Eight Proofs of Absolute Simultaneity

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The conviction that relativistic simultaneity has a conventional nature is shared by many authors, but it will be shown that simultaneity exists in the physical reality and therefore cannot be conventional. If the coefficient - we call it e_1 - of the space variable x in the Lorentz, or other, transformation of time had a conventional nature it should be possible to modify it without touching the empirical predictions of the theory: this expectation can be called Reichenbach-Jammer conjecture ("RJ conjecture"). Given that Einstein's principle of relativity leads necessarily to the Lorentz transformations, and thus also to a fixed nonzero value of e_1, the modification would imply a reformulation of the relativistic idea itself. With respect to the idealized expectation, based on the RJ conjecture, the concrete development of physics produces some exciting novelties. Several phenomena, in particular those taking place in accelerating frames (Sagnac effect, and all that), converge in a strong indication of $e_1 = 0$. This implies absolute simultaneity and a new type of space and time transformations, which we call "inertial". We give eight proofs of absolute simultaneity, deduced from essentially independent normally accepted premises.

1. From General to Equivalent Transformations

In 1977 Mansouri and Sexl [1] stressed that the Lorentz transformations contain a conventional term, the coefficient of the coordinate x in the transformation of time. Starting in 1994 the transformations of the space and time variables between inertial systems were reformulated [2] under very general assumptions. New transformations were obtained containing an indeterminate term, e_1, the coefficient of x in the transformation of time: see Eqs (3) below.

Given the inertial frames S_o and S one can set up Cartesian coordinates and make the following standard assumptions:

i. Space is homogeneous and isotropic and time homogeneous, at least from the point of view of observers at rest in S_o.
ii. Relative to the isotropic system S_o the velocity of light is "c" in all directions, so that clocks can be synchronized in S_o with the Einstein method and one way velocities relative to S_o can be measured.
iii. The origin of S, observed from S_o, moves with velocity $v < c$ parallel to the $+x_0$ axis, that is according to the equation $x_0 = v\,t_0$.
iv. The axes of S and S_o coincide for $t = t_0 = 0$.

The geometrical configuration is thus the usual one of the Lorentz transformations. Assumptions (i) and (ii) are not exposed to objections both from the point of view of the TSR and of any plausible theory based on a privileged system; for the TSR they hold in all inertial systems, in the second case they hold in the privileged system only.

One can show that (i) - (iv) imply transformation from S_o to S of the form

$$\begin{cases} x = f_1(x_0 - v\,t_0) \\ y = g_2 y_0 \\ z = g_2 z_0 \\ t = e_1 x_0 + e_4 t_0 \end{cases} \qquad (1)$$

where the factors f_1, g_2, e_1, e_4 can depend on the velocity v of S measured in S_o.

In deducing (1) an extensive use is made of the space and time homogeneity conditions: see the paper by Lévy-Leblond [3]. This does not mean, however, that the Lorentz transformations satisfy "fully" the homogeneity conditions. In fact they do not. Lévy-Leblond arrives at the transformations (in differential form):

$$dx' = H(a)dx - K(a)dt$$
$$dt' = L(a)dt - M(a)dx$$

where the presence of the diagonal coefficients $H(a)$, $L(a)$ is easy to justify physically: $H(a) \neq 0$, because two events seen from S to have different position ($dx \neq 0$) at the same time ($dt = 0$) must be seen also from S' in different positions $(dx' \neq 0)$; $L(a) \neq 0$, because two events seen from S in the same position $(dx = 0)$ at different times $(dt \neq 0)$ in general must be seen also from S' at different times $(dt' \neq 0)$; also the presence of $K(a)$ is no mystery. One has $K(a) \neq 0$, because two events seen from S in the same position $(dx = 0)$ at different times $(dt \neq 0)$ must be seen from S' in different positions x'. This is like saying that a particle at rest in S must be seen in motion relative to S'.

No justification of the same quality can be found for $M(a) \neq 0$. One can say, of course, that $M(a) \neq 0$ makes it possible that two events seen from S to have different position ($dx \neq 0$) at the same time ($dt = 0$) can be seen from S' to be at different times $(dt' \neq 0)$. It is a standard relativistic conclusion but one cannot see any direct physical justification. For sure it violates the standard formulation of the homogeneity of space. Homogeneous means "equal in all parts." How can one make time depend on a variable specifying in which part one is of a medium equal in all parts? Such a medium would not be homogeneous, because its different parts would have different effects on time.

We add two assumptions based on solid empirical evidence:

v. The two way speed of light is the same in all directions and in all inertial frames:

$$c_2(\theta) = c$$

vi. Clock retardation takes place with the factor R calculated with respect to S_o :

$$R = \sqrt{1 - v^2 / c^2} \tag{2}$$

It should be stressed that the TSR satisfies all these assumptions. The two famous postulates of the TSR (relativity principle and invariance of light velocity) are here replaced by the much weaker assumptions (v) and (v_i).

A seventh assumption, often implicit, is Einstein's "acceleration hypothesis". Taking the example of the rotating platform, in every point of it one can imagine a co-moving inertial frame. A statement correct in the latter frame must be correct also locally with respect to the co-moving rotating platform: this is the acceleration hypothesis. Thus we see that, according to the TSR and respecting the isotropy of space, in every point of the rim the velocity of light relative to the disc is c both clockwise and counterclockwise, independently of disk rotation. Therefore two light pulses moving in opposite directions need the same time to complete the tour and the Sagnac effect goes to zero, contrary to empirical evidence.

The first six assumptions determine the transformations of the space and time variables from S_o to S to have the form of the "Equivalent Transformations" [4] (ET)

$$\begin{cases} x = (x_0 - v t_0) / R \\ y = y_0 \\ z = z_0 \\ t = R t_0 + e_1 (x_0 - v t_0) \end{cases} \tag{3}$$

Reichenbach [5] and Jammer [6] essentially believed that the parameter e_1 is free and can be fixed conventionally by synchronizing clocks in S. We will see, however, that far from being free e_1 must be zero. The one way velocity of light deduced from the ET is given by [4]:

$$\frac{1}{c_1(\theta)} = \frac{1 + \Gamma \cos\theta}{c} \tag{4}$$

where θ is the angle between light propagation direction in S and absolute velocity of S. The parameter Γ is given by:

$$\Gamma = \frac{v}{c} + c\, e_1 R \tag{5}$$

Of course in the TSR one must have the one way speed of light equal to c, which is the same as $\Gamma = 0$, whence one gets the parameter e_1 in the relativistic version.

The Eqs. (3) represent the set of theories "equivalent" to the TSR: if e_1 is varied different theories are obtained. According to the RJ conjecture they should be equivalent for the explanation of experimental results.

2. The Sagnac Effect

Almost a century after the 1913 discovery of the Sagnac effect [7] no satisfactory derivation of it exists based on special relativity and/or general relativity [8]. In the 1913 Sagnac experiment a platform rotated uniformly at a rate of 1-2 rot/sec. In an interferometer mounted on the platform, two interfering light beams, reflected by mirrors, propagated in opposite directions along a closed horizontal circuit. The rotating system included also the luminous source and a photographic plate recording the interference fringes. Sagnac observed a shift of the interference fringes every time rotation was modified. This shift depends on the relative time delay Δt, object of our calculations, with which the two localized light pulses reach the detector.

Most textbooks deduce the Sagnac formula in the laboratory, but say nothing about an observer on the rotating platform. We will see that special relativity predicts a null effect on the platform, but a nonzero value if the platform rotation is studied from the laboratory. Many other theories predict similarly wrong results. Only the theory with $e_1 = 0$ gives a consistent answer.

Consider a clock, marking time t, fixed in a point of the moving inertial system S. Seen from S_o it satisfies the eq. of motion $x_0 = vt_0 + \bar{x}_0$, where $\bar{x}_0$ gives the clock initial position. Substituting x_0 into (1) we get $x = \bar{x}_0 / R$, representing the fixed x of the clock in the frame S, and $t = Rt_0 + e_1 \bar{x}_0$.

Consider two events at different times in the same point of S and write the previous equation twice, first with t_1 and t_{01}, second with t_2 and t_{02}. By subtracting side by side and defining $\Delta t = t_2 - t_1$ and $\Delta t_0 = t_{02} - t_{01}$ we get

$$\Delta t = R \Delta t_0 \tag{6}$$

Eq. (6) is predicted by all ET theories, including the TSR. Eq. (6) is taken to hold also for a clock on the rim of a disk rotating with velocity v by virtue of the "acceleration hypothesis". There is excellent experimental evidence that this assumption is correct, e.g. with the CERN muons [9].

We are interested in the application of (4) to the Sagnac situation. Consider a light source Σ, placed on the disk, emitting two pulses of light in opposite directions. The description given by the laboratory observers is the following: two light flashes leave Σ at time $t_0 = 0$. The first one propagates on a circumference, in the sense discordant from the platform rotation, and comes back to Σ at time t_{01} after circling around the platform. The second flash propagates on the same circumference, in the sense concordant with the platform rotation, and comes back to Σ at time t_{02} after circling around the platform. The circular path can be obtained by forcing light to propagate tangentially to the internal surface of a cylindrical mirror.

For simplicity we assume that the laboratory is at rest in the privileged frame. Pulse propagating in the direction opposite to rotation: the disk circumference length L_0 closes with velocity $c + v$. Then

$$t_{01} = \frac{L_0}{c + v}$$

Pulse propagating in the rotational direction: the disk circumference length L_0 closes with velocity $c - v$. Then

$$t_{02} = \frac{L_0}{c - v}$$

Therefore
$$\Delta t_0 = t_{02} - t_{01} = \frac{2L_0}{c^2} \frac{v}{R^2} \tag{7}$$

This is essentially the Sagnac formula, in good agreement with the experiments.

On the disk, for the ideal experiment we are considering, only cases of light parallel ($\theta = 0$) and antiparallel ($\theta = \pi$) to the local absolute velocity must be studied. Then, the velocity of light has to satisfy (4) and is respectively given by

$$\frac{1}{c_1(0)} = \frac{1 + \Gamma}{c} \quad ; \quad \frac{1}{c_1(\pi)} = \frac{1 - \Gamma}{c}$$

These formulae represent a second application of the acceleration hypothesis: in all ET theories the velocity of light is given by (4) independently of the acceleration of the frame. If the circumference length measured on the disk is L we have

$$t_1 = \frac{L}{c_1(0)} \quad ; \quad t_2 = \frac{L}{c_1(\pi)}$$

Therefore
$$\Delta t = t_2 - t_1 = \frac{2L\,\Gamma}{c} \tag{8}$$

This result, unlike (6) and (7), depends on Γ and then on e_1. This is the reason why requiring the consistency of the equations (6) – (7) – (8) gives the right value of e_1.

Now we require that Δt_0 and Δt describe the same phenomenon. It is obvious that L_0 and L are related by Lorentz contraction:

$$L_0 = LR \tag{9}$$

In words: the circumference length of the rotating platform, measured in the laboratory, equals the (uncontracted) circumference length measured on the platform, times the Lorentz factor.

In comparing Δt_0 and Δt one must take into account the laboratory/disk connection established with (6). By taking the ratio (8)/(7) one gets

$$R = \frac{2L\,\Gamma}{c}\,\frac{c^2}{2L_0}\,\frac{R^2}{v} \tag{10}$$

or, if (9) is applied

$$1 = \frac{c}{v}\Gamma \qquad \Rightarrow \qquad e_1 = 0$$

This is the result we had anticipated: only absolute simultaneity allows one to understand the Sagnac effect.

3. "Sagnac Correction" near the Earth Surface

Two international committees (CCDS and CCIR) in 1980 suggested rules - later universally adopted - for synchronizing clocks in different points of the globe. Two are the methods used. The first one is to transport a clock from one site to another and to regulate clocks at rest in the second site with the time reading of the transported clock. The second method is to send an electromagnetic signal informing the second site of the time reading in the first site. The rules of the committees establish that three corrections should be applied before comparing clock readings:

1. the first correction (velocity effect) is proportional to $v^2 / 2c^2$, where v is the velocity of the airplane, and corresponds to a slower timing of the transported clock;
2. the second correction (gravitational effect) is proportional to $g(\phi)h / c^2$ where g is the total acceleration (gravitational and centrifugal) at sea level at latitude ϕ and h is the height over sea level. It corresponds to a faster timing of the transported clock;
3. the "Sagnac correction" is assumed proportional to $2A_E\omega / c^2$, where A_E is the equatorial projection of the area enclosed by the path of travel of the clock (or of the em signal) and the lines connecting the two clock sites to the centre of the Earth; ω is the Earth angular velocity.

There are no doubts about nature and need of the first two corrections, but the justification of the third one is unconvincing. Kelly's opinion [10] is that the only possible reason to include the third correction is that the eastward velocity of light relative to the Earth is different from the westward.

In fact one can deduce, for a real experiment, the "Sagnac correction" from Eq. (4) applied to a geostationary satellite, for which the satellite itself and the Earth surface can be thought to be at rest on the same rotating platform.

Saburi et al. carried out an important experiment in 1976, before the CCDS and CCIR deliberations, and made clear that "corrections" to the theory were indeed necessary already in the title of their paper. [11] They had two atomic clocks, not quite synchronous, one in a first station *W* (near Washington, USA) the other one in a second station *T* (near Tokyo, Japan), practically on the same parallel of the two cities. The time difference between the two clocks on August 27, 1976 was measured with two different methods:

1. by sending an airplane carrying a third clock (initially synchronous with the one in *W*) from *W* to *T*, via Hawaii (westward);
2. by sending an electromagnetic signal, via a geostationary satellite, again westward.

The uncorrected airplane clock found the *T* clock $9.42\ \mu$s fast with respect to the *W* clock. The velocity correction and the gravitational correction together were estimated to be about $0.080\ \mu$s (to be subtracted to the time shown by the transported clock). By applying such a correction the *T-W* time difference increased to $9.50\ \mu$s.

The em signal carried with itself the time shown by the clock of the transmitting station. Assuming a signal velocity *c*, it was found that the T clock was $9.11\ \mu$s fast with respect to the *W* clock: the discrepancy between the two measurements was $0.39\ \mu$s.

Let L_{WS} and L_{ST} be the Washington-satellite and Tokyo-satellite distances, respectively (see Fig. 1). As most physicists in similar experiments, Saburi and coll. synchronized clocks by imposing that the velocity of light is c, that is in such a way that $t_T - t_W = \left(L_{WS} + L_{ST}\right) / c$, t_W and t_T being the times of signal departure from W and arrival in T as marked by the respective clocks. In order to ensure that this formula was correct for their clocks they had to apply the so called "Sagnac correction" to the clock of the receiving station.

With their approach Saburi et al. made an error because, as we know, the correct velocity of light relative to the rotating

Earth is that given by the inertial transformations, which in the appropriate directions is

$$c_{WS} = \frac{c}{1+\beta\cos\alpha_{WS}} \ , \ c_{ST} = \frac{c}{1+\beta\cos\alpha_{ST}} \tag{11}$$

where $\beta = \omega r / c$ (r = radius of the W-T parallel; w = Earth angular velocity); α_{WS} = angle between line WS and local velocity (normal to radius OW); α_{ST} = angle between line TS and normal to radius OT in Fig. 1. Therefore $\alpha_{WS} = \theta_W - \pi/2$ and $\alpha_{ST} = \theta_T - \pi/2$ where θ_W and θ_T are the angles $O\hat{W}S$ and $O\hat{T}S$ of Fig. 1, respectively.

Eq. (11) is not adopted in this experiment. Having imposed the impossible condition that the speed of light is c the authors had now to apply the mysterious "Sagnac correction" Δt_T on the time of arrival in T. Such a correction, from our point of view, can be calculated by replacing c with c_{WS} and c_{ST} as follows

$$\Delta t_T = \frac{L_{WS}}{c_{WS}} - \frac{L_{WS}}{c} + \frac{L_{ST}}{c_{ST}} - \frac{L_{ST}}{c} \tag{12}$$

which is positive, as $c > c_{WS},\ c_{ST}$.

Using the definition $\beta = \omega r / c$ one has

$$\Delta t_T = \omega r \left(L_{WS}\cos\alpha_{WS} + L_{ST}\cos\alpha_{ST} \right) / c^2$$

but $$r\,L_{WS}\sin\theta_W + r\,L_{ST}\sin\theta_T = 2\,\mathrm{A_E}$$

where $\mathrm{A_E}$ is the area of the quadrangle OWSTO of Figure 1. We have thus provided a full physical justification of the Sagnac correction $2A_E\omega / c^2$. We see that the mystery of the "Sagnac correction" of Earth physics disappears with the inertial transformations.

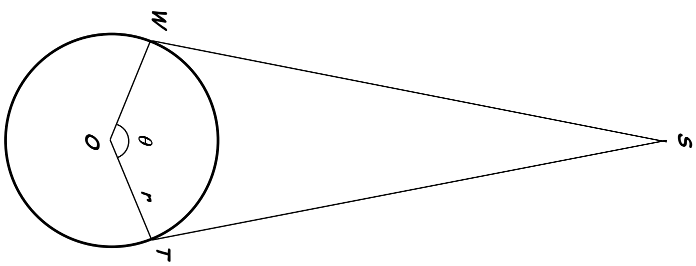

Fig. 1. An electromagnetic signal travels between two points *W* and *T* on the Earth via a geostationary satellite *S*.

4. The Rotating Platform (Again)

It is well known that no perfectly inertial frame exists because of Earth rotation, of orbital motion around the Sun, of Galactic rotation. All knowledge about inertial systems has been obtained in frames having small but non zero acceleration a. For this reason the mathematical limit $a \to 0$ in the theory should be smooth and no discontinuities should arise between systems with small acceleration and inertial systems. This requirement is not satisfied by the existing relativistic theory

Consider an inertial reference system S_0 and assume it is isotropic so that the one-way velocity of light relative to S_0 has the usual value c in all directions. In relativity the latter assumption is true in all inertial frames, while in other theories only one frame satisfying it exists.

In a laboratory there is a circular platform (radius r and center constantly at rest in S_0, which rotates uniformly around its axis with angular velocity ω and peripheral velocity $v = \omega r$. On its rim there is a single clock Σ (marking the time *t*). We assume it to be set as follows: When a clock of the laboratory momentarily very near Σ shows time $t = 0$ then also Σ is set at time $t_0 = 0$. When the platform is not rotating, Σ constantly shows the same time as the nearby laboratory clocks. When it rotates, however, motion modifies the pace of Σ and the relationship between the times t and t_0 is taken to have the general form

$$t_0 = t\,F(v,\ ...) \tag{13}$$

where *F* is a function of velocity and eventually acceleration and higher derivatives of position (not shown). Eq. (13) is a consequence of the isotropy of S_0. There are strong experimental indications that $F(v,\ ...) = 1/R$, with R given by (2). This is however irrelevant for our present needs as the results obtained below hold for all possible F.

We assume that the clock Σ acts also as source and as detector of light. Two light flashes leave Σ at time t_1 and are forced to move on a circumference, by "sliding" on the internal surface of a cylindrical mirror placed at rest on the platform, all around it and very near its border. Mirror apart, the light flashes propagate in the vacuum. The mirror behaves like a source ("virtual") and a source motion never changes the velocity of the emitted light signals. Therefore the motion of the mirror cannot modify the velocity of light. Thus, relative to the laboratory, the light flashes propagate with the usual velocity c.

The description of light propagation given by the laboratory observers is the following: two light flashes leave Σ at time t_{01}. The first one propagates on a circumference, in the sense discordant from the platform rotation, and meets again at Σ at time t_{02} after a full circle around the platform. The second flash propagates on the same circumference, in the sense concordant with the platform rotation, and meets again at Σ at time t_{03} after a full circle around the platform. These laboratory times, all relative to events taking place in a fixed point of the platform very near Σ, are related to the corresponding platform times via

$$t_{0i} = t_i\,F(v,\ ...) \quad (i = 1,2,3) \tag{14}$$

The circumference length is assumed to be L_0 and L, measured in the laboratory S_0 and on the platform, respectively. If $\tilde{c}(0)$ and $\tilde{c}(\pi)$ are the light velocities, relative to the disk, for the flash propagating in the direction of the disk rotation and in the opposite direction, respectively, one can show with a few elementary steps using the very definition of velocity and (14):

$$\begin{cases} \dfrac{1}{\tilde{c}(\pi)} = \dfrac{t_2 - t_1}{L} = \dfrac{L_0}{FL}\,\dfrac{1}{c+v} \\[2ex] \dfrac{1}{\tilde{c}(0)} = \dfrac{t_3 - t_1}{L} = \dfrac{L_0}{FL}\,\dfrac{1}{c-v} \end{cases} \tag{15}$$

From (15) it follows, with $\beta = v/c$:

$$\frac{\tilde{c}(\pi)}{\tilde{c}(0)} = \frac{1+\beta}{1-\beta} \tag{16}$$

Notice that the functions F, L, L_0 have disappeared in the ratio (16). Clearly, Eq. (16) gives us not only the ratio of the two global light velocities for full trips around the platform, but the ratio of the instantaneous velocities as well. In fact the isotropy of the system S_0 ensures, by symmetry, that the instantaneous velocities of light are the same in all points of the rim of the rotating circular disk whose center is at rest in S_0. There is no reason why the light instantaneous velocities relative to the disk should not be equal to one another in the different points of the rim [12] With reference to Fig. 2 we can therefore write

$$\tilde{c}_{\phi_1}(0) = \tilde{c}_{\phi_2}(0) \; ; \; \tilde{c}_{\phi_1}(\pi) = \tilde{c}_{\phi_2}(\pi)$$

where ϕ_1 and ϕ_2 are arbitrary values of the angle ϕ.

Therefore the light instantaneous velocities relative to the disk will also coincide with the average velocities $\tilde{c}(0)$ and $\tilde{c}(\pi)$, and Eq. (16) will apply also to the ratio of the instantaneous velocities [thus we do not need a different symbol for the instantaneous velocities].

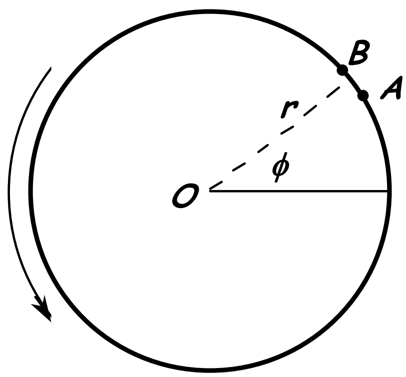

Fig. 2. By symmetry, the velocity of light relative to the disk between two nearby points *A* and *B* does not depend on the angle ϕ fixing the position of the segment *AB* on the rim of the disk.

A small part AB of the rim of a platform, having peripheral velocity v, for a short time is completely equivalent to a small part of a "co-moving" inertial reference frame (endowed with the same velocity). For all practical purposes the segment AB will belong to that inertial reference frame. But the velocities of light in the two directions AB and BA have to satisfy (16). It follows that the one way velocity of light relative to the co-moving inertial frame cannot be c and must instead satisfy

$$\frac{c_1(\pi)}{c_1(0)} = \frac{1+\beta}{1-\beta} \tag{17}$$

The ET (of which the IT are a particular case) predict the inverse one way velocity of light relative to the co-moving system S :

$$\frac{1}{c_1(\theta)} = \frac{1}{c} + \left[\frac{\beta}{c} + e_1 R\right]\cos\theta \tag{18}$$

where θ is the angle between the light propagation direction and the absolute velocity v of . Eq. (18) applied to the cases $\theta = 0$ and $\theta = \pi$ easily gives

$$\frac{c_1(\pi)}{c_1(0)} = \frac{1+\beta+c\,e_1 R}{1-\beta-c\,e_1 R} \tag{19}$$

Clearly, Eq. (19) is compatible with (17) only if $e_1 = 0$. We can see that also our result (17) is consistent with the physics of the inertial systems only if absolute simultaneity is adopted. For a better understanding of the reasons why the TSR does not work consider again the ratio

$$\rho \equiv \frac{\tilde{c}(\pi)}{\tilde{c}(0)} \tag{20}$$

which, owing to (16), is larger than unity. Therefore the light velocities parallel and anti-parallel to the disk peripheral velocity are different! [13]. Thus the TSR predicts for ρ a discontinuity at zero acceleration. While all experiments are made in the real physical world [where $a \neq 0$, $\rho = (1+\beta)/(1-\beta)$], the theory has gone out of the world [$a = 0$, $\rho = 1$]!

5. The Experiment by R. Wang et al.

A very interesting modified Sagnac experiment has been carried out by Ruyong Wang and collaborators [14]. The instrument was designed to decide whether the travel time difference of the Sagnac effect only appears in rotational motion, or if it also appears in rectilinear uniform motion: Results unequivocally in favor of the latter possibility. The Sagnac effect shows that two light pulses, sent clockwise and counterclockwise around a closed path on a rotating disk, take different times to travel the path. The time difference is often written as $\Delta t = 4A\omega / c^2$, where A is the area enclosed by the path and ω is the angular velocity of the disk rotation. For a circular path of radius R one can also write $\Delta t = 2vL / c^2$ where $v = \omega \mathrm{L}$ is the speed of the circular motion, L is the circumference length. Usually the two expressions of Δt are considered equivalent, but the Wang experiment leads to the conclusion that only the second has general validity.

The Sagnac effect has been studied in fiber optic gyroscopes (FOG's). In a FOG, when a single mode fiber is wound to a coil with N turns the effect increases to $\Delta t = 2vL / c^2$, where L is now the total fiber length. A FOG, shown in Fig. 3, contains two semicircular sections with linear fiber connecting the end sections. The fiber moves when the wheels at the two ends rotate. R. Wang calls this new device a fiber optic conveyor (FOC).

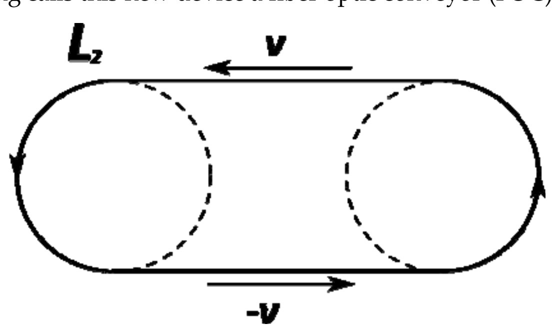

Fig. 3. A FOC including source and detector rotating with the fiber

The conclusion was that the time delay due to uniform translation of a fiber segment with a speed of v and a length ΔL contributes $\Delta t = 2\,v\,\Delta L / c^2$ exactly like a segment of circularly moving fiber. This is in agreement with our approach, which attributes in all cases the same local velocity of light relative to an accelerated reference frame and to the locally co-moving inertial frame. Both in the examined experiment and in our theory the physical difference between linear and curvilinear uniform motions vanishes. A FOC of the form shown in Fig. 3, but with longer rectilinear parts of the fiber, can give additional evidence in favor of the IT. Prof. R. Wang informed that such an experiment has already been performed with a ratio (length of rectilinear parts)/(diameter of circular parts) of 40. Clearly, the circular part of the fiber represents a perturbation. Therefore the experiment provides direct evidence that the velocity of light in inertial systems is not c, but has the values predicted by the IT.

6. The Block Universe

In considering the nature of time let us adopt the relativistic description, with a Minkowski diagram having space in abscissa and time in ordinates. At time $t=0$ an observer U_0 located in the origin of an inertial system S must regard as being objectively real down to the smallest detail all events in space. In this diagram space is represented as x axis, whose equation is $t=0$, and which therefore contains all the events simultaneous with the instantaneous presence of U_0 in the origin at $t=0$.

If we consider a different inertial reference frame S', its axes x' and t' are represented in the Minkowski diagram as straight lines in the plane (ct, x) because of the linearity of the Lorentz transformations. The observer U_0' at rest in S' has the right to attribute reality to all events happening at his present time $t'=0$. The set of these events is of course different from the set of events constituting the reality of U_0. According to the relativity principle it does not make any sense to ask which one of the two observers U_0 and U_0' is correct. Given the complete symmetry between inertial systems, they are both correct. So all the events on the x' axis, whose equation is $t'=0$ and whose inclination depends on the velocity of S' relative to S, can be considered just as real as the events on the x-axis. The Lorentz transformation of time from (ct, x) to (ct', x') reads

$$ct' = \frac{ct - xv/c}{\sqrt{1-v^2/c^2}} \tag{21}$$

where v is the relative velocity of the S and S' frames. Setting $ct'=0$ we get

$$ct = (v/c)\,x \tag{22}$$

This is a straight line with a slope $(v/c)<1$. Therefore, the reality line of the observer U_0' has an inclination in time with respect to that of U_0.

Clearly U_0' will attribute reality to events in U_0's future, which are not part of U_0's present reality. In the previous example, however, these future events are elsewhere and do not belong to the personal future of U_0, who is assumed at rest in the origin $x=0$.

Reality has so far been attributed to a single instant of the future only, but the argument can easily be generalized. Indeed infinitely many reality lines pass through every point of the diagram (ct, x), each such line representing the (relativistic) reality of some legitimate inertial observer. The only restriction regards the inclination of these lines in a diagram (ct, x): it can never exceed $\pi/4$, if all velocities are subluminal.

Thus relativity leads to a strange conception of the universe, in which a single reality fills uniformly past, present, and future: at this present time other observers no less legitimate than I consider my personal future as given in all detail. According to them there is not the slightest freedom that I can use in order to influence the course of events. The impression I have of a reality evolving sometimes in a casual (non deterministic) way, would therefore be entirely subjective. Relativity leads one to accept a hyper-deterministic universe in which the whole future is completely pre-established in the minutest details and in which all sensations of individual freedom (even those limited to very simple events) are pure illusions. [15]

The argument about the block universe can be extended from the TSR to the ET. The transformation of time replacing (21) is

$$t = R\,t_0 + e_1(x_0 - v\,t_0) \tag{23}$$

Obviously, $ct=0$ implies

$$t_0 = \frac{-e_1}{R - e_1 v} x_0 \tag{24}$$

At time $t=0$ an observer U_0 located in the origin of S_0 regards as objectively real down to the smallest detail all events in space. In this diagram space is the x axis (equation $t=0$), and contains all events simultaneous with the presence of U_0 in the origin at $t=0$. The reality line of the observer U_0' has an inclination in time with respect to that of U_0 and also passes through the origin of a Minkowski-type diagram. Clearly, the reality-of-the-future argument of the TSR can be repeated for (24) without any difficulty, and the result is again the block universe.

We can easily see that there is an exception for $e_1=0$ giving the inertial transformations. If we start from the transformation of time of the IT we write

$$t' = Rt \tag{25}$$

Setting $ct'=0$ we get immediately $ct=0$. The meaning is obvious: if we select an arbitrary point of the reality line of S we select at the same time a point on the reality line of any other inertial frame (given the arbitrariness of S').

7. Two Identical Spaceships

Two identical spaceships $\boldsymbol{A}$ and $\boldsymbol{B}$ are initially at rest on the x_0 axis of the (privileged) inertial system S_0 at a distance d_0 from one another [16]. Their clocks are synchronous with those of S_0. At time $t_0=0$ they start accelerating in the $+x_0$ direction, and they do so in the same identical way, in such a way as to have the same velocity $v(t_0)$ at every time t_0 of S_0, until, at a time $t_0=\overline{t}_0$ of S_0, they reach a given velocity $v(\overline{t}_0)$ parallel to x_0; for all $t_0>\overline{t}_0$ the spaceships remain at rest in a new inertial system S, which they concretely constitute. One can easily show that the motion of $\boldsymbol{A}$ and $\boldsymbol{B}$ does not modify the distance d_0 between the spaceships as seen from S_0. The same distance seen from S (call it d) instead increases during acceleration, as the unit-rod measuring it undergoes a progressive contraction. One has:

$$d = \frac{d_0}{\sqrt{1 - v^2 / c^2}} \tag{26}$$

The transformation relating S_0 and S is necessarily the inertial one, if no final clock re-synchronization is applied correcting what was generated during the acceleration. Since $\boldsymbol{A}$ and $\boldsymbol{B}$ accelerate exactly in the same way, their clocks accumulate exactly the same delay with respect to those at rest in S_0. Motion is the same for $\boldsymbol{A}$ and $\boldsymbol{B}$; all effects of motion will necessarily coincide, in particular time delay. Therefore two events simultaneous in S_0 will be such also in S, even if they take place in different points of space. Clearly we have a case of absolute simultaneity and the condition $e_1 = 0$ must hold.

In order to make the point as clear as possible we checked that the velocity in S of a light pulse traveling from $\boldsymbol{A}$ to $\boldsymbol{B}$ when the two spaceships are at rest in S (while, of course, they move with velocity v with respect to S_0) coincides with the inertial velocity of light formula (4) with $e_1 = 0$. In fact we found that the velocity of light in S satisfies (24) with $\theta = 0$. This is what one expects from the inertial transformations since the straight line connecting the spaceships $\boldsymbol{A}$ and $\boldsymbol{B}$ has been assumed parallel to their velocity.

Not only the absolute simultaneity is concretely realized in the moving frame of the two spaceships, but one can find other convincing arguments showing that it gives the most natural description of the physical reality. We will suppose that our spaceships have passengers P_A and P_B, who are homozygous twins. Of course in principle nothing can stop them from re-synchronizing their clocks once they have finished accelerating and the two spaceships are at rest in S. If they do so, however, they find in general to have different biological ages at the same (re-synchronized) S time, even if they started the space trip at exactly the same S_0 time and with the same velocity, as stipulated above. Everything is regular, instead, if they do not operate any asymmetrical modification of the time shown by their clocks [17].

In fact we already concluded that clocks in $\boldsymbol{A}$ and $\boldsymbol{B}$ are retarded in the same way, and that the transformations $S - S_0$ must be the inertial ones. Also the ageing of the twins must have been the same, since at every time before, during and after the acceleration they were in identical physical conditions. Therefore the twins have the same age when the times shown by their clocks are the same if they have been synchronized in S_0 before departure and never modified after. Naturally, P_A and P_B can inform one another of their biological ages (e.g., via telefax) by exchanging pictures in which the times they were taken is marked: the twin receiving a picture can check in his archives that at the time shown on his brother's picture he had exactly the same look, and therefore the same age.

The same experiment is repeated after the acceleration has ended and the spaceships are at rest in the different inertial system S. Now, if the invariance of the velocity of light were a law of nature one should find the same result in S and in S_0, given that the retardation of C_A and C_B (these are the clocks inside $\boldsymbol{A}$ and $\boldsymbol{B}$ respectively) during the accelerated motion is exactly the same. Instead, as we saw, *t*he velocity of light in S from $\boldsymbol{A}$ to $\boldsymbol{B}$, turns out to be given by (4). Notice that the equal retardation of C_A and C_B is expressed by the equality of the proper times of C_A and C_B and is therefore an objective property on which all observers agree. Therefore everything seems to go as if we measured the velocity of light with two clocks, then set backwards their hands by the same amount, then measured again the velocity of light and found a different result. It is a surprise, but the conclusion that $e_1 = 0$ is inescapable.

8. Ron Hatch's Argument

Very interesting results have been obtained by Ron Hatch of NavCom Technology (California). This research on the physics of space and time is carried out by reasoning from the point of view of observers placed in different points of the solar system, an exciting game between the different approaches to relativistic phenomena is being plaid anew outside the terrestrial atmosphere [18]. From the GPS there is irrefutable evidence that clocks run faster when the gravitational potential is increased [19]. But a clock on the earth at noon is closer to the sun than a clock on the earth at midnight. Therefore the clock at noon has a lower gravitational potential from the sun. Experimentally it has been found, however, that there is no apparent clock rate difference between noon and midnight. This is called "the noon/midnight problem."

Different explanations have been attempted, but they all failed to resolve the contradiction. For example, there had been the idea that the earth, the satellites, the clocks are all freely falling in the gravitational field of the sun and cannot therefore feel the action of that field. Not correct, because when a satellite passes from a first position at noon to a second position at midnight it covers a large distance and certainly it must feel the variation of the gravitational potential of the sun, which is to a very good approximation linear in the space separation between the two positions.

The key for resolving the problem came from a simple fact: when data are taken from clocks which are external to the solar system (millisecond pulsars), it is found that earth-based clocks actually do run at different rates at midnight and at noon!

According to Hatch the data collected both by VLBI (Very Long Baseline Interferometry) and GPS (Global Positioning System) indicate that earth-based clocks are biased as function of their position in the direction of the orbital velocity of our planet. The existence of these biases is confirmed by comparison of earth-based clocks with millisecond pulsars. These clock biases are precisely such as to cause the speed of light to appear having the isotropic value "*c*" in any earth centered inertial frame. This shows that the speed of light in reality is not isotropic in the earth centered inertial frames and that the Lorentz transformations are only an artificial structure built up by "Selleri's inertial transformations combined with clock biases." Thus Hatch attributes to the inertial transformations a fundamental role, in agreement with what we are preaching in this paper.

Distant pulsars, which have pulse rates of hundreds of pulses per second, in practice are extremely stable clocks with a slow but very precise change in frequency as they loose energy. These are clocks external to the solar system, but their stability equals that of the very best clocks on the earth. Therefore they can be compared to clocks of all types on the earth. This comparison easily allows one to detect local biases.

In fact, if the comparison of terrestrial clocks with pulsar emissions shows oscillating differences correlated with the earth motion it is unreasonable to assume that they are due to the pulsar that is far away in space. Moreover, there are several pulsars in different parts of the sky that can be used for reciprocal stability tests. The outcome of these considerations is that the pulsars have a very high degree of stability. The pulsar data reveal a diurnal variation in terrestrial clock rate as the earth spins around its axis. More exactly the noon second is about 300 ps shorter than the midnight second. Hatch found the following result: the bias of the clock proper time τ as a function of position in the earth-based frame can be written

$$\Delta\tau = -\vec{v}\cdot\vec{x}/c^2 \tag{27}$$

The meaning of (27) is that a set of inertial transformation applied to a moving frame in an absolute ether can be converted into apparent Lorentz transformations simply by biasing the clock settings. Thus, assuming an ether the TSR can be made to appear as valid simply by biasing the clocks by the appropriate amount as a function of position . We thus see that the clock synchronization data on the Earth surface was hiding an important piece of information concerning the physics of space and time. Thanks to Hatch this hidden information is now openly visible, and it is equivalent to a proof of validity of the IT. It is the seventh proof of this paper.

9. Aberration

The phenomenon of aberration of the starlight is very important in relativistic physics, to the point that Einstein discussed it in his first article on the theory of special relativity.

From the angular deviation of the light of a star, observed during a year, it is possible to deduce the velocity of light. But starlight follows a one way path towards the Earth, a fact which might lead people to believe that aberration allows one to measure the one way velocity of light. Actually it is not so, as all the equivalent transformations predict exactly the same aberration angle, even though the one way velocity is different for different equivalent transformations.

Consider the propagation of a localized light pulse P from the point of view of the privileged reference system S_0 of the equivalent theories, relative to which the velocity of light is the same in all directions. If θ_0 is the inclination with respect to the x_0 axis of the trajectory of P and θ is the inclination of the same trajectory as judged in S, one can prove [20] an aberration formula mathematically identical to the one of relativity, namely:

$$\tan\theta = \frac{c\,R\,\sin\theta_0}{c\cos\theta_0 - v} \tag{28}$$

where v is the velocity of S measured in S_0 and $R = \sqrt{1 - v^2/c^2}$. The quantity c in (28) is the one way speed of light relative to, and, at the same time, the two way speed of light relative to all inertial reference systems.

Therefore, all the quantities entering in the right hand side of (28) are relative to the isotropic system S_0 for which all equivalent theories accept the same value of the velocity of light, and thus the same synchronization of clocks. Clearly, all the equivalent transformations (among which there are Lorentz's) agree on the numerical values of θ_0 and v. Therefore, thanks to (28), for any given reference system S they predict the same value of the aberration angle θ.

Although we are presently unable to identify the privileged inertial system S_0 the previous conclusion is obviously enough for saying that once given (28), we have obtained a complete explanation of aberration from the point of view of the equivalent transformations, based on the existence of a privileged system: if the absolute aberration angle of a star is the same for all S, also the relative aberration angle observed between two moving systems S and S' has to be the same!

Aberration explained in terms of absolute motion, as presented above, provides the resolution of a longstanding problem of the relativistic approach. Einstein deduced the aberration formula (28) from the idea that v is the "velocity of the observer relatively to an infinitely distant source of light." [21] This idea was repeated by many authors, clearly because the use of the relative velocity is the most natural thing to do in a theory, such as the TSR, based on relativism.

If, however, we imagine the stars as molecules of a gas in random motion, we have to admit that the velocity relative to the Earth varies from star to star. This conclusion contradicts the fact that the observed angle of aberration is the same for all stars. In 1950 Ives stressed that "The idea sometimes met with that aberration ... may be described in terms of the relative motions of the bodies concerned, is immediately refuted by the existence of spectroscopic binaries with velocities comparable with that of the earth in its orbit. These exhibit aberrations no different from other stars." [22]

The components of such binary systems at some times can have velocities relative to the Earth very different from one another; nevertheless it is well known that these components exhibit always the same aberration angle, by the way not different from that of single stars. The argument was developed by Eisner in 1967: A distant observer O looks at two stars S_1, S_2 rotating about the center of mass C of the pair. Let C be at rest relative to O (for simplicity), let the orbits of the stars be circular, and let O lie on the normal through C to the plane of the orbits. Then Eisner shows that the stars must appear to describe circular orbits of angular radii ρ_1, ρ_2, which he calculates explicitly. For a very distant observer he finds: $\rho_1 = v_1/c$, $\rho_2 = v_2/c$, where v_1 and v_2 are the velocities of the two stars at the moment of observation and c is the speed of light. The ratio v/c is typically of order 10^{-4} (about 20" of arc) and about one star in three is a multiple system; so that "the skies should be filled with binary stars of apparent separation of order forty seconds." [23]

A further support for Ives' conclusion came from Hayden (1993), who remarked that some astronomical tables list five pages of binaries that can be seen in the Sagittarius alone with a small telescope. A spectroscopic binary, Mizar A, has well known orbital parameters, from which Hayden calculates an observable angular separation of 1′ 10″ .5 if aberration were due to relative velocity. The empirical value is less than 0.01″, clearly incompatible with the relativistic prediction [24].

10. Beyond Relativistic Paradoxes

In the previous sections we saw that several paradoxes of relativity melt away rather easily if one adopts an optimistic philosophy about the possibility to understand nature correctly. Furthermore, this "optimistic" philosophy is not anymore a free choice, but should have become an open scientific possibility as a consequence of the independent proofs of absolute simultaneity. We will now shortly present the solutions of other well known relativistic paradoxes.

1. *The (relativistic) idea that the simultaneity of spatially separated events does not exist in nature* and must therefore be established with a human choice was accepted by Mansouri and Sexl, who fully believed in the conventionality of clock synchronization. In spite of the broad diffusion of this expectation, it has been established that a rational description of physical phenomena (Sagnac effect, linearly accelerating systems, objective reality of inertial observers, superluminal propagations) can be obtained only if absolute simultaneity is adopted: $e_1 = 0$.

   In this way one solves also the riddle of the relativity of reality, given that it is identified by the relativity of simultaneity. The riddle was overcome when it was shown that assuming $e_1 = 0$ all inertial observers have the same reality, where reality is defined by the set of events simultaneous with a given event (e.g., the "here-now" event establishing the local present).
2. *The velocity of a light signal*, considered equal for observers at rest and observers chasing it with velocities as near as possible to c. The answer of a theory based on the ITs is as follows. After having established that $e_1 = 0$, the velocity of light relative to a moving reference frame is given by Eq. (4). Therefore, the speed of the light signal (absolute velocity c) relative to an inertial frame which is running after it (then, $\theta = 0$) with absolute velocity almost equal to that of light ($v \cong c$) has a denominator $\cong 1 + 1 = 2$ and the limit velocity is $c/2$. This is a 50% reduction with respect to the relativistic prediction that remains the old dear c.
3. *Retardation of moving clocks*, phenomenon for which the theory of relativity does not provide a description in terms of objectivity. The objectivity is restored with the inertial transformations in terms of action of the ether on all the periodic phenomena which can be used to measure time. All this is very much in the realistic line of thought of Hendrik Lorentz.
4. *Contraction of moving objects*, phenomenon for which, once more, the theory does not provide a causal description. The objectivity is restored with the inertial transformations in terms of action of the ether on every atom, with reduction of the atomic length in the direction of motion. Also this follows the realistic line of thought of Lorentz.
5. *The hyperdeterministic block universe of relativity*, fixing in the least detail the future of every observer, is now out, having been overcome thanks to the conclusion $e_1 = 0$, meaning that the reality line is unique for all observers, independently of their state of motion.
6. *The conflict between the reciprocal transformability of mass and energy and the ideology of relativism.* The TSR declares all inertial observers perfectly equivalent so depriving energy of its full reality. The retrieval of the objectivity of energy and of the other physical quantities should rather aim at the inequivalence of the different reference frames knowing that there is one at rest in the ether, which has a more fundamental role. The idea can be developed, and the objectivity of energy is fully recovered by working with the IT.
7. *The TSR predicts a discontinuity between the inertial systems and systems endowed with a very small acceleration.* The discontinuity is in the variable ρ, ratio of the velocities of light along two opposite directions. It turns out to be a serious problem for all $e_1 \neq 0$. If one takes $e_1 = 0$, however, the discontinuity does not exist anymore and the relative difficulty is completely overcome.
8. *The propagations from the future towards the past*, generated in the TSR by the eventual existence of superluminal signals. The essence of the causal paradox lies in the impossible requirement that a superluminal propagation may overtake a set of clocks marking a progressively decreasing physical (then, not conventional) time. The particular choice $e_1 = 0$ is selected by several phenomena in which the acceleration has a role, remains by far the best one also in the present context, being the only one not leading to the causal paradox. The same choice avoids the complications of the TSR describing all the propagations as forward in time for all observers.
9. *The asymmetrical ageing of the twins in relative motion in a theory waving the flag of relativism.* The differential retardation effect between separating and reuniting clocks ("clock paradox") can be studied by using a variational method. Both in the TSR and in more general theories with arbitrary e_1 among all possible trajectories of a clock connecting two given points at two given times the rectilinear uniform motion requires the longest proper time. A complete resolution of the clock paradox is so obtained by giving an exhaustive unified description of all possible situations. Relativism does not apply and must be considered obsolete. Velocity (and nothing else) is seen to be responsible for the differential retardation effect. Of course it must be an absolute velocity!

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