

*A Practical Experiment to Observe the Direction of Time.*¹

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Abstract.

This work presents a practical experiment to observe the direction of time. The key insight is that translational frame dragging can only occur with respect to one state of motion, for a surrounding effectively asymptotically flat space, with observation and theory indicating this state of motion to be the state of rest, of the Lorentz-Poincaré Ether Theory. The Ether theory is briefly discussed, along with the observations and assumptions involved in the construction of inertial reference frames. The ether, of spherical universes, is then specifically discussed. The central results are then presented. Concluding remarks are then made, about time and energy.

I. Introduction.

You get what you get when you go for it – Barry Manilow, “Ready to Take a Chance Again”.

Every modern physical theory has a “formalism”, or mathematics, and an “interpretation” that connects the formalism to observation.

The “Standard Special Relativity” (SSR), that Einstein initially propounded and that most physicists imagine, has an interpretation that relativity is an inherent property of space [1,2a]. Observations, most notably from the Michelson-Morley experiments [3,2b], are believed to have established the vacuum speed of light to be the same, in all directions, relative to all observers.

However, as discussed further, below, there is an “Ether” interpretation, of the SSR formalism, which holds relativity to be a quality of observation, in trivial flat space-times, but not a property of space itself [4-10,2c]. Light is held to travel with the same speed, in all directions, only with respect to a unique “rest” state of motion (a luminiferous “medium” is not at issue).

In trivial flat space-time, this “Lorentz-Poincaré Ether” Theory (LPET) and SSR are observationally indistinct. However, we will show that the dragging of inertial frames must break the illusion of flat-space translational symmetry, showing LPET to be correct and SSR not.

We take the “Standard General Relativity” (SGR) formalism, as our classical-gravity model, to aid in understanding frame dragging. However, our insights will force the Ether interpretation, on our model formalism, resulting in a classical Ether theory.

Although we rely on the formalism that most likely applies to our universe, our results apply to any universe or theory exhibiting frame dragging; since frame dragging establishes our results.

Section II discusses the ether in trivial flat space-times, reviewing how assumptions for light velocity, in clock synchronization, lead to the Ether and Standard interpretations of the Special Relativity formalism, and considering kinematics that are helpful in understanding the ether. Section III discusses the very intuitive ether in spherical universes. Section IV presents the central theory and experiment of this work. Section V contains general conclusions. And sections VI and VII respectively contain appendices and references.

II. The Ether in Trivial Flat Space-times.

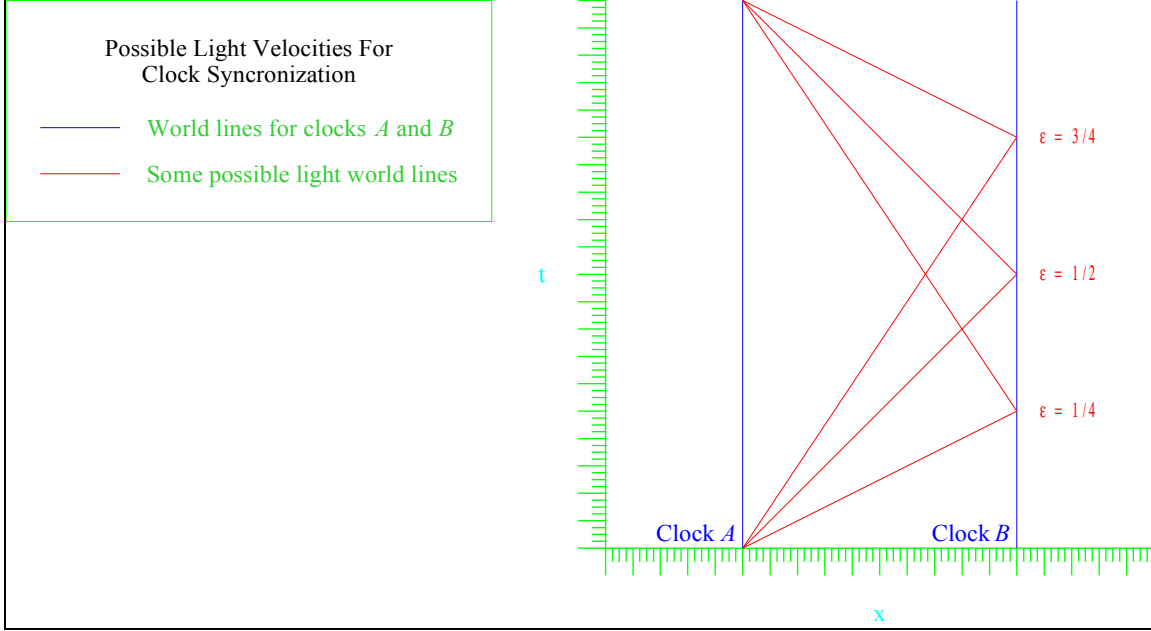
Suppose two separate comoving clocks, *A* and *B*, each with an observer. Light leaves *A*, when *A* reads time t_1 ; arrives at *B* and is reflected, when *B* reads t_2 ; and arrives back at *A*, when *A* reads t_3 . Poincaré (essentially) [5], and later Einstein [1], defined *A* and *B* to be synchronized if:

$$1) \quad t_2 - t_1 = t_3 - t_2.$$

¹ Our main results were achieved in April 2005, and have been disclosed, as part of the work, *Ether, Time, and Energy* (from which most of the text and all figures were taken), to numerous journals and physicists.

We will call this synchronization and the resulting reference frames “Standard”.

Figure 1)



But, as Poincaré first realized, with light as the fastest signal, there is a conundrum [7] – one must know a velocity, to synchronize separated clocks, yet must have separated clocks synchronized, to know any velocity [7,11a]. So our clocks could precisely measure only $t_3 - t_1$ at A , and t_2 at B , with t_2 possibly anywhere between t_1 and t_3 [11a]; and thus we could precisely know only the light’s ‘round-trip, average speed, with the corresponding, velocity magnitudes only established to be greater than half of this. Figure 1) shows a space-time diagram, with the world lines of clocks A and B , in blue, and, in red, some of the light world lines that would be consistent with the synchronization-procedure measurements. Letting $0 < \varepsilon < 1$, Reichenbach accounted for the t_2 possibilities and associated velocities with [11b] [the ε ’s, for the light velocities, depicted in Figure 1), are shown on the right]:

$$2) \quad t_2 = t_1 + \varepsilon(t_3 - t_1).$$

SSR assumes that ε equals one half and thus that light speeds are the same, in all directions, for all observers [1], reducing equation 2) to equation 1) [11c].

However (as we will see), ε equals one half and light speeds are the same, in all directions, only with respect to the ether state of rest; so times and lengths are as they appear, in the Standard rest frame. With the ordinary addition of rest-frame velocities, Standard non-rest frames assume incorrect ε and light-speed values, making their times and lengths illusory. In trivial flat space-times, rest is merely indistinguishable and thus LPET observationally indistinct from SSR; because objects moving with respect to rest are time dilated and length contracted [12,4,7]; so as to create the illusion that such effects occur identically, with respect to all attainable states of motion. Thus do the Michelson-Morley experiments give null results [12,4,2c]. This is LPET.

Length contraction occurs (at macro scales), because photons not only synchronize clocks but also mediate electromagnetism (in Quantum Field Theory). With photons governing lengths, between constituent particles of extended bodies, it is comprehensible that length contraction occurs just so, to make rest unobservable in trivial flat space-times. (Time also involving luminal oscillation, explaining dilation, would completely preclude a conspiracy of nature).

With no reciprocal time dilations or length contractions, or relativistic velocity addition, between reference frames, LPET is perfectly compatible with “common sense”, unlike SSR.

Figure 2)

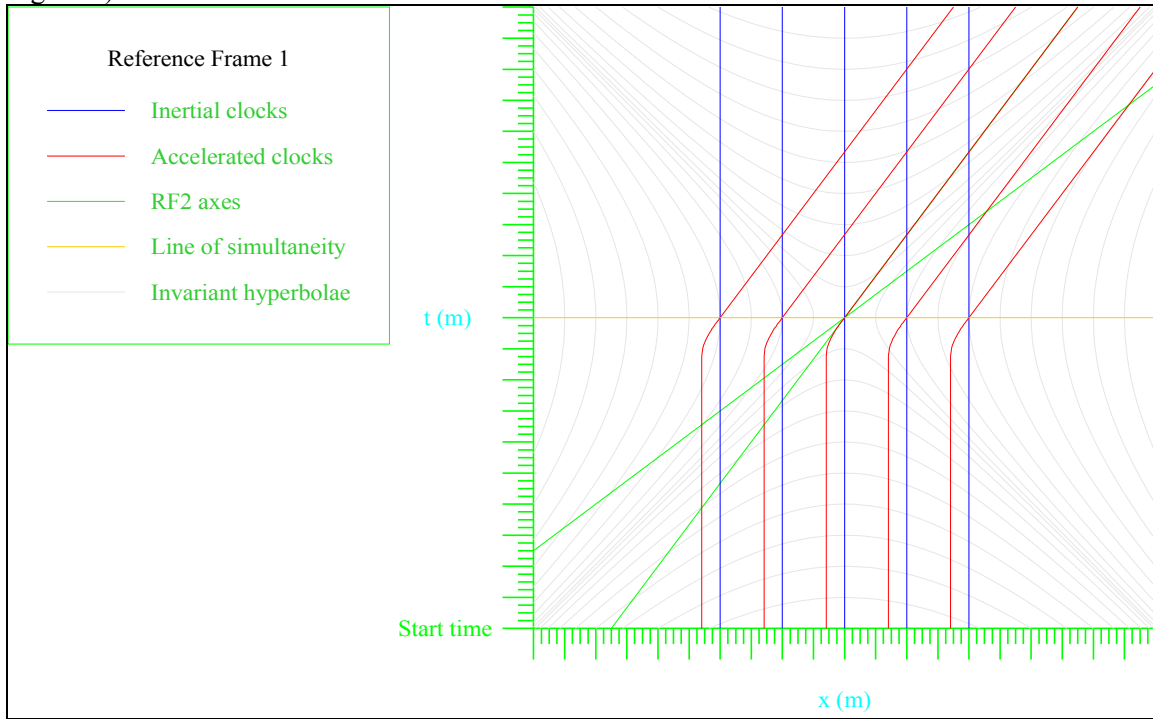


Figure 3)

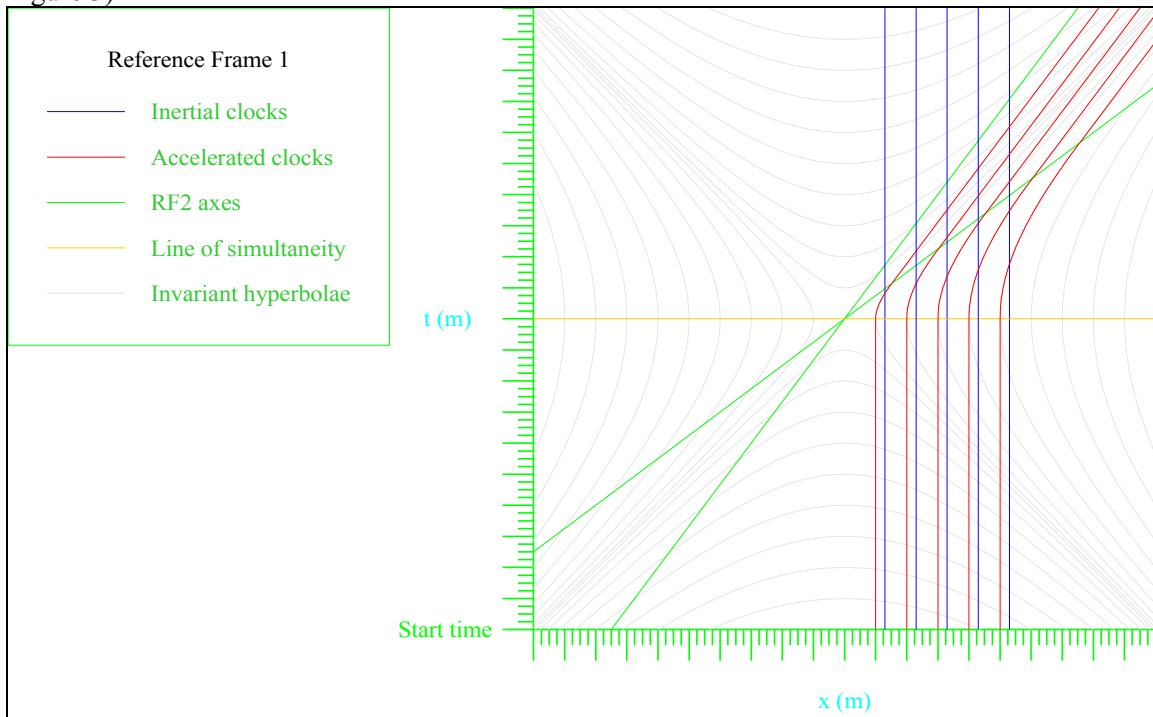


Figure 2) depicts *reference frame* RF1, with two strings of synchronized clocks, one blue and one red. The blue clocks remain stationary in RF1, throughout. The red clocks begin in RF1 and then accelerate into RF2, which is depicted by the diagonal, green axes. The accelerations are simultaneous in RF1 but not in RF2. If the red clocks maintain RF1 synchronization, after they accelerate, an observer referenced to them will continue to see the separations of clocks, in both strings, as identical, with the red clocks all reading identical proper times, each time they pass

respective blue clocks. If RF1 is the ether frame, then the red clocks maintain truly constant separations, between them, through the accelerations.

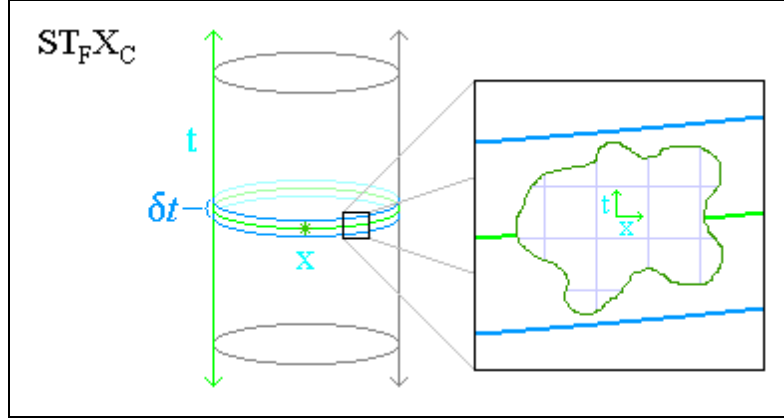
Figure 3) shows another situation for our blue and red clocks. This time, the red clocks follow the invariant hyperbolae, so as to maintain constant proper separations, between them, as they accelerate from RF1 into RF2 [13]. In this case, the separations, between the red clocks, are not truly constant, as is evident if RF1 is the ether frame.

III. Direct Observation of Velocity in a Spherical Universe.

We now turn to a very important example, which clearly demands the ether interpretation of our formalism, providing valuable insight.

Consider one *circular*, spatial dimension, X_C , of a spherical Friedmann-Robertson-Walker (FRW) [14] universe, which, for the moment, we assume to not significantly expand or contract, during our time of observation. This space has a locally *flat*, cylindrical *space-time*, $ST_F X_C$, pictured in Figure 4).

Figure 4)



The space-time, $ST_F X_C$, is locally flat, as depicted by the enlarged local subspace.

$ST_F X_C$ can be given a “tiled” representation, by cutting it open, along its axis, and connecting iterations together [15], as shown in Figure 5).

In Figure 5), we see that $ST_F X_C$ has a Standard reference frame (*ether*), RFE, with a globally continuous space axis [16,15], defining a global inertial observer. Also, blue Twin 1 and red Twin 2 travel from $x = A$, with opposing constant velocities, and yet meet again, to create a “Circular Twin Paradox” that cannot be resolved by an asymmetry from one twin accelerating [16,17]. Furthermore, the discontinuous lines of Twin 1 simultaneity, in blue, indicate that global simultaneity is problematic for non-RFE reference frames [15,16]. For example, if we identify the first and fifth clock pairs, in Figure 2), we get a picture of our clocks, in RFE. However, this causes a problem for RF2. Since the red clocks do not accelerate simultaneously, in this frame; the identified red clock has not a unique time of acceleration. A similar identification, in Figure 3), causes a similar problem, this time indicating that global proper distance is also problematic for non-RFE frames.

As is discussed in the prior literature [15-17], $ST_F X_C$ has a state of rest, and this state of rest resolves the above issues. Assuming there are neither discontinuous, particle jumps, across time, nor any other equivalently strange phenomena, any of which could be described by reference frames with discontinuous world lines and/or lines of simultaneity; RFE is the ether frame, for $ST_F X_C$.² The following are the most important consequences (see [15-17], for further details):

² A full discussion of the assumption, which is very involved, is given in *Ether, Time, and Energy*.

Figure 5)

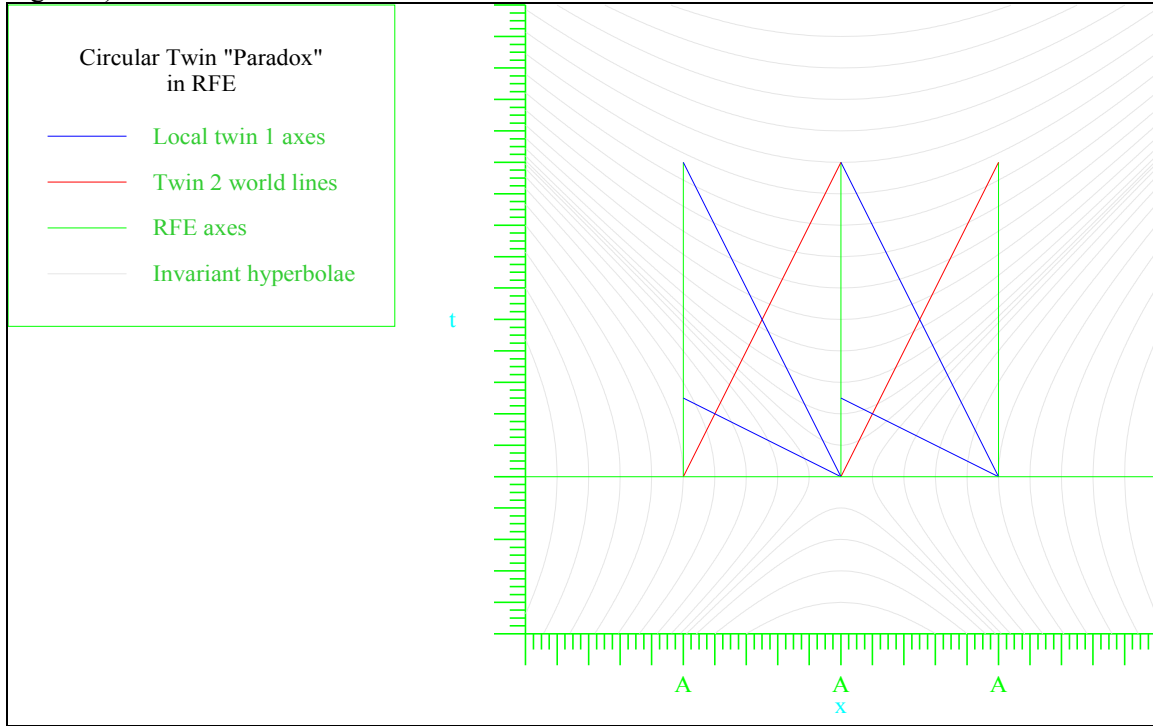
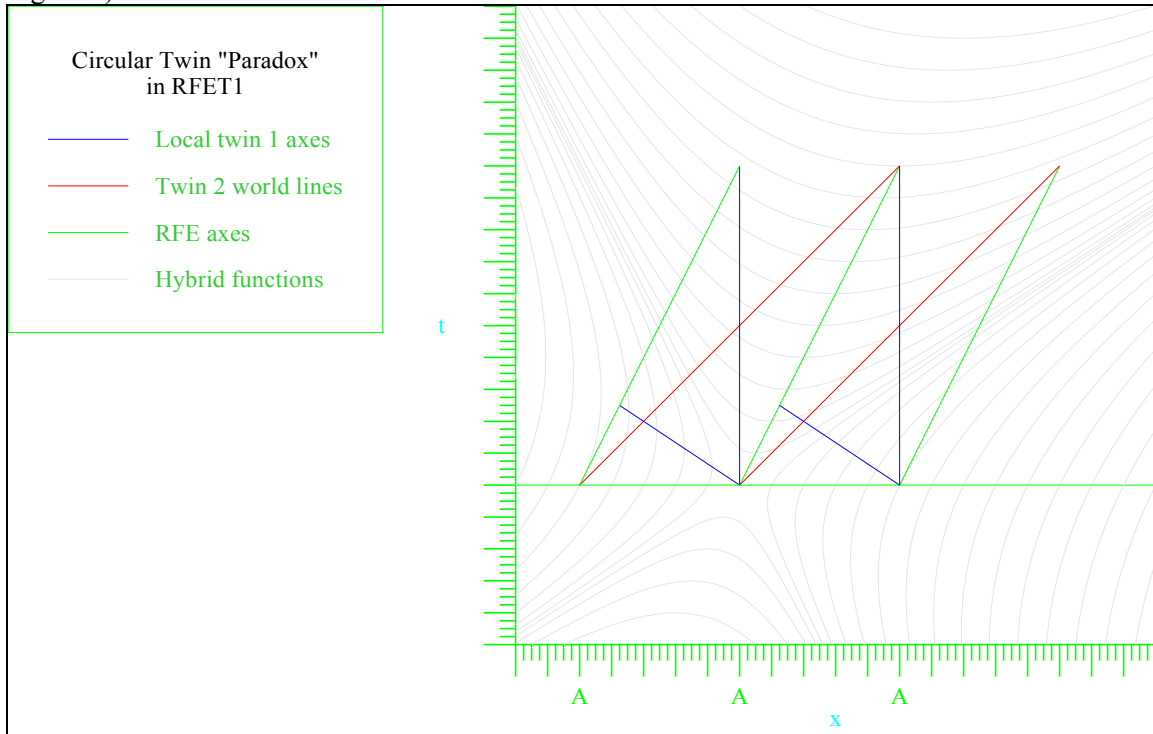


Figure 6)



With γ the Lorentz boost factor, referenced to RFE, the non-RFE time intervals, $(1/\gamma)\delta t_E$, correspond to the RFE time interval, δt_E [17]. Thus, RFE clocks exclusively run fastest [16,17].

RFE synchronization observably provides the only correct view of reality in $ST_F X_C$. Standard non-RFE observers perceive RFE clocks to be simultaneously located in multiple places, with each iteration having a different age [15], and to run slower, when they actually run faster! Also,

objects comoving with non-RFE frames appear to be a factor of γ longer, in those frames, than they appear to be, in RFE, as does the X_C circumference [15]. Again, these illusions result from the incorrect light-velocity assumption, in Standard non-RFE clock synchronization.

Clocks, in any state of motion, can make valid measurements, with the RFE synchronization. Horizontally shearing Figure 5), to make Twin 1's world line perpendicular to the RFE space axis, as depicted in Figure 6), we get the reference frame RFET1, comoving with *Twin 1* but having the *RFE* synchronization. In Figure 2), if RF1 is RFE, then the red clocks constitute such an observer, after they accelerate, if they maintain the RF1 synchronization. The RFET1 light cone is asymmetric, and the invariant hyperbolae have become hybrid functions of motion and synchronization; showing that twin 1 would perceive differing times for light to oppositely circumnavigate X_C [15-17], which prevents a global, Standard, Twin 1 synchronization [15,16].

Each great circle, of our spherical universe, is an X_C , with its own RFE. By symmetry, these RFE's, together, constitute a single time-independent state of rest. All motion is rotational, including that which would locally be perceived as translational, with the ether defining zero rotation on all circles, great and lesser.

LPET is thus the correct theory, for the flat subspaces of our spherical universe. In fact, $ST_F X_C$ applies to circular subspaces, of spatial structures like symmetric wormholes; which already tells us that LPET is correct, in the vast majority of widely contemplated spaces.

In an FRW spherical universe, of varying size, clocks at rest would only geodesically deviate with the size, while clocks translating, along parallel paths, would additionally deviate due to spatial curvature. Resolution of the universal spatial curvature would thus determine rest. The rest frame must be the comoving frame of matter (for isotropy), so it would be easily identifiable.

But it is most fascinating that direct, velocity measurement, at a single spatial point, might be achieved, by sending signals around a universe [17].

IV. The Practical Experiment to Observe the Direction of Time.

Schiff reasoned that energy currents, such as rotating balls or rings, “drag” inertial frames, in patterns like those created by bodies moving in a viscous fluid [18]. Observations of this phenomenon are currently tenuous; however, the Gravity Probe B experiment is under way, to study the Earth's Lense-Thirring and geodetic-precession effects [19].

Consider a stationary, rotating *ball*, B, in an effectively asymptotically flat space. Far from B is a *remote*, inertial reference frame, RFE_R . Any *circle*, L_C , outside of and centered on B, and in the rotational symmetry plane, has a non-inertial cylindrical space-time that looks like $ST_F X_C$, with an angular rest frame, RFE_C , that would rotate prograde, with respect to RFE_R , in proportion to B's angular momentum and in inverse proportion to L_C 's circumference [20]; so light would circle L_C (non-geodesically), faster prograde than retrograde [21,20].

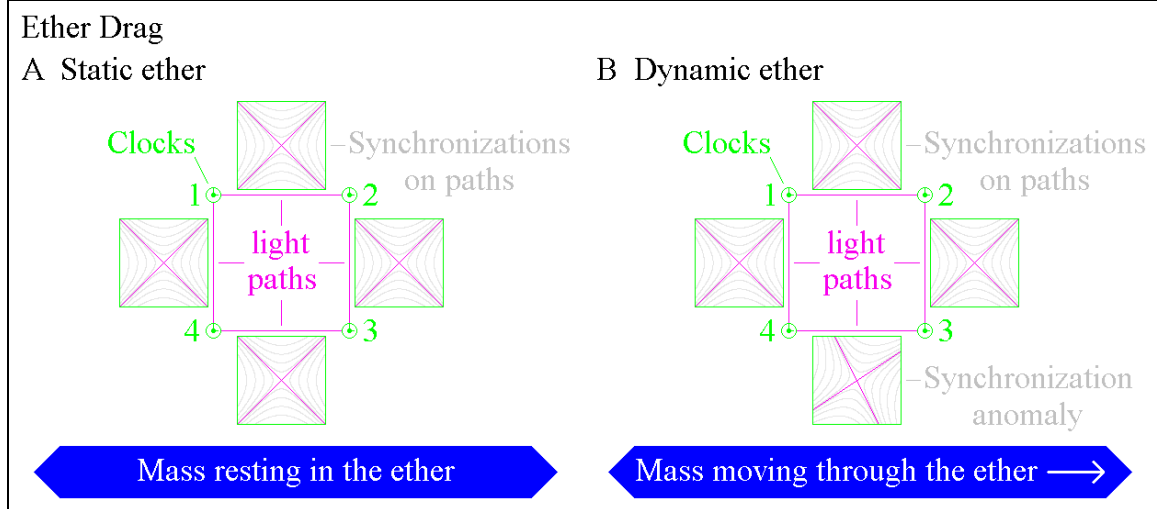
A *remote* inertial *observer*, O_{RA} , on B's rotational *axis*, could see L_C clearly. Information carriers, such as light, would spiral out, creating a picture that is merely rotated [22]. For example, suppose mirrors are held motionless, with respect to RFE_R , so as to guide light around L_C , each with a beacon that flashes, when light hits the mirror. From the beacons, O_{RA} could clearly observe the asymmetrical light propagation [22]. (Half-silvered mirrors, redirecting part of the light, towards O_{RA} , could replace the beacons.)

Along L_C , clocks that are motionless, with respect to RFE_R , could be consistently synchronized; but, due to the asymmetrical light propagation, relative to RFE_R , the resulting reference frame would be asymmetrical [20], like that in Figure 6).

We now show frame drag to break the illusion of flat-space translational symmetry.

Figure 7 A) shows four uniformly moving green clocks, which have some arbitrary velocity, parallel to the axis of a long blue mass, which creates no frame drag. Light signals circumnavigate the magenta light paths (which translate with the clocks), in an equal amount of time, for both directions, as shown by the consistent, individual synchronizations, between the clocks (gravitational time dilation is suppressed).

Figure 7)



In A, four clocks uniformly move, with any velocity, parallel to a long mass that creates no frame drag. Light circumnavigates the paths (which translate with the clocks), in an equal amount of time, for both directions, as shown by the individual synchronizations, between the clocks (gravitational time dilation is suppressed). In B, the mass creates significant frame drag, along its axial direction, causing light to circumnavigate the paths, faster counterclockwise than clockwise, as the synchronization anomaly shows. The anomaly cannot be transformed away; so, with only energy to influence ether, frame drag is ether drag, making rest observable.

Figure 7 B) again shows our clocks and mass; but the mass now creates significant frame drag, along its axial direction, causing light signals to circumnavigate the light paths, faster counterclockwise than clockwise, as shown by the synchronization anomaly, between clocks 3 and 4. The light cones, on the upper and lower paths, do not depend on clock motion; and no resynchronization could make them look the same, on both paths. In particular, this anomaly would exist, were the clocks translating with the mass; and, in fact, any single clock, in Figure 7), could record the differences in times of flight, for oppositely circumnavigating, light signals, with synchronization having no impact at all. Therefore, translational frame drag cannot be Lorentz transformed away, and thus can occur with respect to but one state of motion, for a surrounding effectively asymptotically flat space.

By current observation and theory, there is only energy to influence ether (and vice versa); so symmetry indicates that frame drag occurs with respect to the surrounding ether. Therefore, frame drag is, in fact, ether drag.

Envisioning our mass, in Figure 7 B), as part of a ring of dust, encompassing a great circle of an otherwise-FRW spherical universe, provides further valuable intuition; since it is clear that the ring would drag inertial frames, precisely when rotating with respect to the rest of the matter (were two B's co-rotating, at opposite poles of such a universe, the rest of the universe would be a very wide ring). Then, by symmetry, events recorded by any single clock, in Figure 7 B), can be described by a flat geometry {compare our Figures 5) and 6), with those in [20]}. Suppose that our four clocks comove with the mass; and one clock sends two oppositely circumnavigating, light signals, around the paths. Call the return of the first signal, event *A*, and that of the second, event *B*. The Lorentz transformation, to the Standard frame of the clocks and mass, does not make *A* and *B* simultaneous, as it must, for the frame dragging to disappear; so translational ether drag manifestly cannot be Lorentz transformed away, any more than rotational ether drag.

There is actually no difference, between translational and rotational ether drag. In fact, the rotational ether drag, along any small segment of L_C , constitutes translational drag.

{See Appendix A), for a further technical discussion of ether drag, and Appendix B), for a discussion of Ether and the parameterized post-Newtonian formalism. These are beyond the

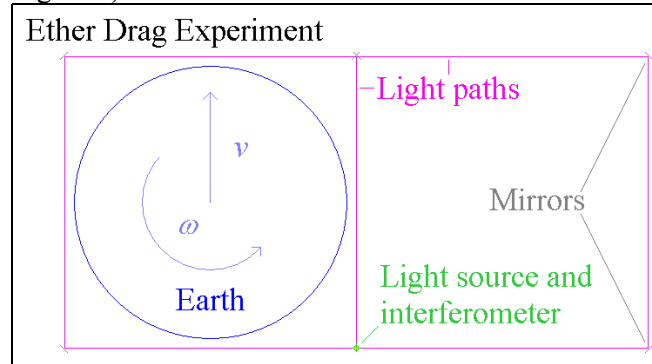
scope, specified by the contest for which this essay was written, and are unnecessary for our results, but address noteworthy technical issues.}

{Recently, other investigators have also realized that translational frame drag cannot be transformed away, around a compact spatial dimension; but with the remaining misconception that it can be, for spatial dimensions that are not compact [23].}

Freely falling clocks and gyroscopes, near ether-dragging bodies like the Earth, also respond to curls in the ether, in conserving momentum and angular momentum, behaving differently from those around similar bodies at rest.

Figure 8) depicts the Earth, in blue, translating with velocity v and rotating with angular velocity ω , relative to the free-space ether. The green apparatuses and magenta light paths translate with the Earth. The light source sends beams along all light paths, which are created by mirrors at the square corners; and the interferometer reads the fringes of recombined returning beams. The left square measures the ether drag, due to the Earth's rotation, in a type of experiment proposed in [24], while the right measures the changing ether drag, due to the Earth's seasonal velocity.

Figure 8)



In this ether drag experiment, the light source sends beams along all light paths, which are created by mirrors at the square corners. An interferometer reads the fringes of recombined returning beams. The left square measures the Earth's rotational ether drag, while the right measures its translational ether drag.

Ether dragging astrophysical systems also infuse light with rest information. For example, a galaxy, translating across the line of sight from Earth to a light source, shifts the source spectrum, depending on both the galaxy's internal angular momentum [25] and momentum. Dragged light can be compared with direct light, to observe rest. In addition, around astrophysical objects, glowing jets, and glowing disks, such as galactic and accretion disks, all shape according to momentum and energy conservation.

V. General Conclusions.

Our results show that the strong equivalence principle [26] does not hold.

With the ether synchronization uniquely correct, time is comprehensible. Each space-time point is in exactly one ether hypersurface of simultaneity, and (with continuous world-lines and ether-frame hypersurfaces, as well as a universe with time that does not uniformly repeat) each world line intersects any ether hypersurface at most once.

As discussed, in section IV, by current observation and theory, there is only energy to influence ether (and vice versa). Thus, Energy motion sets ether motion, and, consequently, the direction of time. This is the proper understanding of notions developed by Berkeley, Mach, Einstein, and many others [27] (though their intent was to obviate absolute space). Therefore, barring something, foreign to current observation and theory, that causes an essentially large-

scale-flat universe to have a nonzero total (possibly angular) momentum, the comoving frame is the free-space-ether frame, in any FRW universe [by isotropy, the comoving frame is the free-space-ether frame, in any large-scale-curved FRW universe, as we saw for such spherical universes, in section III]. Experiments, such as that in Figure 8), should confirm this; but existing data might already contain verification.

Our universe is approximately FRW, assuming observations suggesting large-scale homogeneity and isotropy universally hold [14]; so our free-space-ether frame is seen in the stars.

VI. Appendices.

A) A Technical Discussion of Ether Drag.

For dust translating in the z-direction, in an effectively asymptotically flat space, the nonzero components of the energy-momentum tensor are T_{tt} , $T_{tz} = T_{zt}$, and T_{zz} . Consequently, any applicable metric would have $g_{tz} = g_{zt}$ nonzero; so stationary observers, in essentially free-space, would observe translational ether drag, with light cones tilted, in the direction of the current.

In fact, as in section IV, let us suppose our mass, in Figure 7), to be part of a dust ring, encompassing a great circle of an otherwise-FRW spherical universe, and describe position, on the circle, by an angle, ϕ , referenced to the sphere's center, in hyperspace. Then the applicable metric components, g_{tt} , $g_{t\phi} = g_{\phi t}$, and $g_{\phi\phi}$, for motion on our great circle, are also those, for motion on L_C , with the analogous coordinates; so we can employ analogous calculations to that in [20], further seeing that translational ether drag cannot be transformed away, any more than rotational ether drag.

B) Ether and the Parameterized Post-Newtonian Formalism.

The parameterized post-Newtonian formalism (PPN), along with various observations, is supposed to have precluded a “preferred frame” (see [26] and references therein).

PPN asserts that preferred-frame theories and SGR must have different values, for the “preferred-frame parameters”, α_1 , α_2 , and α_3 ; but the parameters depend on things like the amount of frame dragging produced by unit momentum, and there is no reason why SGR and a preferred-frame theory must differ in such respects. So PPN is problematic.

Indeed, we have seen that the SGR formalism predicts ether drag, and allows its FRW spherical universe, which has an ether frame. Thus, while the SGR formalism has $\alpha_1 = \alpha_2 = \alpha_3 = 0$, which PPN asserts implies no preferred frame; Einstein's equation, itself, demands Ether.

Since our Ether theory has $\alpha_1 = \alpha_2 = \alpha_3 = 0$; these parameters do not test for a preferred frame; and the PPN metric, as currently specified by the parameters [26], is incorrect.

$g_{ti} = g_{it}$ should be measured directly, in a test like that in Figure 8).

VII. References.

- [1] A. Einstein, *Ann. Phys. (Leipzig)* **17**, 891-921 (1905), *Zur Elektrodynamik bewegter Körper*.
- [2] D.C. Giancoli, *General Physics*, [a: Chapt. 39] [b: 747-750] [c: 750] (Prentice-Hall, New Jersey, 1984).
- [3] A.A. Michelson and E.W. Morley, *Am. J. Sci.* **34**, 333-316 (1887), *On the Relative Motion of the Earth and the Luminiferous Ether*.
- [4] H.A. Lorentz, *Proc. Acad. Sci. Amst.* **6**, 809-831 (1904), *Electromagnetic phenomena in a system moving with any velocity less than that of light*, reprinted in *The Principle of Relativity*, 9-34, book first edition (Methuen, London, 1923), book reprint (Dover, London 1952); *The Theory of Electrons and its Applications to the Phenomena of Light and Radiant Heat*, first edition (Teubner, Leipzig, 1909), reprint (Dover, New York, 1952).
- [5] H. Poincaré, *Arch. Néer. Sci. Ex. Nat.* **5** (2), 252-278 (1900), *La théorie de Lorentz et le principe de réaction*.

- [6] H. Poincaré, *La Science et l'Hypothèse* (Flammarion, Paris, 1902); *C. R. Acad. Sci. Par.* **140** (5), 1504-1508 (1905), *La Dynamique de l'Électron*.
- [7] H. Poincaré, *La Valeur de la Science*, Chapt. VIII (Flammarion, Paris, 1905).
- [8] E.T. Whittaker, *A History of the Theories of Aether and Electricity*, v. 1. *The classical theories*, vol. 2. *The modern theories, 1900-1926* (T. Nelson & Sons, London, 1951, 1953), one-volume republication (Dover, New York, 1989).
- [9] S.J. Prokhovnik, *Z. Natur.* **48a**, 925-931 (1993), *The Physical Interpretation of Special Relativity – a Vindication of Hendrik Lorentz*.
- [10] T. Sjödin, *Nuov. Cim. B* **51** (2) 229-246 (1979), *Synchronization in Special Relativity and Related Theories*.
- [11] H. Reichenbach, *Axiomatization of the Theory of Relativity*, [b: 35] [c: 44-45] (Univ. of California Press, Berkeley, 1969), translated by M. Reichenbach, from *Axiomatik der relativistischen Raum-Zeit-Lehre* (Vieweg, Braunschweig, 1924); *The Philosophy Of Space And Time* [a: 126-127] [b: 125-127] [c: 126-127] (Dover, New York, 1957), translated, with omissions, by M. Reichenbach and J. Freund, from *Philosophie der Raum-Zeit-Lehre* (de Gruyter, Berlin, 1928).
- [12] G.F. FitzGerald, *Science* **13** (328), 390 (1889), *The Ether and the Earth's Atmosphere*.
- [13] E.F. Taylor and A.P. French, *Am. J. Phys.* **51** (10), 889-893 (1983), *Limitation on proper length in special relativity*.
- [14] J.B. Hartle, *Gravity: An Introduction to Einstein's General Relativity*, Chapt. 18, 19 (Addison-Wesley, San Francisco, 2003).
- [15] P.C. Peters, *Am. J. Phys.* **51** (9), 791-795 (1983), *Periodic boundary conditions in special relativity*; *ibid.* **54** (4), 334-340 (1986), *Periodic boundary conditions in special relativity applied to moving walls*.
- [16] C.H. Brans and D. R. Stewart, *Phys. Rev. D* **8** (6), 1662-1666 (1973), *Unaccelerated-Returning-Twin Paradox in Flat Space-Time*.
- [17] F.R. Tangherlini, *Nuov. Cim.* **109**, 929-951 (1994), *Light Travel Times around a Closed Universe*; *ibid.* **25**, 1081-1105 (1962), *Postulational Approach to Schwarzschild's Exterior Solution with Application to a Class of Interior Solutions*.
- [18] L.I. Schiff, *Phys. Rev. Lett.* **4** (5), 215-217 (1960), *Possible New Experimental Test of General Relativity Theory*; *Proc. Nat. Acad. Sci.* **46**, 871-882 (1960), *Motion of a Gyroscope According to Einstein's Theory of Gravitation*. Available on the Gravity Probe B website, respectively at: http://einstein.stanford.edu/content/sci_papers/papers/Schiff_PRL_Vol%204-215.pdf and http://einstein.stanford.edu/content/sci_papers/papers/Schiff_LI_1960_110.pdf.
- [19] J.P. Turneure, C.W.F. Everitt, B.W. Parkinson, et al., in *Proceedings of the Fourth Marcell Grossmann Meeting on General Relativity*, ed. R. Ruffini, 411-464 (Elsevier, Amsterdam, 1986), *The Gravity-Probe-B Relativity Gyroscope Experiment: Approach To A Flight Mission*. Available on the Gravity Probe B website, at: http://einstein.stanford.edu/content/sci_papers/papers/TurneureJT_1986_04.pdf.
- [20] A. Tartaglia, *Gen. Rel. Grav.* **32** (9), 1745-1756 (2000), *Geometric Treatment of the Gravitomagnetic Clock Effect*.
- [21] J.M. Cohen and B. Mashhoon, *Phys. Lett. A* **181**, 353-358 (1993), *Standard clocks, interferometry, and gravitomagnetism*.
- [22] Clear observation, of the dragging of inertial frames, by a rotating planet, from the rotational axis, as well as the experiment to observe light traveling faster prograde than retrograde, were disclosed to Dr. Bahram Mashhoon, in an April 21, 2005 telephone conversation; the clear, axial observation, of frame dragging, was also discussed, in an April 26, 2005 e-mail, sent to the same.
- [23] J. Kim and H-C. Lee, [gr-qc/0703091v6](http://arxiv.org/abs/gr-qc/0703091v6), *Black string and velocity frame dragging*.
- [24] R.W. Davies and H. Lass, *JPL Technical Memorandum no. 58* (1970); R.W. Davies, in *Experimental gravitation*, ed. B. Bertotti, 405-413 (Academic Press, New York, 1974).
- [25] I. Ciufolini and F. Ricci, *Class. Quant. Grav.* **19**, 3863-3874 (2002), *Time delay due to spin and gravitational lensing*; *ibid.* **19**, 3875-3881 (2002), *Time delay due to spin inside a rotating shell*.
- [26] C. M. Will, *Liv. Rev. Rel.* **9**, (2006), 3, URL (cited 11/17/08): <http://www.livingreviews.org/lrr-2006-3>, *The Confrontation between General Relativity and Experiment*.
- [27] J.B. Barbour and H. Pfister, *Mach's Principle: From Newton's Bucket to Quantum Gravity*, Vol. 6 of Einstein Studies (Birkhäuser, Boston, 1995).