Recovering the Lorentz Ether

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The description of natural phenomena by observers in motion is a problem that many consider solved once and for all by the Lorentz transformations of the Theory of Special Relativity (TSR), though it was actually was left open. Consequences of my alternative transformations of the space and time variables are: (i) an explanation of the empirical data better than provided by the TSR; (ii) the elimination of those features of the TSR which give rise to paradoxes. This is obtained thanks to the recovery of a preferred inertial frame in which the Lorentz ether is at rest. In the present paper I expound the basic ideas of the research, leaving aside mathematical detail.

1. Difficulties in relativity

The theories of special and general relativity had great success in explaining many known phenomena and in predicting new unexpected effects. They therefore constitute important advances in our knowledge of the physical world, and belong forever to the history of the natural sciences, alongside Newton's mechanics and Maxwell's electromagnetism. It is however very difficult to believe that they are final, immutable forms of knowledge. On the contrary, if there is an important lesson to learn from epistemology (Popper, Lakatos, Kuhn) it is the conjectural, provisional, improvable nature of the foundations of the physical theories of the XXth century.

In March 1949, answering his friend M. Solovine who had sent him a friendly letter for his seventieth birthday, Einstein wrote: "You imagine that I look backwards on the work of my life with calm satisfaction. But from nearby it looks very different. There is not a single concept of which I am convinced that it will resist firmly." [LS] Einstein did not hide the probable transitory nature of his creations. On April 4, 1955, he wrote the last paper of his life. It was a three page long preface (in German) to a book celebrating the fiftieth anniversary of the theory of relativity. It ended with the following words: "The last, quick remarks must only demonstrate how far in my opinion we still are from possessing a conceptual basis of physics, on which we can somehow rely." [EF] One could speak of a solemn declaration of failure, but above all one has to admire not only the scientific, but also the ethical dimension of the great scientist, who had devoted superhuman efforts of an entire lifetime to an attempt to reach the deepest truths of nature and now, approaching the end, declared to posterity: "I did not succeed."

The successes of the relativity theories are very well known. The reciprocal convertibility of energy and mass, the effects of velocity and gravitation on the rates of clocks, the mass of light and the precession of planetary motions—these represent only a partial summary of the great conquests of Einsteinian physics. Nevertheless, it would not be correct to conclude that every comparison of theoretical predictions with experiments has invariably led to perfect agreement. Physics is a human activity, and from us it inherits the habit of parading successes and hiding difficulties and failures. Thus, only silence surrounded the Sagnac effect (discovered in 1913) for which the two relativity theories were unable to offer an explanation, the attempts by Langevin, Post, Landau and Lifshitz notwithstanding.

There are, furthermore, the half explanations of the aberration of starlight and the clock paradox, phenomena for which the mathematical formalism of the theory can reproduce the observations, at the cost of twisting the meaning of symbols beyond justification.

One should never forget that behind the equations of a theory lurks an immense qualitative structure comprising empirical results, generalizations, hypotheses, philosophical choices, historical conditioning, personal tastes, convenience. When one becomes aware of this reality and compares it with the portrait of physics handed down by logical empiricism, which is worth less than a caricature, one easily understands that relativity not only can present weak points alongside its undeniable successes, but can also survive some failures. The correctness of the mathematical formalism is not sufficient to validate a scientific structure as coherent and free from contradiction. I might add that not even unconditional support from hundreds of physicists can ensure that a theory is free of unsolved problems, because far too often, from the time of their university studies, their thinking is oriented toward uncritical acceptance of the dominating theory. Rationality and consent are also different matters in the world of research.

In reality the two relativity theories are brimming with paradoxes. Let us make a list, by no means complete, and limited to the TSR: the velocity of a light signal, which the theory treats as equal for observers at rest and observers pursuing it with velocity 0.99 c; the idea that the simultaneity of spatially separated events does not exist in nature and must therefore be established with a human convention; the relativity of simultaneity, according to which two events simultaneous for one observer are in general not a different observer; the contraction of moving objects and the retardation of moving clocks, phenomena for which the theory does not provide a description in objective terms; the asymmetrical ageing of the twins in relative motion in a theory that carries the flag of relativism; the hyperdeterministic universe of relativity, which establishes the future of every observer down to the last detail; the conflict between the reciprocal transformability of mass and energy and the ideology of relativism, which declares all inertial observers perfectly equivalent, thus depriving energy of its full reality; the existence of a discontinuity between inertial reference systems and frames with a very small acceleration; propagation from the future toward the past, generated in the theory by the possible existence of superluminal signals.

How is it possible that respected experts in relativistic physics believe that these are not real paradoxes? The answer is not difficult and is based on what in Italian is called “*buon senso*” (literally: good sense). This expression is easily translated in all neo-Latin languages, but is absent in other languages. English speaking authors sometimes use “common sense”, which, however, carries a very different idea because common sense is of the majority, and the history of science teaches that in scientific matters the majority is rarely right. On the other hand “*buon senso*” is related to the “*sensate esperienze*” of Galilei. Well, if good sense tells us that a certain prediction of a theory is unreasonable, there are two possibilities. First, it is possible that good sense misleads us, and second that in the theory there are more or less explicit hypotheses that are contrary to the natural order of things and give its predictions an incorrect meaning. Many physicists and philosophers of the XXth century followed the fashion of declaring good sense obsolete, but the second path can easily be taken, and it allows one to get rid of all the paradoxes of relativity.

Naturally, it is not *a priori* obvious that the paradoxes can be eliminated without spoiling the successes of the theory. Nevertheless, it is a fact that the theory reviewed in the present article, based on replacing the Lorentz transformations with the “inertial” transformations, not only explains all that the TSR does, but also succeeds where the latter fails. It explains the Sagnac effect, for example.

2. Conventional simultaneity

Einstein stated the conventional nature of the invariance of the velocity of light explicitly. In his fundamental paper of 1905 he wrote: "We have so far defined only an "A time" and a "B time". We have not defined a common "time" for A and B, for the latter cannot be defined at all unless we establish *by definition* that the "time" required by light to travel from A to B equals the "time" it requires to travel from B to A." [EL, p. 40]. This statement is remarkable for two reasons that show the positivistic leanings of the founder of relativity. First, because it accepts Poincaré's idea that the speed of light is not measurable and can thus only be defined; second, because the word time, appearing five times, is always in quotes, as if it were a dangerous concept. The conventionality of the velocity of light was restated in 1916 when Einstein wrote about the midpoint M of a segment AB whose end points are struck "simultaneously" by two strokes of lightning: "that light requires the same time to traverse the path AM ... as the path BM [M being the midpoint of the line AB] 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 free will." [SG, p. 18]

One method for synchronizing distant clocks that comes to everybody's mind does not work: synchronize them when they are near and carry them to the points where they are needed. It does not work because we know that transport, *i.e.*, the fact itself of possessing a velocity, changes any periodic motion that one might use for measuring time. But we do not know with respect to which inertial system the clock velocity should be considered, and at this stage of the game we are unable to measure it anyway. Given this situation, Poincaré and Einstein decided that the "synchronization" of clocks could be achieved following criteria of any type, provided only they led to an unambiguous identification of events. The author of relativity made the simplest choice, assuming that the speed of light has the same value in all directions in all inertial frames.

In practice, the relativistic synchronization is obtained as follows. Suppose that two identical clocks A and B are at a distance A from one another. A pulse of light starts from A towards B when the clock in A marks time zero; the clock in B is set at time ℓ/c when the pulse arrives there. From synchronization to relativistic simultaneity is a short step. Two instantaneous point-like events in A and B at times t_A and t_B (as marked by the respective synchronized clocks) are simultaneous by definition if $t_A = t_B$. Naturally a good positivist does not wonder whether the two events are really simultaneous: for him only human manipulations matter, and it does not make any sense to think in terms of an objectivity of time. Thus the notion of relativistic simultaneity depends on human stipulations, and not on properties of nature.

Here it is important to stress that the conventional nature of relativistic clock synchronization—and thus the relativistic simultaneity of distant events—opens up very interesting prospects. Let us see why. In general, time could be different in two different inertial reference systems $S_0(x_0,y_0,z_0,t_0)$ and $S(x,y,z,t)$, and the "delay" $t - t_0$ (positive, null or negative) of S over S_0 could depend not only on the time t_0, but also on the geometrical point considered. This happens in the TSR, as the Lorentz transformation of time also contains a space coordinate. In other words (and more generally) the time t marked by a clock in S can also depend on the coordinates x,y,z

of the point at which the clock is positioned, at least until one finds reasons to the contrary (I have found them: see later).

Discussing this problem, H. Reichenbach (1925) examined the following situation: in the system S a flash of light leaves point A at time t_1, is reflected back by a mirror placed at point B at time t_2 and finally returns to A at time t_3. Naturally t_1 and t_3 are marked by a clock near A, while t_2 is marked by a different clock near B. The problem is how to synchronize the two clocks with one another. In the TSR one assumes that the velocity of light on the one-way path A-B is the same as in the two-way path B-A-B, so that

$$t_2 - t_1 = \frac{1}{2}\left(t_3 - t_1\right) \tag{1}$$

This formula defines the time t_2 of the B clock in terms of the times t_1 and t_3 of the A clock. It is the choice (1) which determines the presence of x in the (Lorentz) transformation of time. Reichenbach commented that Eq. (1) is essential in the TSR, but it is not epistemologically necessary. A different rule of the form

$$t_2 - t_1 = e\ (t_3 - t_1) \tag{2}$$

with any $0 < e < 1$ would likewise be adequate and could not be considered false. He added: "If the special theory of relativity prefers the first definition, *i.e.*, sets e equal to ½, it does so on the grounds that this definition leads to simpler relations." [HR, p. 127]

In 1979 Max Jammer discussed Reichenbach's e coefficient, stressing that one of the most fundamental ideas underlying the conceptual edifice of relativity is the conventionality of intrasystemic distant simultaneity. He added: "The "thesis of the conventionality of intrasystemic distant simultaneity" ... consists in the statement that the numerical value of e need not necessarily be ½, but may be any number in the open interval between 0 and 1, *i.e.* $0 < e < 1$, without ever leading to any conflict with experience." [TF, p. 205]

I devoted years of work to the practical confirmation of this intuition. The confirmation came out, ample but with a surprise (see Section 4). In any event, there is an important logical space for different values of e, *i.e.*, in the final analysis, for alternative theories to the TSR! This is why, after a century of relativism, we can open the doors to a different physics without conflict with the enormous volume of experimental results accumulated to date.

3. Two empirical facts

The Earth moves through space at 2-300 km/sec (about 1‰ of the speed of light) as it partakes, with the Sun, in the rotation of the Milky Way (orbital motion round the Sun and daily rotation have velocities ten and a thousand of times smaller, respectively). According to the equations of Galilei-Newton physics, the velocity of light relative to a terrestrial laboratory should depend on the propagation direction. Thus, let $\vec{c}$ be the velocity of a point-source light signal with respect to the preferred system S_0. If $\vec{c}'$ is the velocity of the same signal with respect to a terrestrial laboratory, moving in S_0 with velocity $\vec{u}$, one should have $\vec{c}' = \vec{c} - \vec{u}$. Therefore c' should vary from $c - u$ to $c + u$ when the light propagation direction is changed from parallel to antiparallel to $\vec{u}$.

At first sight it might seem that these first order effects in u/c should be easily observable. One should, however, recall that even before the birth of the TSR Poincaré had argued that it was impossible to measure the velocity of an object propagating between two different points. To understand the motivation behind this unpleasant conclusion, let us consider a light signal traveling from A to B. If in B there is a mirror reflecting the signal back, it is enough to have a clock near A measuring the start and return times t_1 and t_3. The speed of the signal is then given by its definition:

$$c_{ar} = 2d_{AB} / (t_3 - t_1)$$

where d_{AB} is the A-B distance that can be measured in the standard way with a rigid rod. However, this is a two-way velocity, and it is possible for the signal velocities from A to B and from B to A to be different. To measure the latter, two synchronized clocks would be needed, one near A and the other one near B. Unfortunately, during the XXth century nobody knew how to synchronize two distant clocks. All methods that have been thought up give rise to difficulties.

Well before the formulation of the relativity theory, Poincaré discussed the independence of the velocity of light from its direction of propagation, and stated: “That light has a constant velocity and in particular that its velocity is the same in all directions ... is a postulate without which it would be impossible to start any measurement of this velocity. It will always be impossible to verify this postulate directly with experiments.” [HP] Agreeing on the impossibility of measuring one-way velocities, Einstein decided to solve the problem by decree, assuming the invariance of the velocity of light.

This being said, it remains certain that c_{ar} is measurable. Classical physics predicts a variation, due to the Earth’s motion, much smaller than for the one-way velocity. More precisely, if the light propagation direction is modified in a terrestrial laboratory, it predicts variations of the order of $u^2/c^2 \approx 10^{-6}$ for c_{ar}.

One of the most precise measurements of c_{ar} was performed in 1978 by a British group, and it gave the result:

$$c_{ar} = (299{,}792.4588 \pm 0.0002) \text{ km/sec},$$

which was confirmed by subsequent measurements (1987). Thus c_{ar} is known with a precision of 10^{-9}, a thousand times smaller than needed to detect the second order effects due to the Earth's motion. Yet, before and after 1978 the same value was always found, within errors, in agreement with the more indirect experiments (such as the Michelson-Morley experiment) designed to detect the existence of the preferred reference system. Thus we have our first fundamental conclusion:

> *C1. Within a small error the two-way velocity of light is invariant, as it is empirically independent of the propagation direction and the time at which it is measured.*

With their famous 1887 experiment Michelson and Morley concluded that no shifts of the interference figures existed due to the Earth's motion. To explain this, Fitzgerald and independently Lorentz supposed that motion of an object through the ether with velocity $\boldsymbol{u}$ undergoes a shortening in the direction of motion by the factor

$$R = \sqrt{1-\boldsymbol{u}^2 / c^2} \, . \tag{3}$$

In 1900 Larmor considered a system "composed of two electrons of opposite charge" (one would say today: composed of an electron-positron pair), neglected irradiation, and assumed circular orbits around the common centre of mass of the two particles. By also assuming that the whole system was in motion through ether, he proved that the velocity-dependent deformation of the electric fields predicted by classical physics generated exactly the contraction in the bound system postulated by Fitzgerald and Lorentz. Furthermore Larmor found that the orbital period was necessarily increased by R^{-1}. This was the first correct formulation of the idea of a velocity-dependent retardation of clocks.

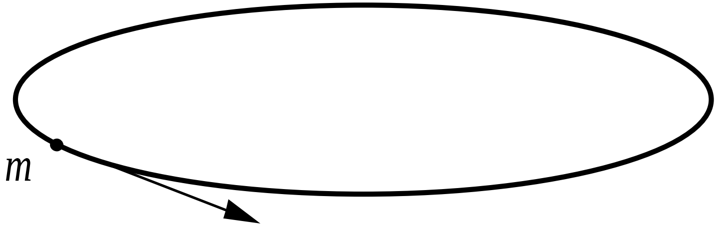


Figure 1. In the CERN storage ring unstable particles (“muons”) circulated with a speed smaller than that of light by only six parts in ten thousand. It was observed that muons disintegrated after a lifetime 29.33 times longer than for muons at rest.

Today the slowing down of moving clocks is very well tested. One of the most convincing experiments was performed in 1977 when the lifetimes of positive and negative muons were measured at the CERN muon storage ring. Muons with a velocity of 0.9994 c, corresponding to a factor $R^{-1} = 29.33$, were circling in a ring with diameter of 14 m, with a centripetal acceleration equal to 10^{18} g. The lifetime t was measured and found to be in excellent agreement with the formula $t = t_0/R$ where t_0 is the lifetime of muons at rest.

The lesson learnt from this experiment concerns the transformation of time: the laboratory time interval t_0 between two events taking place at the same position in the moving system (muon injection and decay) is observed to satisfy $t_0 = t/R$ if compared with the time interval t measured by the moving observer.

Besides this experiment, there is rich evidence from measurements with rectilinear beams of unstable particles that the average lifetime (before spontaneous disintegration) also depends on velocity according to $t_0 = t/R$. These experiments have been repeated so many times, and with such accuracy, that no reasonable doubt remains about the conclusion that the slowing down of moving clocks is a true property of nature.

In the 1972 experiment with macroscopic clocks by Hafele and Keating, six accurately synchronized Cesium atomic clocks were used, and:

1) two were carried by ordinary commercial jets in an eastbound trip around the planet;
2) another two were carried by ordinary commercial jets in a westbound trip around the planet;
3) the last two remained on the ground.

It was observed that with respect to the latter clocks, those on board the westbound trip had undergone a loss of 59 ± 10 ns, while the clocks on the eastbound trip had advanced 273 ± 7 ns. These results were in excellent agreement with the usual formula $t_0 = t/R$, if:

a) one used three different terms R for the three pairs of clocks. The largest (smallest) factor was that of clocks that traveled eastward (westward) for which the Earth rotation velocity added to (subtracted from) the jet velocity. That is, it was necessary to refer movements not to the Earth's surface, but to a reference frame with its origin at the Earth's centre and axes oriented toward fixed directions in the sky;
b) one took into account the effect of the Earth's gravitational field, which varies with altitude and therefore changes the rates of the traveling clocks differently from those on the ground.

The Hafele-Keating experiment has been criticized because not all parameters were under control during the flights. However its results have finally been confirmed by the GPS (*Global Positioning System*) system of satellites [OQ, pp. 81-90]. This system consists of a network of 24 satellites in roughly 12-hour orbits, each carrying atomic clocks on board. The orbital radius of the satellites is about four Earth radii. The orbits are nearly circular. Orbital inclinations to the Earth's equator are about 55°. The satellites have orbital speeds of about 3.9 km/sec in a frame centered on the Earth and not rotating with respect to the stars. Every satellite has on board four atomic clocks marking time with an error of a few nanoseconds per day (ns/day). From every point of the Earth's surface at least four satellites are visible at any time.

The theory of general relativity predicts that clocks in a stronger gravitational field will tick at a slower rate. Thus the atomic clocks on board the satellites at GPS orbital altitudes will tick faster by about 45.900 ns/day because they are in a weaker gravitational field than atomic clocks on the Earth's surface. The velocity effect predicts that atomic clocks moving at GPS orbital speeds will tick slower by about 7.200 ns/day than stationary ground clocks. Therefore the global prediction is a gain of about 38.700 ns/day. Rather than having clocks with such large rate differences, the satellite clocks rates were reset before launch (slowing them down by 38.700 ns/day) to compensate for these predicted effects. The very rich data show that the onboard atomic clock rates do indeed agree with ground clock rates to the predicted extent. Thus the theoretical predictions are confirmed, in particular the slowdown of the clock rate due to the orbital velocity.

We can then state the following second fundamental conclusion:

> *C2. A the rate of a clock in motion with velocity* **u** *slows down by a factor R given by (3).*

We left the question of the reference frame with respect to which u should be calculated on a vague note. In the next section we will take C1 and C2 as fundamental empirical facts and get rid the vagueness by making a specific assumption: its validity will be corroborated by the success of the ensuing theory.

4. The "equivalent" transformations

According to Mansouri and Sexl [MR] the Lorentz transformations contain a purely conventional term, the coefficient of x in the transformation of time. Reconsidering the whole matter, I reformulated the transformation of the space and time variables between inertial systems [S1, S2] starting from very general assumptions. I obtained the "equivalent transformations" containing an indeterminate term, e_1, the coefficient of x in the transformation of time: see Eqs. (4), below.

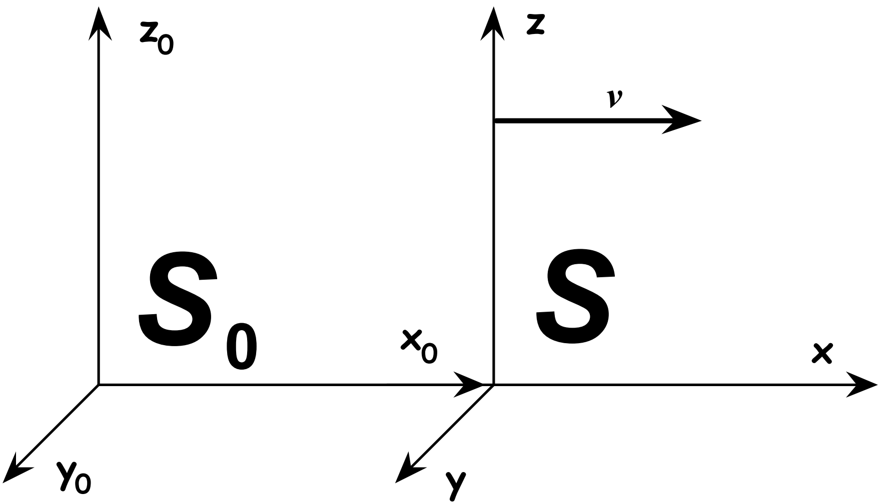


Figure 2. An inertial system S having coordinates (x,y,z) moves with velocity $\upsilon < c$ with respect to the isotropic inertial system S_0 having coordinates (x_0,y_0,z_0). The two sets of coordinates overlap perfectly at $t_0 = t = 0$.

The structure of the reasoning leading to the equivalent transformations is as follows. Given the inertial frames S_0 and S one can set up Cartesian coordinates (see Fig. 2) 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_0;

(*ii*) In the isotropic system S_0 the velocity of light is *"c"* in all directions, so that clocks have to be synchronized in S_0 with the Einstein method, and the one-way velocities relative to S_0 can be measured;

(*iii*) The origin of S, observed from S_0, is seen to move with velocity $\upsilon < c$ parallel to the $+x_0$ axis, *i.e.*, according to the equation $x_0 = ut_0$;

(*iv*) The axes of S and S_0 coincide for $t_0 = t = 0$;

The geometrical configuration is thus the usual one of the Lorentz transformations.

The assumptions (**i**) and (**ii**) are not exposed to objections from the point of view of the TSR or any plausible theory based on a preferred system; for the TSR they hold in all inertial systems, in the second case they are taken to hold in the preferred system itself. Now we add two points discussed in the previous section which, as we saw, are based on solid empirical evidence:

(***v***) The two way velocity of light is the same in all directions and in all inertial frames;

(***vi***) The clock retardation takes place with the usual factor R when clocks move with respect to S_0. Notice that we have now eliminated ambiguities by specifying that R in the formula $t = t_0/R$ has to be calculated in S_0.

These conditions were shown [S1, S2] to reduce the transformations of the space and time variables from S_0 to S to the form

$$\begin{cases} x = \dfrac{x_0 - u\,t_0}{R} \\ y = y_0 \qquad ; \qquad z = z_0\,, \\ t = R\,t_0 + e_1\left(x_0 - u\,t_0\right) \end{cases} \tag{4}$$

with R given by (3). From (4) one can easily see that the "delay" $t - t_0$ of a clock in S, with respect to the passing clock in S_0 in general depends not only on t_0, but also on the point x of S at which the former clock is placed. Only if $e_1 = 0$ is this complication absent. Therefore the physically free parameter e_1 can be fixed conventionally by defining the simultaneity of distant events in S, or, equivalently, by choosing a clock synchronization method in S. Clearly, then, the appropriate definition of e_1 is "synchronization parameter".

The Lorentz transformations of the TSR are a particular case, obtained for $e_1 = -u/Rc^2$, a value that introduces a certain symmetry between space variables and time, forcing the latter to assume a geometrical role in a four dimensional space. In Minkowski's words: "The views of space and time which I wish to lay before you ... are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality." [EL, p. 75].

Different values of e_1 imply different theories of space and time that are empirically equivalent to a very large extent. I checked with explicit calculations that the empirical data are very often insensitive to the choice of e_1: Römer [S5, S6], Bradley [S5, S6, PS], Fizeau [S9], Michelson-Morley [S2, S5, S6], Doppler [PS], the International Atomic Time [MS], *etc*. Thus there are infinitely many theories that explain the results of these experiments equally well. It is remarkable that all such theories are based on the existence of a preferred frame, the only exception being the TSR.

The previous conclusion would seem to agree with the conventionality idea of clock synchronization. There are, however, experimental situations of a different type (linear accelerations, rotating platforms, superluminal signals) which enable one to determine the unique synchronization allowed by nature (which is not the TSR synchronization, but is based on $e_1 = 0$). Obviously this is a very important point, but we cannot discuss it here for reasons of space. All the necessary arguments are given in detail in my papers on linear accelerations [S1, S6], rotating platforms [S2, GS, S4], and superluminal signals [S7].

I proposed that Eq.s (4) with $e_1 = 0$ be called *inertial transformations*. They imply a complete liberation of time from the merely geometrical role into which it had been forced in the Minkowski space, and predict that the velocity of light relative to an inertial system S moving with respect to the preferred frame S_0 is not isotropic. A corresponding anisotropy is predicted for Reichenbach's parameter e.

5. Relativism and the energy idea

The last six sections, starting from the present one, are devoted to the many sectors of physics that the TSR does not describe satisfactorily. Only in one case (Sagnac effect) can one assert that it is impossible to deduce a formula in agreement with experiments from the TSR, while in the other cases it is impossible to give the mathematical symbols a reasonable physical meaning. The theory of inertial transformations will be seen to provide systematically better predictions.

We start from the mass-energy equivalence. The TSR led to the conclusion that an arbitrary object, whose quantity of matter is measured by mass, and pure motion, measured by energy, are transformable into one another and must be considered different forms of a single reality. This conclusion has been confirmed in an enormous number of experiments of nuclear and subnuclear physics, so that it can be considered an irreversible conquest of science. The mass-energy equivalence is expressed by the famous formula $E = mc^2$. The reciprocal transformability of energy and mass was described as follows: "A further consequence of the (special) theory of relativity is the connection between mass and energy. Mass is energy and energy has mass. The two conservation laws of mass and energy are combined by the relativity theory into one, the conservation law of mass-energy." [EI, p. 132]

The new discovery was full of consequences, for example it implied a full continuity between that form of energy diffused in space which is called "field" and the material sources generating it: "From the relativity theory we know that matter represents vast stores of energy and that energy represents matter. We cannot, in this way, distinguish qualitatively between mass and field, since the distinction between mass and energy is not a qualitative one. We could therefore say: Matter is where the concentration of energy is great, field where the concentration of energy is small. But if this is the case, then the difference between matter and field is a quantitative rather than a qualitative one. [...] In the light of the equivalence of matter and energy the division in matter and field is something artificial and not well defined. [...] Matter is where the concentration of energy is high, field is where the concentration of energy is low. But if this is the case, the difference between matter and field is quantitative and not qualitative." [EI, p. 116]

The mass-energy equivalence means that an object can be transformed into pure motion of other objects and, *vice versa*, that it is possible to create matter at the expense of motion. These transformations take place according to the rigorous laws of conservation of energy and momentum. These are absolutely concrete processes: it is possible to make two protons with high enough kinetic energy collide to produce the same two protons with identical properties (mass, electric charge, *etc.*) in the final state, and, additionally, one or several new pieces of matter, for example some p mesons conjured out of nothingness during the collision. That is, they appear to be conjured out of nothingness to a person who believes that matter can neither be created nor destroyed. Actually, if one compares the kinetic energies of the initial and final states, one finds that exactly the kinetic energy has disappeared that is needed to produce the new mass. The following is an example:

$$P + P \rightarrow P + P + p^0$$

and reads as follows: two colliding protons (P + P) give rise to (→) a new physical state including two protons and a neutral p meson (P + P + p^0).

Inverse processes also exist in which energy is created at the expense of mass. The uranium fission reactions are of this type. In this way one sees how false is the belief of the past that matter can neither be created nor destroyed. In reality there is no law of conservation of matter: what is conserved under all circumstances is energy together with its vectorial daughter, the quantity of motion.

It is beyond doubt that the conquests of relativity in terms of the mass-energy relationship described above belong to the philosophical realm of realism. Positivism, however, did not disappear, on the contrary it sought to enforce its domination to the very notion of energy, as we will see next.

Energy has all the right properties to be considered a kind of fundamental substance of the universe: it is indestructible, it enters into all dynamical processes, and matter itself is a localized form of it.

However, the TSR itself strongly denies energy a fundamental role. It does so with its relativism. Every inertial observer assigns a different velocity, and thus a different energy, to any given particle. The relativistic total energy E (kinetic plus rest mass energy) of a particle with rest mass m and velocity u relative to a reference frame S is

$$E = \frac{m c^2}{\sqrt{1 - u^2 / c^2}}$$

where c is the velocity of light. The previous equation holds in all inertial systems $\mathrm{S}, \mathrm{S}', \mathrm{S}'', \ldots$ provided one uses the particle velocity $u, u', u'', \ldots$ relative to each of them. If one asks which is the real value of energy, the TSR answers that all observers are equivalent, so that their answers are all equally valid. And since each of them attributes a different value to the particle energy, none able to choose one energy as "more true" than others, one is forced to conclude that a real energy value does not exist. Consequently, energy is stripped of the property of having a well-defined numerical value.

In 1943 J. Jeans used a very similar argument against the objectivity of forces. For him the essence of all physical explanation is that each particle of a system experiences a real and definite force. This force should be objective as regards both quantity and quality, so that its measure should always be the same, whatever means are employed to measure it—just as a real object must always weigh the same, whether it is weighed on a spring balance or on a weighing beam. But the TSR shows that if motions are attributed to forces, these forces will be apprehended differently, as regards both quantity and quality, by observers who happen to be moving at different speeds, and furthermore, that all their estimates have an equal claim to be considered right. Thus—Jeans concludes—the forces cannot have a real objective existence; they are mere mental concepts that we make for ourselves in our efforts to understand the workings of nature. [JJ, p. 14] Naturally Jeans was immediately able to generalize his argument to all physical quantities: force, energy, momentum, and so on. In his words:

> *But the physical theory of relativity has now shown... that electric and magnetic forces are not real at all; they are mere mental constructs of our own, resulting from our rather misguided efforts to understand the motions of the particles. It is the same with the Newtonian force of gravitation, and with energy, momentum and other concepts which were introduced to help us understand the activities of the world—all prove to be mere mental constructs, and do not even pass the test of objectivity. If the materialists are pressed to say how much of the world they now claim as material, their only possible answer would seem to be: matter itself. Thus their whole philosophy is reduced to a tautology, for obviously matter must be material. But the fact that so much of what used to be thought to possess an objective physical existence now proves to consist only of subjective mental constructs must surely be counted a pronounced step in the direction of mentalism. [JJ, p. 200]*

With a beginning like this it is no surprise that Jeans arrives at the most genuine philosophical idealism:

> *Today there is a wide measure of agreement, which on the physical side of science approaches almost to unanimity, that the stream of knowledge is heading towards a non-mechanical reality. The universe begins to look more like a great thought than like a great machine. Mind no longer appears as an accidental intruder into the realm of*

> *matter. We ought rather to hail it as the creator and governor of the real of matter. [Quoted in PF, p. 235]*

To escape from such unpleasant conclusions there is only one option: giving up that relativism which in the TSR arises from the symmetry of the Lorentz transformations and undoubtedly gives the most natural interpretation of the theory. The retrieval of the objectivity of energy and of the other physical quantities should rather arise from the non-equivalence of the different reference frames. But the non-equivalence is achieved with the inertial transformations, based on the existence of a preferred system, which give back to the mass-energy formula all its great conceptual importance [S3]. Energy can take up its fundamental role, its true value being relative to the preferred inertial system.

6. Einstein's Ether

In the 1905 paper Einstein stated that the introduction of a luminiferous ether could be considered superfluous, given that his theory needed neither an absolutely stationary space endowed with particular properties, nor a medium in which electromagnetic processes, such as the propagation of light, could take place.

In the years of his transition from positivism to realism, Einstein started to reconsider the whole question of the ether [LK] and admitted that, after all, it was still possible to think it as existing, even if only to designate particular properties of space. He stated that during the evolution of science the word "ether" had changed its meaning several times, and that in any event, after the birth of the theory of relativity, it could no longer denote a medium composed of particles. A self-critical position was ripe by then, and in fact in 1919 Einstein wrote to Lorentz: "It would have been more correct if I had limited myself, in my earlier publications, to emphasizing only the non-existence of an ether velocity, instead of arguing the total non-existence of the ether, for I can see that with the word *ether* we say nothing else than that space has to be viewed as a carrier of physical qualities." [Quoted in LK, p. 2]

At this point Einstein rediscovered the importance of the arguments in favor of the existence of an ether medium, such as the existence at every point of space of well-defined inertial reference systems, or, equivalently, the genesis of the inertial forces in the accelerated systems. To explain this fundamental phenomenon he would not invoke an action-at-a-distance of the fixed stars (as was done by Mach), but resorted to well-defined properties of space itself active locally. Therefore he wrote:

> *On the other hand there is a weighty argument to be adduced in favor of the ether hypothesis. To deny the existence of the ether means, in the last analysis, denying all physical properties to empty space. But such a view is inconsistent with the fundamental facts of mechanics. [AR]*

Einstein thought that ether should not be conceived as different from the four dimensional space with real physical properties. In his opinion it did not make much sense to suppose that an absolutely empty geometrical space preexisted and that a substance, the ether, filled it and endowed it with physical properties. Therefore:

> *Physical space and the ether are only different terms for the same thing; fields are physical states of space. If no particular state of motion can be ascribed to the ether, there does not seem to be any ground for introducing it as an entity of a special sort alongside space. [Quoted in LK, p. 123]*

Considering the mechanical nature of the Lorentz ether, Einstein stated that the TSR had given rise to a radical change, consisting precisely of depriving the ether of its last mechanical property that Lorentz had still left it, immobility:

> *More careful reflection teaches us, however, that this denial of the existence of the ether is not demanded by the special principle of relativity. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it,* i.e.*, we must by abstraction take away from it the last mechanical characteristic that Lorentz had still left it. [AR]*

In general relativity Einstein's ether was deprived of all types of motion, and thus also of the possibility of being motionless. In short, it had radically new properties that prevented one from imagining it as composed of parts or particles in any state of motion. This new description was unavoidable if the ether had to look the same in all inertial reference systems. Thus was born the idea of an ether compatible with the TSR, a relativistic ether. This idea can be considered an attempt of compromise between the positivism of the TSR and the realism of the ether. But this time nobody took the great physicist seriously: many liked positivism, a few liked realism, but it seems that they all agreed that the two philosophies should not be mixed together.

What can one say, today, about Einstein's relativistic ether? Well, in the first place that the return to the ether is dictated by what we called above good sense: a space endowed with physical properties can very well be called ether, since war of words is of no interest in physics. In the second place one should, however, add that it is strange and unpleasant to deprive the ether of all states of motion. Einstein, who liked the interpretation of the TSR based on relativism, must have viewed this as inevitable, but today it is no longer unavoidable. Thanks to the inertial transformations, which admit the existence of a preferred inertial system, a full recovery of the Lorentz ether finally becomes possible [S7].

7. The twin paradox

There are two twins, **F** and **G**, and the former decides to take an interstellar trip, while the latter remains on Earth to await his return. The twins are twenty years old when **F** departs. His spaceship accelerates rapidly until it reaches 99% of the speed of light, then it travels until arriving near Mira Ceti, a famous variable star 32 light years away from Earth. When **F** reaches his destination, he stops, quickly takes some pictures of that stellar system, and accelerates back towards Earth, soon reaching the constant speed of 0.99 c. How long will the trip take? The calculation is easy for twin **G**, and gives about 64.6 years (the brief time spent in accelerating is neglected). The situation is different for **F** who experiences (both technologically and biologically) a slowing down of all physical processes. On the moving spaceship everything is slower, from the clocks to the computers to the heartbeats of the space travelers. One could almost say that time itself slows down by the usual factor R which for **F** is $R \cong 0.141$. For twin **F**, then, the voyage in reality lasts $64.6 \times 0.141 \cong 9$ years. When **F** meets **G** again at the end of the voyage he is 29 years old, while **G** is an octogenarian.

A similar experiment was actually performed by Hafele and Keating, as we saw, and their results have been fully confirmed by the GPS satellites. It has to be said that all these real or ideal results are in excellent agreement with the relativistic equations, but very little with the foundational relativism of the TSR. In physics one should always bear in mind that there are two logics present: the mathematical logic of the equations and the qualitative logic of the meaning of the symbols used. Numerical agreement is not enough if the meaning of the theoretical prediction is not what it should be.

In fact, the difference between the times shown by the atomic clocks on board the two flights of the Hafele-Keating experiment could be explained by assuming that in the eastward flight the airplane velocity was added to the Earth's rotational velocity, while in the westward flight the two velocities were subtracted. This meant that *with respect to the surrounding space* one flight was faster. Relativism would instead require that only motions relative to real bodies (such as the Earth's surface) be considered, but from this point of view the eastward and westward flights should produce equal physical effects on the clocks, contrary to observations. Stating that the results of these experiments are in good agreement with the TSR, as several authors do, means forgetting the relativism of the theory, and thoughtlessly calculating with respect to the inertial frame in which the Earth's center is instantaneously at rest.

The problem disappears with the inertial transformations, which are not based on relativism and assume that light propagates isotropically only with respect to the preferred inertial system [S10]. Similarly, in the case of the twin paradox considered above, the troubles arise from treating the movements as symmetrical, as required by relativism. In a theory with a preferred system, the twin ageing less is always the one who feels the effects of larger absolute velocities, and no problem arises.

8. The aberration of light

The phenomenon of aberration of the starlight, discovered by Bradley in 1725, is so important in relativistic physics that Einstein discussed it in his 1905 article on the TSR. From the angular deviation of the light of a star, observed during a year, it is possible to deduce the velocity of light. But the starlight follows a one-way path toward the Earth, and one might believe that aberration allows one to measure the one-way velocity of light. Actually this is not true, as all the equivalent transformations predict exactly the same aberration angle [see Eq. (4)], even though the one way velocity is different for different transformations of the set.

Consider a localized light pulse P from the point of view of the preferred system S_0 of the equivalent theories, relative to which the speed of light is isotropic. If q_0 is the inclination with respect to the x_0-axis of the trajectory of P and q is the inclination of the same trajectory as judged in S, one can prove [S5, S6, PS] an aberration formula mathematically identical to the formula in relativity, namely:

$$\tan q = \frac{c R \sin q_0}{c \cos q_0 - u} \tag{5}$$

All the quantities appearing in the right hand side of Eq. (5) 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 the Lorentz transformations) agree on the numerical values of q_0 and u. Therefore they predict exactly the same value of the aberration angle q for any arbitrary reference system S. Even though we are presently unable to identify S_0, the previous conclusion is obviously enough to conclude that we have thereby obtained a complete explanation of aberration from the point of view of the equivalent transformations, based on the existence of a preferred system. If the absolute aberration angle is the same for all S, the aberration angle observed between two moving systems S and S' has to be the same also!

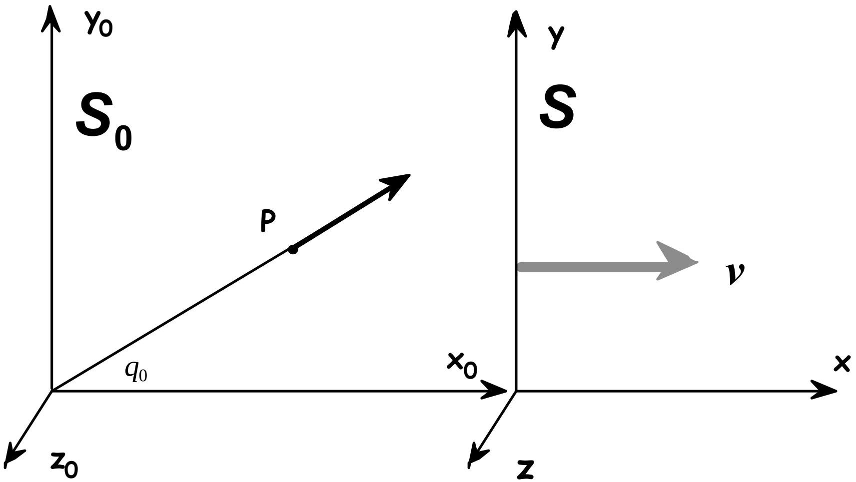


Figure 3. A localized light pulse P propagates in the isotropic inertial system S_0, relative to which the velocity of light is the same in all directions. One seeks to describe the motion of P in the different inertial system S.

The above explanation of aberration in terms of absolute motion provides the resolution of a longstanding problem in the relativistic approach. Einstein deduced the aberration formula (5) from the idea that u is the *relative* velocity of the star-Earth system. This idea was repeated by many authors, *e.g.*, by Møller, clearly because using the relative velocity is the most natural thing in the TSR, based on the philosophy of 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 existence of binary stars gives rise to the same difficulty for the TSR, but more acutely, noting that there are spectroscopic binaries with known orbital parameters and velocities around their center of mass similar to the Earth's orbital velocity. Therefore the components of a binary system can have velocities relative to the Earth very different from one another at some times; nevertheless it is well known that these components always exhibit the same aberration angle—actually not different from that of single stars. Eisner and Hayden developed this critical idea to strengthen Ives' conclusions.

The problem of aberration is completely resolved by the inertial transformations, which predict that the u entering into (5) is the Earth's absolute velocity, and the aberration phenomenon is due to the variations of u generated by orbital motion.

9. The Sagnac effect

In the Sagnac 1913 experiment a circular platform was made to rotate uniformly around a vertical axis. In an interferometer mounted on the platform, two interfering light beams, reflected by four mirrors, propagated in opposite directions along a closed horizontal circuit. The rotating system also included the luminous source and a detector (a photographic plate recording the interference fringes). On the pictures obtained during a clockwise and a counterclockwise rotation with the same frequency, the interference fringes were observed to be in different positions.

This displacement is strictly tied to the difference in time with which a light beam reaches the detectors, and turns out to depend on the disk angular velocity. Sagnac observed a shift of the interference fringes every time the rotation was modified. Considering his experiment conceptually similar to the Michelson-Morley one, he informed the scientific community with two papers (in French) bearing the titles "*The existence of the luminiferous ether demonstrated by means of the effect of a relative ether wind in a* *uniformly rotating interferometer*" and "*On the proof of the reality of the luminiferous ether with the rotating interferometer experiment.*"

The experiment has been repeated many times in different ways, with full confirmation of the Sagnac results. The 1925 repetition by Michelson and Gale is famed for the very large dimensions of the optical interference system (a rectangle about $650\text{m} \times 360\text{m}$); in this case the disk was the Earth itself at the latitude of the experiment. The light propagation times were not the same, as evidenced by the resulting fringe shift. Full consistency was found with the Sagnac formula if the angular velocity of the Earth's rotation was used.

Surprisingly theoreticians took little interest in the Sagnac effect, as if it did not pose a conceptual challenge. For example, as far as I know Einstein's publications never mentioned it.

A first discussion by Langevin came only 7-8 years later, as formally self-assured as it was substantially weak. One of the opening statements is this: "I will show how the theory of general relativity explains the results of Sagnac's experiment in a quantitative way." Langevin argues that Sagnac's is a first-order experiment, on which all theories (relativistic or pre-relativistic) must agree qualitatively and quantitatively, given that the experimental precision does not allow one to detect second order effects: therefore it cannot produce evidence for or against any theory. Then he goes on to show that an application of *Galilean* kinematics explains the empirical observations! In fact his approach is only slightly veiled in relativistic form by some words and symbols, but is really 100% Galilean.

The impression that Langevin, in spite of his claim, could not be satisfied with his explanation is reinforced by his second article of 1937 in which two (!) relativistic treatments are presented. The first treatment is the same as in 1921, this time deduced from the strange idea that the time to be adopted everywhere on the platform is that of the centre of rotation (which is motionless in the laboratory). The second treatment is to define "time" on the platform in such a way as to enforce a velocity of light constant and equal to *c* by starting from a perfect differential. However, this gives rise to the unsolvable problem of the discontinuity for a trip around the disk that I have discussed elsewhere [S10].

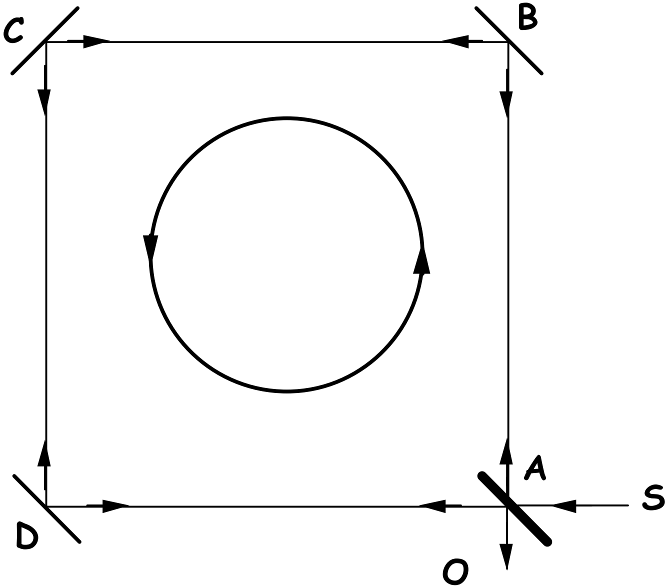


Figure 4. Simplified Sagnac apparatus. Light from the source S is split in two parts by the semitransparent mirror A. The first part moves on the path ABCDAO concordant with the disk rotation, the second part moves on ADCBAO discordant from rotation. The two parts interfere in O.

In 1963 a very influential review paper by Post was published, who seems to agree with the idea that two relativistic proofs of the Sagnac effect are better than one. The first proof (in the main text) arbitrarily uses the laboratory to platform transformation of time $t' = tR$ where R is the usual square root factor of relativity, here written with the rotational velocity. The second proof (in an appendix) starts from the Lorentz transformation $t' = \left(t + \vec{u} \cdot \vec{r} / c^2\right) / R$, but it hastens to make the second term disappear with the (arbitrary) choice of $\vec{r}$ perpendicular to $\vec{u}$. The tendency to cancel the spatial variables in the transformation of time is thus common to Langevin and Post, and shows once more the great difficulty in explaining the physics of the rotating platform with the TSR. The final result can only be a great confusion, to the point that Hasselbach and Nicklaus, describing their own experiment, list about twenty different "explanations" of the Sagnac effect and comment: "This great variety (if not disparity) in the derivation of the Sagnac phase shift constitutes one of the several controversies... that have been surrounding the Sagnac effect since the earliest days."

The tendency by Langevin and Post to get rid of x in the transformation of time somehow anticipates the approach based on the inertial transformations, the only ones among the equivalent transformations providing a rigorous qualitative and quantitative explanation of the Sagnac effect [S10].

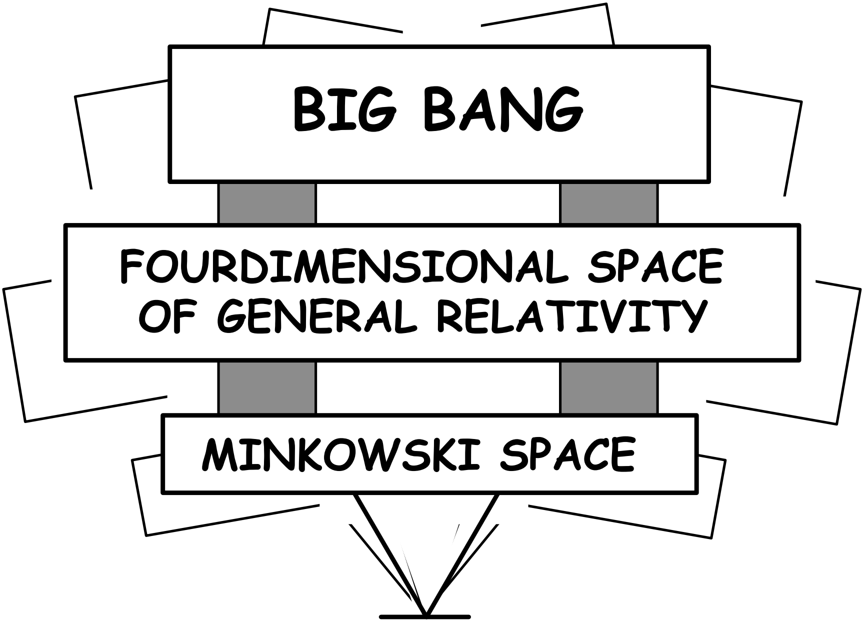
10. Cosmology

A much used method for providing an intuitive understanding of *big bang* is the analogy with the surface of an inflating rubber balloon covered with dots, with the proviso that the real world is, however, the three-dimensional surface of a four-dimensional sphere.

The use of the four dimensions is essential. In fact, in the ordinary three-dimensional space the *big bang* would be a great explosion producing matter, throwing it in all directions and generating galaxies with different velocities. Seen globally, the cosmos would be an irregular structure composed of an empty central region, the "crater of the explosion," an intermediate region containing the galaxies and an external part containing only radiation. Whatever our position might be in the intermediate region, we would see a vault of heaven very different from the basically isotropic one disclosed by the great telescopes. No structure in the three-dimensional space, born from an explosion occurred 10-20 billion years ago, could resemble the universe we observe.

For this reason all the theoretical *big bang* models find it absolutely necessary to introduce a fourth dimension. We should then stress that from a conceptual point of view, these models have a very unstable equilibrium, based as they are on the four-dimensional space of general relativity, in turn derived from the Minkowski space of the TSR. Thus the *big bang* depends strongly on the mixing of space with time of the TSR. In other words, it is in great danger if one modifies the fourth Lorentz transformation. But this is exactly what we did by adopting the inertial transformations and giving up the Lorentz transformations! In the inertial transformations time is made independent of space, and in this way a conception of reality is introduced in which no room is left for a four-dimensional space. In the concept of time separated from space, flowing from a past that cannot be changed to a future that does not yet exist but remains to be built, there is no place for a fourth dimension in which to dip and bend our three dimensional universe.

Forced from the experimental evidence to re-appropriate a space with three dimensions and without curvature, we have to agree that the *big bang* theory cannot be true. No structure of the three dimensional space, originated from an explosion 10-20 billion year old, could represent a universe similar to the one we observe. The *big bang* never happened!



$$ct' = \frac{ct - bx}{\sqrt{1 - b^2}}$$

Figure 5. Unstable equilibrium of the *big bang* model. The model is built on the four dimensional space of general relativity, in turn based on the Minkowski space of special relativity which is entirely dependent on the Lorentz transformation of time.

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