Questioning Einstein: Is Relativity Necessary?

Tom Bethell

4393 Embassy Park Drive NW, Washington, DC 20016

e-mail: tbethell2@verizon.net

I summarize my 2009 book, **Questioning Einstein: Is Relativity Necessary?** [1] which in turn simplifies Petr Beckmann's **Einstein Plus Two** (1987). [2] Beckmann's assumption was that the luminiferous medium, which Michelson failed to detect in 1887, is the local gravitational field, which attenuates with distance from the gravitating body. Overwhelmingly, we are in the Earth's field, which does not rotate with the Earth's rotation. This accounts for the Michelson-Morley null result and predicts an east-west light speed difference and with it a small fringe shift. An "ether" denser near the sun predicts the bending of light rays by Fermat's Principle, and the gravitational red shift. Einstein's equation accounting for Mercury's orbit was published by Paul Gerber, 17 years before general relativity. Both Sagnac (1913) and Michelson-Gale (1924) showed a fringe shift, but were disqualified as tests of SRT because they involved rotating (non-inertial) reference frames. GPS is said to validate special relativity because relativistic adjustments are entered into the orbiting clocks and would not synchronize without them. But the corrections do not refer clock motion to the observer, as relativity requires, but to the non-rotating Earth centered, inertial reference frame. It is a preferred reference frame — not allowed by SRT. The same criticism applies to the Hafele-Keating experiment (1972), in which atomic clocks flown around the world showed an east-west time difference. After 1916, Einstein restored a "gravitational ether," indistinguishable from Beckmann's, but played it down. The book concludes that general relativity gives the right results by a roundabout method. SRT has been falsified, unless rescued by the claim that all experiments on the surface of a rotating globe are non-inertial.

1. Introduction

In the late 19th century, one major anomaly confronted the world of physics—the null result of the Michelson-Morley experiment (1887). Albert Michelson had assumed that the Earth in its orbit moves through the ether—the luminiferous medium in which light rays were assumed to travel. The experiment was designed to show a fringe shift in Michelson's interferometer. But when the apparatus was rotated, no such effect was seen.

The anomaly was resolved by Einstein's special relativity (SRT) in 1905. It has now become conventional to claim that Michelson-Morley played little role in the origins of SRT. Some have claimed that Einstein didn't even know about the experiment. I reject that view, arguing that M-M was at the root of SRT. That was how it was interpreted for many years, until Gerald Holton's contrary view became influential in the 1960s. [3]

More recently, it has been argued that the postulates of special relativity are implicit in the Maxwell Equations. If so, we must assume that Maxwell did not understand his own equations. For it was none other than Clerk Maxwell who suggested the ether-drift experiment that Michelson carried out. But given the postulates of SRT, no fringe shift could possibly have appeared. Therefore the claim that SRT was implicit in Maxwell's own electromagnetic researches must be rejected. [4]

Einstein's SRT was built on two postulates. The first was that all inertial frames are equivalent. The laws of physics work equally well in any such frame. The second is that "light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body."

This, the "speed of light" postulate, was stated in a confusing way, as Einstein's colleague Banesh Hoffmann said. [5] As any physicist knew then, the speed of a wave in any medium is independent of the motion of the source. Petr Beckmann said that if the wing of a seagull taps the water, the speed of the resulting water wave is independent of the speed of the gull. The sound wave created by an airplane proceeds in the air at a speed that is unaffected by the speed of the plane.

Therefore, Einstein seemed to be saying nothing unusual when he postulated that light propagates at a speed that is independent of the speed of the source. In reality, he was saying something very peculiar.

In the same 1905 paper, he assumed that the ether was "superfluous." In which case, no distinction between the motion of the source and that of the observer made sense. There can only be relative motion between them. So when Einstein postulated that the speed of light is unaffected by the motion of the source, what he meant was that it is unaffected by the motion of the observer. He said this explicitly, but not until 1919, in an article for the Times of London. [6]

This brings us to the crux of SRT, and to the claim that has long confused so many students of physics. Intelligent laymen often ask this simple question: If a light beam moves toward you, and at the same time you move toward the light beam, how come you don't simply add your speed to that of the light wave, thereby resulting in a light beam that approaches you at a speed greater than c?

Notice, first, that Einstein *postulated* the constant speed of light. He didn't observe it experimentally. Nor did anyone else. But if we accept his postulates, we must also accept their consequences. What follows is this: If you move toward a light source, space must contract and time must dilate in the moving reference frame to just the extent needed to offset your (the observer's) motion. Speed is a quotient, and if distance and time are both appropriately adjusted, whenever the observer of the light beam moves, then the adjusted distance divided by the adjusted time

will always yield the same unvarying quotient, c. That will satisfy the obligation imposed by Einstein's second postulate.

Hendrik Lorentz worked out the mathematics of this SRT-satisfying maneuver, the Lorentz transformation, in 1895. The more normal addition of velocities (such as "two plus two equals four") is called the "Galilean transformation." [7]

Whether time dilation and space contraction are observed in practice is something I shall come to. For now we should think of them as predictions of SRT. If they have been observed, then the theory is to that extent confirmed. Meanwhile, notice that the adjustment of space and time in response to the observer's motion is a fantastic rearrangement of physical reality as scientists had understood it, leading us into contradictions. These contradictions were the great stumbling block for Petr Beckmann. There had to be a simpler way to interpret what was going on.

We are apt to forget that if a theory postulates something, we are free to reject it. Facts are a different matter. We cannot deny them. Beckmann rejected Einstein's assumption about the speed of light and proposed an alternative that accounted for the facts as they were then known. It has continued to account for further facts that Beckmann did not know about when he wrote Einstein Plus Two. (He died in 1993.)

Before presenting Beckmann's alternative, here is a simple way of looking at the contradiction that SRT implies:

You and I stand next to one another and we are both wearing identical, synchronized watches. I move with respect to you and as I move I observe your watch to run more slowly than mine. You observe nothing unusual about your watch. Now you are the observer of the same events and you observe my watch to be running more slowly than yours. So while this relative motion between our watches is occurring, each watch is observed to be running slower than the other. Why should we accept this? What experiment compels us to accept that the speed of light is a constant, whatever the motion of the light observer may be?

2. Beckmann's Alternative

Michelson's experiment was based on an assumption about the ether that Clerk Maxwell had made explicitly: that the ether is a uniform medium that fills the whole of space. Since the Earth orbits the Sun at a fairly high speed, the Earth must be moving through this medium. The sun could be sailing through space at its own independent velocity, so the Earth could be moving through the universal ether at a velocity that might be higher or lower than its orbital velocity. But at different times of the year, some relative velocity between the ether and the interferometer should easily be detected. But it proved undetectable.

Beckmann proposed a different (but quite simple) way of looking at the ether. He argued that the local gravitational field simply is the light medium. On the Earth's surface, we are overwhelmingly in the Earth's field. The Moon is too (otherwise it wouldn't orbit the Earth). If we move closer to the Sun, the Sun's field will become dominant. And so on.

In other words, the light medium is not uniform. It becomes more attenuated in outer space, and denser in proximity to gravitating bodies. Given this, some predictions of general relativity can immediately be deduced from classical physics. Wave fronts are refracted as they travel through a non-uniform medium. The bending of starlight passing close by the Sun follows directly from Fermat's Principle. It also follows from the multidimensional tensors and non-Euclidean geodesics of general relativity. But Fermat's Principle is far simpler.

Michelson's expected fringe shift depended on the relative velocity between the ether and the Earth's orbital motion. But if the ether simply is the local gravitational field, then that field obviously accompanies the orbiting Earth, as a shadow accompanies a runner. On this view, the fringe shift that Michelson expected to see would not be there.

But the Earth also rotates on its axis, and the gravitational field does not swing around with the Earth. So the Earth rotates through its own field. Prof. Howard Hayden (U. Conn emeritus) suggested the metaphor of a woman wearing a hooped skirt. When she walks, the skirt moves forward with her. But if she does a pirouette, (assuming a circular waist and no friction) she will rotate within her skirt.

If this analogy holds for the Earth and its field, then Michelson's experiment would expect to show a fringe shift but one that is very much smaller than anticipated in 1887. In fact, it would be four orders of magnitude smaller. The Earth's orbital velocity is about one hundred times greater than its rotational velocity in mid latitudes. And because the Michelson experiment looks for a second-order effect, that multiple has to be squared.

So we are looking for an effect ten thousand times smaller than the one that Michelson expected. This is the key prediction of Beckmann's theory. When Beckmann was writing his book, he did not expect so small an effect to be detectable. Certainly Michelson's 19th century equipment could not have seen 0.00004 of a fringe shift, instead of the 0.4 of a fringe that was expected.

3. The Brillet-Hall Experiment

Beckmann did not know that a highly sensitive interferometer experiment had already been conducted at his own university in 1979. Alain Brillet and John L. Hall did the most precise modern analogue of Michelson-Morley—a "tour de force of precision measurement," as Hayden called it. [8] It was sensitive enough to have detected the much smaller fringe shift, and it might have done so. But Hall was not looking for it, and he assumed that the fringe shift he saw was "spurious," caused by experimental error. (He won the Nobel Prize for Physics in 2005, but not for this experiment.)

The experimenters were looking for an "anisotropy" in space. With the Sun itself moving at an estimated 300 kilometers per second in the direction of the Virgo cluster, could such a directional effect be detected? Given the assumption that the Earth is enveloped by its own ether, or gravitational field, no such effect would appear. But the tiny rotational effect that Beckmann predicted (probably) was seen. Hall reported "a spurious nearly sinusoidal frequency shift at the table rotation rate." But the "varying gravitational stretching" of the apparatus might have caused it. The axis of the rotating table may not have been "perfectly vertical," he wrote.

It was suggested to Hall that the experiment should be redone. Unfortunately, he said in an interview, the interferometer he used in 1979 had been stored at the Rocky Mountain Arsenal in "the place where they made nerve gas." Government officials

declined to return it. [6] Today, apparently, all interferometers used in such experiments are "cemented to the floor" and point in a fixed direction with respect to the lab. In this way they are vibration-free and use the Earth's rotation to "sweep" the interferometer beam across the skies in search of some anisotropy.

But all such experiments will fail if the lab itself is immersed in the Earth's field, which inevitably travels with the Earth. Modern interferometers are precise enough to detect the small fringe shift that Beckmann's theory predicts. But now Michelson's experimental design is passé. The physics establishment is not interested in redoing a Michelson-Morley experiment with much greater sensitivity. The result, it seems, they already know. What is needed is an interferometer as accurate as Hall's, but one that also rotates in the laboratory frame (just as Michelson's did).

4. Earlier Demonstrations of a Fringe Shift

4.1. Sagnac Experiment

Experiments by Georges Sagnac in 1913 [10] and by Michelson and Gale in 1924 [11] had used interferometers with contrarotating light beams and both showed a fringe shift. Sagnac's paper, published in 1913, showed a fringe shift which is not in dispute and is used as a navigational device in modern aircraft. His apparatus consisted of a platform 20 inches in diameter and an interferometer with four mirrors at the perimeter. It can be rotated like a record turntable. When two light beams are sent around the platform in opposite directions, from one mirror to the next and then reunited, the combined light beams showed the familiar interference fringes. As the platform is rotated, the mirrors move away from the light beam in one direction, and approach it in the other. As the table speed increases, the position of the fringes shifts.

4.2. Michelson-Gale Experiment

The Michelson Gale experiment of 1924-25 is rarely mentioned, even in textbooks. "Misner, Thorne and Wheeler's big book Gravitation has some 1600 references but Michelson-Gale is not among them," Hayden wrote. Michelson was, in a sense, putting Beckmann's (subsequent) theory to the test. How would the Earth's rotation affect an interferometer experiment with contra rotating light beams? It was Beckmann's discovery of this rarely reported experiment, while he was studying physics in Czechoslovakia in the 1950s that led to his formulation of the idea that the local gravitational field is key to understanding the elusive ether.

To detect such a fringe shift, the apparatus had to be much larger than anything yet seen. It enclosed a rectangle 2010 feet from east to west and 1113 feet from north to south. Air currents caused interference fringes to be unstable, so the apparatus used evacuated pipes paid for by the City of Chicago. Contra-rotating beams indeed showed a fringe shift. They key was that the rotating Earth produced a small difference in measured light velocity in the two east west legs. They were a fifth of a mile apart and therefore in slightly different latitudes. As the earth rotates, the east-west leg closer to the equator moves faster (relative to the gravitational field) than the leg further to the north.

Michelson's daughter wrote that the experiment "took place at Clearing, Illinois, on the prairie some ten miles west of the university, in the bitterly cold weather of early December, 1924." [12]

Einstein knew of the experiment, and in fact discussed it with Michelson in Chicago in 1921. He admired the "ingenious" way he overcame the difficulty "that we are not able to change the direction of the Earth's rotation." The Earth could not be rotated back, to see if the interference fringes had shifted during its rotation. Michelson did this by adding a second, much smaller interference loop that served to produce a "fiducial mark from which to measure the displacement" in the larger circuit.

The experiment demonstrated a small fringe shift, close to the predicted value. But the Einsteinians were able to find an escape route, thereby protecting the special theory from falsification. SRT applies only to inertial reference frames, in which no unbalanced forces are allowed. But because Michelson-Gale depended on the Earth's rotation, centrifugal forces and curvilinear paths are inevitably present. Therefore it was non-inertial. A similar argument was used against the Sagnac experiment, in which the apparatus was rotated. The equations of special relativity cannot incorporate an acceleration even as small as the three thousandths of one-g experienced in Michelson Gale.

But both the Sagnac and the Michelson-Gale results could be predicted using the complicated mathematics of general relativity. So the Einsteinians succeeded in turning the tables on their critics. Instead of falsifying special relativity, these two experiments were construed as having confirmed general relativity.

Petr Beckmann pointed out how unsatisfactory this was. The big difference between the ether-based explanation of Michelson-Gale, and GRT was this: The classical explanation "follows from the Galilean principle of relativity in a few lines of high school algebra, whereas Einstein's general theory does it with multidimensional complex tensors in space-time and non-Euclidean geodesics."

In an interview, John Hall raised the question whether any experiment done on the surface of the Earth can be considered truly inertial. All such experiments are all done on the "surface of a spinning ball," he said. Gravitational forces are inevitably present. So "if you turn up the sensitivity, it is completely sure that there is some effect," such as the fringe shift that Michelson eventually showed in Michelson-Gale, or (perhaps) that himself had shown in Brillet-Hall but considered to be "spurious." [9]

In practice, then, general relativity has acted as an escape route for Einsteinians whenever an experiment threatens to falsify special relativity. If a highly accurate Michelson-Morley experiment were completed and a fringe shift were shown unambiguously, the probable conclusion would be that the experiment was non-inertial and therefore SRT didn't apply. Special relativity therefore seems to be an unfalsifiable theory, and as such unscientific by Karl Popper's criterion.

It's worth noting that Albert Michelson, like Hendrik A. Lorentz, and Ernst Mach, never accepted special relativity theory.

5. Stellar Aberration and Binary Stars

Another celestial observation really does seem to falsify special relativity, however. That is the stellar aberration exhibited by binary stars. Discovered in the 18th century by the English astro-

nomer James Bradley, stellar aberration, is a small change in the apparent direction of a star depending on its direction relative to the Earth's orbit. Just as someone walking in vertical rain must incline his umbrella forward if he is to stay dry, so telescopes must be inclined slightly ahead of the expected position if the light from a given star is to appear in the telescope's lens. [13]

Stellar aberration is the same for all stars in a given direction, reaching a maximum of about 20 seconds of arc for stars perpendicular to the Earth's orbital direction. If the Earth is moving directly toward or away from a given star, its light is not aberrated.

Some, including Michelson, argued that an entrained ether might be the cause of the Michelson-Morley null result. After his original experiment, in 1881 (without Morley), Michelson concluded that the absent fringe shift had shown "that the ether in the vicinity of the Earth is moving with the Earth." The big problem, he conceded, was that this contradicted "the generally received theory of aberration." The great majority of physicists accepted that stellar aberration disallowed an entrained ether.

Beckmann argued that the ether (field) is entrained at the Earth's surface but that there is a transition region beyond the moon's orbit. [2] For Einstein, of course, there was nothing to be entrained. But he was obliged by the postulates of special relativity to claim that stellar aberration was simply a function of the relative motion of the observer (on the Earth) and the star in question. This held up as long as the motion of the stars relative to the sun was unknown. And no one at the time did know the proper motion of the stars. So Einstein felt justified in referring to "the fixed stars," which is what they had been called for centuries, to distinguish them from planets.

The special theory "enables us to predict the effects produced on the light reaching us from the fixed stars," Einstein wrote in 1916. Aberration was "due to the relative motion of the Earth with respect to those fixed stars," and his theory gave a result "found to be in accord with experience." [14]

That worked fine if the stars really were "fixed." The only remaining motion was the orbital motion of the Earth and this gave the observed aberration. But in 1889 Edward Pickering had discovered spectroscopic binary stars, orbiting a common center of mass so closely that they appear as a single star even in the most powerful telescopes. The two stars of Mizar A, in the handle of the Big Dipper, are only 18 million miles apart. Their separate character is apparent only from the alternating Doppler shifts in their spectral lines. They orbit one another at a velocity of 50 kilometers per second, or 1.7 times the Earth's orbital velocity.

It follows that even if we still don't know the true velocity of the binary systems with respect to the sun, we do know that there is a difference, sometimes large, between the separate stars of the binary system relative to us. In the case of Mizar A, at a given moment in its 104-day cycle, one star is approaching us at the high velocity of 50 kilometers per second (relative to the center of mass of the system) while the other star is moving away from us at the same velocity. Irrespective of the movement of the system as a whole, then, the twin elements of the orbiting pair are moving at velocities that exceed the Earth's orbital velocity by quite a large margin.

By Einstein's formula, alternating back and forth aberrations should therefore be observed, corresponding to the period of their orbits. The aberration angle of each star should increases and then decrease as they circle each other. This would be easily observable by modern instruments. The differential aberration would be so large that the stars would become visibly separate in the sky before closing again. In the case of Mizar A, the angular separation of the binary components would be more than a minute of arc. But they always remain as an unresolvable point in the sky. And because binary systems are so common, we should be seeing this back and forth apparent motion of binary components all over the heavens. But we never do.

This criticism of SRT was made in 1950 by Herbert Ives, the director of optical research at Bell Labs. [15] It was repeated by Edward Eisner, also of Bell Labs, in 1967. [16] Thomas E. Phipps made the same criticism in 1989. [17] He "reiterated Ives's point for the benefit of a new generation of physicists." If source motion mattered at all, he wrote, "astronomy would be a vestige of its present self and there would be no such thing as a constant of aberration." He reserved his criticism for "certain physics textbooks," some of them leaving students "flatly misinformed."

More recently Milton Rothman, an emeritus professor of physics at Trenton State College allowed that "the derivations of the aberration angle found in past textbooks do no solve the problem correctly." In Everything's Relative (2003) his son Tony Rothman wrote that "the relative velocity of the star and the Earth cannot be the right one to use." [18]

Binary stars, our best source of information about the mass and size of stars, have long been important to astronomy. They may also falsify the special theory of relativity.

6. Space Contraction and Time Dilation: The Evidence

6.1. Space Contraction

Turning now to the experimental evidence for the predictions of special relativity: The contraction of length, one of the most famous predictions, has never been observed, either in the heavens or upon Earth. Pictures of foreshortened space ships, flying at high speed are all imagined by artists in accordance with theory. Hendrik Lorentz, who had first proposed such contraction, said in 1910 that relativistic length contraction was something that could "actually be observed" in photographs. But Arthur I Miller said that "almost half a century later James Terrell (1959) showed that the contraction of a moving body in the direction of its motion could not be seen on a photograph." [19] Nor has it been observed in the half century since Terrell's observation.

6.2. Time Dilation: Mesons or Muons

Time dilation is a more complex issue. The evidence may be summarized this way. It has been observed that clocks slow down when they pass through the local gravitational field, but this is a very different thing from saying that time slows down in a reference frame that moves relative to an observer.

It has been shown that Earth-bound atomic particles called mesons (or muons) observed in the Rockies reaching the Earth from outer space have longer half lives than those studied on the ground. Mesons are construed as giving strong support for time dilation and SRT. "The muon lifetime experiments provided

strong evidence for the reality of time dilation," Leo Sartori wrote in Understanding Relativity. "No other plausible explanation has been suggested." [20]

George Gamow was a good Einsteinian, but in something that he wrote he inadvertently disclosed what surely was happening. The "slowing down of all physical processes in fast moving systems was observed directly in the case of the decay of mesons… coming down to the surface of the Earth at extremely high speed," he wrote. The slowing down of "physical processes" inside particles is not at all the same thing as time slowing down. So we may ask: Are mesons' internal clocks slowing down, or is time slowing down?

If the relativistic view is correct, we must abide by the first postulate of SRT, which imposes the same result from the other reference frame. If we were to fly to Earth with the speeding meson, we would observe (by Einstein's theory) everything proceeding more slowly on the Earth's surface. We would observe the spatial contraction of the Rocky Mountains before we were brought to an abrupt halt by the granite surface. No such observations have been made from this "other" reference frame. Until they are, the relativists are in a weak position when they claim that speeding mesons confirm time dilation.

Beckmann's theory predicts that such a test (in which the observer accompanies the speeding muon) would show clocks on Earth running fast relative to muon clocks. For if the physical processes of the muon are slowed down by their motion through the gravitational field, Earth clocks would show no such retardation. They just sit there on the Earth's surface, not minding how swiftly muons come rushing at them. So the two theories make different—opposite—predictions. In relativity, the observed change in the muon half life is attributed to its motion with respect to an observer. Beckmann's theory argues that real physical changes take place within the particles as they race through the gravitational field.

7. Flying Atomic Clocks: Hafele-Keating

A test in 1971, in which atomic clocks were flown around the world in opposite directions, is often said to the best confirmation of time dilation. But on closer examination it confirmed Beckmann's theory, although that is not the way it is usually represented. The unexpected result was that the eastbound clocks lost time (59 nanoseconds) while westbound clocks gained time (273 nanoseconds) —both compared to a reference clock at the Naval Observatory in Washington.

Analyzing what happened in Science (1972), J. C. Hafele wrote that a "remarkable feature" was that of "directional dependence" for time dilation. [21] The "relativistic time offset accumulated by a clock during circumnavigation of the Earth depends both on the direction of the circumnavigation and on the Earth's rotational speed." This "seems to have been overlooked in the past," Hafele added. [22] Indeed Einstein had said nothing about time dilation depending on the direction in which a clock is moved. But Beckmann's theory had foreseen exactly that.

Hafele and Keating might have been tempted to say that Einstein's theory seemed to be wrong. Instead, they substituted another reference frame, compared with which it truly could be said that "moving clocks ran slow." By this means they seemed

to rescue Einstein's theory, but they did so by amending it in a way that detached it from Einstein's postulates and brought it into alignment with Beckmann's theory.

Clifford Will, in his account of the experiment, said that the comparison clock in Washington was non-inertial, because it was rotating along with the Earth, "so we can't simply compare the flying clock directly with the ground clock." Instead, we must "compare the rates of both clocks to a set of fictitious clocks that are at rest with respect to the center of the Earth." [23] Hafele and Keating had also said that the flying clocks must be compared to the "hypothetical coordinate clocks of an underlying non-rotating (inertial) space."

Underlying non-rotating inertial space is a mouthful but an important one. SRT was here (and henceforth) quietly changed. No longer is it motion with respect to the observer that causes time dilation. It is motion with respect to a real block of space within which the Earth rotates.

Operationally, as readers may have noticed, it is the same thing as the local gravitational field. The old idea was that the effect-producing motion (yielding time dilation) was with respect to the observer. The new idea is that the motion of clocks through the local gravitational field slows down time. Yet as Hayden noted, Hafele and Keating "do not ask, let alone answer, whether time itself is dilated, or processes are simply slowed by moving through the gravitational field."

There is an additional reason why Hafele-Keating's understanding of time dilation, endorsed by Clifford Will, does not confirm Einstein's theory. The Earth-centered, non-rotating inertial frame is a preferred reference frame, and as such violates the first postulate of special relativity (in which inertial frames must be equivalent to one another). Hafele-Keating needed a frame with respect to which the moving clocks would slow down; and only the Earth centered frame would give that result. Other inertial frames gave the wrong result so a preferred frame was substituted. But it violated the cardinal rule of relativity.

An additional complication brings general relativity into the picture. Whereas clocks moving horizontally through the field run slower, at a higher altitude they speed up. A clock moving at a high altitude therefore experiences contrary effects. Eastbound clocks lost 184 nanoseconds as a result of horizontal motion, but gained 144 nanoseconds in the thinner field. General relativity [GRT] enters the calculations in the thinner gravity field. But GRT does give the right results (by a complex method) so here the relativistic corrections for the gravitational effect on clock rates are applied correctly.

The Naval Observatory clock moving around with the rotating globe did render its frame non-inertial, therefore disqualifying it as a proper standard for special relativity. So the Earth centered inertial frame was substituted. But the clocks on the planes could also have been disqualified as non-inertial, because they circumnavigated the globe. There wasn't an inertial frame in sight. By strict Einsteinian rules, then, the whole experiment could have been ruled out of court. It was nonetheless admitted into the canon of relativity-confirming experiments, perhaps because a reinterpretation of its results seemed compatible with relativity. But the reinterpretation using the Earth-centered frame was decidedly more compatible with Beckmann's theory.

8. Flying Atomic Clocks: GPS

Some of these criticisms also apply to the Global Positioning System, which has "relativistic" corrections built into it. Its system of atomic clocks orbiting 11,000 miles above the Earth do stay synchronized, as they must if the system is to work. And it does. The question is: Are the corrections really Einsteinian? Answer: the altitude corrections use general relativity theory correctly, but the correction for the horizontal motion of clocks through the field disagrees with SRT. As with Hafele-Keating, GPS corrects for the motion of clocks with respect to a non-rotating Earth-centered inertial frame, not with respect to the observer on the Earth's surface.

The problem, according to SRT, is that clocks moving relative to one another cannot be synchronized. Leo Sartori put it exactly that way in Understanding Relativity: "Clocks in relative motion cannot be synchronized." Why not? "Such clocks keep time at different rates." [24] This is the famous problem of the "relativity of simultaneity." Einstein's second postulate obliges us to accept that time proceeds at different rates for differently moving clocks.

GPS clocks that move in different planes with respect to the equator also move with respect to each other; and with each passing moment, all these clocks are moving at varying speeds with respect to an observer on the Earth's surface. So Einstein's theory, strictly applied, implies that GPS clock synchronization would be impossible.

In the planning stage some GPS consultants raised this objection and there was uncertainty whether the system would work. Neil Ashby, the leading academic expert in the field, served as a consultant in the 1970s and he reports that making corrections to bring it into line with relativity theory was "controversial." [25]

The issue was put to the test in 1985 when orbiting satellites and atomic clocks made it possible to send radio waves around the world. As with Hafele-Keating, an east-west time difference was found. Synchronization of GPS clocks could not be achieved with the assumption that light speed is constant in all directions. [26]

If you try to Einstein synchronize a series of clocks around the globe, Ashby wrote, the last will be out of synch with the first. Closure of the ring is impossible. Ashby attributed this "significant error" to "simple minded use of Einsteinian synchronization." But "simple minded" meant literal, and he was telling us that Einstein's postulates were not workable. Synchronization was achieved by referring clock motion, as before, to the non-rotating Earth centered inertial frame. [27]

"A consistent spacetime coordinate system for a 'patch' that encompasses Earth and its GPS satellites" is considered permissible, Ashby wrote. That way, the system designers did not have to "resort to more than one time variable."

The satellites move at different speeds with respect to the observer, who is not at the center of the globe. A strictly Einsteinian velocity correction would have to be different at each moment for each satellite. Attempting to enter such constantly changing corrections, depending on the location of tens of thousands of observers all over the world would have made the system unworkable and perhaps logically impossible.

But the clocks do all move through the Earth centered patch of space at the same velocity, so one system-wide clock rate correction was made, pre-launch, to offset motion through the field. A larger correction adjusted for the attenuated gravitational field 11,000 miles up. As Peter Galison put it, "the weaker gravitational field would leave the satellite clocks running fast (relative to the Earth's surface) by 45 millionths of a second per day." [28]

Notice "clocks" ran fast, not time. He was right about that.

A note about the orbit of Mercury. Einstein's equation correctly accounting for the orbit's precession was given by general relativity in 1915. But in 1898 a German schoolmaster named Paul Gerber had published Einstein's formula, without benefit of relativity, in an obscure physics journal. [29] Ernst Mach drew attention to it in his textbook on mechanics. Einstein later said that he had not known about Gerber's derivation, and that "experts" had also told him that it was "wrong through and through." Petr Beckmann rederived Gerber's formula by a different method. But I am already way over my head here and curious readers should turn to chapter 20 of my book.

9. Conclusion

By strict application of Einstein's postulates, neither length contraction nor time dilation has yet been observed. Some bring up the famous equation E = mc2, which was derived by Einstein using relativity theory. But as John Stachel wrote (in an email to the author), it was also derived by Einstein without relativity theory. So what physical facts oblige us to accept special relativity? I know of none.

I conclude with this parallel. The search for Michelson's fringe shift is analogous to the much earlier search for stellar parallax. For many years (until 1838) it could not be seen, although it was implicit in the Copernican system. The problem was that earlier astronomers could not imagine that the stars were so far away. Stellar parallax was a reality, but much smaller than most people (Kepler included) had thought. The fringe shift in Michelson's 1887 interferometer was also a reality, I argue, but much smaller than most observers had thought. Eventually, I predict, its reality will be recognized.

References

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