Lorentz Invariance as a Dynamic Symmetry

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If all the forces of nature can be reduced to those which follow from a linear combination of a scalar and vector potential, as in electrodynamics, Lorentz invariance can be derived as a dynamic symmetry. All that has to be done is to assume that there is an all pervading substratum or ether, transmitting those forces through space, and that all physical bodies actually observed are held together by those forces. Under this assumption bodies in absolute motion through the substratum suffer a true contraction equal to the Lorentz contraction, and as a result of this contraction clocks in absolute motion go slower by the same amount. The velocity of light appears then to be equal in all inertial reference systems, if Einstein's clock synchronization convention by reflected light signals is used and which presupposes this result. The Lorentz contraction and time dilation measured on an object at rest relative to an observer who gained a velocity by an accelerated motion is there explained as an illusion caused by a true Lorentz contraction and time dilation of the observer.

Both the special relativistic kinematic interpretation and this alternative dynamic interpretation give identical results only in the adiabatic limit where the accelerations are small, because if the Lorentz contraction is a real physical effect, it must take a finite time. However, to break the peculiar interaction symmetry with the ether, and which in the dynamic interpretation is the cause for the Lorentz invariance, the accelerated motions must involve rotation. Only then can non-adiabatic relativity-violating effects be observed and which would establish a preferred reference system at rest with the ether. Under most circumstances relativity-violating effects resulting from such a dynamic interpretation of special relativity would be very small and difficult to observe, a likely reason why they have evaded their detection in the past. For the rotating earth a residual sideral tide has been observed with a superconducting gravimeter, and which could be explained by an "ether wind" of about 300 km/sec at rest with the cosmic microwave background radiation. However, because of the observational uncertainties in measuring the terrestrial tides no definite conclusion can be drawn. A number of new experiments are therefore needed to decide the question regarding a possible weak violation of special relativity.

1. Introduction

Quantum theory, one of the most fundamental theories, is believed to be a theory for all possible objects, not just those actually realized. One therefore may ask the question if the theory of relativity cannot somehow be derived from quantum mechanics. According to Einstein, the Lorentz transformations express a symmetry of space and time. If this is true the theory of relativity cannot be a theory of objects and must remain unexplained by quantum mechanics. There is however, an alternative interpretation of the Lorentz transformations, by Lorentz and Poincaré, quite different from Einstein's interpretation, but which nevertheless explains all the same experimental material as well. It predates Einstein's theory and goes back to Fitzgerald. In this alternative older interpretation, the Lorentz transformations derive from real physical deformations of bodies in absolute motion through a substratum or ether. Abolished as being an unnecessary hypothesis by Einstein, the ether reentered into physics through quantum mechanics, assigning the vacuum a zero point energy. About the reality of this vacuum energy can be no doubt. Most convincingly it proves its existence through the phenomenon of spontaneous emission. The undisputable reality of the quantum ether therefore raises the question if the older interpretation, which says that the Lorentz transformations are caused by true physical deformations of bodies in absolute motion through a substratum, is perhaps closer to the truth. As an expression of an intrinsic space-time symmetry, special relatively is purely kinematic, in contrast to the Lorentz-Poincaré interpretation, explaining this symmetry as an illusion caused by true physical deformations, and which therefore is dynamic.

Against the special theory of relativity a similar case can be made as it has been made against Non-

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Euclidean geometries in physical space. As Poincaré has shown, one equally well could argue that a space believed to be Non-Euclidean is in reality flat, and that all bodies in space suffer an equal position-dependent deformation, giving an observer the illusion of a curved space. This different, albeit mathematically equivalent description however, rests on the assumption that the bodies occupying this hypothetical space adjust themselves adiabatically to a new changed state of deformation, if moved to a different location. In reality though, it would take a finite time for any physical body to assume a new equilibrium shape. Therefore, if a body in such a hypothetical space would be moved sufficiently fast from one place to another, in a time shorter than it would take the body to assume a new equilibrium, the question whether the space is truly Non-Euclidean or not, could then be decided by non-adiabatic experiments.

A very similar situation exists with regard to the special theory of relativity if one compares it with the alternative dynamic theory by Lorentz and Poincaré, because the dynamic theory makes the assumption that a body changing its absolute velocity against a substratum changes its shape adiabatically. But there too, a real physical body needs a finite time to assume a new shape, and if the change in absolute velocity occurs with such a high rate of acceleration, that the body cannot change its shape fast enough, Lorentz invariance would be violated. The significance of discovering such non-adiabatic relativity-violating effects would be of course very profound. If the dynamic interpretation is true, then Lorentz invariance could be derived from quantum mechanics through the physical deformations. Special relativity would thereby emerge as an approximate theory, valid only in the adiabatic limit of slow changes in the absolute velocity.

It is most interesting that the only kind of interactions leading to the deformations needed must have the same form as the electromagnetic forces, leaving open the strength of these interactions. The underlying more fundamental symmetry would there be the Galilei group. This would fit neatly into a theorem discovered by Jauch [1], according to which the fundamental kinematic symmetry group of quantum mechanics is the Galilei group, with a linear combination of a scalar and vector potential as the only allowed form the interaction can have. Moreover, the restriction to this narrow choice of the permitted interactions makes gauge invariance a property derived from Galilei invariance, in contrast to modern elementary particle theories where the gauge principle must be introduced as an additional hypothesis which cannot be derived from Lorentz invariance. In the contexct of Jauch's theorem one may therefore ask if the truly fundamental interactions have all the form of electromagnetism expressed in a preferred system at rest with a substratum, and from which both special relativity and the gauge principle can then be derived. If this should be true, interactions with different properties would have to be explained as composed forces, in particular the weak and strong force. For the compositeness of the weak force speaks its short range, a property it shares with the Van der Waals and nuclear force, known to be composed.

In the Weinberg-Salam model, the unification of the electromagnetic and the weak force was only possible through the introduction of the symmetry breaking massive Higgs particle, but the Higgs mechanism by itself speaks for the existence of a substratum, because it has an almost identical counterpart in the Landau-Ginzburg theory of superconductivity, which by its very nature is a substratum theory. The occurrence of a symmetry breaking mechanism may perhaps always be a sign of composed forces, which should even be true for gravity because it violates Lorentz invariance.

An attempt to derive all fundamental forces of nature from electromagnetism, is in a sense a reversal of Einstein's program to explain all forces, but in particular electromagnetism, as generalizations of gravity with a curved space-time model. The hypothesis that all fundamental interactions are electromagnetic in nature is also supported by the energy mass relationship $E = mc^2$. As Hasenöhrl [2] had shown a long time ago, this formula can simply be derived from Maxwell's equations, considering electromagnetic radiation entrapped inside a box.

To explain the theory of relativity along the lines of thought originally developed by Lorentz and Poincaré, has been revived more recently by Janossy [3], Builder [4] and Prokhovnik [5].

2. The Fitzgerald-Lorentz Contraction as a Dynamic Effect

Under the hypothesis that all fundamental interactions have the same form as electromagnetism, the deformation of a body, if set into absolute motion through a substratum, can simply be derived using Maxwell's equations. This assumption is certainly correct if one wants to compute the deformation of a macroscopic body which is held together by electromagnetic forces.

The equations of electrodynamics for the scalar and vector potentials [6] (in electrostatic cgs units) are

$$\begin{aligned} -\frac{1}{c^2}\frac{\partial^2 \Phi}{\partial t^2} + \nabla^2 \Phi &= -4\pi\varrho(\boldsymbol{r},t)\,, \\ -\frac{1}{c^2}\frac{\partial^2 \boldsymbol{A}}{\partial t^2} + \nabla^2 \boldsymbol{A} &= -(4\pi/c)\,\boldsymbol{j}(\boldsymbol{r},t)\,, \end{aligned} \tag{2.1}$$

to be supplemented by the invariance under gauge transformations

$$\begin{aligned} \Phi &\to \Phi - \frac{1}{c}\frac{\partial \Lambda}{\partial t}\,, \\ \boldsymbol{A} &\to \boldsymbol{A} + \nabla \Lambda\,, \end{aligned} \tag{2.2}$$

where for Lorentz gauge, the function Λ satisfies the wave equation

$$-\frac{1}{c^2}\frac{\partial^2 \Lambda}{\partial t^2} + \nabla^2 \Lambda = 0\,. \tag{2.3}$$

After Φ and $\boldsymbol{A}$ have been computed from these sets of equations, the electric and magnetic fields are given by

$$\begin{aligned} \boldsymbol{E} &= -\nabla\Phi - \frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t}\,, \\ \boldsymbol{H} &= \nabla \times \boldsymbol{A}\,. \end{aligned} \tag{2.4}$$

For a body which is in a state of static equilibrium, the electric charge and current distributions inside the body are related to Φ and $\boldsymbol{A}$ by

$$\begin{aligned} \nabla^2 \Phi &= -4\pi\varrho(\boldsymbol{r})\,, \\ \nabla^2 \boldsymbol{A} &= -(4\pi/c)\,\boldsymbol{j}(\boldsymbol{r})\,, \\ \nabla^2 \Lambda &= 0\,. \end{aligned} \tag{2.5}$$

For a given charge and current distribution, the potentials Φ and $\boldsymbol{A}$ can then be computed by an integration over the solid body with the result

$$\Phi = \int \frac{\varrho(\boldsymbol{r}^*)}{|\boldsymbol{r}-\boldsymbol{r}^*|}\,\mathrm{d}\boldsymbol{r}^*\,, \quad \boldsymbol{A} = \frac{1}{c}\int \frac{\boldsymbol{j}(\boldsymbol{r}^*)}{|\boldsymbol{r}-\boldsymbol{r}^*|}\,\mathrm{d}\boldsymbol{r}^*\,. \tag{2.6}$$

In keeping with the hypothesis of a substratum or ether, (2.1) – (2.6) are assumed to be true only for a system at rest with the ether. To see what will happen to the body if set into motion against the substratum we make the Galilei-transformation

$$x' = x - vt\,, \quad y' = y\,, \quad z' = z\,, \quad t' = t\,, \tag{2.7}$$

where x', y', z', and t' are measured in a frame moving with the body, and where v is an absolute velocity against the substratum.

In carrying out these transformations with regard to (2.1) and (2.3), the scalar and vector potentials change from Φ to Φ', $\boldsymbol{A}$ to $\boldsymbol{A}'$, and Λ to Λ'. The result is

$$\begin{aligned} &-\frac{1}{c^2}\frac{\partial^2 \Phi'}{\partial t'^2} + \left(1-\frac{v^2}{c^2}\right)\frac{\partial^2 \Phi'}{\partial x'^2} + \frac{\partial^2 \Phi'}{\partial y'^2} + \frac{\partial^2 \Phi'}{\partial z'^2} \\ &\quad = -4\pi\varrho(\boldsymbol{r}',t')\,, \\ &-\frac{1}{c^2}\frac{\partial^2 \boldsymbol{A}'}{\partial t'^2} + \left(1-\frac{v^2}{c^2}\right)\frac{\partial^2 \boldsymbol{A}'}{\partial x'^2} + \frac{\partial^2 \boldsymbol{A}'}{\partial y'^2} + \frac{\partial^2 \boldsymbol{A}'}{\partial z'^2} \\ &\quad = -(4\pi/c)\,\boldsymbol{j}(\boldsymbol{r}',t')\,, \\ &-\frac{1}{c^2}\frac{\partial^2 \Lambda'}{\partial t'^2} + \left(1-\frac{v^2}{c^2}\right)\frac{\partial^2 \Lambda'}{\partial x'^2} + \frac{\partial^2 \Lambda'}{\partial y'^2} + \frac{\partial^2 \Lambda'}{\partial z'^2} = 0. \end{aligned} \tag{2.8}$$

We now specialize (2.8) to the limiting situation, where a new equilibrium state has been established within the solid body, after it has been accelerated to the absolute velocity v. In a new state of equilibrium one has to put $\partial/\partial t' = 0$. According to (2.7) one can put everywhere $y' = y$ and $z' = z$. The result on (2.8) is

$$\begin{aligned} &\left(1-\frac{v^2}{c^2}\right)\frac{\partial^2 \Phi'}{\partial x'^2} + \frac{\partial^2 \Phi'}{\partial y^2} + \frac{\partial^2 \Phi'}{\partial z^2} \\ &\quad = -4\pi\varrho(x',y,z)\,, \\ &\left(1-\frac{v^2}{c^2}\right)\frac{\partial^2 \boldsymbol{A}'}{\partial x'^2} + \frac{\partial^2 \boldsymbol{A}'}{\partial y^2} + \frac{\partial^2 \boldsymbol{A}'}{\partial z^2} \\ &\quad = -(4\pi/c)\,\boldsymbol{j}(x',y,z)\,, \end{aligned} \tag{2.9}$$

$$\left(1-\frac{v^2}{c^2}\right)\frac{\partial^2 \Lambda'}{\partial x'^2}+\frac{\partial^2 \Lambda'}{\partial y^2}+\frac{\partial^2 \Lambda'}{\partial z^2}=0\,.$$

Comparing (2.5) with (2.9), the l.h.s. of (2.9) takes the same form as the l.h.s. of (2.5) if one puts

$$\Phi' = \Phi\,,\quad \mathbf{A}' = \mathbf{A}\,,\quad \Lambda' = \Lambda \tag{2.10}$$

and

$$\mathrm{d}x' = \mathrm{d}x\sqrt{1-v^2/c^2}\,. \tag{2.11}$$

That the r.h.s. of (2.9) then also assumes the same form as the r.h.s. of (2.5) can be seen as follows: Consider a rod of length l with the rod axis directed along the x-coordinate, and with one end of the rod having the coordinate $x = 0$. Before set into motion the integrals (2.6) over the rod extend from $x = 0$ to $x = l$. Under the transformation (2.11) the rod changes its length to $l\sqrt{1-v^2/c^2}$. The integrals however, remain invariant under this change of length because the contraction increases the charge and current density by the factor $1/\sqrt{1-v^2/c^2}$. This means that after set into absolute motion through the substratum and after having assumed a new equilibrium, the rod has contracted by the factor $\sqrt{1-v^2/c^2}$. This contraction, though, is unobservable for a comoving observer who uses measuring rods held together by the same kind of forces and which therefore suffer the same kind of contraction.

As can be seen from this derivation, the contraction is not instantaneous and must take a finite time. Increasing the velocity of a body moving against the substratum results in a contraction, but decreasing this velocity would result in an expansion. Furthermore, a true change in the state of the body is only possible if its velocity is changed by going through an acceleration. A kinematic change in the velocity of a body, which takes place if an unaccelerated body is observed from an accelerated frame of reference, does not lead to a true contraction or expansion of this body. This statement seems to contradict the results of the special theory of relativity, predicting an observed contraction even for a kinematic change in the velocity. The paradox is resolved if one takes into account the true physical deformation suffered by the observer who has changed his state of absolute motion. The observed contraction of the unaccelerated body is thereby interpreted as an illusion caused by the deformation of the measuring devices used by the observer. It does not occur in the unaccelerated body undergoing a relative change of velocity, but only in the observer. The occurrence of an absolute contraction or expansion not only is sufficient to derive the Lorentz transformations as a dynamic effect, but it also removes the ambiguity one encounters in the theory of relativity regarding the reality of the contraction effect.

The factor $(1 - v^2/c^2)$ on the l.h.s. of (2.9) can be seen as the reason for the contraction effect because it can be interpreted as a Doppler effect acting on the fields inside a body held together by electromagnetic forces. It always occurs under the Galilei transformation of a wave equation. From this perspective the negative outcome of the Michelson-Morley experiment is almost trivial. The arms of the interferometer are held together by electromagnetic forces and therefore must suffer the same deformations caused by the Doppler effect as the light paths, thereby exactly compensating each other.

The derivation of the contraction effect was done under the simplified assumption that the atoms of the solid body are in a static equilibrium. This assumption is justified only in the classical limit, for which quantum effects can be neglected. In quantum theory the zero point energy fluctuations of a mechanical system composed of atoms lead to a pressure and which can be seen as a result of Heisenberg's uncertainty principle. In the x-direction, and along which the motion through the substratum shall take place it is

$$m\,\Delta v\,\Delta x = \hbar\,. \tag{2.12}$$

Under the contraction, Δx changes from Δx to $\Delta x\sqrt{1-v^2/c^2}$. If all interactions are electromagnetic, the mass must have an electromagnetic origin and one can assign to the electromagnetic energy E an electromagnetic mass $m = E/c^2$, by the kind of reasoning first used by Hasenöhrl [2], without any reference to the theory of relativity. Then, if a photon of energy $E = h\nu = hc/\lambda$, with a mass $m = h/c\lambda$ is entrapped in box as a standing electromagnetic wave in the x-direction, its energy, and hence its mass, will change if the box is contracted in the x-direction by the factor $1/\sqrt{1-v^2/c^2}$, from $h/c\lambda$ to $(h/c\lambda)/\sqrt{1-v^2/c^2}$. This means, the mass m in eq. (2.12) will change to $m/\sqrt{1-v^2/c^2}$, making the product $m\Delta x$ invariant under this change. As a result, the contracted solid body will experience the same zero point pressure as in a reference system at rest in the substratum.

3. The Clock Retardation Effect

The absolute contraction effect leads to an absolute time dilation effect, as can be seen immediately: Under our assumption that all interactions resemble electromagnetism, propagated with the velocity of light through a substratum, all clocks can be viewed as light clocks, consisting of a rod with a mirror attached to both of its ends, and in between which a light signal is reflected back and forth. If the rod is at rest in the substratum, and if the length of the rod is l, the time needed for a signal to be sent back and forth is

$$t_0 = 2\, l/c\,. \tag{3.1}$$

If the rod is set into motion with the absolute velocity v against the substratum, and with the rod axis inclined against the direction of v by the angle φ, measured before it was set into motion, then the projection $l \cos\varphi$ of the rod in the direction of motion will be shortened to $l\sqrt{1-v^2/c^2}\,\cos\varphi$, with the projection $l \sin\varphi$ perpendicular to the direction of v remaining unchanged (see Figure 1). As seen from a system at rest with the substratum, the moving rod will therefore appear to be inclined under the angle ψ given by

$$\operatorname{tg}\psi = \gamma \operatorname{tg}\varphi\,, \quad \gamma \equiv 1/\sqrt{1-v^2/c^2}\,. \tag{3.2}$$

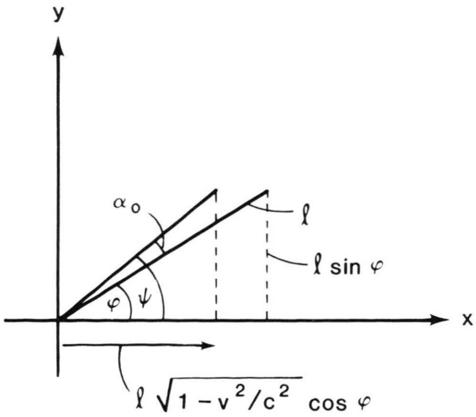

Fig. 1. The projections of a rod of length l along the y and x axis seen by an observer at rest in the substratum: $l \sin\varphi$, $l\cos\varphi$ for a rod at rest and $l\sin\varphi$, $l\sqrt{1-v^2/c^2}\cos\varphi$ for a rod moving with an absolute velocity v into the x-direction.

The length of the rod changes from l to l' by

$$l' = l\sqrt{1-(v^2/c^2)\cos^2\varphi} = \frac{l}{\gamma\sqrt{1-(v^2/c^2)\sin^2\psi}}\,. \tag{3.3}$$

In the frame of the moving rod the light velocity is anisotropic, and for the to and fro directions is given by

$$c_+ = \sqrt{c^2 - v^2\sin^2\psi} - v\cos\psi$$
$$c_- = \sqrt{c^2 - v^2\sin^2\psi} + v\cos\psi\,. \tag{3.4}$$

The time for a to and fro light signal, as measured by an observer at rest with the substratum, is now

$$t' = l'/c_+ + l'/c_- = \gamma t_0\,. \tag{3.5}$$

Therefore, as seen from an observer at rest with the substratum, the light clock goes slower by the factor $\sqrt{1-v^2/c^2}$. The clock retardation effect is therefore explained as a direct result of the contraction effect suffered by bodies in absolute motion through a substratum. This assignment of the clock retardation effect as an absolute effect removes all the paradoxes of the time dilation effect, like the twin paradox.

As it was true for rods with regard to their lengths, only clocks which change their state of absolute velocity, by going through an accelerated motion, change their rate. The observed change in the rate of a clock by a purely kinematic change of its velocity relative to an observer who changes his absolute velocity by going through a state of accelerated motion, is, as the contraction of an unaccelerated rod, seen as an illusion caused by a change in the deformed state of the observer.

4. The Apparent Constancy of the Velocity of Light

The principle that the velocity of light is constant and isotropic in all inertial reference systems, and which is fundamental for the special theory relativity, seems to contradict the anisotropy of the light propagation predicted in an absolute theory expressed by (3.4). The contradiction is resolved if one analyzes the way in which the velocity of light is measured within the framework of special relativity, because it is easy to show that the outcome of a measurement, always resulting in the same velocity, is a consequence of Einstein's clock synchronization convention. According to this convention two clocks A and B are synchronized if

$$t_B = \tfrac{1}{2}(t_A^1 + t_A^2)\,, \tag{4.1}$$

where t_A^1 is the time a light signal is emitted from A to B, reflected at B back to A arriving at A at the time t_A^2, and where it is *assumed* that the time at which the reflection at B takes place is t_B. In taking for t_B the arithmetic average of t_A^1 and t_A^2, the assumption that the velocity of light is isotropic and constant in all reference systems is already implicitly contained. It is therefore not surprising that the measured velocity of light, using Einstein's clock synchronization convention, will always turn out to be equal to c in all inertial reference systems. Einstein's constant light velocity postulate and his clock synchronization convention are therefore a tautology.

From an absolute point of view, the following would be true instead: If t_R is the true, absolute, reflection time of the light signal at clock B, one has for the out and return journeys of the light signal from A to B and back to A, if measured by an observer in an absolute system at rest with the substratum:

$$\begin{aligned} \gamma(t_R - t_A^1) &= d/c_+\,, \\ \gamma(t_A^2 - t_R) &= d/c_-\,, \end{aligned} \tag{4.2}$$

where d is the distance between both clocks, and where c_+ and c_- are given by (3.4). Adding the equations (4.2) one obtains

$$c(t_A^2 - t_A^1) = 2\gamma d\sqrt{1-(v^2/c^2)\sin^2\psi}\,. \tag{4.3}$$

If an observer at rest with the clock wants to measure the distance from A to B, he can measure the time a light signal takes in going from A to B and back to A. If he assumes that the velocity of light is constant and isotropic in all inertial reference systems, including the one he is in and which is moving together with A and B with the velocity v against the substratum, this distance is

$$d' = (c/2)(t_A^2 - t_A^1)\,, \tag{4.4}$$

and because of (4.3):

$$d' = \gamma d\sqrt{1-(v^2/c^2)\sin^2\psi}\,. \tag{4.5}$$

Comparing this result with (3.3), one sees that he would obtain the same distance d', if he uses a contracted rod as a measuring stick, or Einstein's constant light velocity postulate. The velocity of light he will measure between A and B by using (i) a rod to measure the distance and (ii) the time it takes a light signal in going from A to B and back to A, of course, will turn out to be equal to c, because according to (4.4)

$$\frac{2d'}{t_A^2 - t_A^1} = c\,. \tag{4.6}$$

Rather than using a *reflected* light signal to measure the distance d', and which assumes that c is constant and isotropic in both directions, the observer at A may try to measure the one-way velocity of light by first synchronizing the clock B with A and then measure the time for a light signal to go from A to B. However, since this synchronization procedure also uses reflected light signals, the result is the same. For the velocity he finds

$$\frac{d'}{t_B - t_A^1} = \frac{d'}{(1/2)(t_A^1 + t_A^2)} = \frac{2d'}{t_A^2 - t_A^1} = c\,. \tag{4.7}$$

If instead of d' one would take the absolute distance d, measured by an observer at rest with the substratum, and the absolute time $\gamma(t_A^2 - t_A^1)$, the velocity would turn out to be

$$c' = \frac{c}{\gamma^2\sqrt{1-(v^2/c^2)\sin^2\psi}}\,. \tag{4.8}$$

One easily verifies that this velocity is given by

$$\frac{1}{c'} = \frac{1}{2}\left(\frac{1}{c_+} + \frac{1}{c_-}\right). \tag{4.9}$$

But if one takes the distance d' and the time $t_B - t_A^1$, as it was done to arrive at the result (4.7), the average to and fro light velocity is there the arithmetic average

$$c' = \tfrac{1}{2}(c_+ + c_-)\,. \tag{4.10}$$

Furthermore, by subtracting the equations (4.2) one finds that

$$t_R = t_B + (\gamma/c^2)\,v\,d\cos\psi\,. \tag{4.11}$$

This relation shows that from an absolute point of view the "true" reflection time t_R at clock B is only then equal to t_B if $v = 0$.

This last relation can be used to show that the synchronization of clocks by "slow transport" will lead to the same synchronization-convention by reflected light signals, used by Einstein. In the synchronization by slow clock transport, two clocks, A and B, which are relative at rest and having initially the same location, are synchronized at their common location. Thereafter, clock B is slowly transported to another location and where it is again brought to rest relative to clock A. This synchronization procedure can be analyzed in the ether rest frame, where both clocks move with the absolute velocity v. If in this frame, $\boldsymbol{d}$ is the vector from A to B and if τ is the time to transport clock B over the distance d, one has

$$\boldsymbol{d} = \tau \cdot \delta \boldsymbol{v} \tag{4.12}$$

where $\delta \boldsymbol{v}$ is the additional velocity given clock B to move it away from clock A. Slow transport then simply means that $\delta \boldsymbol{v} \ll \boldsymbol{v}$. If the frequency standard in the ether rest frame is ν_0; the clock A has the frequency

$$\nu_A = \nu_0 \sqrt{1 - v^2/c^2} \, . \tag{4.13}$$

During its slow transport relative to clock A, clock B has the frequency

$$\nu_B = \nu_0 \sqrt{1 - (\boldsymbol{v} + \delta \boldsymbol{v})^2/c^2} \, . \tag{4.14}$$

One then finds in first order of $\delta \boldsymbol{v}/c$

$$\nu_A - \nu_B \simeq \frac{\nu_A \boldsymbol{v} \cdot \delta \boldsymbol{v}/c^2}{1 - v^2/c^2} \, . \tag{4.15}$$

The frequency shift results in a phase shift $\Delta\phi$ between both clocks which is

$$\Delta\phi = (\nu_A - \nu_B)\,\tau = \frac{\nu_A \boldsymbol{v} \cdot \boldsymbol{d}/c^2}{1 - v^2/c^2} \tag{4.16}$$

and the phase shift results in a time shift of the clocks. If t_A and t_B are the respective readings of the clocks in their frame of reference, their time shift is

$$\gamma(t_A - t_B) = \frac{\Delta\phi}{\nu_A} = \frac{\boldsymbol{v} \cdot \boldsymbol{d}/c^2}{1 - v^2/c^2} \tag{4.17}$$

hence

$$t_A = t_B + (\gamma/c^2)\, v\, d \cos\psi \, . \tag{4.18}$$

Comparing this result with eq. (4.11) one sees that by putting $t_A = t_R$, clocks synchronized by slow transport give the same reading as clocks synchronized by reflected light signals, with exactly the same time shift $(\gamma/c^2)\, v\, d \cos\psi$. Therefore, making a supposedly one-way light velocity experiment using clocks synchronized by slow transport cannot reveal a light velocity anisotropy, if it exists, and can only lead to the constant isotropic value c. This can also be shown in a more direct way. Let d' be the distance in the reference system of the clocks, and which can be measured with a solid rod, and let t_B be the time reading of clock B, at the moment a light signal emitted from clock A arrives at clock B. The light velocity measured would then be

$$c' = d'/t_B \tag{4.19}$$

whereby d' can be expressed through the distance d measured in the ether rest frame by eq. (4.5), and whereby in the ether rest frame d is given by

$$d = c_+ \gamma t_A \, . \tag{4.20}$$

With the expression for c_+ (eq. (3.4)), d' (eq. (4.5)) and t_A (eq. (4.18)) one can compute c', with the result that

$$c' = c \, . \tag{4.21}$$

The synchronization by slow clock transport is therefore equivalent to Einstein's synchronization by reflected light signals.

One may even contemplate a mechanical synchronization of clocks through a rotating shaft, but there again, the same time shift would result due to a twist, caused by the Lorentz contraction acting on the rotating shaft [3]. We therefore see that all different synchronization methods appear to lead to the same clock synchronization, making it impossible to measure the one-way velocity of light. This fact underlines the beauty of Einstein's clock synchronization convention by reflected light signals, because it permits to eliminate a prefered reference system, and with it the complexity of an anisotropic light propagation with which an absolute formulation of the theory would have to work. But one can not say it is experimentally proven that the velocity of light is constant and isotropic in all reference systems, because the outcome of such an experiment is predetermined by the clock synchronization convention, and by which a "one-way" light velocity anisotropy, if it should exist, remains hidden. If Einstein's kinematic interpretation of the Lorentz transformations is correct, there will be no absolute reference system. One can then simply dispose of the substratum as Einstein did, and assume that the velocity of light is constant and isotropic in all inertial reference systems. But if the dynamic interpretation is true instead, there must be observable non-adiabatic, Lorentz-invariance-violating effects, establishing an absolute reference system, and with it an anisotropic "one-way" velocity of light.

5. The Lorentz-Transformations

According to Einstein's first postulate the velocity of light shall be constant in all inertial reference systems. Applied to two inertial reference systems $I_A(\mathbf{r}_A, t_A)$ and $I_B(\mathbf{r}_B, t_B)$ in relative motion to each other this condition leads to

$$r_A^2 - c^2 t_A^2 = K(r_B^2 - c^2 t_B^2), \tag{5.1}$$

where K is a constant. Einstein's relativity principle, according to which there shall be no distinction between the two systems I_A and I_B, requests with equal justification that also

$$r_B^2 - c^2 t_B^2 = K(r_A^2 - c^2 t_A^2). \tag{5.2}$$

Equations (5.1) and (5.2) can be simultaneously true only if $K = \pm 1$. The negative sign must be excluded from the identy when the I_A and I_B reference systems are the same. One therefore has

$$r_A^2 - c^2 t_A^2 = r_B^2 - c^2 t_B^2. \tag{5.3}$$

One immediately verifies that (5.3) satisfies the Lorentz transformations for a uniform motion with the velocity v along the x-axis:

$$\left.\begin{aligned} x_A &= \gamma(x_B - v t_B), \\ y_A &= y_B, \\ z_A &= z_B, \\ t_A &= \gamma(t_B - v x_B/c^2) \end{aligned}\right\} \tag{5.4}$$

because

$$r_A^2 - c^2 t_A^2 = \gamma^2 (x_B - v t_B)^2 + y_B^2 + z_B^2 - c^2 \gamma^2 (t_B - v x_B/c^2)^2 = r_B^2 - c^2 t_B^2. \tag{5.5}$$

In the substratum interpretation of the Lorentz transformations by Lorentz and Poincaré, the same clock synchronization convention by reflected light signals is used as in Einstein's theory. This again makes the velocity of light equal and constant in all inertial reference systems provided the measurement is carried out with clocks synchronized according to this prescription. Therefore, with regard to an $I_s(\mathbf{r}_s, t_s)$ system at rest with the substratum one has

$$r_A^2 - c^2 t_A^2 = K(r_s^2 - c^2 t_s^2). \tag{5.6}$$

Equation (5.6) then satisfy the transformation formulas

$$\left.\begin{aligned} x_A &= \sqrt{K}\, \gamma_A (x_s - v_A t_s), \\ y_A &= \sqrt{K}\, y_s, \\ z_A &= \sqrt{K}\, z_s, \\ t_A &= \sqrt{K}\, \gamma_A (t_s - v_A x_s/c^2), \\ \gamma_A &\equiv 1/\sqrt{1 - v_A^2/c^2}, \end{aligned}\right\} \tag{5.7}$$

where v_A is the absolute velocity of the I_A system against the I_s system, assumed to take place in the positive x-direction. To determine K, a different absolute reasoning than in Einstein's theory is here used. It considers a rod held together by electromagnetic forces, or forces acting like electromagnetic forces. If moved through the substratum along its axis it is contracted by the factor $\sqrt{1 - v_A^2/c^2}$. For this contraction to follow from (5.7) requires to make $K = 1$. One therefore can write

$$r_A^2 - c^2 t_A^2 = r_s^2 - c^2 t_s^2 \tag{5.8}$$

but also

$$r_B^2 - c^2 t_B^2 = r_s^2 - c^2 t_s^2 \tag{5.9}$$

and hence

$$r_A^2 - c^2 t_A^2 = r_B^2 - c^2 t_B^2, \tag{5.10}$$

which is the same as (5.3), again leading to the Lorentz transformations.

Even though the final result of both theories is the same, the physical meaning is very different. In Einstein's theory the contraction and clock retardation effect result from the property of a space-time with a constant light velocity for all inertial reference systems, whereas in the substratum approach by Lorentz and Poincaré it results from an assumed single physical effect and which is the contraction of a physical body in absolute motion against the substratum. Because this contraction effect can be derived from the property of electromagnetic forces, the substratum interpretation of the Lorentz transformations can be seen as a derivation of special relativity from an underlying deeper reality.

6. Relativity-Violating Effects

In the dynamic interpretation the Lorentz contraction takes a finite time, and it must therefore lead to effects violating special relativity. By observing these effects, a reference system at rest with the substratum can be determined.

A change in the absolute velocity against the substratum is accompanied by an acceleration. Therefore, let us assume that all the volume elements of some body are accelerated along a straight line in the same way, such that the body would not change its geometric shape. After the acceleration is completed and the body released from the accelerating forces, it would undergo a Lorentz contraction. This contraction would take a finite time, but an experiment measuring this time would not be capable to establish an absolute reference system, and therefore not be a test for or against special relativity for the following reason: According to the kinematic restrictions of special relativity different acceleration programs would have to be applied for different volume elements of the body, whereby the body would continuously change its shape as to satisfy the Lorentz contraction formula in each moment during its accelerated motion. Accelerations along a straight line are therefore unsuitable to break the peculiar interaction symmetry with the substratum and which according to the dynamic interpretation is the cause for the observed Lorentz invariance.

A rather different situation arises if a rotational motion is superimposed on a linear motion because according to a theorem by Herglotz [6] and Noether [7] such a superposition cannot be performed within the kinematic restrictions of special relativity. Experiments involving rotational motion are therefore suitable to break the interaction symmetry with the substratum. If a body moves with a constant velocity against the substratum, a superimposed rotational motion would change its orientation relative to the direction of its absolute motion, and it would therefore suffer an oszillatory contraction and expansion. Furthermore, if the rotation is sufficiently fast, the contraction and expansion will not be in phase with the rotational motion. Moreover, if the time for the contraction to take place is of the same order as the time to complete a rotation, a resonance would be excited, greatly amplifying a presumed relativity-violating effect. Apart from macroscopic bodies, such effects could even occur in atoms, nuclei or subnuclear particles with a large angular momentum. If the presumed substratum is at rest with the cosmic microwave background radiation, these rotational motions would be superimposed on a velocity of about 300 km/sec.

The contraction and expansion of the rotating objects can be thought of being communicated by compressional and surface waves. The propagation of these waves is in general very complex. However, for two very simple configurations, a rod, and a cross composed of two equal rods, both of which can serve as models for most moving complex bodies of interest, these waves reduce into compressional and bending waves with very simple properties. The case of a rotating rod was previously considered by Atkins [8], and the case of a rotating cross by the author [9].

For a better perspective, both cases are put together in Figure 2. Introducing a Cartesian coordinate system, the rod and cross lie in the $x-y$ plane, with the axis of rotation into the z-direction through the center of the rod and the cross. In a reference system at rest with the earth, the rod and the cross move along the positive x-direction with the same absolute velocity v as the earth. If both are at rest in the substratum, the length of the rod

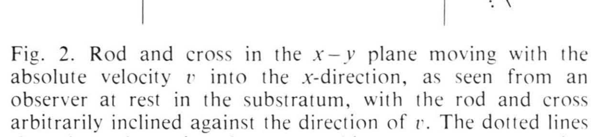

Fig. 2. Rod and cross in the $x-y$ plane moving with the absolute velocity v into the x-direction, as seen from an observer at rest in the substratum, with the rod and cross arbitrarily inclined against the direction of v. The dotted lines show how the rod and cross would appear to a co-moving observer.

shall be l, and the four arms of the cross made up of two rods with the length l shall intersect under a right angle. If moving under the angle φ with the velocity v against the substratum, and without having an intrinsic superimposed rotational motion, both the rod and cross are deformed as shown by the dotted lines in Fig. 2, if viewed from an observer at rest with the substratum. For a comoving observer at rest with the rod and cross, both the rod and cross would appear undeformed because the observer himself would suffer the same kind of deformation.

If the rod is inclined under the angle φ before it was set into motion, it suffers a contraction which reduces its length to

$$l' = l\sqrt{1-(v^2/c^2)\cos^2\varphi}\,. \tag{6.1}$$

Assuming that $v \simeq 300$ km/sec, which is the velocity against the microwave background radiation, one has $v^2/c^2 \simeq 10^{-6}$. It is therfore possible to expand (6.1) to obtain the change in the length of the rod with sufficient accuracy:

$$\Delta l = l - l' \simeq (l/2)(v^2/c^2)\cos^2\varphi\,. \tag{6.2}$$

Under this change in its length, the rod is deformed relative to a mean length $\bar{l} = l(1-(1/4)(v^2/c^2))$ by

$$x_0 = (l/4)(v^2/c^2)(1-2\cos^2\varphi) = -(l/4)(v^2/c^2)\cos 2\varphi\,. \tag{6.3}$$

With regard to the cross we are interested in the change of the angle φ, deformed under the absolute motion against the substratum from φ to ψ by the angle $\alpha_0 = \psi - \varphi$. Because $\operatorname{tg}\psi = \gamma \operatorname{tg}\varphi$, one can put for $\alpha_0 \ll 1$:

$$\operatorname{tg}\psi = \operatorname{tg}(\varphi+\alpha_0) \simeq (\alpha_0 + \operatorname{tg}\varphi)/(1-\alpha_0 \operatorname{tg}\varphi)$$

and hence

$$\alpha_0 \simeq \frac{(\gamma-1)\operatorname{tg}\varphi}{1+\gamma \operatorname{tg}^2\varphi}\,. \tag{6.4}$$

For $v^2/c^2 \simeq 10^{-6}$ one can put $1+\gamma\operatorname{tg}^2\varphi \simeq 1 + \operatorname{tg}^2\varphi = 1/\cos^2\varphi$ and $\gamma - 1 \simeq (1/2)(v^2/c^2)$. One therefore has with sufficient accuracy

$$\alpha_0 \simeq (1/4)(v^2/c^2)\sin 2\varphi\,. \tag{6.5}$$

If the special theory of relativity is correct, the deformation functions for x_0 and α_0 remain valid if the rod and cross rotate with an angular velocity ω, putting $\varphi = \omega t$. If the Lorentz-Poincaré theory is correct, this will only be true if the angular velocity is sufficiently low, to give the rod and cross in each moment enough time to assume the static equilibrium form predicted by the Lorentz contraction formula. If the angular velocity is not that small the deformation functions x and α, replacing x_0 and α_0, are instead determined by the differential equations

$$\ddot{x} + 2\,\omega_1 \dot{x} + \omega_c^2 x = -(l/4)(v^2/c^2)\,\omega_c^2 \cos(2\,\omega t) \quad \text{(rod)}\,, \tag{6.6a}$$

$$\ddot{\alpha} + 2\,\omega_1 \dot{\alpha} + \omega_b^2 \alpha = (1/4)(v^2/c^2)\,\omega_b^2 \sin(2\,\omega t) \quad \text{(cross)}\,, \tag{6.6b}$$

where

$$\omega_c \simeq \frac{\pi}{l}\sqrt{\frac{E}{\varrho}}\,, \tag{6.7a}$$

$$\omega_b \simeq \frac{\pi d}{l^2}\sqrt{\frac{E}{\varrho}} = \frac{d}{l}\,\omega_c\,, \tag{6.7b}$$

$$\omega_1 = \frac{8}{9}\,\frac{\chi T \varepsilon^2 E}{\varrho c_p d^2}\,. \tag{6.7c}$$

The rod and the two bars of which the cross is composed, with the length l and thickness d, have the following material constants: E = Young module, ϱ = density, χ = heat conduction coefficient, T = absolute temperature, ε = thermal expansion coefficient, and c_p = specific heat at constant pressure.

Equations (6.6a) and (6.6b) have the solutions

$$x(t) = A_c \cos[2(\omega t + \delta_c)]\,, \tag{6.8a}$$

$$\alpha(t) = A_b \sin[2(\omega t + \delta_b)]\,, \tag{6.8b}$$

where

$$A_c = -\frac{(l/4)(v^2/c^2)\,\omega_c^2}{\sqrt{(\omega_c^2 - 4\,\omega^2)^2 + 16\,\omega_1^2\,\omega^2}}\,, \tag{6.9a}$$

$$A_b = \frac{(1/4)(v^2/c^2)\,\omega_b^2}{\sqrt{(\omega_b^2 - 4\,\omega^2)^2 + 16\,\omega_1^2\,\omega^2}}\,, \tag{6.9b}$$

$$\operatorname{tg} 2\,\delta_c = -\frac{4\,\omega_1\,\omega}{\omega_c^2 - 4\,\omega^2}\,, \tag{6.10a}$$

$$\operatorname{tg} 2\,\delta_b = -\frac{4\,\omega_1\,\omega}{\omega_b^2 - 4\,\omega^2}\,. \tag{6.10b}$$

Even though these formulas have been derived under the assumption that the rod and cross are macroscopic objects, they can be qualitatively also applied by adjustments of the material constants to microscopic objects.

For macroscopic objects there exists in addition to the material constants listed the tensile strength σ. It sets an upper limit for the rotational velocity. One finds for this maximum rotational velocity reached at the rim of the object

$$v_{rot}^{max} \simeq \sqrt{\sigma/\varrho}\,. \tag{6.11}$$

If this rotational velocity is reached at the distance $l/2$ from the axis of rotation, it implies a maximum angular velocity

$$\omega_{max} = (2/l)\sqrt{\sigma/\varrho} \tag{6.12}$$

and one finds

$$\left.\begin{aligned} \omega_{max}/\omega_c &\simeq \sqrt{\sigma/E} \\ \omega_{max}/\omega_b &\simeq (l/d)\sqrt{\sigma/E} \end{aligned}\right\}. \tag{6.13}$$

The deformation functions $x(t)$ and $\alpha(t)$ have resonances which for $\omega_1 \ll \omega_c$, $\omega_1 \ll \omega_b$ are located at $\omega_{res} \simeq \omega_c/2$ and $\omega_{res} \simeq \omega_b/2$. For solids one typically has $\sqrt{\sigma/E} \simeq 0.1$. Therefore, for compression waves one has $\omega_{max} \simeq 0.1\,\omega_c$, far below the resonance. For bending waves, however, the resonance can be reached by making $l/d \gtrsim 10$.

For compression waves far below the resonance, that is if $\omega \ll \omega_c$, one finds

$$x(t) \simeq -\frac{l}{4}\frac{v^2}{c^2}\frac{\omega_c^2}{\sqrt{(\omega_c^2-4\,\omega^2)^2+16\,\omega_1^2\,\omega^2}} \cdot \cos(2\,\omega t)\,. \tag{6.14a}$$

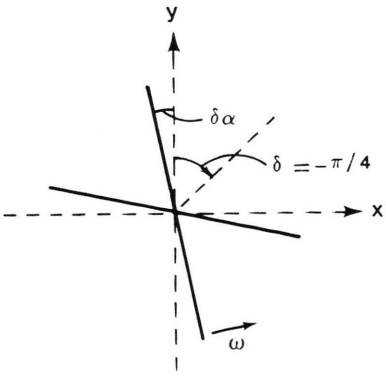

Fig. 3. Distortion and phase-shift of cross at resonance for bending waves.

For bending waves far below the resonance one likewise finds

$$\alpha(t) \simeq \frac{1}{4}\frac{v^2}{c^2}\frac{\omega_b^2}{\sqrt{(\omega_b^2-4\,\omega^2)^2+16\,\omega_1^2\,\omega^2}} \cdot \sin(2\,\omega t)\,. \tag{6.14b}$$

For bending waves one can even reach the resonance, where for $\omega_1 \ll \omega_b$ one has

$$\alpha_{res} \simeq (1/8)(v^2/c^2)(\omega_b/\omega_1)\sin(2\,\omega t-\pi/2)\,. \tag{6.15}$$

For a comoving observer the deformations $x_0(t)$ and $\alpha_0(t)$ are unobservable because they are compensated by his own deformation. He therefore can only observe the differences*

$$\begin{aligned} \delta x &= x - x_0, \\ \delta\alpha &= \alpha-\alpha_0. \end{aligned} \tag{6.16}$$

For $\omega \ll \omega_c$, well below the resonance and for $\omega_1 \ll \omega_c$ one finds for the residual change in the rod length with sufficient accuracy

$$\delta x_- \simeq -l(v^2/c^2)(\omega^2/\omega_c^2)(1-2\,\omega_1^2/\omega_c^2) \cdot \cos(2\,\omega t)\,, \tag{6.17a}$$

and likewise for $\omega \ll \omega_b$ and $\omega_1 \ll \omega_b$, for the residual change in the angle

$$\delta\alpha_- \simeq (v^2/c^2)(\omega^2/\omega_b^2)(1-2\,\omega_1^2/\omega_b^2)\sin(2\,\omega t)\,. \tag{6.17b}$$

δx_- and $\delta\alpha_-$ are here in phase with $x_0(t)$ and $\alpha_0(t)$.

At resonance one finds for $\delta\alpha$

$$\delta\alpha_{res} \simeq (1/8)(v^2/c^2)(\omega_b/\omega_1)\sin(2\,\omega t-\pi/2) \tag{6.18}$$

with the maximum deformation lagging behind the Lorentz contraction by 45° (see Fig. 3).

For $\omega \gg \omega_b$, well above the resonance one finds

$$\delta x_+ \simeq (l/4)(v^2/c^2)(1+\omega_c^2/4\,\omega^2)\cos(2\,\omega t) \tag{6.19a}$$

and

$$\delta\alpha_+ \simeq -(1/4)(v^2/c^2)(1+\omega_b^2/4\,\omega^2)\sin(2\,\omega t)\,, \tag{6.19b}$$

* Strictly speaking these differences are valid for the reference system at rest with the substratum. If expressed in a comoving reference system, there will be corrections of the order $(v/c)^4$, but effects of this order have been neglected in all our approximations.

in opposite phase to $x_0(t)$ and $\alpha_0(t)$. From these relations we see that above resonance the maximum deformations saturate to the values $\delta x_\infty^{\max} = (l/4)(v/c)^2$ and $\delta \alpha_\infty^{\max} = -(1/4)(v/c)^2$.

According to Atkins [8] there are two observations which deserve to be analyzed in this context, the deformation of the earth, measured with a superconducting gravimeter by Warburton and Goodkind [10], and the experiment by Brillet and Hall [11]. If the substratum is at rest with the microwave background radiation, one would have $v \cong 300$ km/sec and with v directed under an angle of almost 90° against the earth axis.

For the deformed earth the excentricity e is related to δx by

$$\delta x/l \simeq -e^2/2\,, \qquad (6.20)$$

where $\delta x/l = \delta R/R$, with R equal the earth radius. The change in the gravitational force at the surface of an oblate spheroid is [12]

$$\Delta g/g \simeq -(e^2/30)(1-3\sin^2\theta)\,, \qquad (6.21)$$

where θ is measured from the equator of the spheroid. This expression takes into account the lateral expansion of the deformed spheroid with the Poisson number set equal to 1/2. If the "ether wind" intersects the earth axis by 90°, the pole of the oblate spheroid will move on the earth's equator. The maximum $\Delta g/g$ will there be experienced by an observer for whom the pole of the deformation spheroid has the same geographic longitude. The observation in question was carried out at a geographical latitude of 34°, which means that for the maximum value of $\Delta g/g$ one has to set $\theta = 90° - 34° = 56°$. With this value one finds for the maximum

$$\Delta g/g \simeq e^2/30 \simeq -(1/15)\,\delta x/l\,. \qquad (6.22)$$

For δx one has to choose the maximum value for δx_-. We put $\omega_c = \omega_E \simeq 1.95\times 10^{-3}\,\sec^{-1}$, taken from seismological data valid for the ${}_0S_2$-deformation oszillation [13]. For the earth one also has $\omega_1 \ll \omega_E$. One therefore finds ($\omega = 2\pi/T$, T = one day = 86400 seconds)

$$\Delta g/g \simeq (1/15)(v/c)^2(\omega/\omega_E)^2 \simeq 9\times 10^{-11}\,. \qquad (6.23)$$

This result compares well with the measured maximum value $\Delta g/g \simeq 7\times 10^{-11}$ obtained by Warburton and Goodkind**. The phase in the variation of Δg leads to less certain conclusions if it is compared with the direction of the cosmic microwave background radiation.

For the Brillett-Hall experiment we have the following parameters [14]: $l = 30$ cm, $\sqrt{E/\varrho} \simeq 6$ km/sec, $\omega_c \simeq 6\times 10^4\,\sec^{-1}$, $\omega = 0.2\,\sec^{-1}$, $\omega_1 \sim 600\,\sec^{-1}$.

One therefore can put $\omega_1 = 0$ since $\omega_1/\omega_c \ll 1$. From (6.17a) we thus obtain for the maximum value of $\delta l/l$

$$\delta l/l \simeq (v/c)^2(\omega/\omega_c)^2 \simeq 10^{-17}\,. \qquad (6.24)$$

Experimentally a value of $\delta l/l \simeq (1.5\pm 2.5)\times 10^{-15}$ was observed, too large to be explained as a relativity-violating effect. However, just an about 10 fold increase in the rotational velocity of the interferometer would have reached a comparable value (from (6.24)) in $\delta l/l$.

Much better appears the prospect with bending waves. There very large, even macroscopically large effects are possible in principle with bending waves at resonance [9]. Experiments involving bending waves could therefore become crucial to decide in between the kinematic and dynamic interpretation of the Lorentz transformations and they could, of course, also establish the absolute reference system, needed for a complete dynamic formulation of the theory.

Finally we discuss possible relativity-violating effects in atomic physics. The most precise measurements have been reached for the hydrogen atom. The forces holding the electron in its orbit are electrostatic and are propagated with the velocity of light. We therefore may put $\omega_c = \pi c/r_B$, where r_B is the Bohr radius***. The electron velocity in the lowest orbit is $v_0 = \alpha c$ ($\alpha = 1/137$), implying a rotational frequency $\omega = v_0/r_B = \alpha c/r_B$. We therefore have $\omega/\omega_c = \alpha/\pi$. Because $\delta x/l \sim \delta r_B/r_B \sim |\delta\varepsilon/\varepsilon|$, where $\delta\varepsilon$ is the level shift

** We cannot agree with the analysis of the same problem by Atkins [8] who claims the value measured by Warburton and Goodkind would require that $v \sim 30$ km/sec instead of the 300 km/sec suggested by the microwave background radiation.

*** This is a plausible assumption because it is the electric potential which is a c number, and it, therefore, should give a lower limit for a possible relativity-violating effect. How good this assumption really is, can only be decided by a detailed quantum electrodynamic analysis.

relative to the state of the circling electron, one finds from (6.17a)

$$|\delta\varepsilon/\varepsilon| \simeq (v/c)^2(\alpha/\pi)^2 \simeq 5\times 10^{-12}. \quad (6.25)$$

Since $\varepsilon \simeq 10$ eV, one has $\delta\varepsilon \simeq 5\times 10^{-11}$ eV, a value at the limit of the experimental art. To observe a relativity-violating effect one would have to align polarized hydrogen atoms, first parallel and thereafter perpendicular to the "ether wind," with the aim to find an energy shift between these two alignments. The experiment would have to be carried out involving transitions into $l \geq 1$ angular momentum states, because only those possess a rotational motion.

The effect would be of comparable smallness as the effects observed in experiments demonstrating parity-violation through the electroweak interaction (~ 1 eV versus ~ 300 GeV, that is small by the order $\sim 3\times 10^{-12}$). Even though the relativity-violating effect would not be parity-violating, it would act like a force which does not conserve angular momentum. This therefore raises the question if the discrepancies reported in these experiments could have their cause in a weak violation of special relativity.

The relativity-violating effect would be substantially larger for hydrogen-like atoms of nuclear charge $Z \gg 1$, stripped of all its electrons but one. There one has $\omega_c = \pi c Z/r_B$, and $\omega = (\alpha c/r_B)\, Z^2$, and hence $(\omega/\omega_c)^2 = (\alpha Z/\pi)^2$. One there would have

$$|\delta\varepsilon/\varepsilon| \simeq (v/c)^2(\alpha/\pi)^2 Z^2 \simeq 5\times 10^{-12} Z^2. \quad (6.26)$$

Furthermore, ε scales there as Z^2, and hence $\delta\varepsilon$ scales as Z^4.

One of the most precise experiments quoted in support of special relativity has been done by Forston et al. [15]. It involves nuclear magnetic resonance and its accuracy implies that a relativity-violating effect should be less than $\delta\varepsilon \simeq 2\times 10^{-21}$ eV. The precession frequency in this experiment was of the order $\omega \simeq 10\ \text{sec}^{-1}$. The nuclear frequency is of the order $\omega_0 \simeq 0.1\, c/R$, where $R \simeq 10^{-12}$ cm is the nuclear radius. With these values the nonadiabatic, relativity-violating energy shift would be

$$|\delta\varepsilon/\varepsilon| \simeq (v/c)^2(\omega/\omega_0)^2 \simeq 10^{-46}. \quad (6.27)$$

With $\varepsilon \simeq 10^6$ eV, which is typical for a nucleus one finds $\delta\varepsilon \simeq 10^{-40}$ eV. The value is very much smaller than the lower limit of $\delta\varepsilon \simeq 2\times 10^{-21}$ eV in the above quoted experiment. In spite of its great accuracy, this experiment is therefore unsuitable to detect nonadiabatic relativity-violating effects.

7. Can All the Forces of Nature be Reduced to Electromagnetism?

The derivation of Lorentz invariance as a dynamic symmetry did rest on the assumption that the interaction transmitted by the substratum has the same form as electromagnetism, therefore raising the question, if all forces of nature are in some sense electromagnetic. As in modern field theories, the interaction constants could still vary by many orders of magnitude. The gravitational interaction for example, which under normal conditions is very feeble, is believed to become strong at the Planck scale.

A reduction of all forces to electromagnetism would mean that the weak, the strong, and the gravitational force have an electromagnetic core. The unification of the electromagnetic and weak interaction in the Weinberg-Salam model cannot be considered a reduction to electromagnetism along these lines. This model in fact has serious blemishes. They show up in the short range of the weak force and the need to insert certain parameters "by hand."

Leaving aside the question regarding the nature of the weak force as unresolved, we are still left with the strong and gravitational forces. One outstanding property of electromagnetism is that electric charges come with different signs, with the sum of the charges adding up to zero. If the strong and gravitational forces are peculiar forms of electromagnetism, one would expect that this property, of the charges canceling each other out, somehow survives. In the strong interaction a quite similar cancellation of different charges in fact occurs. The charges are there called "color," and they always "add up" to a colorless combination. In gravitation, negative masses enter through the field, and many cosmologists believe that in our universe the positive masses of all matter are compensated by the negative masses of all gravitational fields.

If the strong interaction is a camouflaged electromagnetic interaction, the color charge would have to be a form of electromagnetic charge. A hint as to what this charge might be could be the empirical fact of electric charge quantization, because it strongly speaks for the existence of magnetic monopoles. The most simple model to assign color to magnetic charge is probably the one proposed by Schwinger [16]. In this model the quarks are dually charged particles, with electric charges equal to $\pm(1/3)\,e$ and $\pm(2/3)\,e$, and likewise magnetic charges equal to $\pm(1/3)\,g$ and $\pm(2/3)\,g$. According to Dirac one then has the quantization rule

$$eg = 2\,\hbar c \tag{7.1}$$

making the magnetic interaction

$$g^2/\hbar c = 4\times 137 \tag{7.2}$$

superstrong. The magnetic monopole hypothesis would also make it plausible why quarks cannot be observed as free particles. Consider two magnetic monopoles of opposite sign separated by the distance r, at which their potential energy will be

$$E_{\text{pot}} = -g^2/r\,. \tag{7.3}$$

Their total energy mc^2 can be estimated by the uncertainty principle:

$$mc^2 \simeq \hbar c/r\,. \tag{7.4}$$

From (7.3) and (7.4) it follows that

$$E_{\text{pot}}/mc^2 = -g^2/\hbar c \gg -1\,. \tag{7.5}$$

Therefore, if an attempt would be made to separate two monopoles from each other, such an attempt would be foiled by magnetic vacuum breakdown producing a pair of monopoles attaching themselves to the two monopoles one tries to separate. Qualitatively the same happens in quantum chromodynamics if one wants to isolate a colored particle.

One other peculiar property of quantum chromodynamics are the quadratic terms of two vector potentials in the force equation. We can easily show that this property can be qualitatively understood as an underlying electromagnetic effect. Two magnetic monopoles separated by a small but finite distance can be seen as a thin magnetic solenoid with a monopole attached to each end of the solenoid [17, 18]. The interaction of two such solenoids is then a superposition of forces acting between the uncompensated parts of the magnetic charges and the interaction of the two magnetic flux tubes. It is the second contribution which shall interest us here. If the first flux tube has a magnetic moment $\boldsymbol{m}_1$ and the second one $\boldsymbol{m}_2$, and if both are separated by the distance r, the vector potential of $\boldsymbol{m}_1$ at the position of $\boldsymbol{m}_2$ is

$$\boldsymbol{A}_1 = \frac{\boldsymbol{m}_1\times\boldsymbol{e}_r}{r^2} \tag{7.6}$$

and likewise of $\boldsymbol{m}_2$ at the position of $\boldsymbol{m}_1$

$$\boldsymbol{A}_2 = -\frac{\boldsymbol{m}_2\times\boldsymbol{e}_r}{r^2}\,, \tag{7.7}$$

where $\boldsymbol{e}_r$ is a unit vector along r. One then finds that the force acting on $\boldsymbol{m}_2$ by $\boldsymbol{m}_1$ is

$$\begin{aligned} \boldsymbol{F} &= \nabla\,(\boldsymbol{m}_2\cdot\operatorname{curl}\boldsymbol{A}_1) \\ &= 2\,\nabla\,[(\boldsymbol{e}_r\times\boldsymbol{A}_1)\cdot(\boldsymbol{e}_r\times\boldsymbol{A}_2)\,r] \\ &= 6\,(\boldsymbol{e}_r\times\boldsymbol{A}_1)\cdot(\boldsymbol{e}_r\times\boldsymbol{A}_2)\,\boldsymbol{e}_r \end{aligned} \tag{7.8}$$

and finally

$$\boldsymbol{F} = 6\boldsymbol{A}_1\cdot\boldsymbol{A}_2\,\boldsymbol{e}_r\,. \tag{7.9}$$

An explanation of the strong force along these lines is also supported by the occurrence of a strong Lorentz-force $\boldsymbol{F}_{\text{L}} = e(\boldsymbol{v}/c)\times\boldsymbol{H}$ caused by the strong magnetic field in the flux tube connecting two quarks. Strong spin dependent forces have in fact been observed in the collision of polarized protons [19]. It was as if the quarks acted like vortices. This effect is difficult to explain with quantum chromodynamics.

Turning finally to gravity, a hint in the right direction may be obtained from MacCullagh's "ether" formulation of Maxwell's vacuum field equation [20] and which predates Maxwell's theory by many years. MacCullagh's equations are

$$\left.\begin{aligned} &\varrho\frac{\partial \boldsymbol{v}}{\partial t} = -\frac{k}{2}\operatorname{curl}\boldsymbol{\varphi}\,, \\ &\frac{\partial \boldsymbol{\varphi}}{\partial t} = \frac{1}{2}\operatorname{curl}\boldsymbol{v}\,, \\ &\operatorname{div}\boldsymbol{v} = \operatorname{div}\boldsymbol{\varphi} = 0\,, \end{aligned}\right\} \tag{7.10}$$

where $\boldsymbol{v}$ is the ether velocity vector. Making the assignment

$$v = \alpha E\,, \quad \varphi = -\beta H\,, \tag{7.11}$$

where α and β are constants depending on the chosen units relating v and φ to E and H, (7.10) go over into Maxwell's vacuum equation. In the "ether" form (7.10), Maxwell's equations are nonrelativistic Newtonian equations for the velocity v. From the substratum point of view this property is not surprising because if the substratum is the cause of the relativistic effects it should itself not be subject to these effects.

MacCullagh's equations show that electromagnetic phenomena are connected with oszillatory motions of the ether, and which suggests that gravitational fields may be connected with convective modes of the ether. If set into convective motion, the ether would then deform bodies, as in the Lorentz-Poincaré interpretation of special relativity, and bodies placed in the flowing ether would feel a force. At alternative theory of gravity developed along these lines can predict all observed linear and nonlinear effects of general relativity. In particular it also gives the same correct 4-fold larger emission rate of gravitational waves if compared with a naive electromagnetic analogy [21]. The theory reduces to a nonrelativistic Newtonian equation of motion for the ether with a scalar and vector potential. Outside an attractive spherical mass M, for example, the ether would assume the radial velocity obtained from the nonrelativistic Newtonian equation of motion

$$v^2 = 2\,GM/r\,. \tag{7.12}$$

The flowing ether would lead to a radial deformation of all bodies by the amount $\sqrt{1 - v^2/c^2}$, and a slowing down of clocks by the same factor. This immediately leads to Schwarzschild's line element:

$$\mathrm{d}s^2 = \frac{\mathrm{d}r^2}{1 - \dfrac{2\,GM}{c^2 r}} + r^2(\sin^2\theta\,\mathrm{d}\varphi^2 + \mathrm{d}\theta^2) - c^2\left(1 - \frac{2\,GM}{c^2 r}\right)\mathrm{d}t^2\,, \tag{7.13}$$

which also can be obtained from Einstein's theory, but only after solving the nonlinear gravitational field equations.

For $r < 2\,GM/c^2$ one has for the ether velocity $v > c$. According to (2.9), all matter within this region and held together by electromagnetic forces (including all elementary particles held together by those forces) would therefore become unstable. This would prevent the formation of black holes and might explain the large energy release of quasi-stellar radio sources.

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