RELATIVITY AND GPS

Ronald R. Hatch

(Section I: Special Relativity)

Introduction

The satellites of the global positioning system (GPS) travel around the earth in 12-hour periods in near-circular orbits. All of the satellites contain extremely precise atomic clocks whose rates depend both upon satellite velocity and altitude. An observer bound to the earth, in an airplane or in a satellite may determine his precise location by obtaining signals from several satellites simultaneously. This paper discusses the implications of GPS on Einstein's special theory of relativity. A subsequent paper will discuss the general theory.

"Relativistic" effects within the Global Positioning System (GPS) are addressed. Hayden [1] has already provided an introduction to GPS, so the characteristics of the system are not reviewed.

There are three fundamental effects, generally described as relativistic phenomena, which affect GPS. These are: (1) the effect of source velocity (GPS satellite) and receiver velocity upon the satellite and receiver clocks; (2) the effect of the gravitational potential upon satellite and receiver clocks; and (3) the effect of receiver motion upon the signal reception time (Sagnac effect) . There are a number of papers which have been written to explain these valid effects in the context of Einstein's relativity theories. However, quite often the explanations of these effects are patently incorrect. As an example of incorrect explanation, Ashby [2] in a *GPS World* article, "Relativity and GPS," gives an improper explanation for each of the three phenomena listed above.

The three effects are discussed separately and contrasted with Ashby's explanations. But the Sagnac effect is shown to be in conflict with the special theory. A proposed resolution of the conflict is offered.

The Sagnac effect is also in conflict with the general theory, if the common interpretation of the general theory is accepted. The launch of GPS Block II satellites capable of intersatellite communication and tracking will provide a new means for a giant Sagnac test of this general theory interpretation. Other general theory problems are reviewed and a proposed alternative to the general theory is also offered.

Velocity Effects upon the Clock Rates.

The fundamental question of velocity is always: "Velocity with respect to what?" Ashby, in the opening paragraph of his abstract, states:

> Important relativistic effects arise from relative motions of GPS satellites and users, ...

And Ashby also states, at the start of a section on time dilation:

> First, clocks in relative motion suffer (relativistic) time dilation,...

But these statements are patently untrue of GPS. It may appear to be a subtle difference, but it is very important to note that the GPS satellites' clock rate and the receiver's clock rate are ***not*** adjusted as a function of their velocity relative to one another. Instead, they are adjusted as a function of their velocity with respect to the chosen frame of reference—in this case the earth-centered, non- rotating, (quasi) inertial frame.

The difference is easy to illustrate. GPS receivers are now routinely placed on missiles and other spacecraft. Spacecraft receivers can be used to illustrate Ashby's error. For illustrative simplicity, let us assume two "Star Wars" spacecraft are equipped with GPS receivers. Let one of the spacecraft move in an orbit such that the spacecraft follows a GPS satellite at a close and constant separation distance. Let the second "Star Wars" spacecraft move in the same orbit but in the opposite direction. The nominal velocity of a GPS satellite with respect to an earth-centered non-rotating frame is about 3.87 kilometers per second. Using this frame, the computed clock rates should slow by:

$$f = f_0\sqrt{1-(v/c)^2} \qquad (1)$$

For low velocity compared to the speed of light, the change in frequency is approximated by $1/2\,(v/c)^2$. Using this expression, one obtains a frequency decrease of 8.32 parts in 10^{11} for GPS satellites. Now, consider the first "Star Wars" receiver, which is following the GPS satellite. Since it has the same velocity relative to the earth-centered non-rotating frame, its frequency will be reduced by the same amount as the frequency of the GPS satellite; and there will, therefore, be no apparent relativistic shift in frequency of the received signal. This is, of course, also what one would get using the special theory of relativity, since there is no relative velocity between the first "Star Wars" spacecraft and the GPS satellite.

However, for the second "Star Wars" spacecraft moving in the opposite direction in the orbit, the results are dramatically different. Relative to the earth-centered non-rotating frame, this second spacecraft's speed is no different than the speed of the first spacecraft or the speed of the GPS satellite. Thus, the expected frequency shift is the same 8.32 parts in 10^{11}. This means that, in the earth-centered non-rotating frame, there is no apparent relativistic shift in frequency between the second "Star Wars" spacecraft and the GPS satellite, even when the relative velocity between the spacecraft receiver and the GPS satellite is 7.74 kilometers per second (approaching each other at twice the orbital speed). But, if Ashby were right, the relativistic induced difference in frequency between this second "Star Wars" spacecraft and the GPS satellite would be 33.28 parts in 10^{11}. (Four times the amount a receiver stationary in the earth-centered non-rotating frame would see.)

Is this large discrepancy in expected frequency difference detectable? Not really. The special theory, in addition to claiming the frequency received is a function of the relative velocity, also claims that the speed of light is isotropic relative to the (observer) receiver; and the GPS system uses the earth-centered non-rotating frame and also assumes the speed of light is isotropic in that frame. Jorgenson [3], ironically calling upon work by Ashby, shows that, if one chooses a frame based upon the instantaneous velocity of the second "Star-Wars" satellite receiver, one gets exactly the same received-frequency difference when one combines the relativistic clock shift with the Doppler and aberration effects. Jorgenson makes the following statement:

> In considering alternative coordinate frames, the differences in special relativity exactly counterbalance those in classical Doppler. Einstein's special relativity is the great equalizer of coordinate systems. We are given the option of choosing the one most convenient to our needs, and in the case of GPS, this is an earth-centered inertial frame.

But Jorgensen confuses the special theory claims with the claims of the Lorentz ether theory. Indeed, many people claim that they are equivalent. However, as we shall see later, there is direct experimental evidence which supports the Lorentz ether theory over the special theory. Whenever a frame is chosen which does not coincide with the receiver or observer, experiment demands that the speed of light be treated as non-isotropic as far as the receiver or observer is concerned. But this is anathema to the special theory, since it is a direct contradiction of the special-theory teaching that the speed of light is always isotropic relative to the observer (Einstein's "convention" that the round-trip time of a light pulse is composed of two equal time intervals for the outgoing and incoming pulse). And it is this aversion to non-isotropic light speed, as we will see later, which is responsible for the myriad attempts to explain the Sagnac effect without admitting that it simply arises from the choice of an isotropic frame in which the receiver is moving.

Ashby is guilty of claiming that clocks run at a rate determined by their relative velocity. In fact, the rate at which clocks run must be computed using the clock velocity with respect to the chosen isotropic light-speed frame. This is consistent with the Lorentz ether theory but not with the special theory.

Gravitational Effects upon the Clock Rates

The experimental evidence shows that the gravitational potential affects: (1) the rate at which clocks run; (2) the speed of light; and (3) the size of physical particles. In order to demonstrate these effects without excessive use of mathematics, let us simply define a scale factor, s, slightly less than one, which is used to multiply or scale the parameter of interest. This scale factor is a direct function of, and can be computed from, the gravitational potential. The lower the gravitational potential the smaller the scale factor becomes. The scale factor is defined as:

$$s = \sqrt{1 - \frac{2GM}{rc^2}} \qquad (2)$$

where G is Newton's gravitational constant, M is the mass causing the gravitational potential, r is the distance from the center of the gravitational potential.

Consider first those experiments which show that clocks run slower the lower they are in the gravitational potential. The clocks run slow (measured time appears dilated) as compared to the rate at which they would run if they were located external to the gravitational field. The comparative clock rate is given in terms of the scale factor, s, defined above as:

$$f = sf_e \qquad (3)$$

where: f_e is the rate the clock would run if it were external to the gravitational potential

Several experiments show that clocks run slower the lower they are in the gravitational field. There are three evidences for this within the GPS system itself. First, the GPS monitor-station clocks demonstrate the effect. The monitor station at Colorado Springs runs faster because of its near mile-high elevation than it would run if it were located at sea level.

Second, the effect is also demonstrated by the reference clocks in the GPS tracking stations. The tracking stations provide the data which are used to compute the predicted GPS orbits for uploading and subsequent broadcast of the estimated GPS satellite position. It is observed that all clocks at sea level in an earth-centered non-rotating frame run at the same rate. A clock at sea level at the equator runs slower because of the earth's spin, but that same spin via centrifugal force causes the earth to assume an oblate shape so that the clock at the equator is located at a higher gravitational potential. At this higher gravitational potential, the clock runs faster per equation (3). The net result is that the velocity effect and the gravitational-potential effect exactly cancel, and the equatorial sea-level clock runs at the same rate as the polar sea-level clock.

The third GPS demonstration that clocks run slower in a lower gravitational potential is given by the GPS satellite clocks. The eccentricity of the GPS orbits causes the satellites to move up and down in the gravitational field. When the satellite is at perigee, it is closer to the earth, the gravitational potential is lower and the satellite speed is higher. The lower gravitational potential causes the satellite clock to run slower per equation (3), and the increased satellite speed also causes the satellite clock to run slower per equation (1). The two effects are exactly equal and add together to give the net change in the frequency of the satellite clock. At apogee the satellite is in a higher gravitational potential and the velocity of the satellite is lower. Each of the two effects causes the clock to run faster and again adds together to give the total change in the clock frequency. The integral of the clock-rate effect gives the net correction to the clock time. The cyclical-clock-time correction about the mean as a result of the orbital eccentricity is given by:

$$\Delta t = -4.42807633 e A^{1/2} \cos E * 10^{-10} \qquad (4)$$

where:: e is the eccentricity, A is the semi-major axis, and E is the eccentric anomaly.

The derivative of this equation gives the frequency as a function of the eccentricity, semi-major axis and eccentric anomaly. The effect of both the velocity and the gravitational potential is included.

There are a number of other experiments which have been performed which show the gravitational effect upon clocks. One of the better known experiments was the flying of atomic clocks around the world by Hafele and Keating [4]. In this experiment adjustment had to be made for the faster rate at which the clocks ran at the altitude of the aircraft on which they were ferried.

One other experiment is often directly cited as showing that clocks run faster at higher altitudes. Specifically, Pound and Rebka [5] showed that the gamma rays emitted from a radioactive source 22 meters above a tuned absorber of gamma waves was shifted to a higher frequency so that the resonant absorption was reduced. The amount of shift in the wavelength corresponded directly to that predicted by equation (3). However, this experiment is often explained, not in terms of a changed clock rate (frequency of emitted gamma rays), but instead as a change in the energy of the gamma waves as a result of their falling in a gravitational field. Which explanation is correct? They appear to be mutually exclusive. For, if the gamma waves are simply emitted with a higher frequency and shorter wavelength, no extra energy and additional shortening of the wavelength needs to be imparted as they fall in the gravitational field, else the effect would appear to be double that actually observed. In addition, an increase in the frequency due to the action of the gravitational field would violate the conservation of the number of cycles transmitted. All experimental evidence is that cycles are always conserved. The number received plus the number in transit must equal the number transmitted.

Ashby [2] calls upon the equivalence principle and uses an accelerating elevator to show that one would expect the wavelengths and frequency of photons to increase as they fall in a gravitational field. But this also violates the conservation of cycles and cannot be a valid explanation for the observed change in frequency. As with the Pound and Rebka experiment, there is direct evidence that clocks at a higher gravitational potential run just enough faster to explain the observed decrease in wavelength. No additional decrease in wavelength appears to be needed from the gravitational fall of the photons.

Do electromagnetic waves pick up energy as they fall in a gravitational field? If it does, why isn't the observed increase in frequency doubled and the conservation of cycles violated? The experiments of I. I. Shapiro shed some light on this question. Beginning in 1966, Shapiro [6] showed that the gravitational potential of the sun causes radar signals reflected back from Venus and Mercury to be delayed. The effect is strongest when Venus and Mercury are almost directly opposite the earth in their orbits. The amount of delay shows that the speed of light is decreased by two units of the scale factor. That is, the computed gravitational-scale factor described above affects the speed of light by the square of the scale factor—it is multiplied by the scale factor twice.

$$c = s^2 c_e \qquad (5)$$

where c_e is the speed of light external to the gravitational field.

Thus, we have direct and unambiguous evidence that the speed of light becomes slower as the gravitational potential is decreased. But, if such a decrease in the speed of light is locally undetectable and the clock rate used to measure that speed only counteracts one-half of the decrease in speed, then lengths must also contract in a decreased gravitational potential by the same scale factor as the clock rate. Thus, the two effects combine together to make the change in the speed of light locally undetectable. In fact, the bending of light near the sun also supports the decrease in length at lower gravitational potentials. The bending effect is twice that computed classically by the gravitational force upon the (mass equivalent) energy and is caused entirely by the speed-of-light velocity gradient. The length in a gravitational potential is given by:

$$l = s l_e \qquad (6)$$

where l_e is the length scale external to the gravitational field.

Now we can see that photons falling in a gravitational field do not increase in energy. Even though they do decrease in wavelength the frequency does not change. The apparent change in frequency is caused by the change in frequency of the local unit of comparison. Thus, claiming as Ashby did that the frequency of the GPS signals increase as they fall is incorrect. It would violate the conservation of cycles. The apparent gravitational increase in energy is not real. It appears to increase only because the standard of comparison (the energy radiated by a similar atom at a decreased gravitational potential) is decreased. The higher frequency of the GPS clock at its greater gravitational potential is in fact the source of the increased frequency and decreased wavelength of the received signal.

An expression has already been given in equation (4) for the clock-time variation due to the eccentricity of the orbit. But there is a bias change in the clock frequency of the GPS satellite clocks at the time of their launch. The change in the gravitational potential at the surface of the earth to the gravitational potential at the satellite orbital height causes an increase in the average rate at which the clock runs of 5.311 parts in 10^{10}. As stated in the first section, the speed of the GPS satellites in orbit causes a clock frequency decrease of 8.32 parts in 10^{11}. These two effects combine to give a net increase in frequency of 4.479 parts in 10^{10}. These two frequency-biasing effects and the additional small mean effects of the earth oblateness, sun and moon are compensated before launch by setting the frequency low by 4.45 parts in 10^{10}.

The Sagnac Effect

There are probably more conflicting opinions expressed about the Sagnac effect than any other "relativistic" effect. The review here of the Sagnac effect will be brief. The reader is referred to Hayden and Whitney [7] for a more comprehensive discussion of the effect. The most commonly held erroneous belief is that the effect is caused by rotation. Ashby states:

> In the rotating frame of reference, light will not appear to go in all directions in straight lines with speed c. The frame is not an inertial frame, so the principle of the constancy of the speed of light does not strictly apply. Instead, electromagnetic signals traversing a closed path will take a different amount of time to complete the circuit.

In point of fact, rotation is only incidentally involved with the Sagnac effect. The Sagnac effect is the result of a non-isotropic speed of light and arises any time an observer or measuring instrument moves with respect to the frame chosen as the isotropic light-speed frame. And it is here that the Sagnac effect runs into trouble with the special theory. The special theory by postulate and definition of time synchronization requires that the speed of light always be isotropic with respect to the observer. And this is where the special theory is in error—the Sagnac effect illustrates that error.

Since relativists do not like to admit that non-isotropic light speed exists, they attempt to explain the effect by other mechanisms. The most commonly referenced paper on the Sagnac effect is by E. J. Post [8]. He claims:

> Thus in order to account for the asymmetry [between the clockwise and counterclockwise beams] one has to assume that either the Gaussian field identification does not hold in a rotating frame or that the Maxwell equations are affected by rotation.
>
> All existing evidence for the treatment of non-reciprocal phenomena in material media points in the direction of modified constitutive relations, not in modified Maxwell equations.

Thus, Post claims the effect is caused by some underlying property of space which arises during rotation. As we shall see, this is an inadequate explanation. To his credit, Post also said:

> The search for a physically meaningful transformation for rotation is not aided in any way whatever by the principle of general space-time covariance, nor is it true that the space-time theory of gravitation plays any direct role in establishing physically correct transformations.

In this quote, Post clearly excludes the general theory as a source of explanation for the Sagnac effect.

But others have claimed the Sagnac effect is caused by acceleration and, thus, is properly handled by the general theory of relativity. Ashtekar and Magnon [9] give an analysis of the Sagnac effect within the general theory. Their development is very abstruse, but it appears that they get the Sagnac effect from rotation precisely because they do not get an isotropic velocity of light relative to the receiver at all times.

Another general relativity derivation of the Sagnac effect has been given by Deines in a paper titled "Missing Relativity Terms in GPS" [10]. Deines ascribes his results to a derivation by Nelson [11] for a rotating coordinate frame in a weak gravitational field. Deines gives an equation (9) which he says contains three missing relativity terms which arise due to the rotation of the earth. The last of the three terms is just the clock effect due to the receiver velocity. While he is correct that this last term is real, its effect in practice is insignificant. Since GPS receivers must solve for the clock time of the receiver in any case, they typically use low-quality internal clocks and any velocity correction due to their motion is below the clock frequency noise level.

Deines claims that the other two terms, together with a changed coefficient of the third term, give rise to the Sagnac correction. However, he uses two different integration limits to get his desired result. The integration limits used to recover the Sagnac effect are, in fact, magic—choose whatever limits are needed to recover the effect. Deines argues that the two terms are the derivative of the Sagnac effect and that their integral is therefore the Sagnac effect. However, the only way to get the effect by integration would be to collocate the receiver and satellite at the time of launch and to integrate from the time of launch of the GPS satellite to the present time instant.

To the extent the two additional clock-rate terms are real, they simple describe the time derivative of the Sagnac effect and are exactly what one obtains using classical means. But all high precision GPS applications correct for the Sagnac effect. Thus, contrary to Deines' claims, these relativistic correction terms are not missing. Again, like the Ashtekar and Magnon results, to the extent the results are valid, they simply indicate that within the general theory the speed of light is not always isotropic with respect to the moving observer; and, thus, they are in conflict with the special theory.

The presence of the Sagnac effect in the GPS system clearly shows that none of the explanations listed above are adequate, for the path of the radiation from the GPS satellite to the receiver clearly follows a straight line and the instantaneous velocity of the receiver, while due to the earth's spin, is not affected significantly by the radial acceleration during the instant of reception. This observation validates Ives' [12] claim that the Sagnac effect is not caused by rotation. In 1938 Ives showed by analysis that the measured Sagnac effect would be unchanged if the Sagnac phase detector were moved along a cord of a hexagon-shaped light path rather than rotating the entire structure. Thus, he showed the effect could be induced without rotation or acceleration. Let's assume we fly a GPS receiver on an airplane in a slightly curved path with respect to the earth's surface, such that its path with respect to the earth-centered non-rotating frame is a straight line of constant velocity. I know of no one who would argue that such a receiver would not be required to apply a correction for the Sagnac effect. The only way he could avoid applying a Sagnac correction would be to change the chosen frame of reference to his own inertial frame.

Furthermore, the general-theory results (assuming they have been properly derived) are in conflict with the special theory to the extent that they do not give isotropic light speed with respect to the moving observer. The conflict with the special theory is illustrated by comparing the derivation of the Thomas-precession effect with what that same derivation would give for a Sagnac effect.

Goldstein [13], in his development of the Thomas precession, states:

> Consider a particle moving in the laboratory system with a velocity *v* that is not constant. Since the system in which the particle is at rest is accelerated with respect to the laboratory, the two systems should not be connected by a Lorentz transformation. We can circumvent this difficulty by a frequently used stratagem (elevated by some to the status of an additional postulate of relativity). We imagine an infinity of inertial systems moving uniformly relative to the laboratory system, one of which instantaneously matches the velocity of the particle. The particle is thus instantaneously at rest in an inertial system that can be connected to the laboratory system by a Lorentz transformation. It is assumed that this Lorentz transformation will also describe the properties of the particle and its true rest system as seen from the laboratory system.

Thus, with the help of this additional postulate, acceleration within the special theory can be handled by successive infinitesimal Lorentz transformations (Lorentz boosts). These Lorentz boosts give rise to the Thomas precession because successive Lorentz transformations combine to form a single Lorentz transformation plus a coordinate rotation. But, if we apply the same logic to the Sagnac experiment, no Sagnac effect can be expected. Specifically, since the detector is always in an instantaneous inertial frame (with isotropic light speed), the velocity of light arriving at the detector from both directions ought to be the same at all times.

An Alternative to the Special Theory

We are left with a problem. The special theory, at least as amended for accelerations, clearly disagrees with the Sagnac results. In addition, the velocity effects were also inconsistent with the special theory in that they depended on the velocity relative to the earth-centered frame rather than the velocity of the receiver relative to the source, as the special theory predicted. Solutions have been offered which rely upon ether-drag hypotheses, in which the speed of light is isotropic with respect to the earth's gravitational field or the earth's gravitational potential or the earth's magnetic field. At one time I thought that ether drag proportional to the earth's gravitational potential was a viable solution. However, Charles M. Hill brought to my attention data from VLBI experiments which could not be reconciled with the ether-drag hypothesis. More recently, Hill [14] has shown, via an analysis of millisecond pulsar data, that clocks on the earth have cyclic variations due to the eccentricity of the earth's orbit around the sun. The component of this clock variation due to the earth's orbital velocity clearly indicates that the earth does not drag the surrounding ether with it. Thus, while it is still true we cannot measure the absolute ether drift caused by the earth's orbital motion, we can now measure the variation in the ether-drift velocity.

There is, in my opinion, only one valid alternative to the special theory consistent with the experimental evidence. Specifically, the Lorentz ether theory offers a valid alternative. Many have claimed that the Lorentz ether theory is distinguished from the special theory only by metaphysical considerations. However, as we shall see, such is not the case. Figure 1 is a schematic illustrating the relationship between the Lorentz ether theory and the special theory. On the right-hand side, the frame defined by the cosmic background radiation (CBR) is designated by a circle. This is assumed to be the absolute ether frame for the Lorentz ether theory. It is just another frame for the special theory. In the middle of the figure, a circle designates the earth-centered frame with non-isotropic light speed. The Mansouri and Sexl (MS) [15] transformation is used to map experiments from the isotropic CBR frame to the earth-centered non-isotropic frame. (I will refer to the transformation as the MS transformation, however, it was earlier described by Tangherlini and later its inverse and composite transformations by Selleri.) The MS transformation is designated by the line connecting the two circles. The MS transformation accounts for both clock slowing and length contraction as a function of the speed relative to the CBR frame. Unlike the Lorentz transformation, the MS transformation is reciprocal rather than symmetrical. Thus, an observer in the earth-centered non-isotropic frame would see clocks run faster and lengths expanded in the CBR frame. The MS transformation is nothing more than a Galilean transformation adjusted for clock slowing and length contraction effects. The MS transformation preserves an absolute simultaneity of time.

On the left-hand side, a circle represents the earth-centered frame with isotropic light speed. The special theory says that this frame can be directly related to the CBR frame with isotropic light speed via a Lorentz transformation. This transformation is indicated by the horizontal line connecting the two circles.

But there is another line which connects the earth-centered non-isotropic frame with the earth-centered isotropic frame. This line represents Poincare's principle. Poincare's principle states that, if lengths are contracted and time slows down as a function of the velocity relative to the absolute frame, then there is no way via experiment to distinguish between the non-isotropic ether frame and the isotropic frame. (Common means to synchronize clocks within the frame lead to clock biases which make the speed of light appear isotropic.) Thus, one is lead to the same Lorentz transformation via the two upper paths of Figure 1 in the Lorentz ether theory. Specifically, the MS transformation and Poincare's principle (clock biasing) together validate the Lorentz transformation.

Thus, we can arrive at the Lorentz transformation via two different paths; but the interpretation of the transformation is profoundly different for the two paths. The special theory says one must always transform to the observer's frame so that the speed of light is always isotropic with respect to the observer. In fact, the special theory claims that light in transit is automatically transformed to the new frame. By contrast, the Lorentz ether theory says that any inertial frame we wish can be used as the isotropic light-speed frame—we simply cannot tell which frame is the true frame. But, whichever frame is chosen as the isotropic frame, that frame defines an absolute simultaneity and observers moving with respect to that frame see non-isotropic speeds of light. Since the Lorentz ether theory corresponds to an absolute ether theory (we simply do not know which inertial frame is the absolute frame), we are not free to change frames in the middle of an experiment. Thus, Lorentz boosts, which are valid in the special theory, are invalid in the Lorentz ether theory.

The difference in the two theories can be clearly illustrated via their interpretation of the famous twin paradox. Let Stella move away from Terrance at 0.6 times the speed of light for two years per her own clock, turn around (instantly) and travel back at the same speed. We will find that Terrance's clock will read 5 years when Stella returns and her own clock will read only 4 years. If we put a video camera on Terrance's clock, transmit it to Stella, have Stella show it on a video monitor next to her own clock and then video record the two clocks, we will have a record of the combined effect of clock rate and Doppler shift (transit time) between the two clocks.

This record will show that, for the first two years, the video of Terrance's clock as shown on Stella's monitor will appear to be running one-half as fast as her own clock. Thus, his clock will be reading one year on her monitor when she turns around. But, for the next two years as she journeys back, Terrance's clock will appear to run twice as fast on her monitor as her own clock. Thus, while her own clock reads two years plus two years when she returns, Terrance's will read one year plus four years when she arrives back.

As expected per Poincare's principle and the Lorentz ether theory, the video recording of the clock rates is consistent with the choice of any absolute frame. Figures 2, 3 and 4 show the Minkowski diagram for the choice of (1) Stella's initial frame, (2) Terrance's frame, and (3) Stella's final frame respectively. The magic of relativity is illustrated by appending the first half of Figure 2 with the second half of Figure 4 and is shown in

Figure 5. The special theory says that, as Stella accelerates, the signal in transit spread out over 1.5 light years with a source Doppler which doubles the wavelength of the signal in transit (Figure 2) has to be modified so that the signal in transit has a source Doppler which cuts the wavelength in half (Figure 4). This magic is theoretically accomplished by changing the time history of the signal in transit. The farther away the signal, the more its history (time change) has to be modified. While the Lorentz ether theory says simply pick a frame for the whole experiment and let the speed of light be non-isotropic for at least one portion of the trip, the special theory resorts to magic so that the speed of light can always be isotropic

The Sagnac effect is very simple to explain in the Lorentz ether theory. It is not a direct result of rotation or acceleration. It simply arises any time the receiver is moving with respect to the chosen isotropic light-speed frame. (The only unique feature of rotation is that one cannot pick the observer as the isotropic frame because of the observers acceleration.) If the receiver is moving in the chosen absolute frame, the speed of light is not isotropic; and the Sagnac effect is simply the adjustment for the non-isotropic light speed. It is easy to show that Sagnac's original rotating experiment will give the same results (in agreement with his experiment) independent of the choice of absolute isotropic frame. By contrast, the experimental evidence is loud and clear: It is not valid to perform instantaneous Lorentz boosts per the special theory to keep the speed of light isotropic with respect to the Sagnac phase detector. The Sagnac effect on GPS signals in transit proves that the special theory magic does not keep the light speed isotropic relative to the moving receiver..

Our objective has been met. There is more than a metaphysical difference between the Lorentz ether theory and the special theory. The Sagnac effect clearly argues in favor of the Lorentz ether theory. But, it must be admitted, a new problem has been created. If Lorentz boosts are not valid, the standard explanation for the Thomas precession of the electron has been invalidated. And, since the general theory did not support the special theory with regard to the Sagnac effect, it cannot be expected to give an alternate derivation of the Thomas precession. What is the solution? I have shown elsewhere [16], that Thomas precession can be explained by unbalanced length contraction and mass increase when one part of a spinning object adds to the velocity of translation while another part subtracts. If the spinning object is then accelerated along its spin axis it will experience a torque. Note that this explanation is valid only for spinning objects while the special theory claims the effect occurs on all accelerated objects.

Finally, the claim that Lorentz boosts are invalid is also supported by the aberration of the light from binary stars. Whitney [17] has developed this topic in some detail.

Conclusion

The three relativistic effects which must be considered in GPS have been addressed. The gravitational effects are consistent with the general theory of relativity, even though inadequate explanations are often provided. The effect of velocity on the rate at which clocks run is not consistent with the special-theory predictions that it should be a function of relative velocity between source and receiver. In addition, the presence of the Sagnac effect is itself inconsistent with the special theory. It was shown that the Lorentz ether theory provides a better explanation of the GPS relativistic effects than does the special theory.

In a second paper, we shall show that a modified Lorentz theory, with an elastic compressible ether in which material particles are standing waves, is capable of replacing the general theory and resolving some of the existing problems with the general theory.

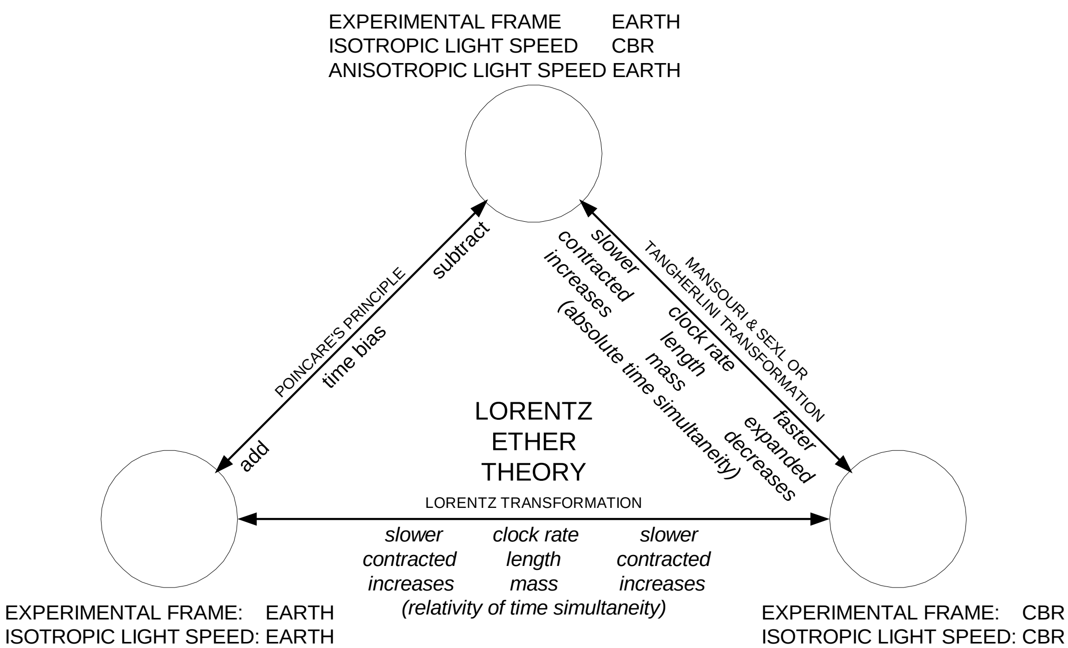

Figure 1 The Relationship between Lorentz ether theory and the special theory

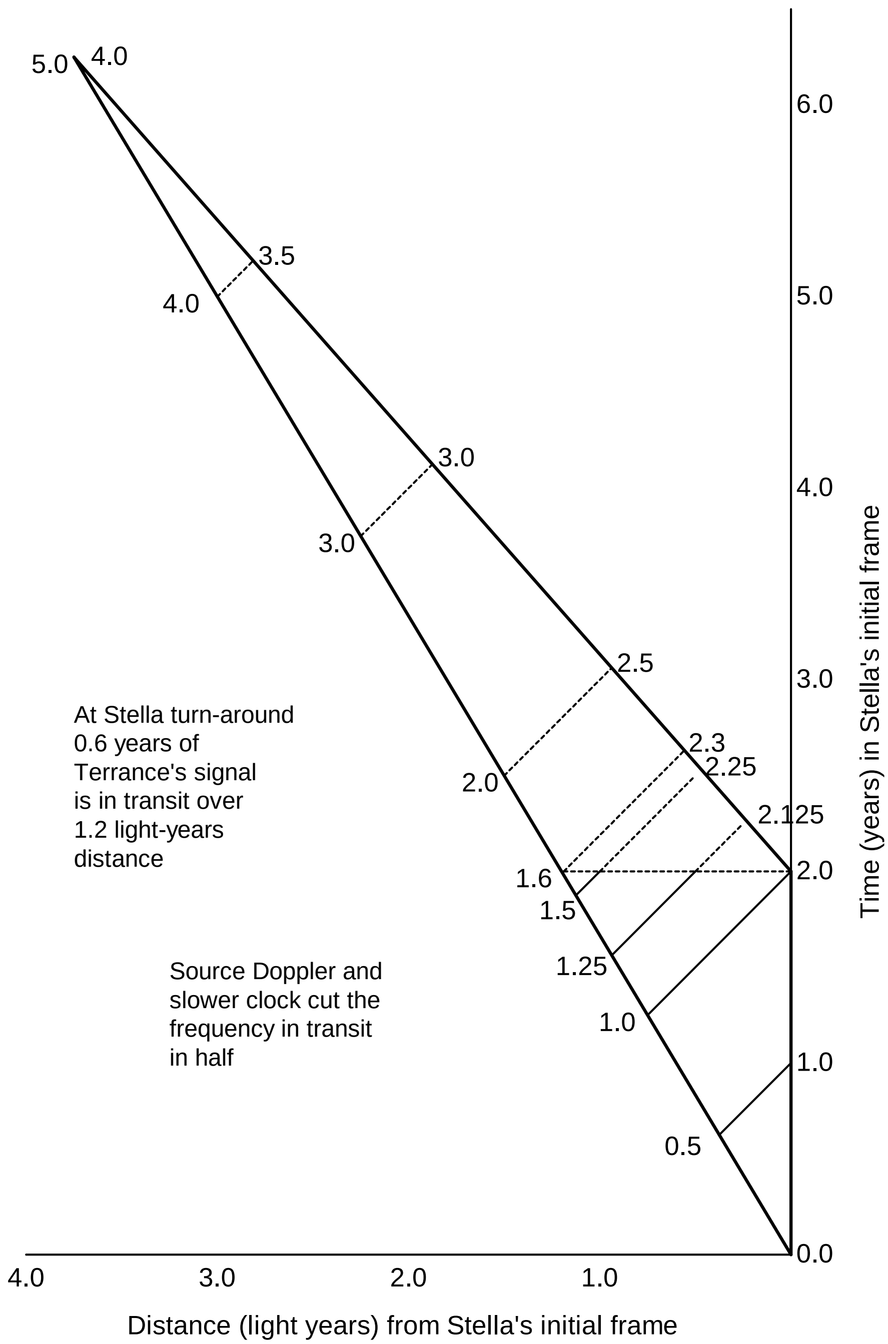

Figure 2: Minkowski diagram for Stella's initial frame

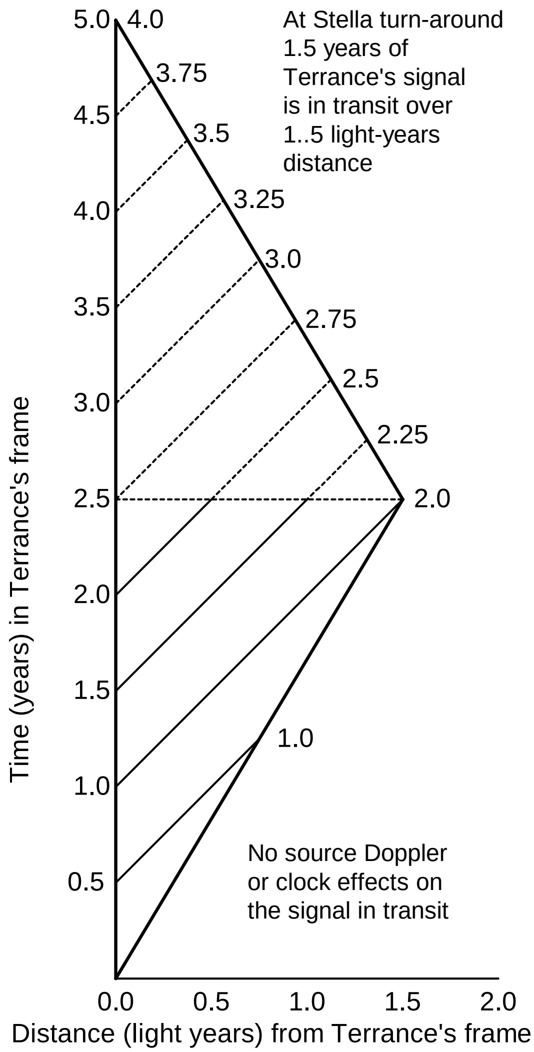

Figure 3: Minkowski diagram for Terrance's frame

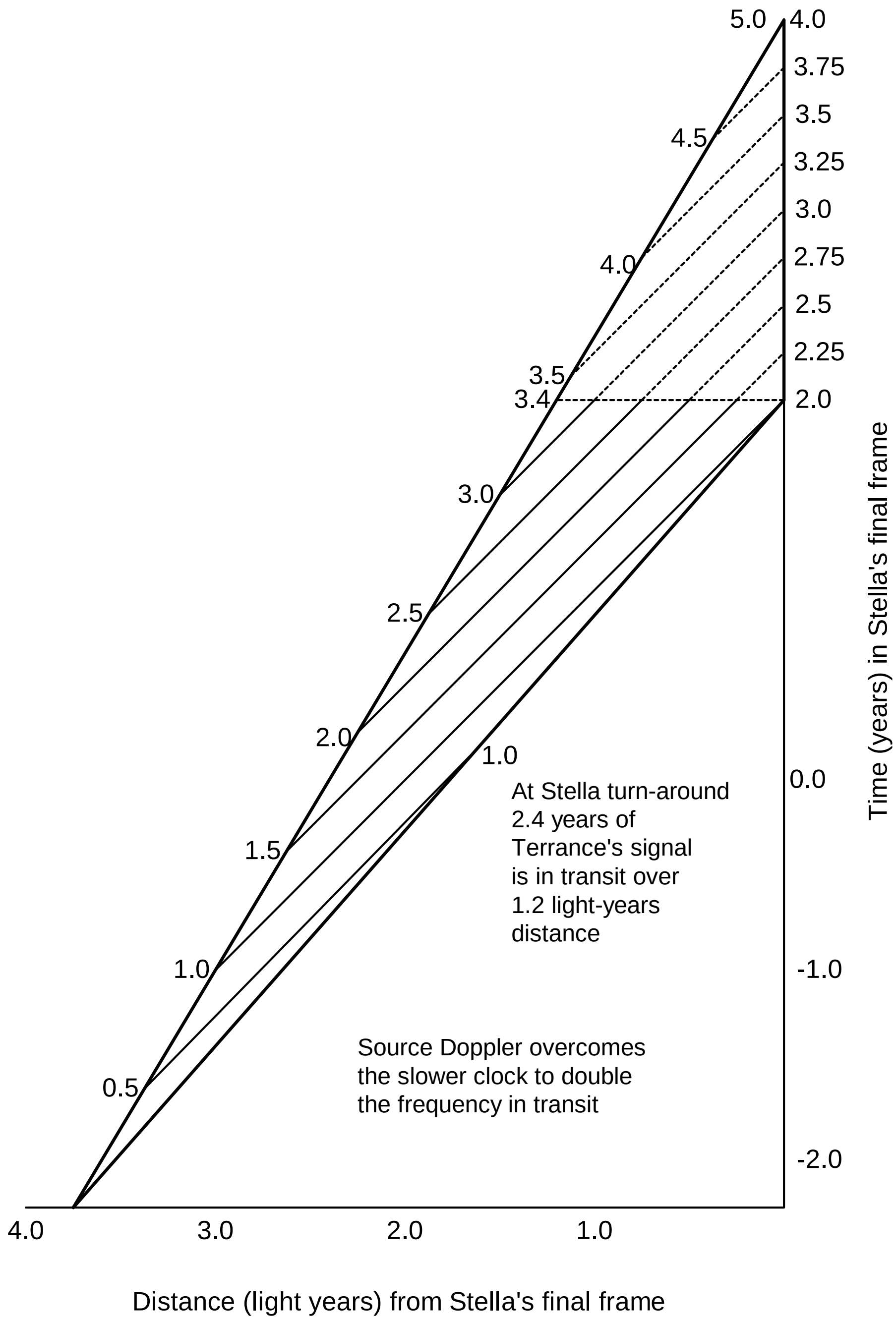

Figure 4: Minkowski diagram for Stella's final frame

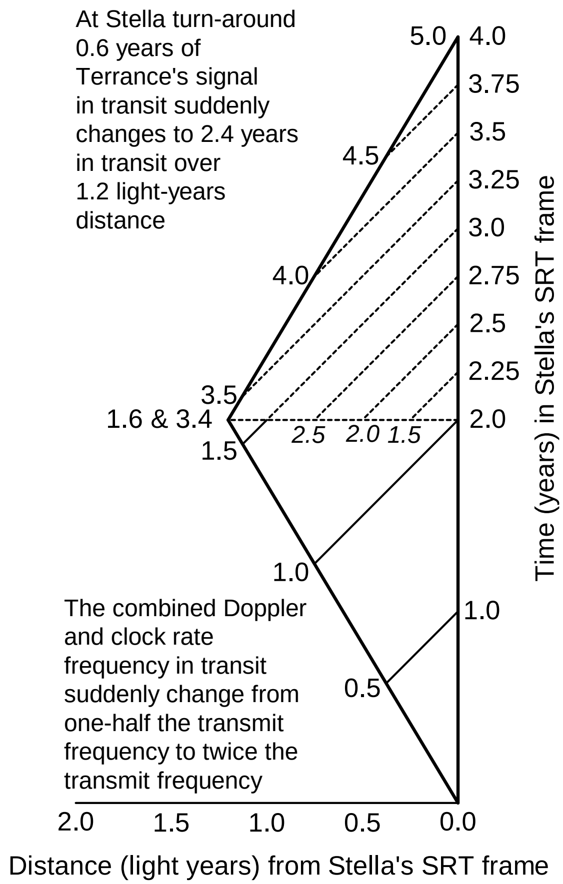

Figure 5: Minkowski diagram for Stella's SRT frame

RELATIVITY AND GPS — II

In the first paper we showed that the global positioning system (GPS) strongly supports the Lorentz ether theory over that of Einstein's special theory. In this second paper, we take a close look at several problems with the general theory. Particular attention is focused on the claim of the general theory that an object in free-fall is not acted upon by any forces and, hence, defines its own Lorentz frame. One aspect of this claim can be refuted by the new GPS satellites which are capable of inter-satellite tracking. A modification of the Lorentz ether theory is proposed which resolves the general theory problems. In addition, the new theory predicts experimental results at variance with the general theory for several experiments to be performed in the near future.

Introduction

GPS clock and Sagnac effects were dealt with in the first paper. In that paper we also dealt with the gravitational-potential effects upon the rate at which a clock runs. As we saw, Ashby's explanation of the decreased wavelength of signals sent from the satellite improperly ascribed the decrease to the falling of photons in a gravitational field. However, even though his explanation was clearly incorrect, the results were still in agreement with the general theory when a correct explanation was found. In this paper we focus upon several real problems with the general theory—some acknowledged as problems and some not. The claim that the earth in free-fall defines its own Lorentz frame may be refuted by the GPS system in the near future. The launch of the new GPS Block II satellites, capable of inter-satellite tracking, I believe, will provide evidence that the general theory is incorrect—at least as it is generally interpreted.

To solve the problems with the general theory, a solid elastic ether is proposed and is shown to be compatible with the Lorentz ether theory. This modified Lorentz ether theory is a natural gauge theory and provides some simple explanations, as well as providing some interesting insight into several puzzling aspects of modern physics.

Problems with the General Theory

There are at least four apparent problems with the general theory. Each will be described briefly. First, Yilmaz [18] claims that the equations of the general theory predict that no attractive force will be present between two parallel plates of infinite extent. Most physicists believe that, if this is so, it represents a failure of the general-theory equations.

Second, the general theory claims that space is curved due to the presence of energy. But, as Schwarzschild [19] shows, the zero-point energy of vacuum fluctuations is so large that, per the general-theory equations, space should have a curvature at least 120 powers of 10 greater than that actually observed.

Third, Shapiro and Teukolsky [20] show that a football-shaped distribution of mass can collapse in such a way that, if the general theory is correct, a gravitational singularity (infinite force) can be formed which is not inside of a black hole. This means that the singularity should cause infinite forces on matter external to the singularity. Very few physicists believe in infinite sources. Furthermore, prior to Shapiro and Teukolsky's demonstration, almost all believed in "cosmic censorship", i.e. that all such singularities were inside black holes where they could safely be ignored.

Fourth, it is the claim of most general-theory specialists that a freely falling object in a gravitational field can always be described in its own Lorentz frame, i.e. that no force of acceleration acts on the frame. This has several implications.

An Alternative to the General Theory

Each of the above problems will be addressed at least briefly. But, first, an alternate theory based upon an elastic solid ether is proposed. This alternative is compatible with the Lorentz ether theory and extends it to gravitational phenomena.

Our first assumption is that matter is composed of ether standing-wave structures. There are a number of experiments which support such an assumption. But, for the present development, it is simply a presupposition. See, for example, the model of the electron proposed in *Escape from Einstein* [21]. Because of the spin and the nonlinearity of the ether elasticity, such dynamic distortions cause a net decrease in the ether density within the standing-wave structure and an associated increase in the ether density outside the standing-wave structure. The decrease in the internal ether density is associated with the particle's mass, and the increase in the external ether density is associated with the particle's gravitational potential.

The effects of gravitational potential described above can be easily matched to the effects of ether density. If we assume a classical relationship between density and (longitudinal) waves of distortion in a solid, i.e. the speed of light is inversely proportional to the square root of the density, it is clear that the effects of mass on the external ether density must be given by:

$$\rho = \frac{\rho_e}{s^4} \approx \rho_e\left(1 + \frac{4GM}{rc^2}\right) \qquad (7)$$

where ρ_e is the ether density external to the gravitational potential, and s is the scale factor defined in equation (2)

This equation shows that the expected change in ether density (gravity potential) is proportional to the inverse of the radial distance. Thus, the excess ether density induced by the mass of the particle is allocated approximately linearly between all the spherical shells surrounding the particle, with the closest having the least excess ether. But, because the nearby shells of the same thickness have smaller volume (by the square of the radius), the increase in density in the nearby shells is larger. This is simply another way of saying that the compressive pressure of the ether has reached a steady state value.

All physical units can be expressed in terms of a local scale (gauge) of length, time and mass. Only the mass as a function of gravitational potential has not already been determined directly from experiment. There are heuristic arguments which can be made; but, again, for brevity, let us simply assume that the mass as a function of gravitational potential is given by:

$$m = \frac{m_e}{s^3} \qquad (8)$$

where m_e is the mass external to the gravitational potential.

Equations (3), (6) and (8) describe the local gravitational gauge of the three fundamental units. (The time scale is the inverse of the frequency scale given in equation 3.) All other units of measurement can be described locally in terms of these fundamental units. This scale or gauge development of the effects of gravitational potential (ether density) reveals several fascinating insights. For example, it becomes immediately apparent that the source of gravitational potential energy is the decrease in rest-mass energy with decreased gravitational potential. This decrease in rest-mass energy results from the change in gauge of the speed of light and of mass. All presently verified effects of gravity are consistent with this simple model of elastic-ether gauge effects.

Before pursuing the differences between this gravitational gauge theory and the general theory of relativity, it is instructive to relate this solid elastic-ether model to the Lorentz ether theory. The velocity gauge effects are easiest to explain in two separate steps: an energy-free step and an energy-dependent step. First, assuming particles are (spinning) standing waves of disturbance in the ether, the structural integrity is maintained by the propagation of disturbances at the speed of light from any one portion of the structure to the other portions of the structure. An unchanged energy for the structure can result only if the size of the structure is adjusted so that the average time for a disturbance in one part of the structure to affect other portions of the structure remains unchanged as the velocity is changed. This demands that the structural size be reduced in each dimension by the mean two-way change in the velocity of light. Thus, if we define a scale factor, γ, which is greater than one and given by

$$\gamma = \frac{1}{\sqrt{1 - v^2 / c^2}} \tag{9}$$

we find that the transverse dimensions of the standing-wave particles are reduced by $1/\gamma$ and the longitudinal dimension is reduced by $1/\gamma^2$. The only change to the particle caused by the apparent change in the speed of light relative to the moving structure is the size of the particle. Its energy and mass remain unchanged.

The second step in relating the elastic-ether theory to the Lorentz ether theory is to describe the energy-dependent changes which must occur. First, as stated above, mass is related to a local reduction in ether density inside the particle structure. The gravitational effect of a mass can be equated to a spherical volume of radius GM/c^2 in which the ether is completely excluded, i.e. a "vacuum ball." (The gravitational radius of the earth is 0.45 centimeters.) But, if we were to move such a mass, it is clear that the reaction rate of the ether would cause the moving "vacuum ball" to become larger (by the factor γ), because the reaction rate of the ether around the ball can move only at the speed of light. But the larger effective size due to movement, without a corresponding increase in the speed of light, means that length, time and mass will become dilated as compared to the same stationary particle.

When we combine the two steps described above, we match the two critical factors associated with the Lorentz ether theory. Specifically, the dimension of a particle moving through the ether shrinks by the factor $1/\gamma$ in the longitudinal dimension but is unchanged in the transverse dimensions. Time is dilated by the factor γ. While it is not required to match the Lorentz ether theory, mass is increased by the factor γ.

Addressing the Problems

Finally, the structure is in place to address individually the problems with the general theory mentioned above. First, we address the "Yilmaz" problem. Yilmaz has claimed that the general theory predicts that no gravitational attraction would exist between two infinite (very large size compared to thickness) parallel plates of mass separated by a small distance. Charles Misner and William Unruh [18] have reportedly taken up the challenge to explain such "strange" behavior. But why is the non-attraction considered strange? The elastic ether theory also predicts non-attraction from two infinite parallel plates. Since all shells (plates) surrounding the two plates have the ether compressed by equal amounts, there is no ether gradient and, hence, no force on either plate—once the ether density is equalized between the outside and inside portions of the two plates. Since finite plates should exhibit reduced gravitational attraction, the effect may be subject to experimental confirmation.

The second problem with the general theory—the expected huge curvature of space due to the huge energy of "zero point" oscillations in the vacuum (ether)—is easily resolved by the ether-gauge theory and is quite similar to the prior solution. Yes, energy causes a compaction of the surrounding ether. But the "curvature of space" arises from the gradient of the ether density. Thus, a uniform energy density, such as is caused by the "zero point" oscillations, does not result in any curvature, i.e. there is no ether-density gradient.

Shapiro and Teukolsky demonstrate a real hole in the general theory (the third problem mentioned above). But the same problem does not arise in the ether-gauge theory. When the ether-density model is employed, it becomes evident that black holes and infinite gravitational fields simply cannot exist. If a massive body were to shrink in size due to gravitational attraction such that it approached its "gravitational radius," the ether would be completely excluded from inside that radius; and, since particles are standing waves in the ether, they could not exist inside the black-hole radius. And as shown in a recent paper [24] the gravitational force is self-limiting so that black holes cannot form. Presumably two very dense neutron stars colliding would largely disintegrate into electromagnetic radiation. Even more intriguing, such disintegration radiation may be the source of the strange gamma-ray bursts, which seem to be of intergalactic origin. Tsvi Piran [25] presents a convincing argument that gamma-ray bursts are the result of colliding neutron stars. Per the general theory, such collisions are expected to be a significant source of gravitational waves; and the eventual detection of such waves in coincidence with gamma-ray bursts, Piran says will confirm his diagnosis. However, the modified Lorentz ether theory yields two significant differences from Piran's predictions.

First, the modified Lorentz theory predicts that colliding neutron stars will not form a black hole. Instead, the neutron stars would presumably explode in a gigantic burst of radiation, in which a significant percentage of the mass would be converted into radiation. This expectation actually is supported by Piran's data. He indicates that only a small percentage of the neutron binaries' energy would be needed to generate the observed gamma-ray bursts. However, it is clear from the mechanism which he proposes (and the associated figure) that such radiation would be far from isotropic. A directional beam of radiation, similar to the radiation from the neutron pulsar itself, could be expected. But this, in turn, would imply that only a small percentage of the colliding neutron binaries in the observable universe would emit gamma-ray bursts in the direction of the earth. But, from Piran's calculations, the *Compton Observatory* apparently sees every neutron binary collision in its field of view. This strongly suggests a near isotropic generating mechanism.

The modified Lorentz ether theory also indicates that gravitational waves are nothing more than electromagnetic waves [22]. The clear prediction of the new theory is that gravitational radiation will never be detected. Thus, Piran's coincidence test will never be executed.

The fourth and last problem with the general theory mentioned above is the claim that no force of acceleration acts on a freely falling frame. From this claim many other claims arise. As one example, Kip Thorne [26] claims, while discussing Stanford's Gravity Probe B experiment, that a body orbiting the earth, since it is in free fall, will not experience any Thomas precession. (Since our model ascribes the torque causing the Thomas precession to a spin velocity induced mass imbalance, gravity which acts on mass directly will not cause a precession—not because it is not a force but because it acts on the center of mass.) Stanford's Gravity Probe B experiment involves the launching of an extremely precise gyroscope into earth orbit. The launch is currently planned for about the year 2000.

The Sagnac Effect Again

However, the claim, which we are most interested in pursuing here, is that the Sagnac effect should not exist in a freely falling frame. In a rather thorough review of the Sagnac effect, Anderson, Bilger and Stedman [27] make the following statement:

> Incidentally, the final suggestion of Michelson [21], that the orbital motion of the Earth around the sun be detectable in a sufficiently gargantuan ring interferometer, is not consistent with general relativity: a freely falling point object (the whole earth in this context) defines a local Lorentz frame.

This is a rather amazing statement. I know of no way to interpret it other than as a claim that the Sagnac effect cannot be used to detect the approximately one degree of earth rotation per day which is related to the earth's orbital motion. But, if this rotation is undetectable, the measured rotation (Sagnac experiment fixed to the earth) with this component removed must become the rotation per a standard 24-hour day rather than the rotation per sidereal day. The implication, as Howard Hayden [28] points out, is that, if true, a Sagnac experiment using the inter-satellite communication links of the newer GPS satellites should yield a null result when computed relative to a frame rotating at a rate of once per year. There is no reason that this experiment cannot be performed in the near future, when a sufficient number of the new GPS satellites with inter-satellite communication and ranging capability are in orbit. But there is already evidence that the statement is untrue.

Let us look at the proposed experiment more closely. It turns out that the critical concept is time versus clocks. If time is slowed by decreased gravitational potential, Anderson et al. are interpreting the general theory correctly; and, in fact, no Sagnac effect should be measured. On the other hand, if clocks simply slow down as a function of the decrease in gravitational potential and a universal flow of time, independent of local clock measurements, exists, then clearly the proposed Sagnac experiment can be used to measure the angular rotation due to the orbiting earth. Note that the equations for an elastic solid ether are virtually identical with the general theory equations. However, just as with the Lorentz transformation, the ether interpretation is substantially different. The general theory ascribes a change in the rate at which clocks run to a change in the flow of time. By contrast, the ether theory ascribes the clock rate-change to an environmental effect.

But it is not difficult to illustrate that treating the whole earth as a point object and, hence, a single local Lorentz frame poses some problems. Several cases of four distinct objects in free-fall orbit about the earth can be used to illustrate one of them. First, let's impart a position and velocity to the four objects such that they all have the same orbital period; but two are in a perfect circular orbit, one slightly behind the other. One of the two remaining is placed slightly above the two that are in circular orbit, and one is placed slightly below. Approximately 1/4 of an orbit later they will all have the same orbital distance from the earth, and 1/2 an orbit later the above and below objects will have interchanged their position. But the other two will remain in their same relative position. There is no transformation, Lorentz or otherwise, which will properly map the changing relationship of these freely falling objects.

To illustrate the problem further, if the objects above and below the two in circular orbit are given the exact velocity such that they are also in precise circular orbits, their orbital periods are changed such that the particles diverge from each other—not a very useful Lorentz frame.

Finally, let's attach the four particles to each other. If they are all balanced in weight, assuming no rotation, the four particles will orbit the earth; but the particular particle farthest from the earth will change (i.e. no rotation in an inertial frame) as the combined object passes through each quadrant of the orbit. This is clearly not an acceptable Lorentz frame, since the direction of the velocity vector is constantly changing relative to the four particles, which define the frame.

But what if the four particles are attached to each other and the upper and lower particles are made heavier than the other two? Now there is a gravity gradient or tidal *force* (sorry, Anderson et al. to use the word 'force'—would you rather describe the effect as a force-free divergence of the acceptable Lorentz frames?) which causes the four objects to maintain their same relative positions with respect to the earth. The moon in orbit around the earth illustrates this arrangement by keeping the same face directed toward the earth. Now this gravity-gradient stabilized frame has some interesting characteristics. The objects do maintain the same constant orientation with respect to the common velocity vector. And it is not difficult to show that the gravity gradient and differential velocity are precisely such as to cause all identical clocks located anywhere upon such a composite object to run at the same rate. Saying this another way, the earth's gravitational gradient and the orbital velocity gradient of the moon are such that their effect on any clock located on the moon exactly cancels (in an earth-centered frame). This is shown below.

The change of the clock rate with respect to a radial change in the distance from the gravitational source is given by the derivative of equation (3). Specifically, the effect of the gravitational gradient upon the clock rate is:

$$\frac{df}{dr} \approx \frac{GM}{r^2c^2} \qquad (10)$$

The orbital velocity at any point on a gravity-gradient stabilized object is given by, $r\dot{\theta}$. Substituting this expression into equation (1) and taking the derivative gives:

$$\frac{df}{dr} \approx -\frac{r\dot{\theta}^2}{c^2} \qquad (11)$$

But, for a circular orbit, the value of $\dot{\theta}^2$ is given by $\frac{GM}{r^3}$; and, when this is substituted into equation (11), it becomes clear that the two clock-rate effects cancel.

In conclusion, as far as clocks are concerned, it appears to be valid to claim that the earth, or any object in free fall, can be treated as occupying its own local Lorentz frame—at least if it is in a circular orbit. But, as already mentioned, Hill has shown, using external pulsar timing sources, if the object is not in circular orbit, the local clock rate will vary as a function of the changing gravitational potential and orbital velocity. Clearly, this is behavior different from an unaccelerated frame. In addition, according to the elastic-solid extension of Lorentz's ether theory, it is the clock behavior which is changed, not time. Thus, we can still expect to detect the Sagnac effect caused by the orbital rotation of the frame.

Now let's look directly at what our elastic-ether theory predicts for a GPS-based Sagnac experiment around the earth. Can it detect the angular rotation due to the earth's orbit of approximately 1^0 per day? It is easier to show the expected result if we modify our Sagnac experiment a bit. Specifically, let us use a wedge-shaped light path and send the two beams in different directions around only 1/2 of the total path. As shown in Figure 1, the light source will be at about the mid-point of the left side of the wedge, and the phase detector will be at about the same position on the opposite side. Because of the small size of the light path as compared to the total orbit, it is valid to approximate the outer leg of the light path as a segment whose length is $r_o\theta$ and the inner leg of the light path as a segment of length $r_i\theta$. The light source will be positioned such that the two light beams arrive at the start of the outer and inner segments of the light path at the same time. Similarly, position the detector such that, if the light beams arrive at the end of the outer and inner segments at the same time, they will arrive at the detector at the same time. Thus, our Sagnac detector simply measures the relative amount of light-travel time across the outer and inner light paths. Clearly, the light-travel times must be equal, if this detector is to rotate through an entire circle in one year without detecting any motion.

But it is not difficult to show that the outer light path is longer than the inner light path, even when the paths are adjusted for the gravitational potential effect on the speed of light. This can be shown easily by simply dividing the two distances by the respective light speed given in equation (5). Thus, it is the clear prediction of the ether theory that a Sagnac experiment using cross-linked GPS satellites should be capable of refuting the Anderson et al. prediction of the general theory.

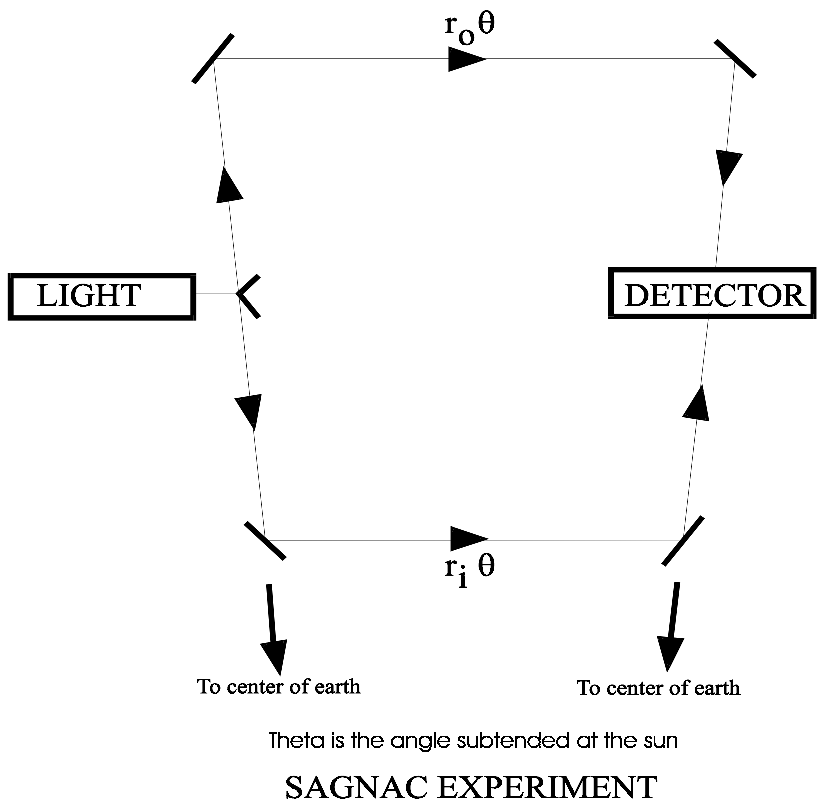

Figure 1 Around the World Sagnac Experiment

But there is already experimental evidence that the prediction is incorrect. Ironically, in the very same paper, Anderson et al. point out how precise current Sagnac gyroscopes have become. In fact, the third author of the paper, Stedman, works at a facility which apparently has the world's most accurate ring-laser gyroscope. The precision is claimed to be a 12 order of magnitude improvement over the Michelson-Gale experiment, while using an encompassed area 276,000 times smaller. Because of temperature-induced drifts, the authors indicate that the accuracy of the earth-rotation measurement is much less but still good to about 0.1% of the rotation rate. But this accuracy is 2.7 times the orbital-rotation rate and is thus easily measured by the existing ring-laser system. Why did they not tell us the measured rotation rate? I am very sure that it includes the earth's orbital-rotation rate.

The Stanford Gravity Probe B (GPB) experiment was mentioned above. It involves a mechanical gyroscope, but I know of no physicist who would argue that a mechanical and an optical gyroscope would give different results. It is the intent of GPB to measure the Lense-Thirring frame dragging from earth rotation and the geodetic precession (spin-orbit and space curvature effects). The former will amount to about 0.05 arc seconds per year and the latter to about 6.9 arc seconds per year. By contrast, if the gyroscope were affected by the orbital rotation, an additional anomalous precession of 1,296,000 arc seconds per orbit results. This insensitivity of mechanical gyroscopes to orbital rotation is clearly illustrated by the early TRANSIT (Navy navigation) satellites. During launch the satellites acquired a large spin, and the satellites themselves acted like large mechanical gyroscopes. In order to point the transmit antenna toward the earth, a boom with attached mass had to be deployed to cause gravity-gradient stabilization. But the satellite spin had to be removed before the gravity-gradient stabilization could occur—precisely because a gyroscope can measure (i.e. is not itself affected by) the orbital rotation.

Another Prediction

Incidentally, I have already predicted [23] that Gravity Probe B will detect a different amount of geodetic precession than that predicted by the general theory. I used a rather long argument to conclude that the predicted spin-orbit component (2.3 arc seconds per year) was only half the size it should be. The rest of the geodetic precession was due to space curvature and contributed 4.6 arc seconds per year. A simple method of arriving at my new prediction is to note that, if one measures time with a clock external to the gravitational field (local clock rate is immaterial), the "space curvature" (gradient of ether density) is twice what the general theory predicts. This leads directly to my prediction that the total geodetic precession measured by GPB will be 9.2 arc seconds per year rather than the general theory prediction of 6.9 arc seconds per year.

Before leaving the subject of freely falling frames and GPB, note the following quote from Thorne [26]:

> ...In our gravitational problem the Thomas precession is absent because the gyroscope is presumed to be in a free fall orbit i.e., it is not accelerated relative to local inertial frames; there are no "boosts."

I argued earlier that Lorentz boosts are invalid. Thus, I have no problem with the absence of Thomas precession. (Of course, as I have been arguing, I disagree with Thorne's reason it is absent.) However, Thomas precession is real; and, if Lorentz boosts are not the cause, another mechanism is needed. As mentioned in part I, Thomas precession arises naturally as a result of the composite velocity effects (mass increase and length contraction) on a moving spinning object which is accelerated orthogonal to its translation velocity. But, it does not apply to gravitational acceleration because gravity acts on the center of mass—not the center of spin.

Conclusions

Four problems with the general theory were presented. An alternative theory was proposed of a solid elastic ether which constituted a particular representation of the Lorentz ether theory. This new theory was shown to provide a simple resolution to the general theory problems. The particular claim of the general theory that a freely falling body is not acted upon by external forces was explored at length. It is clearly not valid. It predicts gyroscopic behavior which is clearly not realized. In addition, it should be capable of direct falsification with the launch of the new GPS satellites capable of inter-satellite tracking.

Finally, several predictions have been made in the course of the development. Specifically, it is predicted: (1) that gravitational radiation will never be detected; (2) unambiguous evidence for a black hole will never be found; and, (3) the amount of geodetic precession measured on the Gravity Probe B experiment will be one-third greater than that predicted by the general theory.

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