionally ascribed to covariance.

4. Crucial Experiment

SRT itself, being so well-buttressed by relationships to the rest of established physics, marks only the tip of the iceberg. It is highly unlikely that a new paradigm could successfully emerge to replace SRT without upsetting other apple carts as well – genuinely new premises being unlikely to affect only one set of presumptions. Our proposed *collective time* paradigm is built upon no fewer than four mutually-supporting departures that challenge accepted approaches in four areas of physics. These confrontations represent (1) two opposed views of time (Platonic vs. Einsteinian), (2) two opposed views of mathematical form preservation (invariance vs. covariance), (3) two opposed views of spatial metricity (length invariance vs. Lorentz contraction), and (4) two opposed views of electromagnetic field description (Hertzian vs. Maxwellian). Within each of these two sets of opposed views there is consistency and mutual support. Each being taken together as a distinct whole, the sets lend themselves to experimental testing. Two such tests have been proposed elsewhere [3] and will be reviewed here. Only one proves valid.

The first, the valid one, concerns stellar aberration, dependent on the one-way propagation of light. It amounts to a crucial test for Einstein's special theory. Einstein himself always welcomed such tests, but his followers have failed to follow through in this instance. SRT, and Maxwell's theory on which it rests, unambiguously predict a stellar aberration angle [3], [5]

$$\alpha_{\text{SRT}} = \sqrt{1-\ell^2}\left(\frac{v}{c}\right) + \frac{\ell\sqrt{1-\ell^2}}{2}\left(\frac{v}{c}\right)^2 + O\left(\left(\frac{v}{c}\right)^3\right), \qquad (11)$$

where $\ell = -\sin\theta\cos\phi$. The angles θ and ϕ are defined by picturing the earth's orbit as lying in the plane of the ecliptic, with the starlight's propagation vector lying in a plane *P* normal to the ecliptic and inclined at polar angle θ, the earth's orbital velocity being *v* and its position at azimuthal angle ϕ, measured from a direction normal to *P*. The first-order term in (11) has been known since Bradley, but to this day the second-order term remains unverified.

There are two reasons this needs to change. First, for many years the Very Long Baseline Interferometry (VLBI) system has been claiming resolutions apparently adequate to measure the second-order term in (11); so test *feasibility* is in little doubt. Secondly, there is now a plausible test theory [3], [6], termed *neo-Hertzian electromagnetism* (a modification of Maxwell's theory similar to the Hertzian one discussed above but employing invariant proper time as the time parameter, so that formal invariance is consistently manifest – see Appendix A), which leads to a predicted [3], [6] aberration angle

$$\alpha_{\text{neo-Hertzian}} = \sqrt{1-\ell^2}\left(\frac{v}{c}\right) + O\left(\left(\frac{v}{c}\right)^3\right). \qquad (12)$$

Third-order terms being unobservable, and the second-order term being conspicuously absent from (12), it is apparent that this alternative theory differs from SRT in a way that should be observable, and should test both Maxwell's theory and SRT that rests upon it.

The second experiment to be described is of entirely different character. It was proposed in Ref. [3] as supposedly crucial, but will be shown here to be *not crucial*. Despite this shortcoming it will be highly instructive to consider. It concerns the speed of light as measured in orbit. A dual-function atomic clock can be designed to use a single cloud of atoms, the natural oscillations of which are measured by two counters, one set to measure proper time and the other compensated to measure collective time. Thus in the same housing one has effectively two clocks – the motion-compensated one running always objectively faster (*i.e.*, counting more "seconds" between any two events) than the proper-time one. (Here for simplicity we continue to omit consideration of gravity's effects on timekeeping. In fact the necessary compensation for gravity in orbit works in the opposite direction from the motion compensation.) Such a proposal, to employ two clocks of the kind specified, has been made independently by Buenker [7]. His reasonings parallel those discussed here, except for being based on physical light-speed invariance rather than length invariance. In consequence of this difference his conclusions differ in important respects from the present ones.

Let such a dual-function clock be put into earth-centered circular orbit, in the manner of the GPS, and let an apparatus to measure light speed be included in the satellite payload. Consider this apparatus to be a rigid bar terminated at both ends by light-pulse reflectors. Let the oscillation period of the pulse between these reflectors be measured by the co-moving dual-function clock. Since the two clocks of the latter run at different rates, they cannot both measure pulse speed c. Two different numbers will therefore be obtained for "light speed." When the apparatus is in orbit, which of the clocks will measure c – the proper-time clock or the compensated one?

SRT replies unambiguously, by Einstein's second postulate, that the proper-time (Einstein) clock will measure c. This presumes that the Lorentz contraction of the rigid bar occurs for motion parallel to that bar. (Because of anisotropy of the Lorentz contraction, and isotropy of time measurement, Einstein's theory does seem to predict anisotropy of the light-speed quotient. But let it pass … no relativist would admit such a glitch.) However, we have here postulated [Eq. (3)] that the bar length is invariant. In that case it seems that the compensated (collective time) clock must measure *c*, regardless of apparatus orientation, provided the light behaves intrinsically the same in orbit as on earth. That was the assumption made in Ref. [3] in arriving at the prediction that the compensated clock would measure *c* in orbit. Had this been correct, the experiment would have been crucial between SRT and the present theory.

However, the above vital proviso that the light itself behaves physically in the same way when the detector is in orbital motion and when it is at rest on earth is inconsistent with neo-Hertzian electromagnetism (as I should have noticed at the time). From Appendix A, Eq. (A.7), we see that that theory predicts a wave propagation speed

$$u = \pm\sqrt{c^2 - v_d^2} + \mathbf{k}\cdot\mathbf{v}_d \rightarrow \pm c/\gamma_d \,,$$

the first-order term $\mathbf{k}\cdot\mathbf{v}_d$ being unobservable by Potier's Principle [3], so that only the second-order slowing of light speed by a γ-factor associated with motion at velocity $\mathbf{v}_d$, imparted to the light detector, is predicted to be observable. This light-speed slowing should be just as objectively real as the clock-rate slowing produced by the same physical motion. Since the two types of physical slowing are quantified by the identical factor γ_d, their effects cancel exactly, with the result that light-speed in orbit is *measured* by the co-moving proper-time clock to have the same numerical value *c* as on earth. That is, if the experiment is performed on earth with the same apparatus, the proper-time clock will measure *c* and, as we have seen, the compensated clock (being pre-compensated for orbital conditions) will measure the false value c/γ at the earth's surface; whereas if the experiment is performed in orbit the resulting slowing of atomic oscillations would cause the proper-time clock to measure γc and the compensated clock to measure *c*, *provided light behaviors are inherently identical on earth and in orbit*. But in fact we have seen that neo-Hertzian theory denies this proviso and claims an objective physical slowing of light in the moving orbital system by a γ-factor. Such factual slowing causes the *measured* values to decrease by that factor, so in orbit the proper-time clock measures *c* and the compensated clock measures c/γ. Another way to put it is that the "real" slowing of light speed in orbit is not measurable by a proper-time clock but only by a compensated clock. By this way of speaking, only collective time (CT) is "real," because only CT discloses the underlying physics, which otherwise is hidden by "measurement." In the same way, we have noted, only CT discloses the "real" distinctions among past, present, future – allowing these to become global conceptions suited for use in quantum physics (as well as in everyday life).

Thus the claim made in [3] that this orbital experiment would be crucial for distinguishing SRT from the present theory is incorrect. Both theories (rightly understood) predict that the proper-time clock will measure *c* in orbit. A somewhat similar experiment has in fact already been done. Braxmaier et al. [8] have used a cryogenic optical resonator at rest in their laboratory for six months to verify the secular constancy of light speed. The earth's changes of inertial system presumably mimic those of an apparatus in orbit (although they mimic neither the clock-rate slowing nor the light-speed slowing effect of orbital motion, so the issue remains murky). Buenker has suggested [7] that the clock-rate slowing in orbit could be compensated by an isotropic alteration of the light-speed-measuring apparatus's dimensions, assuming the light speed to be physically invariant in all environments. Thus there are two rival explanations of *measured* orbital light-speed numerical invariance compatible with the objective reality of clock-rate slowing in orbit: (1) length is invariant while light speed physically slows (the explanation offered here), (2) length changes isotropically while light speed is physically invariant (Buenker's suggestion). There is no obvious direct experiment to dictate the choice between these two (both of which disagree with the Lorentz transformation). But the stellar aberration experiment, if it yielded results in agreement with neo-Hertzian electromagnetism, would provide strong guidance for a choice. This is such an easy experiment, requiring essentially no new outlay for equipment and yielding such valuable physical information, that it would seem frivolous to look for better testing options at this time.

5. Remark on Test Theories

There seems to be a widespread misapprehension among theorists about how to test a theory. A meaningful, or truly testing, "test theory" is not one that proceeds from the same premises as those of the theory under test. To aim for additional decimal places [8], working from the same premises, is not to test those premises. It is to grind water in the same mortar.

We have seen an illustration here: Supposedly, the postulate of relativity, combined with the postulate of light-speed constancy, leads uniquely, by the inexorability of pure logic, to SRT. This has been held up to the public and to students of physics as a model of human rationality in action. But the present alternative theory, *compatible with both those postulates*, leads to an entirely different set of conclusions and world picture. What causes this? An entirely different set of underlying premises. I have noted some of the distinctions previously. The main one is a drastically different conception of both the physics of light (electromagnetism) and the mathematics of its description. Another is a different conception of the meaning and mathematics of "inertial transformation." Putting these and other significant differences together into a consistent package leads to a new synthesis that entirely upsets the "logic" of SRT's postulational approach – not by refuting it but by setting it aside, by relegating it to the dustbin of history.

The basic issue is not one of physics: Whether the present theoretical alternative is supported or refuted by the crucial experiment here proposed, or by others that time may reveal, is immaterial to the point of principle made in this section: It is high time physicists and philosophers concerned with the mathematical description of nature developed some working humility through recognition of the inherent limitations of their settled notion of what it is that "tests" a theory. To ride high on a theory merely because it checks out to endless decimal places is to ride for a fall. What needs to be tested is always the premises – to avoid what in statistics would be called *systematic errors*. And the premises are hardest to test, because they rest upon subtle webs of interlocking suppositions, upon presumptions difficult to analyze, even to identify.

In other words, hard work is needed, and that nobody wants to do – and nobody is rewarded for doing. Rather, in historical practice anybody who ventures even to suspect systematic errors is professionally ostracized. Rare individuals may seek the hard way, but professions invariably take the easy way, the consensus way, the feel-good way. And what does that tell us about likely rates of "progress"? The subtext here is human nature. Hard scientists are neither taught nor want to recognize an antagonism, if not actual antithesis, between science and human nature. Therefore human nature trips them up every time. The reason they are called hard scientists is that's the way they fall.

In the proposed VLBI experiment the two theories under test, the SRT-Maxwellian and neo-Hertzian forms of electromagnetism, although otherwise in general agreement, make specific predictions that disagree in a measurable way. Such alternative possibilities are precisely what proper test theories are designed to expose. They should not be *assumed* non-physical without the conclusive evidence furnished by actual testing. Test-test-test better than jaw-jaw-jaw.

6. Acknowledgment

For a number of expository improvements incorporated in this paper I wish to thank Oleg Missevich of Minsk. I am also much indebted to Robert J. Buenker for calling to my attention the apparent incompatibility of observational evidence [8] with one of the supposedly "crucial" experiments I had mistakenly proposed [3].

References

[1] Hertz, H. R., 1962, *Electric Waves*, translated by D. E. Jones (New York, Dover).

[2] Eichenwald, A. A., 1903, *Ann. Phys. (Leipzig)* **11**, 1, 421.

[3] Phipps, Jr., T. E., 2006, *Old Physics for New* (Montreal, Apeiron).

[4] Margenau, H. and Murphy, G. M., 1943, *The Mathematics of Physics and Chemistry* (New York, Van Nostrand).

[5] Aharoni, J., 1965, *The Special Theory of Relativity* (London, Oxford), Appendix.

[6] Phipps, Jr., T. E., 1991, *Phys. Essays* **4**, 368-372.

[7] Buenker, R. J., 2008, *Apeiron* **15**, 254-269.

[8] Braxmaier, C., Müller, H., Pradl, O., Mlynak, J., Peters, A., and Schiller, S., 2002, *Phys. Rev. Lett.* **88**, 010401.

[9] Ahronov, Y. and Bohm, D., 1959, *Phys. Rev. (Ser. 2)* **115**, 485-491.

Appendix A. Review of Neo-Hertzian Electromagnetism with Proof that Lorentz Force Inheres in the Field Equations

Attention will be confined to the case of electromagnetism in vacuum. The Hertzian theory referred to in the text parameterizes time with non-invariant frame time *t*, but we shall here treat instead the more fundamental version that uses invariant proper time τ (of the field detector). The resulting explicitly invariant theory has been termed [3] "neo-Hertzian." The basic Hertzian idea of using total time derivatives is retained. We summarize the main features of the theory and go on to treat the force law. A more complete account is given in Ref. [3]. The neo-Hertzian field equations for the invariant forms of the field quantities are

$$\nabla \times \mathbf{B} - \frac{1}{c}\frac{\mathrm{d}\mathbf{E}}{\mathrm{d}\tau} = \frac{4\pi}{c}\mathbf{j}_m , \tag{A.1}$$

$$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\mathrm{d}\mathbf{B}}{\mathrm{d}\tau}, \tag{A.2}$$

$$\nabla \cdot \mathbf{B} = 0 , \tag{A.3}$$

$$\nabla \cdot \mathbf{E} = 4\pi\rho . \tag{A.4}$$

where τ is the field detector proper time, $\mathbf{j}_m = \mathbf{j}_{Max} - \rho\mathbf{v}_d$, $\mathbf{j}_{Max}$ being the Maxwell source current (measured by a field-cum-current detector at rest at the field point) and the $-\rho\mathbf{v}_d$ term being the convective result of field (or current) detector motion through the field point at velocity $\mathbf{v}_d$. The above equations differ from those appearing on the sweatshirts of MIT freshmen only in the replacement of $\partial / \partial t$ by $\mathrm{d} / \mathrm{d}\tau$. The wave equation in free space,

$$\nabla^2 \mathbf{E} - \frac{1}{c^2}\frac{\mathrm{d}^2\mathbf{E}}{\mathrm{d}\tau^2} = 0, \tag{A.5}$$

has a d'Alembertian solution [3]

$$\mathbf{E} = \mathbf{E}_1\left(\mathbf{k}\cdot\mathbf{r} + \left(k\sqrt{c^2 - v_d^2} - \mathbf{k}\cdot\mathbf{v}_d\right)t\right) + \mathbf{E}_2\left(\mathbf{k}\cdot\mathbf{r} - \left(k\sqrt{c^2 - v_d^2} + \mathbf{k}\cdot\mathbf{v}_d\right)t\right), \tag{A.6}$$

$\mathbf{E}_1$ and $\mathbf{E}_2$ being arbitrary functions, wherein we have reintroduced frame time t via Eq. (8), with $\gamma = 1/\sqrt{1-(v_d/c)^2}$. (Collective time t_0, further discussed below, may alternatively and advantageously be used for t here.) It will be observed that the frame-time measured phase velocity consistent with (A.6), namely,

$$u = \frac{\omega}{k} = \pm\sqrt{c^2 - v_d^2} + \frac{\mathbf{k}}{k}\cdot\mathbf{v}_d, \tag{A.7}$$

is not a constant c except in the Maxwell special case $\mathbf{v}_d = 0$. Otherwise, for $\mathbf{v}_d \neq 0$, there is an apparent first-order photon convection effect by the moving detector. This first-order effect has been shown [3] to be *unobservable* for the same reason ("Potier's Principle") that an ether wind is unobservable. By contrast, the second-order effect shown in (A.7) is independent of the direction of $\mathbf{v}_d$ and should be physically real in the sense of affecting measurements. The detector velocity $\mathbf{v}_d = \mathbf{v}_d(t)$, being that of a point particle, is *not* a "velocity field," $\mathbf{v}_d = \mathbf{v}_d(x, y, z, t)$. We do not pause to derive these results here.

In order to discuss electromagnetic force it is desirable to express the field quantities in terms of potentials. This is done invariantly by means of

$$\mathbf{E} = -\nabla\phi - \frac{1}{c}\frac{\mathrm{d}\mathbf{A}}{\mathrm{d}\tau}, \qquad \mathbf{B} = \nabla\times\mathbf{A}, \qquad \text{(A.8a,b)}$$

where again τ is detector proper time and the field quantities represent their invariant versions. These transform invariantly,

$$\mathbf{E}' = \mathbf{E}, \qquad \mathbf{B}' = \mathbf{B}, \qquad \text{(A.9a,b)}$$

and also

$$\phi' = \phi, \qquad \mathbf{A}' = \mathbf{A}, \qquad \text{(A.10a,b)}$$

under a neo-Galilean transformation of the form

$$\mathbf{r}' = \mathbf{r} - \mathbf{v}_0 t, \qquad t' = t/\gamma_0, \qquad \text{(A.11a,b)}$$

where $\mathbf{v}_0$ is the (constant) velocity between primed and unprimed inertial systems and $\gamma_0 = \sqrt{1-\left(v_0/c\right)^2}$, a measure of the clock-rate difference of the two systems. Note that the inverse of (A.11b) is by conventional algebra $t = \gamma_0 t'$, an asymmetrical form that reflects the objective *asymmetry* of proper-time clock rates referred to in the text. This contrasts with the Lorentz transformation, which asserts a formal clock-rate *symmetry*. The clock slowing implied by (A.11b) is presumed [3] to reflect a basic physical effect of work done on a clock in changing its state of motion – *i.e.*, in changing its energy or action state – that alters its running rate objectively but reversibly (compared to an inertial clock on which no work is done).

If, by applying the clock-rate correction factor γ_0, one of the Master Clocks at rest in each of the two relatively-moving inertial systems described by (A.11) is brought into rate-agreement with the other, a mutually-consistent collective time t_0 results, so that a true Galilean transformation, $\mathbf{r}' = \mathbf{r} - \mathbf{v}_0 t_0$, $t_0' = t_0$, links the two systems. Other amenities follow, such as Galilean velocity addition,

$\mathbf{v}''=\mathbf{v}'+\mathbf{v}$, with distant non-radiative *force actions* being instantaneous on hyperplanes of constant t_0 and obedient to Newton's third law ("bootstrapping" violations of which have been claimed by SRT but never observed in the laboratory). In this connection it may be reaffirmed that t and t_0 are essentially equivalent forms of *frame time*, in that both can be measured by an inertial Master Clock. The only difference is that for t the spatially-distributed "slave clocks" must *co-move* with the Master, all in zero or constant gravity; whereas for t_0 the slave clocks are individually compensated to allow *arbitrary* motions in arbitrary gravity fields. The Master Clock runs at its natural proper-time rate (in zero or constant gravity). Thus collective time t_0 represents a sort of spatially-extended form of proper time – an invariant communication of the Master Clock's "personality" to clocks throughout the universe – and to other Master Clocks, as required to effectuate universally the Galilean invariance $t_0'=t_0$. For a proof of the practicality of such an evolution, we can thank the GPS.

Identifying the timelike part of (A.8a) and applying (8) and the general force rule (9a) from the text, we have

$$\begin{aligned} &\mathbf{E}_{\text{inv}}^{(\text{timelike})}=-\frac{1}{c}\frac{\mathrm{d}\mathbf{A}}{\mathrm{d}\tau}=-\frac{1}{c}\gamma\frac{\mathrm{d}\mathbf{A}}{\mathrm{d}t}=\gamma\,\mathbf{E}_{\text{lab}}^{(\text{timelike})} \\ &\rightarrow \mathbf{E}_{\text{lab}}^{(\text{timelike})}=-\frac{1}{c}\frac{\mathrm{d}\mathbf{A}}{\mathrm{d}t}=-\frac{1}{c}\left(\frac{\partial\mathbf{A}}{\partial t}+\left(\mathbf{v}_d\cdot\nabla\right)\mathbf{A}\right) \end{aligned}. \quad \text{(A.12)}$$

Similarly, applying rule (9b) to the spacelike part of (A.8a), we have

$$\mathbf{E}_{\text{inv}}^{(\text{spacelike})}=\mathbf{E}_{\text{lab}}^{(\text{spacelike})}=-\nabla\phi\,. \quad \text{(A.13)}$$

Consequently,

$$\mathbf{E}_{\text{lab}} = \mathbf{E}_{\text{lab}}^{(\text{spacelike})} + \mathbf{E}_{\text{lab}}^{(\text{timelike})} = -\nabla\phi - \frac{1}{c}\left(\frac{\partial \mathbf{A}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{A}\right), \quad (A.14)$$

where for simplicity the subscript has been dropped from $\mathbf{v}_d$. Similarly,

$$\mathbf{B}_{inv} = \mathbf{B}_{\text{inv}}^{(\text{spacelike})} = \mathbf{B}_{\text{lab}}^{(\text{spacelike})} = \mathbf{B}_{\text{Max}} = \nabla\times\mathbf{A}, \quad (A.15)$$

where $\mathbf{B}_{\text{Max}}$ is the Maxwell **B**-field. Applying the vector identity

$$\nabla(\mathbf{a}\cdot\mathbf{b}) = (\mathbf{a}\cdot\nabla)\mathbf{b} + (\mathbf{b}\cdot\nabla)\mathbf{a} + \mathbf{a}\times(\nabla\times\mathbf{b}) + \mathbf{b}\times(\nabla\times\mathbf{a}) \quad (A.16a)$$

to the special case $\mathbf{a} = \mathbf{v}(t)$, $\mathbf{b} = \mathbf{A}$, we find

$$(\mathbf{v}\cdot\nabla)\mathbf{A} = \nabla(\mathbf{v}\cdot\mathbf{A}) - \mathbf{v}\times(\nabla\times\mathbf{A}). \quad (A.16b)$$

Using this and (A.15) in (A.14), we obtain

$$\mathbf{E}_{\text{lab}} = -\nabla\phi - \frac{1}{c}\left(\frac{\partial \mathbf{A}}{\partial t} - \mathbf{v}\times\mathbf{B}_{\text{Max}} + \nabla(\mathbf{v}\cdot\mathbf{A})\right). \quad (A,17)$$

Finally, we note that the total laboratory-observable force on a “test charge” q (or on our field-detector “particle,” if it bears such a charge) is q times *the electric force on unit charge*, the latter being the definition of the neo-Hertzian $\mathbf{E}_{\text{lab}}$-field. Thus

$$\mathbf{F}_{\text{lab}} = q\mathbf{E}_{\text{lab}} = q\left(\mathbf{E}_{\text{Max}} + \frac{\mathbf{v}}{c}\times\mathbf{B}_{\text{Max}} - \frac{1}{c}\nabla(\mathbf{v}\cdot\mathbf{A})\right), \quad (A.18a)$$

inasmuch as the Maxwell **E**-field is

$$\mathbf{E}_{\text{Max}} = -\nabla\phi - \frac{1}{c}\frac{\partial \mathbf{A}}{\partial t}. \quad (A.18b)$$

Eq. (A.18a) will be recognized as the Lorentz force law with an added term dependent on **A**. So,

$$\mathbf{F}_{\text{lab}} = \mathbf{F}_{\text{Lorentz}} - \frac{q}{c}\nabla\left(\mathbf{v}\cdot\mathbf{A}\right). \tag{A.19}$$

Since the extra force term is the gradient of a scalar quantity, it integrates to zero around any closed path, and thus would not show up in normal closed-circuit experiments. Its effects might conceivably be detectable in plasma experiments – as affecting diffusion rate, etc., or in other forms of open-circuit experiments. It has never to date been reported as unambiguously observed, and may in fact be counter-indicated by recent experiments of A. L. Kholmetskii.

We have shown that the Lorentz force law is implicitly contained in the invariant neo-Hertzian field equations. Two features are to be noted: (1) The observable force on the test charge q is entirely electric, expressed as q times the Hertz-type electric field $\mathbf{E}_{\text{lab}}$. There is no "magnetic" force, as such. (2) The extra force term depends on vector potential **A**. There is no way of expressing the total force on the test charge in terms of fields alone … the potential has to come into it. Since a non-zero vector potential can exist outside a long (counter-wound) solenoid, where the fields vanish, the possibility arises to use the extra term in (A.19) to account for Aharonov-Bohm effects [9] in a classical way, without reference to quantum mechanics. This has not been explored.