What the Atomic Clocks Tell Us

Foreword

Einstein writes in "The Fundaments of Theoretical Physics" (Science, 24th May 1940): *The content of the special theory of relativity can be condensed into one sentence: All the laws of nature must comply with the requirement that they are covariants in their corresponding Lorentz-transformed frames. From this it follows that two events happening far away from each other are not invariant, and also that the dimensions of a rigid bodies and the clock rates depend on their motions.*'

On the other hand, the special theory of relativity also is defined by so-called postulates: a) *The velocity of light is constant in all inertial reference frames (i.e. for all observers moving in a straight line at a constant velocity).* b) *It is also the greatest velocity obtainable.* c) *All laws of nature work the same way in all inertial reference frames.* d) *No reference frame possesses a preferential status (the relativity principle).* It is commonly understood that these postulates are of primary kind and that expressing them mathematically requires the adoption of the Lorentz transformation, but, as per Einstein's above-quoted statement, the Lorentz transformation is *the* law of nature on which everything is based.

But, as Raimo Lehti in his referenced [21] book on page 480 asks: '*The relativity principle, is it about laws or phenomena?*' This subject is brilliantly discussed in the referenced book, comment 5: *Relativity Principle, Covariance Principle and Equivalence principle*' Lehti refers to Vladimir Fock's statement ([21], p. 481): *It is essential to differentiate clearly the physical principle, which postulates corresponding* ***phenomena*** *in different reference systems, and the simple requirement that the* ***formulas*** *have to be covariant when one moves from one reference frame to another.*' Fock also concludes ([21], p. 498], that Einstein intermingled '*the physical covariance and the formal covariance*'.

It was not possible to research the subject of phenomena versus equations in the proper way by using the clocks before the 1970's because there were no atomic clocks. All the clocks described in the vast literature about the theory of relativity before that time, and mostly still today, are imaginary clocks, thought-experiments. In those experiments the same clock could display different readings to different observers at the same time. Now we can perform those thought-experiments with real clocks, and there cannot be but one reading present at any one time in those clocks. We also have obtained plenty of real-clock data about the propagation times of radio signals in our solar system. We do know what the physical reality of the velocity of light is. Does this correspond the formalism of relativity, the equations? That is the topic of this paper.

1. The Lorentz Covariance

Let there be two coordinate frames, K and K' (Figure 1), their relative velocity in the direction of the x-axis being v. Events are described in the K-coordinate frame by using three location coordinates and one time coordinate: x, y, z and t. The same event is defined in K' as x', y', z' and t'. To satisfy the requirement that the mathematical description of an event must be the same in both coordinate systems, we have to transform the unprimed coordinates to primed ones by some suitable means. When we further require that the velocity of light has to have the same value c in both coordinate frames, our transformation formulas become (Lorentz transformation):

$$x' = (x - vt)/\sqrt{(1 - v^2/c^2)} = \gamma(x - vt) \qquad (1.1)$$

$$y' = y \qquad (1.2)$$

$$z' = z \qquad (1.3)$$

$$t' = (t - xv/c^2)/\sqrt{(1 - v^2/c^2)} = \gamma(t - xv/c^2) = \gamma t - \gamma xv/c^2. \qquad (1.4)$$

We have marked $\gamma = 1/\sqrt{(1 - v^2/c^2)}$.

The rule of velocity addition in classical physics, i.e. the Galilean transformation, produces the following transformation results:

$$x' = x - vt \qquad (1.5)$$

$$y' = y \qquad (1.6)$$

$$z' = z \qquad (1.7)$$

$$t' = t. \qquad (1.8)$$

Accepting that the velocity of light is the greatest obtainable velocity takes us in the theory of relativity to the following formula for combining velocities:

$$W = (v + w)/(1 + vw/c^2). \qquad (1.10)$$

Here v is the speed of K'-frame in K-frame along the x-axes and w is the speed of the object in K'-frame along x'-axes. W is then the speed of the object in K-frame.

The corresponding Galilean transformation is, of course, just the (vector) sum of the velocities:

$$W = (v + w). \qquad (1.11)$$

As we now evaluate equations (1.1) and (1.5), we notice that all the points in the K'-frame, as measured in K', have moved further than the points in K (x' > x). Denominator $\sqrt{(1 - v^2/c^2)}$ is called length contraction. According to the Lorentz transformation, the person at rest measuring a rod in motion thus finds it shorter than the measurer moving along with the rod.

As we evaluate equations (1.4) and (1.8), we notice from the first term $[t/\sqrt{(1 - v^2/c^2)}]$ that $t' > t$, i.e. that *the same event* to happen takes longer in the K'-frame than in the K-frame. If we, for example, employ clocks in which N_S is the number of ticks for one second, then in the K'-frame more time is needed for the ticks to reach N_S than in K-frame. Thus, there exists the following relationship between the two clock frequencies:

$$f' = f \sqrt{(1 - v^2/c^2)} = f/\gamma. \qquad (1.12)$$

This is called time dilation. When we speak of clock-measured duration, we, in fact, refer to the number of counts presented in the cumulative period counter. The event is one and the same, and presents itself in only one way in nature. Should two clocks show a different total time for an event, this means that their counters have registered different numbers of periods. This, again, means that their tick-frequencies are different from each other. To time, this does not need to mean anything, because the effect can purely depend on the physical structure of clocks.

When we label the clock-timed durations in symbols ΔT and $\Delta T'$, the same dependency between them exists as between the frequencies in equation (1.12):

$$\Delta T' = \Delta T \sqrt{(1 - v^2/c^2)} = \Delta T/\gamma. \qquad (1.13)$$

The clock in K'-frame thus ticks slower than the one in K by factor $\sqrt{(1 - v^2/c^2)}$. This clarification is necessary, so that we would not input accidentally the time readings of the clocks in equation (1.4), where term γ is the factor of the unprimed t. Quantities t and t' in equation (1.4) represent the actual duration of the event when the event is taking place alternatively in K or K'.

The second term $\gamma(xv/c^2)$ of equation (1.4) shows that the time in K' depends on location x. This is what is called the relativity of simultaneity. Because the observer attached to K'-frame does not notice the slowing down of his clock, time to him is:

$$t_{K'} = t' - x'v/c^2. \qquad (1.14)$$

Thus, also in a moving reference frame, the phenomenon of time being dependent on location is observable. However, it is not possible to see the difference in the clock displays, because, to be noticeable, distance x' must be huge, and the observer cannot see both clock displays at the same time.

The location-dependency of time as calculated by using the Lorentz transformation has a clear physical connection to the synchronization method as executed in the theory of relativity. According to the theory of relativity, two clocks become synchronized when light travels back and forth between them in the following way: Let two clocks A and B in Figure 1 be distance x apart on the x-axis. A sends a pulse of light to B, who reflects it back. The A clock shows the total back and forth time to be ΔT. A now sends to B his present displayed reading, plus half of ΔT, i.e. $T_0 + ½ \cdot \Delta T$. At the moment the signal reaches B, it becomes also B’s displayed reading.

If the velocity of light is the same in both directions, then A and B will display the same reading all the time, provided that the ticking rates are kept the same. This is what is happening in K-frame in Figure 1.

Let us now assume that a second coordinate frame, K_G, moves at velocity v in the direction of the x-axis in K (Figure 1). The interdependency between the coordinate frames we further assume to be the Galilean transformation, i.e. the simple velocity addition dependency. In this case then the velocity of light, in the forth direction, is c – v, and in the back direction, c + v. The total back and forth time for the travel is:

$$\Delta T = x/(c - v) + x/(c + v) = 2x/[c(1 - v^2/c^2)]. \qquad (1.15)$$

Thus, A sends half of this duration to B. B's displayed time now becomes $T_0 + x/[c(1 - v^2/c^2)]$, and the time it took for the signal to travel to B is x/(c – v). The outcome of this is that at the time B receives the signal, A's displayed reading is $T_0 + x/(c - v)$ and B's displayed reading is $T_0 + x/[(1 - v^2/c^2)]$. The difference between the B-clock and A-clock displays thus is:

$$\Delta T = x/[c(1 - v^2/c^2)] - x/(c - v) = xv/(c^2 - v^2) \cong xv/c^2. \qquad (1.16)$$

Both the observer in the K frame and the one in the K_G-frame experience these events in the same way. For both of them, x = x, y = y and t = t. However, as per the theory of relativity, the observations in K_G frame must be wrong because the velocity of light in relation to the observer cannot be anything else than c. Thus the real observations should emerge when the K_G-frame quantities v and t get transformed by using the Lorentz equations, i.e. $x = x'\sqrt{(1 - v^2/c^2)}$ and $\Delta T = \Delta T'/\sqrt{(1 - v^2/c^2)}$. Substituting these equalities in equation (1.16), we obtain:

$$\Delta T' = x'/c - x'(1 - v^2/c^2)/(c - v) = x'/c - x'(c + v)/c^2$$
$$= x'/c - x'/c - x'v/c^2 = -x'v/c^2 \qquad (1.17)$$

The synchronization result is then the Lorentz-transformed result, i.e. the same we obtained in (1.14). *Synchronization and Lorentz transformation are but two different ways to express the same thing, i.e. the dependency of time on location in a coordinate frame.* The term xv/c^2 is called *clock bias.*

The time dilation and length contraction do not much affect the clock bias in synchronization. (If we do not take those into account, the difference is as given in equation (1.16); the value of the difference depends on the squared term v^2/c^2 The difference due to this is at practical distances and obtainable speeds so small that it can possibly be discovered only in the sixth decimal.) This reflects the fact that time dilation and length contraction have minor effects only on velocity of light traveling in one direction. The velocity of one-way light can only be measured with two clocks, and then thanks to the clock bias the result is always the constant c. This can be seen in the K'-coordinate frame, Figure 1.

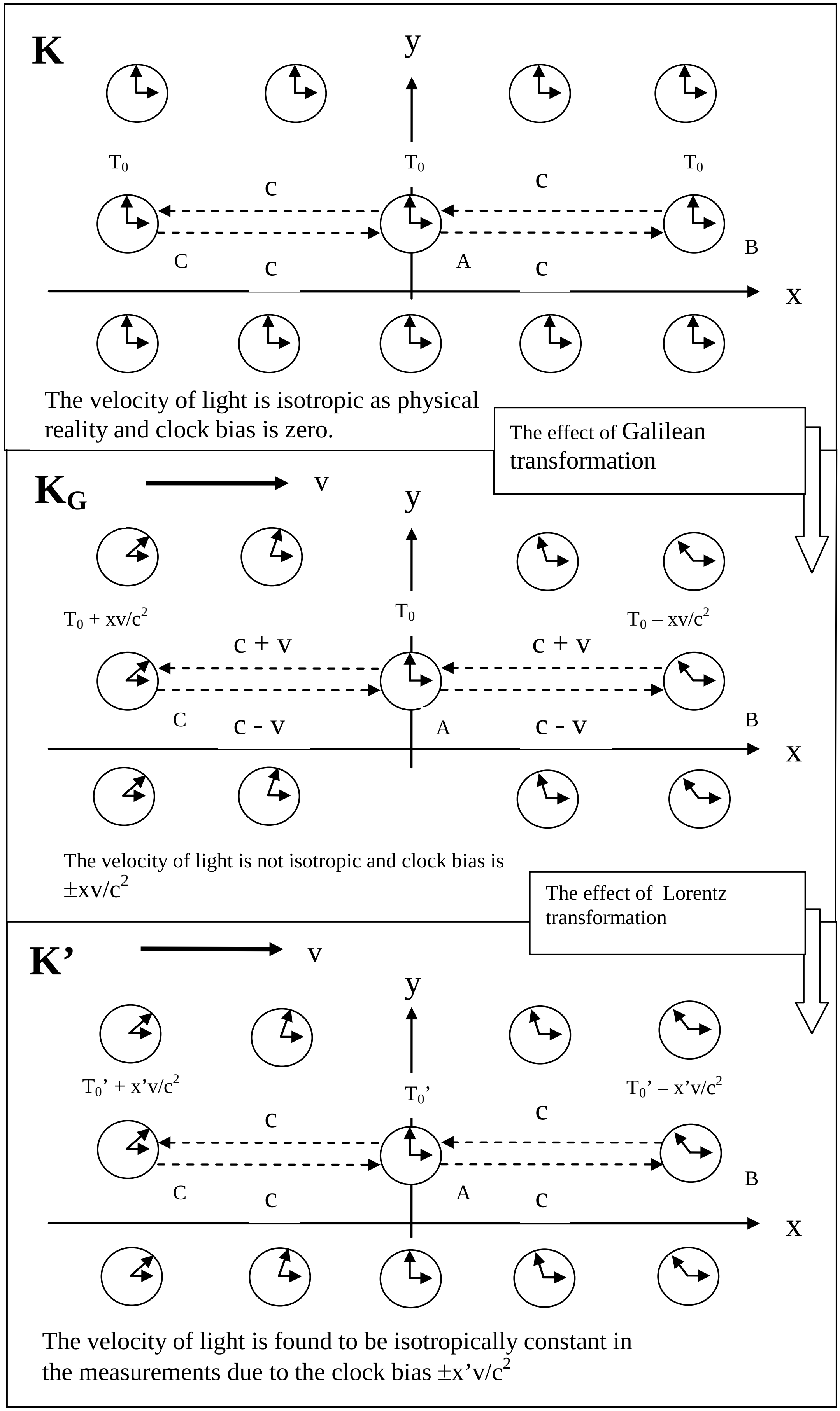

Figure 1. The relationships between reference frames

Let us now pay closer attention to the one-way measuring process of the velocity of light in the Lorentz-transformed coordinate frame K'. The one-way velocity of light is measured with clocks A and B, synchronized in the manner previously described. The displayed reading, T_{A0}', in the center-clock A is sent to clock B on the right by means of a radio signal. At the time the signal leaves clock A, clock B reads $T'_{B0} = T'_{A0} - x'v/c^2$ The physical velocity of light is that shown in the K_G frame, namely $\Delta T = x/(c - v)$. But in the K'-frame $\Delta T = \Delta T'/\sqrt{(1 - v^2/c^2)}$ and $x = x'\sqrt{(1 - v^2/c^2)}$. By substitution in the ΔT-equation we get:

$$\Delta T'/\sqrt{(1 - v^2/c^2)} = x'\sqrt{(1 - v^2/c^2)}/(c - v) \qquad (1.18)$$

$$\Delta T' = x'(1 - v^2/c^2)/(c - v) = x'(c + v)/c^2 = x'/c + x'v/c^2. \qquad (1.19)$$

When this duration is added to the displayed reading T'_{B0}, we get the new displayed reading, T'_{B1}, in clock B at the moment the signal from A arrives.

$$T_{B1}' = T_{B0}' + \Delta T' = T_{A0}' - x'v/c^2 + x'/c + x'v/c^2 = T_{A0}' + x'/c \qquad (1.20)$$

When we now deduct from the ‘time received’ reading in clock B the ‘time-sent’ reading in clock A, we arrive at:

$$T'_{(A-B)} = T'_{B1} - T'_{A0} = x'/c. \qquad (1.21)$$

The result shows that the velocity of light from A to B is a constant, c. We observe, however, that it is not the real, physical velocity. The outcome is possible only because in clock B there existed a different reading (clock bias) caused by the synchronization operation.

Terms time dilation and length contraction make it possible to present an illusion *that the two way travel time of light is invariant* By the described synchronization process another illusion is created: that the velocity of *one-way light is invariant*. (In the opinion of this author the situation parallels with the case in which one tries to prove that the length of a rod does not depend on temperature and does it by always measuring the rod with another rod made of the same material at the same temperature.)

In the theory of relativity it is *preset* that the *displayed readings* in the clocks synchronized in the described manner is an accepted definition of simultaneity. When we further take into account that the theory of relativity defines that time at a certain point location in space is the displayed reading at that location, we arrive at the fundamental claim in the theory of relativity: *There exists no independent time; there exists only time that is location-dependent, e. g. space-time.* This leads into talks about location-dependency of time, as if it were a property of nature, while forgetting that what is involved here is only an agreed way of human beings to use clocks

The dependency of time on location, xv/c^2, indicates that the *velocity of light is not isotropic* ($v \neq 0$) in the coordinate frame in question. An observer anywhere can calculate his velocity in relation to light by first performing the synchronization and then noting what the time difference between the clocks is. This was not possible before the 1970’s, but now, in the time of atomic clocks and satellite technology, it can be done. From that, many interesting things follow.

2. Simultaneity

2.1 Observations Made with Atomic Clocks and Simultaneity

Let us discuss the experiment in which identical clocks are located in San Francisco (SF) and New York (NY), ref [6]. The clocks are synchronized in accordance with the procedure as presented in the theory of relativity. Because the velocity of radio signals is believed to be constant in relation to the surface of Earth, the displayed reading in both clocks should now be the same at all times.

The observer in the North Pole (NP) checks out what is happening. He is at rest in the Earth-centered, non-rotating coordinate frame. We call it ECI frame (Earth-Centered Inertial frame). NP is convinced that in his coordinate frame the velocity of light is constant and, therefore, its is from SF to NY (c – v) and from NY to SF (c + v), where v represents Earth's circumferential velocity in the direction of the propagating radio wave. NP thus believes that in the clocks there exists a difference because of synchronization, $L_{SN}v/c^2$, which in the SF frame be labeled as $L'_{SN}v/c^2$.

Obviously, the clock in NY runs slow from that in SF by the reading value of $L'_{SN}v/c^2$. Placing the distance between the cities, L'_{SN}, and the route component of Earth's circumferential velocity into the equation, results in 14 ns. We have a situation here where the observer in SF claims that his clock and the one in NY display exactly the same time whereas the observer in NP claims that there is a 14-ns difference present in the readings. This, of course, cannot be the case in a real world; there can be only one reading present in the clock in NY. Which is it?

To prove that his view is correct, the observer in SF takes his clock and drives to NY. Upon arriving, he indeed finds the clock readings to be the same. Quite so, says the observer in NP, but while moving your clock—no matter how slowly—you experienced additional velocity over the rotational velocity of Earth. During your journey I counted cumulatively all the generated pulses in SF, NY and in the clock you took along with you. My results were that your clock accumulated a delay of $L'_{SN}v/c^2$ (= 14 ns) compared to the stationary clocks, i.e. exactly as much as the clock in NY originally was slow. (This experiment has really been conducted [5]. Correspondingly, a clock was transported from Washington to Paris [4] and from Washington to Tokyo—with the above-described results.)

SF now performs another experiment. He sends his clock reading to NY where it is registered, together with the NY reading, at arrival. The difference between in the displayed readings is exactly L'_{SN}/c. Next, NY sends his reading to SF where it is registered together with the SF reading at its arrival. Again, the difference is exactly L'_{SN}/c. Look, says the observer in SF, my clock measurements prove that the speed of light is the same in both directions.

The NP-observer replies:

Your result shows constancy for the velocity of light only because the method of synchronization you used left the clocks with a time delay that happens to agree with your result (How this happens was explained in Introduction). The method of synchronization employed guarantees that be velocity v whatever, the speed of light in one direction, measured by using two clocks, is always c. Therefore, your results do not tell anything about the *physical* light speed in relation to the surface of Earth.

We do get the true speed if we know what the true displayed readings of the clocks are at any same instant. You in SF have no means of figuring that out when basing your observations on your coordinate frame. But you can send a signal from SF to NY, and in the opposite direction also, via the North Pole (A satellite or an airplane could be up there to reflect the signal).

The distance from the poles to all latitude points is always the same, and the rotation of Earth does not affect that distance. The distance traveled by a radio signal is the same in both directions for both of us in our respective reference frames, without any doubt. The difference in displayed readings of the two clocks is revealed by transmitting displayed clock readings in both directions. In reality, we can obtain simultaneous displayed readings from any clock on Earth in the near-Earth space by using GPS-satellites. When this was done in the discussed case, the result, in fact, was 14 ns.

Let us conduct such an experiment that we can make use of clocks in one place; then, we do not need to argue about whether events are simultaneous or not. We send a radio signal around Earth in the direction of the rotation and in the opposite direction. We check to see if they arrive at the same time (Report on a performed experiment in ref [10]). They did not arrive at the same time. Now we are actually watching clocks at one location, so we obviously have to agree on their displayed readings. The difference appears to be exactly what we get when we assume that the speed of light differs in both directions by the amount of Earth's rotational velocity.

Let us conduct the same experiment with several clocks, also. In an airplane we transport one clock in Earth's rotational direction (East) and a second one in the opposite direction (West). We leave a third clock on the ground. We set the clock readings identical, of course, before we start of the experiment. According to the SF observer—that because both of them have traveled at the same speed compared to the one on the ground—both of them should display the same delay-difference to the ground clock. If my claim is correct, then the East-moving clock has moved at velocity $v_L + v_M$ and the West-moving clock at velocity $v_L - v_M$, and the clock on the ground at velocity v_M. (v_M is Earth's circumferential velocity and v_L the airplane's ground velocity.) The East-going clock would be going fastest, the clock on the ground second fastest and the West-going the slowest. (The West clock actually moves tail first eastward). My prediction is, therefore, that the clock moving East will have run slow and the clock moving West will have run fast compared to the clock on the ground. When we both check the readings afterwards, we notice that this, in fact, is the case. (This experiment was done in 1971 and is known as Hafele-Keating Experiment [7]. The result: The East-going clock was slow (59 ns ± 10 ns) and the West-going clock was fast (273 ns ± 7 ns.)

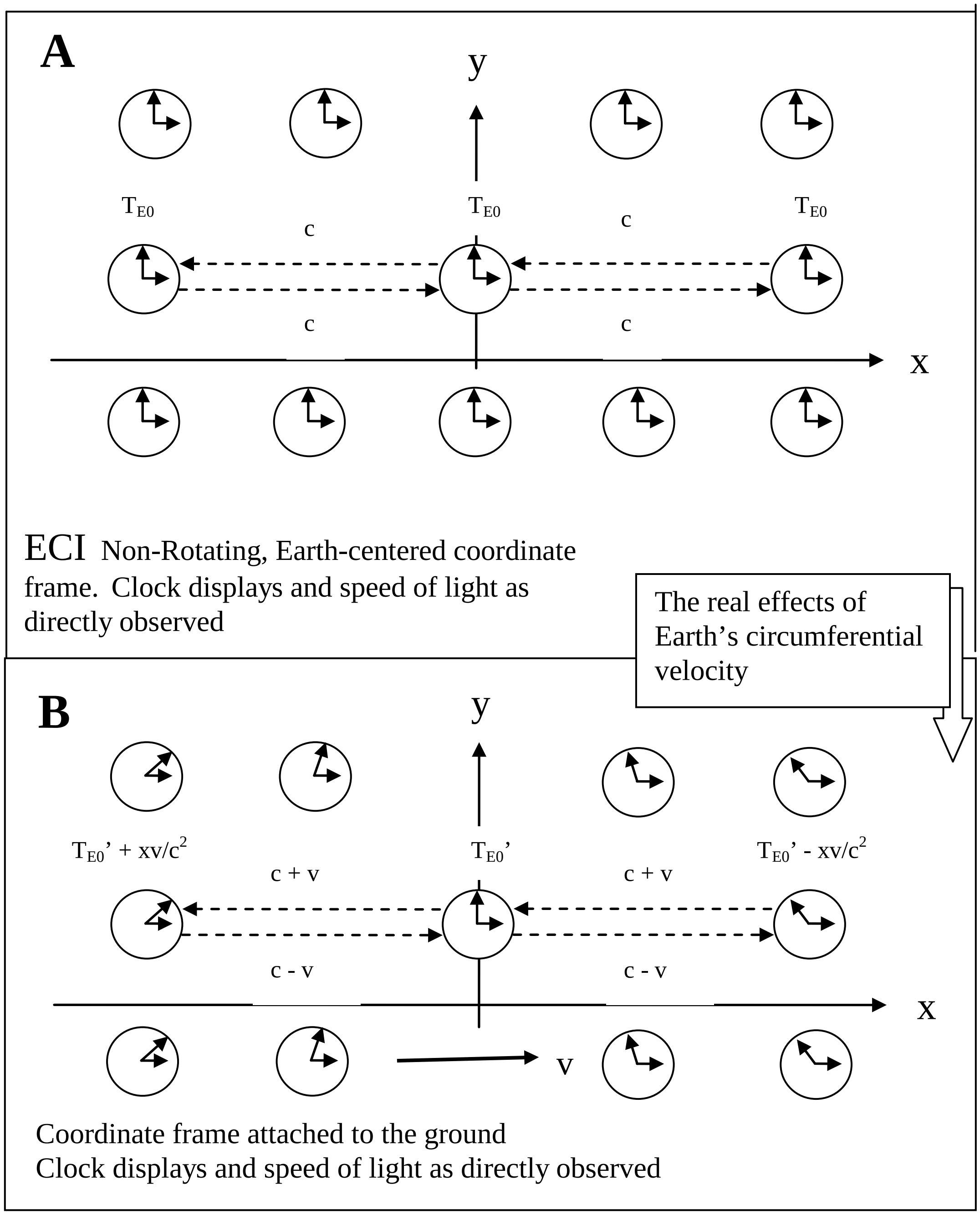

Figure 2. The speed of light and clock displays in different coordinate frames.

Undoubtedly, we now have enough experimental data to draw our final conclusions. In Figure 2, the upper A frame is my coordinate frame, the non-rotating Earth-Centered coordinate frame. It is normally called the Earth-Centered Inertial frame, ECI-frame. We will later learn that light possesses in ECI-frame a physically isotropic property. Once synchronized, my clocks always display the same reading at any one moment.

The lower B frame is your coordinate frame. You are moving at velocity v in reference to me. The same light that I see as isotropic in velocity varies in relation to you between values c ± v. When you now synchronize your clocks in the manner previously described, they contain the difference (clock bias), xv/c^2, appearing as either a plus or minus term, depending on the direction from you.

Therefore, the speed of light, c, measured by you is only illusory and the displayed readings in your clocks only your conclusions—because you cannot see them at the same time. In reality, the displayed readings remain in the positions shown in the B frame and your speed of light is c ± v. We have shown, by employing atomic clocks, that the Lorentz transformation does not change physical reality.

2.2 Simultaneity—History

In the theory of relativity the "time" of an event is the displayed reading of a clock at the event location. (Einstein writes: (ref. [1] Chapter 8)

"…we understand by the ' time' of an event the reading (position of the hands) of that one of these clocks which is in the immediate vicinity (in space) of the event. In this manner a time-value is associated with every event which is essentially capable of observation"

In the theory of relativity *simultaneity is the sameness of displayed clock readings*. In Einstein's time there was no means to confirm the absolute sameness of clock readings in clocks far apart each other. Among others, H. Poincaré discussed this problem in his many publications starting as early as 1898 [6]. He states about synchronization of clocks by employing a forth and back light ray, in the case when the time of propagation of light is not the same in both directions, the following (Excerpt from Poincaré's publication in 1904, ref [6])

"The watches adjusted in that manner do not mark, therefore, the true time, they marked what one may call the local time, so that one of them goes slow on the other. It matters little since we have no means of perceiving it. All the phenomena which happen at A, for example, will be late, but will be equally so, and the observer who ascertains them will not perceive it since his watch is slow; so as the principle of relativity would have it, he will have no means of knowing whether he is at rest or in absolute motion."

Poincaré clearly says that synchronization produces "local time" and that it is not the same as the "true time". It is practical to employ "local time" to describe simultaneity because the observers do not have any better means. Einstein, too, remarks that his definition of simultaneity does not presuppose any knowledge about the physical isotropicity of speed of light (Excerpt from ref [1], Chapter 8):

"I maintain my previous definition nevertheless, because in reality it assumes absolutely nothing about light. There is only one demand to be made of the definition of simultaneity, namely, that in every real case it must supply us with an empirical decision as to whether or not the conception that has to be defined is fulfilled. That my definition satisfies this demand is indisputable. That light requires the same time to traverse the path $A \longrightarrow M$ *as for the path*

B⟶ M is in reality neither a supposition nor a hypothesis about the physical nature of light, but a stipulation which I can make of my own freewill in order to arrive at a definition of simultaneity."

The fundamental statement that ‘so be it’ because it is not possible to observe the differences in clock outputs is no longer true, as we have already seen and will later find out further. (Einstein’s understanding about the physical nature of light is unclear. Already in the footnote of the aforementioned paragraph Einstein speaks about the invariance of the speed of light as being a “physical hypothesis”.

Einstein copied Poincaré’s idea into his 1905 article (without mentioning the source). However, he disposed the “true time” and claimed that the only time we need is the one witch *the clocks display*, e. g. “local time” Clocks and time are causally connected with each other. The clocks at points A and B no longer were apparatuses functionally regulated by their mechanisms, but rather they mystically displayed time that nature had fixed right into those points in space. “Time” in the clocks no longer was a means to describe change, but the physical driver working in the changes themselves. Non-material time affects causally clocks made of matter!? (We do not need to be concerned about the mechanisms, says Feynman in ref [18]).

In the books and articles about the theory of relativity the operation of synchronization by means of light rays is discussed as if it were an actual routine job. In actuality, it became possible to synchronize clocks first only after the atomic clocks entered the scene and after the digital radio communication has sufficiently developed sometimes in the 1970’s. Einstein’s “empirical solution” remained only a “thought experiment” during his lifetime. But now we have a device, whose capability to differentiate is 10^{-15} seconds (if not even better now). The distance light travels in that time is only three parts of one per ten thousand in millimeters. We also know what the physical velocity of light is in our observation frames, so that we can read clock displays simultaneously with absolute certainty. Not today could Einstein “decide freely on what the definition of simultaneity is” In spite of all the proof, why does modern physics still hang on to that definition?

3. Some More History

3.1 The Sagnac and Michelson-Gale Experiments

In 1913, Sagnac performed the experiment illustrated in Figure 3. It incorporates a light source and a receiver (interferometer) on a rotating platform. Light gets reflected around a rectangle in both directions at the four corner mirrors. The effect of Earth’s motion cancels out during the light’s round trip because the effect is the same in both directions. On the right in Figure 3 the rectangle has been turned into a circle because its mathematical manipulation is more descriptive.

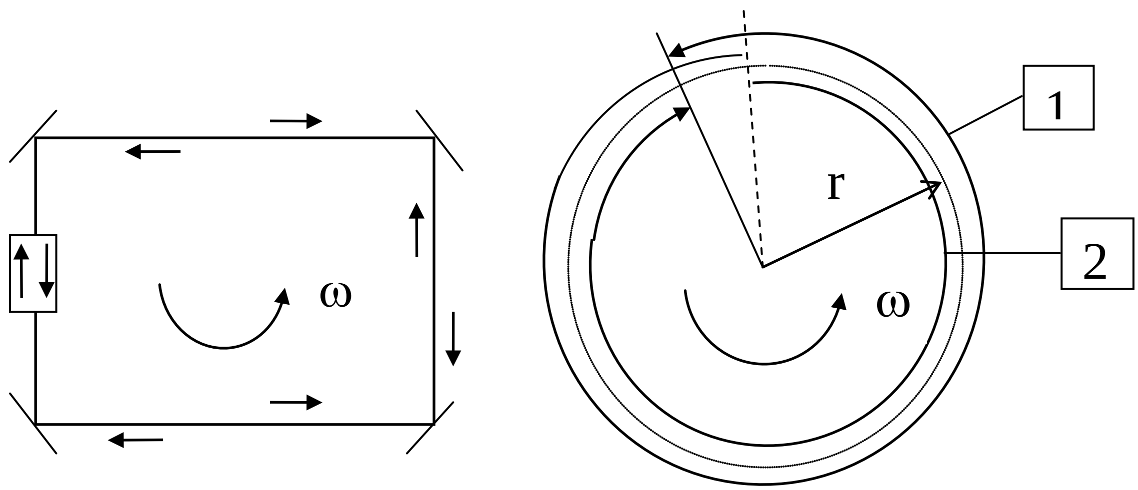

Figure 3. The Sagnac Experiment.

The velocity of light in relation to the turning platform is calculated by using the simple Galilee's equation. The velocity of light in relation to the disk clockwise is c – ωr and counterclockwise c + ωr. The travel times and the difference between them are:

$$t_1 = 2\pi r/(c - \omega r) \quad (3.1)$$

$$t_2 = 2\pi r/(c + \omega r) \quad (3.2)$$

$$\Delta t = t_1 - t_2 = 4\pi r^2\omega/[c^2(1 - \omega^2 r^2/c^2)] \cong 4A\omega/c^2. \quad (3.3)$$

A is the area of the circle enclosed by the light rays. Of course, it was not possible to measure directly the difference in time units—only the corresponding phase difference with an interferometer:

$$\Psi = 2\pi\Delta t/T \quad (3.4)$$

The time for a period, T, is: $T = \lambda/c$, thus the phase difference becomes:

$$\Psi = 4A\omega/\lambda c \times 2\pi. \quad (3.5)$$

The same calculation for the rectangular shape produce the same result. In that case A is the area of the rectangle. The experiment yielded exactly the result as in equation (3.5).

In 1925 A. A. Michelson and H. G. Gayle performed the Sagnac experiment with a large rectangle constructed into terrain by using pipes from Chicago's water supply plant. The lengths of the sides were 621.6 m East-West and 339.2 m North-South. The pipes were evacuated of air. The rectangle was now Earth-driven. The effect of Earth's orbital motion cancels out in a closed circle. Calculations using equation (3.5) produced:

$$\Psi/2\pi = 4A\omega/\lambda c = 0.236 \pm 0.002 \qquad (3.6)$$

Here A is the projection of the rectangle in the Equatorial plane and ω is Earth's angular velocity. The measured result was 0.230 ± 0.005.

The Michelson-Gale experiment revealed that the velocity of light differed in relation to Earth's surface by the amount of Earth's circumferential velocity. It would not have been necessary to wait 46 years for the atomic clocks to show the same thing. (A. A. Michelson is the same gentleman who partnered in the famous Michelson-Morley experiment. He performed many very accurate optical measurements and was awarded Nobel prize in 1907. Nobody could find an error in the Michelson-Gayle experiment, either. Yet, the relativists, Einstein himself at the forefront, remained dead silent about this experiment. In 1925 media already had created a superhuman out of Einstein, and the theory of relativity had become a political ideology.)

4. Earth-Centered Inertial frame (ECI-frame)

The measurement of quantitative time is always based on some kind of a period-repeating apparatus. We only have to believe that the chosen apparatus repeats periods at a constant frequency.

The theory of relativity predicts that the ticking rate of clocks slows down as velocity increases by the following formula:

$$f_A = f_B\sqrt{(1 - v_{(A-B)}^2/c^2)}. \qquad (4.1)$$

The atomic clocks have proved to be devices that function in accordance with this equation. In equation (4.1) $v_{(A-B)}$ is the velocity of A in relation to B, i.e. the relative velocity. In theory of relativity A and B can also change places, i.e. A can take the position that B is moving in relation to A, and so B's clock then runs slower than A's clock.

$$f_B = f_A\sqrt{(1 - v_{(B-A)}^2/c^2)}. \qquad (4.2)$$

In the theory of relativity the explanation of even this paradox is based on the relativity of simultaneity (a third clock is employed [11]). Another explanation is that every inertial coordinate frame is an independent frame of observation in itself. Therefore, there are two events, unrelated to each other, at works here, so that equations (4.1) and (4.2) are not valid at the same time. They represent two different realities—reality is tied to the observer. At least for the time being no observation has confirmed the reciprocality of the coordinate frames.

Our observations about atomic clocks do not honour the principle equality in observer-frames. The coordinate frame in which Earth is the center, the ECI frame, *has a special status*. In other words, the clocks at the North and South Pole are the rest clocks with highest frequency f_{v0} All the other clocks moving in relation to ECI-frame have a lower frequency:

$$f_v = f_{v0}\sqrt{(1 - v_{ECI}^2/c^2)}. \qquad (4.3)$$

f_v is the frequency of the clock in motion at such a moment when its velocity is v_{ECI}, be the shape of the trajectory, i.e. the direction of the velocity, whatever.

On Earth's surface and in the near-space, the laws of nature thus grant special status to one coordinate frame. In comparing the ticking rate of clocks we never should use the relative velocity between them, but the ticking rate for each clock must first be calculated from its state of motion in the ECI frame, and then the resulting frequencies must be compared:

$$f_A = f_{v0}\sqrt{(1 - v_{A(ECI)}^2/c^2)} \quad (4.4)$$

$$f_B = f_{v0}\sqrt{(1 - v_{B(ECI)}^2/c^2)}. \quad (4.5)$$

We can solve the frequency of clock A in relation to clock B by using equations (4.4) and (4.5):

$$f_A/f_B = \sqrt{(1 - v_{A(ECI)}^2/c^2)}/\sqrt{(1 - v_{B(ECI)}^2/c^2)} \quad (4.6)$$

This ratio corresponds to observations and it cannot be changed by imagining one or the other observer to be at rest. For all the clocks on Earth and Earth's near-space, the ECI frame is the preferred frame [2, 3 and 8].

So far we have discussed the effect of velocities on clocks without taking into account gravitation. According to the theory of relativity, the gravitation also affects clock frequency as per the following equation:

$$f_g = f_{g0}\sqrt{(1 - 2GM/rc^2)} \cong f_{g0}(1 - GM/rc^2) \quad (4.7)$$

Here f_{g0} is the frequency of the clock when the gravitational potential is zero, i.e. for example in the case where the clock is infinitely far from a mass concentration. G is Newton's gravitational constant and M is the mass of the mass concentration. The atomic clocks conform to this equation.

There exists no "basic clock" granted by nature. The basic clock humankind uses is matter of agreement. In their times the clocks were well-constructed pendulum clocks, chronometers. Their ticking rate depends on gravitation in the opposite direction to that of the atomic clocks. As gravitation weakens, they slow down and in the weightless space, for example in a satellite, they would stop running altogether. The clocks are driven by the physical processes tied to their structural configuration—not by time. A clock has no knowledge about it measuring time. It is a clock only because the human beings have so agreed.

The present basic clock is the cesium-133 atomic clock. The period it needs to generate 9.192.631.770 ticks defines the duration of one second. This means simply that many ticks – not that many ticks per second - for it is impossible to measure the frequency of the basic clock. Should that clock be brought anywhere in the universe, the time the device needs to produce the said number of ticks is one second in that location. The tick-numbers generated by other clocks in the same time can be compared to the tick-numbers of the basic clock, and, for example, can be subjected to adjustment, but never the opposite way. This is what humankind has consented to, a law of nature it is not. The stability of the best atomic clocks is one to 10^{15}, and we are on the way to even better stability.

The dependency of frequency of atomic clocks on motion and gravitational potential is perhaps tied to the physical structure of atoms. Hardly is it time that moves atoms around, but the causes reside rather in the direction of Mach's principle. The same phenomenon may provide an explanation to the dependency of lifetime of particles to velocity in particle accelerators.

5. Global Positioning System (GPS)

There are 24 satellites (recently 3 back-up satellites added) in the GPS, Figure 4. They orbit Earth at a distance of approximately four Earth-radiuses from the center of Earth (at a height of c. 20,000 km from Earth's surface). They are in sets of four and form six planes at a 55-degree angle to the Equatorial plane. This method ensures that from every point on Earth's surface there always is a sufficient number of satellites visible. The velocity of the satellites is about 3.9 km/s. At different locations on Earth there are five ground stations managing the system.

There is an atomic clock in every satellite. The ground stations have similar clocks. Although the ticking rates on ground are the same, the clocks differ as soon as the satellite is on its orbit. The difference is caused by the different gravitational potential and the different velocities in the afore-said manner [equations (4.3) and (4.7)]. Thus, the frequencies are calculated separately for each clock by substituting the distance from Earth's center for r and the velocity of the clock in the ECI frame for v. The result is that the satellite clock gains 45,900 ns/24-h and loses 7,200 ns/24-h compared to the clocks on Earth's surface. The combined effect thus is that the satellite clock runs fast by 38,700 ns/24-h. When this difference is taken into account in such a way that the pulse count for one second in the satellite's pulse-counter correspondingly is changed, the end result is a clock in the satellite that runs exactly at the same ticking rate as the ground clocks on a geoidal plane. A geoid is a plane on which Earth's mass and rotation together affect clocks so that the combined effect is constant.

In principle, the clocks are synchronized with radio signals the way the theory of relativity directs. In synchronization, when the fact that the velocity of radio signals (light) in the ECI frame is constant in any direction, is met with, there will be no difference in their clock outputs. This way it is possible to set all the clocks to a reading that is exactly the same at any instant in time. Once the ticking rates, too, have been equalized in the aforementioned manner, the absolute simultaneity is conserved in the clocks irrespective of their location. All the clocks in

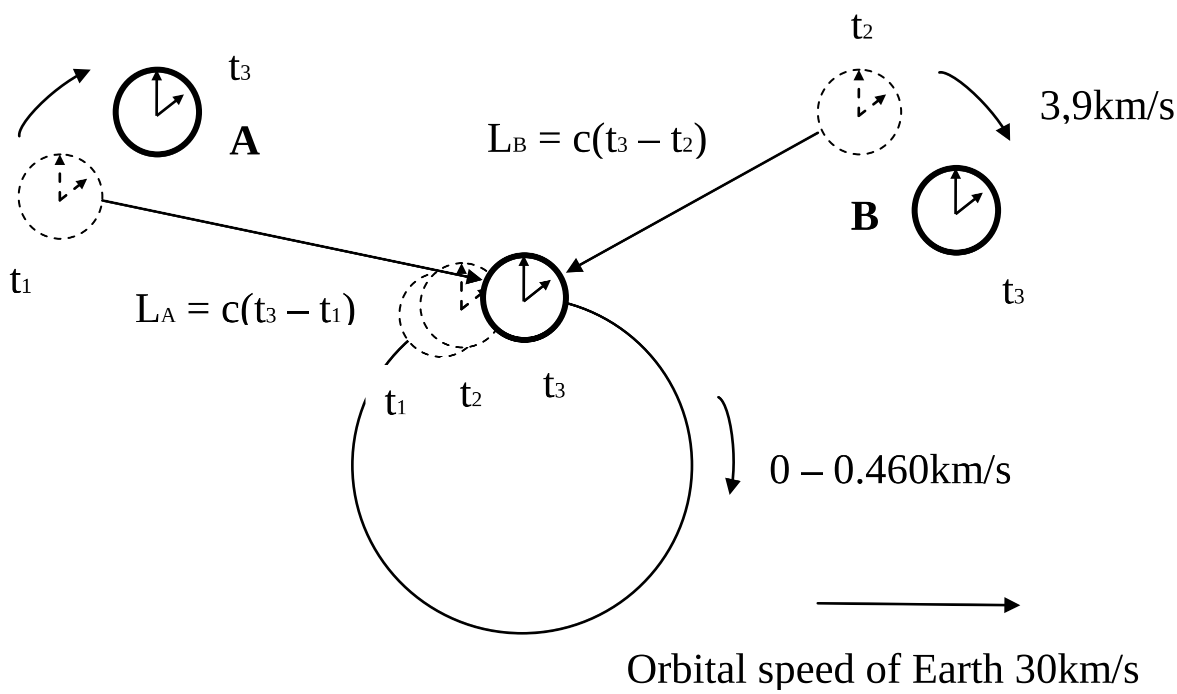

Figure 4. The principle of the GPS.

the system now display the same GPS time. The main station of the ground stations keeps track that there will not be any cumulative differences in the clocks. The clock frequencies can be made identical to extreme accuracy because even a minute difference grows to a noticeable one as time passes. The differences are easily corrected by transmitting a corrective signal.

The ground stations also constantly position-scan the satellites by using two radio frequencies and calculate every location at every instant. The verification about location is sent to a satellite at every 1.5-second interval. Thus, the satellite is capable of sending a radio signal that contains information about its location and the clock time at the instant that the signal is transmitted.

The time it takes for light to travel from the satellite to the requester is of the size of 0.08 s, i.e. 80,000,000 ns. Observations have confirmed that the velocity of light in the ECI frame in all directions, at all distances and in all seasons is constant to a very high degree of accuracy. This means that *the starting point of the radio signal remains at its original location* in the ECI frame while the satellite itself continues its journey. Thus, the task at hand is to define the requested location in the ECI frame in relation to four fixed points.

The receiver registers, at the same time, the messages received from three satellites. The difference in the time between signal transmitted and signal received, multiplied by the velocity of light, gives the receiver's distance from each satellite. As the messages also contain the exact location of each satellite in the ECI frame, the receiver's small computer can calculate the requester's location. The clock in the receiver (especially in the inexpensive ones) is not so accurate as the satellite clock. Now that the receiver knows its location quite precisely, it also knows its distance from the fourth satellite. From there, it receives information about the location and the transmission-start time and computes how much its own clock differs from the one in the satellite. This corrected reading is used to make a new, more exact determination of the location.

The transmitter frequencies are 9 - 10 GHz, i.e. the wavelength is in the neighborhood of 20 cm. The instant referred to in the transmitter must be included with better accuracy than that into the wave queue. It is done by means of an into-the-wave-queue-coded-pulse queue, to which the receiver compares its own pulse queue. (PRN (Pseudo Random Noise) code).

The accuracy of the clocks and other technical equipment is sufficient to determine location in the millimeter range. Nature sets limits, however. There is a layer containing electrical charges, the ionosphere, in the atmosphere at height 70 - 130 km. The thickness and the charge it contains vary with the incoming radiation from space (e.g. solar wind). The northern lights are thus formed, also. The ionosphere has an effect on the travel velocity of the radio signal. Thus, it causes an error in the computed location because the receiver assumes that the velocity is constant.

This situation can be improved by using so-called D-GPS, i.e. differential positioning. In D-GPS the requester makes use of a second receiver on Earth's surface, a receiver that knows its coordinates. This assisting receiver continuously computes its location utilizing the GPS signals and compares the result with the coordinates it knows to be correct. This way it knows how much the GPS is in error at that instant and at that location (e.g. the differences in latitude and longitude degrees). The Earth station continually transmits these error readings to the requesters, so that the requester's receivers can make the automatic corrections. The closer the requester, the more exact the correction, because the ionospheric space changes are in a low slanted angle as per location. For example, the taxicabs in Helsinki use D-GPS—without it they would be often driving on top of buildings on street map display. Large areas, for example those close to airports, are covered with many ground stations. A so-called WAAS, Wide Area Augmentation System, is thus created. Air traffic navigation becomes more reliable.

The requester on the surface of Earth moves with a velocity of 0 - 460 m/s, depending on his location between the pole and Equator. This motion has to be factored in (together with the requisition's own motion in relation to Earth's surface) by using the normal Galilee's formula - the differential velocity between light and the requester as inputs. This motion corresponds to a shift of 0-37 m during the travel time of the radio signal. The Consultative Committee for the Definition of the Second and The International Radio Consultative Committee have agreed that this error correction is to be done so that the travel time is added by:

$$\Delta t = 2\omega/c^2 \times A_E \qquad (5.1)$$

A_E is the area projected on the Equatorial plane for a sweeping vector, the point of origin of which is at Earth's center and the arrowhead of which tracks the signal route. ω is Earth's angular velocity. The difference is positive if the arrowhead sweeps from West to East, and negative in the opposite case. The width of the difference is just the same as we obtained in the Sagnac experiment. Consequently, the correction is called the Sagnac correction [10].

Without the support of a ground station, an accuracy of 5 - 10 meters can be achieved with a wrist-worn device used by hikers. In differential positioning, the accuracy is up to 0.5 meters. By measuring the satellite signals over a long period and by using advanced computer programs to eliminate errors of various origins, it is possible to achieve astonishing millimeter accuracy used in cartography [15].

The GPS-satellites now transmit two radio frequencies L_1 and L_2 in the 9 - 10 GHz band (3 - 30 cm waves). L_1 is for civilian use and L_2 only in military use (its PRN code is secret). By the end of year 2007, there are plans to add three new frequencies. This way it will become possible to compare the travel time differences between five different frequencies and to study the ionospheric effect without involving the support stations on the ground. The goal is to achieve an accuracy of 1 – 2 mm in short-time measurements [22].

6. ECI Bubble in the Universe

What the atomic clocks tell us can be interpreted so that we live in a bubble closed off from the rest of the universe, inside which the ECI frame forms up the rest-coordinate frame for all shared events. The velocity of light in that frame is constant or at least almost constant. Even if it actually were changing a little by the varying distance from the center of Earth, the isotrophicity is conserved. Therefore, it would appear that the ECI frame is a physical inertial coordinate frame.

6.1 The ECI Frame in the Solar System

It is obvious that the Sun also creates a physical inertial coordinate frame around itself. This is called the SSB (Solar System Barycenter) frame. The Solar System moves in the Milky Way Galaxy and along with our Galaxy, compared to the distant stars and e.g. the 3K background radiation, at least ten times faster that the orbital velocity of Earth. No effect, for example, on the radio signal propagation times of probes have been noticed due to this velocity. For example, the distance to Pioneer 10 was over 100 AU prior to it becoming silent, and the two-way travel time of the radio signal was even in the neighborhood of 26 hours, i.e. huge in relation to the accuracy of measurements. Navigation of probes is founded on the velocity of the radio signals being isotropic in the SSB frame. Navigation today is so unbelievably precise that it was possible to guide the NEAR probe, 300,000,000 km away, onto the surface of the EROS asteroid, only 30 km in diameter. This task is comparable to guiding a molecule on to the end of a hair 300 m away. It would be quite anthropocentric to claim that the Earth-centered, non-rotating coordinate frame were the only physical inertial coordinate frame in the universe and that all the other coordinate frames were such only thanks to the Lorentz transformation. We would return to the pre-Copernican time.

Earth is enclosed in the Sun's frame as is the Moon in Earth's frame. Next we study the effects of the SSB (Sun) frame on the atomic clocks inside the ECI frame.

The x-axes of ECI coordinate frame is attached to a distant star. It thus maintains its direction in the same way as a passenger car in a Ferris wheel. The velocity of every coordinate point in the SSB frame is the same, always, i.e. the same as the orbital velocity of the point at Earth's center. Often mistakenly it is assumed that the velocity of a satellite between Earth and the Sun is less than the velocity of one behind Earth (as viewed from the Sun) [9]. This is not the case, however. Every point in the ECI frame traces a circle having the same radius, but the center points of the circles are not exactly at the same place. Thus, the variation in the distance from the Sun does not cause any variation in the velocity or in the centric acceleration in the SSB frame [15].

The GPS clocks, circling along with Earth's surface or as satellites around Earth, have varying distances from the gravitational center of the Sun system, however. As a result of this, the gravitational potential of the Sun varies for each clock at a different rate. Calculations give a cumulative variation of ±12 ns/round to the space satellites. This corresponds to observations as well [9, 15].

Once the GPS clocks have been synchronized previously described manner in the ECI frame they -- according to the theory of relativity -- should not be synchronized in the SSB frame. In Figure 4 the velocity of a radio signal in the SSB frame to clock B, for example, is lower in the forth direction than back direction. After synchronization the observe at SSB should be able to see that the clock in B runs slow compared to the ground clock by the display reading of $L_B v_{L/orb}/c^2$, in which $v_{L/orb}$ is the Earth's orbital velocity in direction of radio signal. No such difference is seen in the GPS clocks—and must not also the observer in SSB see the same numbers

The orbital velocity of Earth is not exactly constant, though. It varies because of the eccentricity of Earth's orbit. When diving into the perihelion Earth's velocity increases and also the Sun's gravitational potential increases. If the clocks in the ECI frame sense this, they all should slow down. We can-not notice that by staring at the clocks in the ECI frame, but what if we "look outside"? Out there, there are clocks, too. By comparing the frequencies of the atomic clocks to the frequency of a distant pulsar, the clocks have been noticed to be slowing down. All the atomic clocks thus sense the velocity of their own inertial coordinate frame "collectively", i.e. all the clocks slow down by the same multiplier. It shows, that the frequency of a clock at rest in the ECI frame depends on the clock frequency in the SSB frame according to the following equation:

$$f_{v0/ECI} = f_{v0/SSB}[1 - ½v_{orb}^2/c^2]. \qquad (6.11)$$

The way the mechanism works, therefore, is that the clocks at rest in the ECI frame confirm to the time dilation in relation to the clock at rest in the SSB frame and that the other clocks in the ECI frame confirm to time dilation in relation to the clock at rest in their own frame. The clocks are series-connected this way, so that the observer in the SSB frame cannot calculate the frequency of any single ECI clock without taking into account the ECI frame.

The ECI frame is not that much-used space ship described in the books about relativity—the space ship that travels at an enormous speed; to the travelers inside the ship the clocks display the readings tied to the coordinate frame of the ship, and to the outsiders the readings are tied to their coordinate frame. In conclusion, this is not the case—the atomic clocks display the same reading to all observers and choose their rest-coordinate frame themselves.

6.2 Stellar aberration

The phenomenon is the following: When the same star is observed in time half a year apart, the aim of the telescope must be changed for the star to appear at the center of the bottom of the telescope. If the star is in the perpendicular direction to Earth's orbital plane, the tilt-value is ±20.5" *in the direction of Earth's travel*. The angle is equal to argtan v/c, where v is Earth's orbital velocity. The need for correction is the same for all stars. The aberration of the light from the Moon is only 0.7" .

The explanation as per classical physics, i.e. the raindrop theory, is the following: If rain drops fall vertically toward the ground at velocity v, and an upright tube moves along with the ground surface at velocity v, the tube must be tilted forward by angle arctan v/c, so that the droplets entering at the top would fall to the bottom of the tube. The raindrop theory thus produces the correct result. It can be found in many physics textbooks even though it clearly is contradictory to the theory of relativity. Namely, it requires that the speed of light to an observer in Earth's inertial coordinate frame (i.e. inside the telescope at rest) would have to be $\sqrt{(c^2 + v^2)}$, i.e. greater than c.

The raindrop theory goes, however, against some observations too. In 1871 G. B. Airy was smart enough to fill a telescope with water. Because the velocity of light in water is 30% less than in air, the need for angle correction in the telescope would have to increase, according to the raindrop theory. No change was necessary, though. The incoming light ray is already in its tilted direction as it arrives to the top of the telescope.

All this was known at the time the theory of relativity was born. Yet, Einstein in his famous 1905 article explained that aberration was caused by the difference in the light source and observer velocities. Then, for example, the twin stars would each have a different angle of aberration. Observations show, however, that this is not the case. All light around Earth is velocity-wise equal (homogenized by the SSB frame) irrespective of its origin. The theory of relativity thus set a prerequisite for itself to explain the aberration of starlight in such a way that the speed of light in relation to Earth remains constant - but the angle is dependent on the orbital speed of Earth though. It was not easy by far. A long-lasting arm wrestle followed—at times buried as unresolved—but which occasionally still continues [12]. The most "orthodox" might be the one that is based on the relativity of simultaneity [17], [19]. The explanation is as follows:

The starting point is the SSB frame in which the ECI frame moves and, therefore, the observations are Lorentz-transformed in the ECI frame. Let us assume that the x′-axis of the ECI coordinate frame is in the direction of Earth's orbital motion. Let the photon from a star be at height H at moment t = 0. SSB coordinates $y = H - ct$ and $x = 0$ then describe its progression downward. When x and t are transformed into ECI coordinates by Lorentz transformation, i.e. $x = \gamma(x' + vt')$ and $t = \gamma(t' + vx'/c^2)$, the result is the location coordinates in the ECI frame:

$$x = 0 = \gamma(x' + vt'), \text{ so that } x' = -vt' \qquad (6.2.1)$$

$y = H - ct$, so that $y' = H - ct' = H - c\gamma(t' + vx'/c^2) = H - ct'/\gamma$. (6.2.2)

This shows that the velocity components in the ECI frame are:

$v_{x'} = v$ and $v_{y'} = c/\gamma = c\sqrt{(1 - v^2/c^2)}$. (6.2.3)

The squared sum of these components is c^2, so that the scalar value of the velocity of light in ECI remains unchanged, as it should. The direction of the photon's velocity vector has, however, turned in the ECI frame by the angle whose tangent is:

$\tan\alpha = v_{x'}/v_{y'} = v/[c\sqrt{(1 - v^2/c^2)}] \cong v/c$. (6.2.4)

When Earth's orbital velocity 30 km/h is substituted in the equation, the result for α is the very observed 20.5″.

Why does this explanation not satisfy everyone? Well, because it violates the relativity principle. According to the relativity principle, no coordinate frame has a preferential status. Every observer in any inertial frame has the right to assume his own coordinate frame to be the rest coordinate frame (the Galilean frame) and to view that the others move in relation to himself. To explain his own observations he does not need to alter his coordinate quantities. He applies the Lorentz transformation to the other coordinate frames that move in relation to him. Also, in principle, no one can assume that his coordinate frame moves at any other velocity in relation to light than that of velocity c. The theory of relativity, at least in its original form, presupposed that the coordinate frames are of infinite size. Therefore, all the light-emitting points exist already in the observer's coordinate frame and no kind of coordinate frame motion to some light outside the coordinate frame is created.

This theoretical argument is now no longer that meaningful, for a much bigger conflict has risen. The explanation using the Lorentz transformation requires, namely, that its time-location term xv/c^2 is valid in the ECI frame. This would mean that in the GPS clocks there would be a corresponding real difference, clock bias. This is not the case, however, as we have seen earlier. The explanation in the theory of relativity to the aberration of starlight is thus heavily contradictory to the observations made possible by today's technology.

6.3 Annual Doppler

The phenomenon is the following: On its orbit around the Sun, Earth moves toward some star for half a year and away from it for the second half a year. This causes a *variation in the wavelength* of the light received from the star If the value of the variation is $\pm\Delta\lambda$ in relation to the average value λ_h, then, from that, Earth's orbital velocity can be calculated with the simple formula:

$v_{orb} = \Delta\lambda/\lambda_h \cdot c$. (6.3.1)

The phenomenon is called Annual Doppler. The explanation is the following: We know the wavelength of light in the Sun-centered, non-rotating coordinate frame, the SSB frame. It is the average value measured during one year or the momentary value at the instant when Earth moves perpendicularly to the light ray coming from the star in question. Let us now suppose that the x-axes of the Earth-centered non-rotating coordinate frame and the SSB frame point straight at the star. Let us further assume that Earth travels directly toward the star, i.e. in the direction of the x-axis, at velocity v. In this case the Lorentz transformation is the following:

$$x_E = \gamma(x_S - vt) \tag{6.3.2}$$

$$t_E = \gamma(t_S - vx/c^2). \qquad (6.3.3.)$$

Let the duration of one period be T_S in SSB and the wavelength λ_S and the corresponding quantities T_E and λ_E in ECI. Then, of course:

$$\lambda_S = cT_S \tag{6.3.4}$$

$$\lambda_E = cT_E \quad . \tag{6.3.5}$$

We now investigate the case in which, in both coordinate frames, the wave front is observed to be shifting the distance of one wavelength, i.e. $x = \lambda_S$. By attending to equation (6.3.3), we get:

$$cT_E = \lambda_E = c\gamma(T_S - v\lambda_S/c^2) = \gamma(cT_S - v\lambda_S/c) = \gamma\lambda_S(1 - v/c)$$

$$\cong \lambda_S(1 - v/c) \tag{6.3.6}$$

$\gamma = 1/\sqrt{(1 - v^2/c^2)}$, so that its effect is very small.

We arrive at the results observed. The explanation, however, is based on the same assumption as in the aberration case, i.e. in the one that ECI is a Lorentz-transformed frame. This would mean that, in ECI, time is location-dependent, i.e. that simultaneity is relative. This being the case, the explanation of the Annual Doppler is troubled with the same problems as that of the aberration

6.4 The Background Doppler Phenomenon

The phenomenon is the following: Earth receives from every direction in space microwave radiation corresponding to the c. 3K temperature of a blackbody. The radiation is thought to be delayed echoes from the Big Bang. In the wavelength of the radiation, however, exists a difference, the maximum and minimum in which are on the opposite sides of Earth. If the difference in the wavelength is treated as a Doppler phenomenon, it corresponds to about one-thousandth of the velocity of light, i.e. about 300 km/s [14].

It is possible to apply to this case the same explanation as to the case of the Annual Doppler when we take the rest frame of the background radiation as a preferred frame.

7. Final Conclusions

The developments in technology have given us possibilities which Einstein's contemporaries could not even dream about. These include:

a. Clocks, whose accuracy is one to 10^{15} (if not even better)
b. We can monitor frequencies with cumulative counters, set them from distance and read them from distance
c. We can set readings into clocks from distance and read them from distance
d. We can transmit information digitally encoded.

On point d it should be noticed that, in the radio signal, information coded digitally remains unchanged despite the gravitational potential and velocity variations, and in any interchanged coordinate frame. That is the true invariant of nature. As a result of all this, we do not need to say as did Feynman still in the 60's: *But if one clock always appears to run at a different velocity compared to another clock, then from the view point of the first clock also the other one runs at a different velocity."* We do not need to be content with that "the things are the way they look" but now we know at what frequencies clocks truly run and what readings they display. We know that the frequency changes are real physical phenomena appearing in clocks, not the changes that took place in the message carriers conveying information about them.

The observations brought up by atomic clocks about the frequency variations, clock bias and the speed of radio signals in different frames make the Lorentz covariance of ECI and SSB coordinate systems controversial. It looks like the nature has already answered to Vladimir Fock's question *'is the covariance corresponding **phenomena** or **formulas**'*

The world of science and that of engineering seams to stand divided in this question. The scientific community is not even willing to discuss whether, instead of the change of time, the question would simply be of matter and energy in conventional physics. Yet, engineers build fine-working systems basing them on "clock dilation" and on the law of the indestructibility of digital information.

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