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# CONTRACTION OF MOVING BODIES AS AN ELECTRODYNAMIC EFFECT.

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Abstract. In this article, the change of dimensions of uniformly moving rigid bodies is considered as a physical effect. The macroscopic change of the body dimensions is caused by the displacement of equilibrium points of ions of the crystal lattice due to the change of the interatomic potential. Some applications of the obtained results to the interpretation of the Michelson-Morley and Kennedy-Thorndike experiments are considered.

This effect can create great difficulties in the way to accelerate macroscopic bodies (spaceships, for example) to subluminal velocities.

## 1. Introduction

The concept of the contraction of moving bodies originated as an evolution in the search for the ether drift effect. While the concept of an ether is now commonly accepted as false, in the XIX century, it was the dominant explanation for the existence of a medium whose vibrations generate electromagnetic fields. Maxwell developed a model to explain electric and magnetic phenomena using the æther, a model that led to what are now called Maxwell's equations and the understanding that light is an electromagnetic wave. Consequently, the detection of this medium appeared rational. Studies of stellar aberration have revealed that this medium is not carried along by moving sources, necessitating an inertial frame associated with this non-dragged ether. The second assumption that stems from the mechanical model of the æther is that only in this frame the light has his true speed $c$ - in other frames, velocity $v_{\rm frame}$ of the frame adds to or subtract from the true speed

$$c_{\rm frame} = c \pm v_{\rm frame}\,.$$

If very precise measuring instruments had been developed by $1880^{th}$, the above relation (change in the speed of light) could be verified by direct measuring the speed of a light beam emitted by some source fixed to the ground. But this would require measuring the propagation of light to within 0.1% ('the velocity $v$ of the Earth in its orbit divided by $c$). At that time, such measurement accuracy was unattainable.

In 1881 Michelson found a way to detect deviation of the speed of light emitted by a source located on the ground. More precise measurements, made by Michelson and Morley in 1887 [1], confirmed that the velocity of light emitted by a source linked with the Earth does not depend on $v$.

Because the model of stationary æther explained the results of most experiments to determine its type (stationary or dragged medium), FitzGerald and later Lorentz suggested a hypothesis to "save" this model. These scientists proposed that moving bodies contract in the direction of their motion, and the contraction factor, which is the same as the contraction factor of the electromagnetic field created by a moving charge, is $\sqrt{1-(v/c)^2}$.

The contraction hypothesis is important in explaining the null results of most experiments made in the late $\text{XIX}^{th}$ and early $\text{XX}^{th}$ centuries in attempts to detect the Earth's motion in



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the ether. Lorenz himself substantiated his assumption with the following argument [2]:
'Such a change in length of the arms in Michelson's first experiment, and in the size of the stone plate in the second, is really not inconceivable as it seems to me.

Indeed, what determines the size and shape of a solid body? Apparently the intensity of molecular forces; any cause that could modify it, could modify the shape and size as well. Now we can assume at present, that electric and magnetic forces act by intervention of the aether. It is not unnatural to assume the same for *molecular forces*, but then it can make make a difference, whether the connecting line of two particles, which move together through the ether, is moving parallel to the direction of motion or perpendicular to it.'

Curiously, this Lorentzian assumption went untested for over 100 years, even though these molecular forces are now well understood. Let us fill this gap by considering how interatomic forces change during the motion of a rigid body and whether a change in these forces can lead to a contraction in the size of this moving body.

Using some results of solid state physics, it can be shown that when a body moves at a constant velocity $v$, the distances between the ions, that form the structure of the material of this body, change. Changes in these distances lead to a change in the sizes of the body itself. This contraction differs from the contraction in the size of a moving charge proposed by Lorentz. But if the Lorentz contraction in the size of the charge cannot be measured, the proposed change in the size of bodies during their movement is in principle possible to measure.

It gives simple explanation of the null results not only of the MM experiments but the experiments made by Kennedy and Thorndike (KTh) as well [3]. In opposite to the special relativity, any assumptions on change of the time passage are not needed.

The structure of this article is as follows. In Sec. II, it will be considered how the conditions of electrostatic equilibrium of the ions in the lattice of some crystalline body change if this body moves uniformly. The change in equilibrium of the ions in the crystalline lattice leads to new equilibrium points that causes the sizes of the whole body. In Sec. III, the obtained results will we applied to interpretation of the measurement data of the MM and KTh experiments.

Also, it should be noted that the basic results of this article have been obtained before in work of Stefan von Weber and the present author [4].

## 2. Contraction of the moving bodies due to the convection potential

Let us consider how the internal forces between the atoms forming the structure of the rigid bodies (parts of the experimental setup) change when these bodies move. According to [5], 'the attractive electrostatic interaction between the negative charges of the electrons and the positive charges of the nuclei is entirely responsible for the cohesion of solids'.

When a solid body moves, all its charges move in parallel. Thus, the Coulomb interaction between the charges changes to the electromagnetic interaction described by the Lorentz force expression. Thus, the force which would be exerted by electric, $\boldsymbol{E}$, and magnetic, $\boldsymbol{B}$, fields on another ion moving with a velocity $\boldsymbol{v}$ parallel to that of the original ion producing the field is,

$$\boldsymbol{F} = e\left(\boldsymbol{E} + [\boldsymbol{v}\times\boldsymbol{B}]\right)\ , \tag{1}$$

The values of the EM fields can be found from the expressions for the Liénnard-Wiechert potentials written in the 'present time' coordinates. The force is given by

$$\boldsymbol{F} = e^2\left[-\boldsymbol{\nabla}\left(\frac{1}{s}\right) + (\boldsymbol{v}\cdot\boldsymbol{\nabla})\frac{\boldsymbol{v}}{c^2 s} + \frac{\boldsymbol{v}}{c^2}\times\left(\boldsymbol{\nabla}\times\frac{\boldsymbol{v}}{s}\right)\right]\ , \tag{2}$$
$$s = \sqrt{(x-x'^2) + (1-v^2/c^2)\left[(y-y')^2 + (z-z')^2\right]}\ .$$

Here, $x, y, z$ and $x', y', z'$ are the coordinates of the interacting ions, and $x$-axis is assumed to be parallel to $\boldsymbol{v}$, without restriction of generality. Neglecting the sign, Eq. (2) can be presented as [6]

$$\boldsymbol{F} = e^2 \boldsymbol{\nabla} \left( \frac{1 - v^2/c^2}{s} \right) = e^2 \boldsymbol{\nabla} \Psi \ ,$$

$$\Psi = \frac{1 - v^2/c^2}{\sqrt{(x - x'^2) + (1 - v^2/c^2)\left[(y - y')^2 + (z - z')^2\right]}} \ , \tag{3}$$

where the scalar function $\Psi$ is called the *convection potential.* It follows from Eq. (3) that for the system of the moving charges, the electrostatic potential is changed to the convection potential.

Since the electrostatic potential determines the equilibrium points of ions in the crystal lattice of a certain solid when the latter is at rest, it can be assumed that if this body is in motion, then the convective potential should determine the equilibrium points of ions also in this case. It follows from Eq. (3) that when the speed of the body changes, the value of the convection potential also changes. Therefore, the equilibrium positions of the ions must also change. Let us find out how the new equilibrium points depend on the body velocity.

To do this, it would be reasonable to consider the motion of some solid body consisting of an ionic crystal (for example, a NaCl crystal). This choice of body material is due to the intention to reduce the analysis of the behavior of a solid body to the analysis of electrostatic forces that ensure equilibrium of the crystal lattice. Indeed, it is possible to calculate the change in the equilibrium points of the lattice ions of some perfect metal. In this case, the distribution of conduction electrons in the lattice should be taken into account. The dominant factor determining the location of ions at lattice sites is the force of electrostatic repulsion between ions, but this force is shielded by a negative spatial charge due to conduction electrons. So even in this case the problem can be reduced to an electrostatic one. This can be established from considering the Hamiltonian of the crystal (Chapter 1.3 of the book [7], Eq. (1.3.1))

$$H = \frac{1}{2} \sum_l \frac{\boldsymbol{p}_l^2}{m} + U(\boldsymbol{R}_1, \boldsymbol{R}_2, \ldots \boldsymbol{R}_l, \ldots) \ , \tag{4}$$

where the potential energy of the crystal is only a function of distances $\boldsymbol{R}_1, \boldsymbol{R}_2, \ldots \boldsymbol{R}_l, \ldots$ between the atoms of the lattice ((Eq. 1.3.3) of Ref. 5). Thus, in the equilibrium configuration, when the atoms are located exactly at lattice sites, one obtains

$$\frac{\partial U}{\partial \boldsymbol{r}_l} = 0 \quad ; \quad \boldsymbol{r}_1 = \boldsymbol{r}_2 = \ldots = \boldsymbol{r}_N = 0 \tag{5}$$

for all $\boldsymbol{r}_l = \boldsymbol{R}_l - l\boldsymbol{a}$, $\boldsymbol{a}$ is the vector of elementary lattice cell. In the solid state problems, when studying the dynamical properties of a crystal, the potential energy is represented as

$$U(\boldsymbol{r}_1, \boldsymbol{r}_2, \ldots \boldsymbol{r}_l, \ldots) = U_0 + \sum_{l,l'} \boldsymbol{r}_l \boldsymbol{r}_{l'} \frac{\partial^2 U}{\partial \boldsymbol{r}_l \partial \boldsymbol{r}_{l'}} \ , \tag{6}$$

where $U_0$ is the minimum of the electrostatic energy of NaCl crystal. Let us assume that when the lattice is being at rest, the distance between two neighbor ions is $d$. Then $U_0$ for the cubic lattice,

$$U_0 = W_{rest} = - \sum_{\substack{l,\, m,\, n=0 \\ l+m+n \neq 0}}^{\infty} \frac{(-1)^{l+m+n} 2^3 e^2}{\sqrt{(ld)^2 + (md)^2 + (nd)^2}} = - \frac{2^3 e^2}{d} \sum_{\substack{l,\, m,\, n=0 \\ l+m+n \neq 0}}^{\infty} \frac{(-1)^{l+m+n}}{\sqrt{l^2 + m^2 + n^2}} \ , \tag{7}$$

where summation over $l$ corresponds to summation of the ions along the $x$ axis, summation over $m$ does along the $y$ axis and summation over $n$ does along the $z$ axis; the singular term with $l = m = n = 0$ is excluded. For the body at rest, only Coulomb potential acts between the ions of the lattice.

When the crystal acquires some velocity, the Coulomb potential changes to the convection potential. The forces (Eq. (3)) between ions change and the distances between ions must change in order to ensure a minimum of the potential energy of the lattice. It is reasonable to assume that since the process of crystal acceleration is adiabatic (much slower than the ability of ions to move) this process conserves constancy of the minimum of the potential energy.

If the Coulomb potential in Eq. (7) changes to the convention potential, Eq. (3), the potential energy of the lattice becomes,

$$W_{mov} = -\sum_{\substack{l,m,n=0\\ l+m+n\neq 0}}^{\infty} \frac{(-1)^{l+m+n}(1-v^2/c^2)2^3e^2}{\sqrt{(ld)^2 + (1-v^2/c^2)\left[(md)^2+(nd)^2\right]}}\ , \tag{8}$$

Comparing Eq. (7) to Eq. (8) shows that the total internal energy of the lattice increases with the velocity. It means that the ions are not located at the points of equilibrium and it is necessary to find new points of location of the ions in such a way that the magnitude of $W_{mov}$ will be equal to the value of $W_{rest}$. To do it, let us consider partial sums over $m$, $n$ and $l$ separately. One has for Eqs. (7) and (8) at $m = n = 0$

$$W^{\|}_{rest} = -\frac{2e^2}{d}\sum_{l=1}^{\infty}\frac{(-1)^l}{l} \quad ; \quad W^{\|}_{mov} = -\frac{2e^2}{d}\sum_{l=1}^{\infty}\frac{(-1)^l(1-v^2/c^2)}{l}\ . \tag{9}$$

The total energy does not change if the magnitudes of $W^{||}_{rest}$ and $W^{||}_{mov}$ are equal. Because the only parameter, which can change in Eq. (9), is the interatomic distance $d$, the equivalence of these quantities is provided by changing the interatomic distance in $x$ direction as

$$d^{\|}_{rest} = \frac{d^{\|}_{mov}}{1-v^2/c^2} \quad \Longrightarrow \quad d^{\|}_{mov} = (1-v^2/c^2)d^{\|}_{rest}\ . \tag{10}$$

Respectively, analysis of partial sums at $l = 0$ gives

$$W^{\perp}_{rest} = -\frac{2^2e^2}{d}\sum_{\substack{m,n=0\\ m+n\neq 0}}^{\infty}\frac{(-1)^{m+n}}{\sqrt{m^2+n^2}} \quad ; \quad W^{\perp}_{mov} = -\frac{2^2e^2}{d}\sum_{\substack{m,n=0\\ m+n\neq 0}}^{\infty}\frac{(-1)^{m+n}(1-v^2/c^2)}{\sqrt{m^2+n^2}}\ . \tag{11}$$

and the interatomic distances which are transversal to the motion direction for the lattice at rest and the moving lattice are connected (due to cross contraction) as

$$d^{\perp}_{rest} = \frac{d^{\perp}_{mov}}{\sqrt{1-v^2/c^2}} \quad \Longrightarrow \quad d^{\perp}_{mov} = \sqrt{1-v^2/c^2}\,d^{\perp}_{rest}\,. \tag{12}$$

Using conditions (10) and (12), one can evaluate changing the distance between two arbitrary ions separated by $l$, $m$ and $n$ sites ($d^{\|}_{rest} = d^{\perp}_{rest} = d$)

$$\begin{aligned} d_{mov}(l,m,n) &= \sqrt{l^2\left(d^{\|}_{mov}\right)^2 + \left[m^2+n^2\right]\left(d^{\perp}_{mov}\right)^2} = \\ &= \sqrt{\left(1-v^2/c^2\right)^2(ld)^2 + (1-v^2/c^2)\left[(md)^2+(nd)^2\right]}\,. \end{aligned} \tag{13}$$

Using Eq. (13), we calculate the electrostatic energy of the moving lattice taking into account that the transversal component of the interatomic distance should enter into the formula with the factor $(1-v^2/c^2)$

$$W_{mov} = -\sum_{\substack{l,m,n=0\\ l+m+n\neq 0}}^{\infty} \frac{(-1)^{l+m+n}(1-v^2/c^2)2^3e^2}{\sqrt{\left[d^{\parallel}_{mov}(l,m,n)\right]^2 + (1-v^2/c^2)\left[d^{\perp}_{mov}(l,m,n)\right]^2}} =$$

$$-\sum_{\substack{l,m,n=0\\ l+m+n\neq 0}}^{\infty} \frac{(-1)^{l+m+n}(1-v^2/c^2)2^3e^2}{\sqrt{(1-v^2/c^2)^2\,(ld)^2 + (1-v^2/c^2)(1-v^2/c^2)\left[(md)^2+(nd)^2\right]}} =$$

$$-\frac{2^3e^2}{d}\sum_{\substack{l,m,n=0\\ l+m+n\neq 0}}^{\infty} \frac{(-1)^{l+m+n}}{\sqrt{l^2+m^2+n^2}} = W_{rest}\ . \tag{14}$$

The above equation shows that if the conditions (10) and (12) are fulfilled, the total electrostatic energy of the lattice does not change with velocity.

This is an important result for the analysis of the electrodynamics of the moving bodies. It is easily to find that any other kinds of changing the interatomic distances of the lattice do not provide the minimum of the electrostatic energy when the body is being in motion. For example, if we assume that only relativistic contraction of the bodies occurs, *i.e.* the interatomic distance changes only in direction of motion,

$$d^{\parallel}_{mov} = \sqrt{1-v^2/c^2}\,d^{\parallel}_{rest} \quad ; \quad d^{\perp}_{mov} = d^{\perp}_{rest}\ , \tag{15}$$

we have for $W''_{mov}$ taking into account Eqs. (8) and (15)

$$W''_{mov} = -\frac{2^3e^2}{d^{rel}_{rest}}\sum_{\substack{l,m,n=0\\ l+m+n\neq 0}}^{\infty} \frac{(-1)^{l+m+n}(1-v^2/c^2)}{\sqrt{(1-v^2/c^2)\,(l)^2 + (1-v^2/c^2)\left[m^2+n^2\right]}} =$$

$$-\frac{\sqrt{1-v^2/c^2}\,2^3e^2}{d^{rel}_{rest}}\sum_{\substack{l,m,n=0\\ l+m+n\neq 0}}^{\infty} \frac{(-1)^{l+m+n}}{\sqrt{l^2+m^2+n^2}} = -\sqrt{1-v^2/c^2}\,W_{rest}\ , \tag{16}$$

and the electrostatic energy of the lattice does not reach its minimum since $W''_{mov} > W_{rest}$.

Thus, from the 'energetic' point of view, the true changes of interatomic distances is give by which ensure the minimum of the crystalline lattice energy.

If the interatomic distances change in accordance to Eqs. (10) and (12), the whole sizes of the moving body must change as

$$L^{\parallel}_{mov} = \left(1-v^2/c^2\right)L^{\parallel}_{rest} \quad ; \quad L^{\perp}_{mov} = \sqrt{1-v^2/c^2}\,L^{\perp}_{rest}\ . \tag{17}$$

It is useful to note that the ratio the contraction factor for this change of the moving body sizes and corresponding ratio for relativistic (rel) and the Lorentz-FitzGerald (L-F) changes is the same

$$\left.\frac{L^{\parallel}_{mov}}{L^{\perp}_{mov}}\right|_{conv.pot} = \left.\frac{L^{\parallel}_{mov}}{L^{\perp}_{mov}}\right|_{rel} = \left.\frac{L^{\parallel}_{mov}}{L^{\perp}_{mov}}\right|_{L-F} = \sqrt{1-\frac{v^2}{c^2}}\ . \tag{18}$$

The results obtained in this chapter will be used in the analysis of the experiments intended to detect a motion of the Earth in the ether. Explanation of the 'null results' of these experiments is based on assumption of the sizes contraction of the experimental apparatus. Let us consider whether a type of contraction caused by change of interatomic potential can explain these 'null results'.

## 3. Application of the above results to interpretation of the Michelson-Morley and Kennedy-Thorndike experiments

The most known experiment intended to detect the motion of our planet in the ether has been made by Michelson and Morley [1] (the scheme of this experiment is given in Fig. 1).

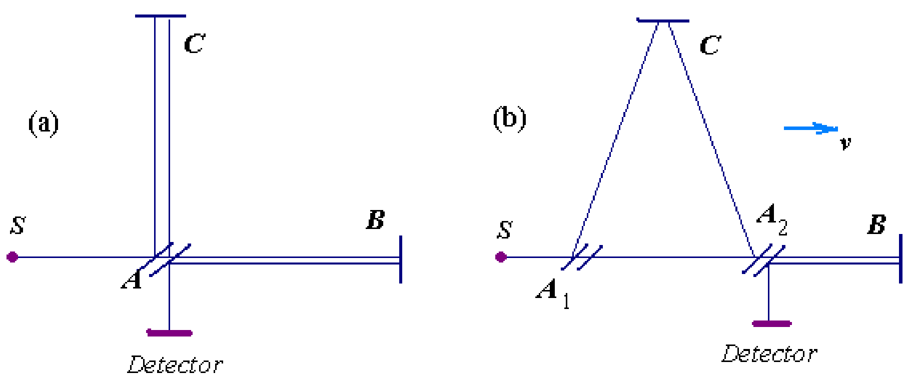


Figure 1. The scheme of the MM experiment. (a) the interferometer is being at rest with respect to the cosmic background radiation frame, and (b) the interferometer moves with the velocity $v$ with respect to this frame. $AB$ and $AC$ are the arms of the interferometer, $A$, $B$ and $C$ the mirrors, $s$ the source of the light.

The optical paths of the light beam in the Michelson interferometer are determined by the lengths of the arms $AB$ and $AC$ supporting the mirrors. In the original MM experiment, the authors assumed that the lengths of both arms of the apparatus are equal. But let us consider the general case when the lengths of the arms are different, that is the length of the path $AB$ for the Michelson interferometer at rest is $L^{\|}_{rest}$ and the length of the path $AC$ is $L^{\perp}_{rest}$.

A motion of the Earth with respect to the ether can be detected if the fringe shift takes place when the velocity of the Earth changes. The authors supposed the fringe shift can be caused by change of difference in times $t_{ACA} - t_{ABA}$ of traveling the light beams in their paths. Let us calculate this difference when the apparatus is at rest and when it moves with the velocity $v$ with respect to some frame rigidly linked with the stationary ether.

For the apparatus being at rest, this difference is

$$\Delta t_{rest} = 2\frac{L_{AC}}{c} - 2\frac{L_{AB}}{c} = \frac{2}{c}\left[L^{\perp}_{rest} - L^{\|}_{rest}\right] . \tag{19}$$

Since the arms of the apparatus are made of the solid state material and, therefore, they should contract in accordance to Eq. (17), while the frame with the interferometer moves. Thus, the difference is

$$\begin{aligned} \Delta t_{mov} &= \frac{L_{A_1CA_2}}{\sqrt{c^2-v^2}} - \frac{L_{A_1B}}{c-v} - \frac{L_{AB_2}}{c+v} = \\ &= 2\frac{L^{\perp}_{rest}\sqrt{1-(v/c)^2}}{\sqrt{c^2-v^2}} - \frac{L^{\|}_{rest}(1-(v/c)^2}{c-v} - \frac{L^{\|}_{rest}(1-(v/c)^2}{c+v} = \frac{2}{c}\left[L^{\perp}_{rest} - L^{\|}_{rest}\right] . \end{aligned} \tag{20}$$

The result (22) shows that the difference in time of traveling the light beams in the interferometer arms does not change if the apparatus, which was initially at rest, begins to move in the stationary ether. Therefore, the fringe shift cannot be observed, as it was found in the MM and KTh experiments. Thus, this type of the moving bodies contraction, Eq. (17), explains the 'null results' of the experiments intended to detect the motion of the Earth in a stationary ether.

One aspect of the result, Eq. (17), should be noted. For this type of contraction, the traveling times of light beams in the interferometer are equal regardless of whether the device is moving or at rest. This means that for the explanation of the null result of the MM experiment it is not necessary to involve the idea of the change of time passage depending on the velocity of the inertial frame.

It should also be noted that since all experiments with interferometers, and in modern modification with resonance cavities, are actually experiments with stationary external conditions (fast changing processes are absent), their 'null results' are explained by any type of the moving body contraction, *i.e.* given by Eq. (17) or by relativistic, or the Lorentz-FitGerald contraction.

Now let us consider the experiments made by Kennedy and Thorndike [3]. The authors stated that due to certain modification of the MM experimental setup, *namely* the usage of the interferometer arms of different lengths they were able to prove relativistic change of the time passage. However, it is not so.

□ First, the authors inferred a change in the passage of time not on the basis of direct measurement of this effect, but on the basis of null results of a shift in the interference pattern. However, factors other than changes in the passage of time could give these null results.

□ Second, the authors made the incorrect assumption that they were able to make measurements in two inertial reference frames.

Essential propose of the authors is that they accept existence of two inertial frames, $S'$ and $S$ (attached, for instance, to the surface of the Earth) which moves practically uniformly with velocity $v$ with respect to the first frame. And what is more important that the author accept a possibility to make measurements in both inertial frames. According to the special relativity, passing times ($t$ in $S$ and $t'$ in $S'$) are connected by relation $t = t'\sqrt{1-(v/c)^2}$. If a value of the velocity is comparable to the speed of light, the factor $\sqrt{1-(v/c)^2}$ would give different passing time in these frames.

However, Kennedy and Thorndike's assumption that it is possible to make measurements in two inertial frames is a weak point in their argumentation. The only inertial frame is accessible to perform the experiments is the frame rigidly linked with the Earth. It is impossible to perform the experiments using an apparatus like Michelson interferometer, which velocity is about 30,000 meters per second relatively to the laboratory frame. The possibility to check some effect, assuming a velocity of the apparatus relatively to the frame of the stationary ether changes, is to change orientation of the apparatus. In this case, orientation of arms of the interferometer should change. But such a turn only provides change of the velocity vector but not its absolute value.

As the authors wrote 'It was intended when the experiment was proposed to look chiefly for an effect of a change of velocity due to the orbital rather than the rotational motion of the Earth. However with the first apparatus constructed, in which the mirrors were mounted in invar frames, it was found impossible to eliminate a slow, rather irregular variation in the interference pattern which would have masked the effect sought; hence it was decided to concentrate on the possible rotational effect.', *i.e.* on the effect which can be caused by daily rotation of our planet. But during one day, change in orbital velocity of the Earth is too small comparatively to the velocity itself. Hence the Lorentzian factor $1/\sqrt{1-(v/c)^2}$ does not change while the apparatus turns with rotation of the Earth.

But carrying out experiments under conditions when only the orientation of the interferometer relative to the (hypothetical) ether changes, and the Lorentz factor $\sqrt{1-(v/c)^2}$ does not change, allows us to explain the null result by the Lorentz-FitzGerald contraction as well. Let us show this.

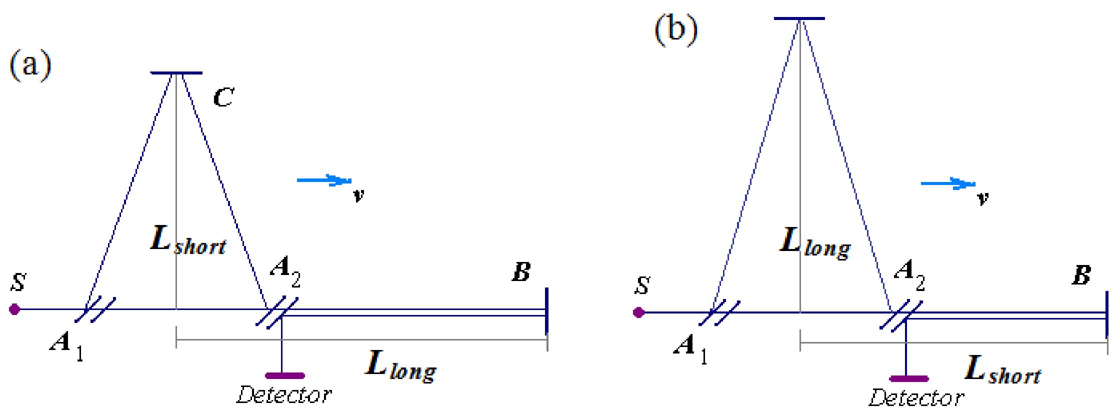


FIGURE 2. Shceme of theexperiment with different lengths of the interferometer arms.

In orientation of the apparatus shown in Fig. 2a (the long arm is directed along the velocity vector and only the arm $AB$ is contracted), the

$$\begin{aligned} \Delta T'_{mov} &= \frac{L_{A_1CA_2}}{\sqrt{c^2-v^2}} - \frac{L_{A_1B}}{c-v} - \frac{L_{AB_2}}{c+v} = \\ &= 2\frac{L_{short}}{\sqrt{c^2-v^2}} - \frac{L_{long}\sqrt{1-(v/c)^2}}{c-v} - \frac{L_{long}\sqrt{1-(v/c)^2}}{c+v} = \frac{2}{\sqrt{c^2-v^2}}\left[L_{short}-L_{long}\right] . \end{aligned} \tag{21}$$

In orientation of the apparatus shown in Fig. 2b (the short arm is directed along the velocity vector and only the arm $AB$ is contracted), the

$$\begin{aligned} \Delta T''_{mov} &= \frac{L_{A_1B}}{c-v} + \frac{L_{AB_2}}{c+v} - \frac{L_{A_1CA_2}}{\sqrt{c^2-v^2}} = \\ &= \frac{L_{short}\sqrt{1-(v/c)^2}}{c-v} + \frac{L_{short}\sqrt{1-(v/c)^2}}{c+v} - 2\frac{L_{long}}{\sqrt{c^2-v^2}} = \frac{2}{\sqrt{c^2-v^2}}\left[L_{short}-L_{long}\right] . \end{aligned} \tag{22}$$

The equality $T'_{mov} = T''_{mov}$ means that the fringe shift should not be observed for different lengths of the interferometer arms for the Lorentz-FitGerald contraction. Thus, in opposite to the statement of Kennedy and Thorndike, the Lorentz-Fitzgerald type of contraction is suitable to explain the results of the KTh experiments because the absolute velocity of our planet with respect to the microwave background radiation frame does not change during a day (the authors of [3] estimate this change at 200 km/sec, which is less than 0.1% from the Earth's orbital velocity).

Since three types of the contraction are described in this work, it would be reasonable to consider a difference between them, or in the other words, difference in their meaning.

## 4. The difference in three types of the moving body contraction

Historically, the first type of contraction that was supposed to explain the results of the ether drift experiments was the Lorentz-FitzGerald contraction. These scientists based their assumptions on the effect of changing the EM field created by a uniformly moving charge. If the equipotential surfaces of a charge at rest are perfect spheres, then the equipotential surfaces of a charge moving at a constant velocity $v$ are oblate spheroids contracted along the line of motion by $\sqrt{1 - v^2/c^2}$, the so-called 'Heaviside ellipsoids' (Fig. 1 of [12]). This factor is exactly the same one that could explain the null results of Michelson and Morley's experiments.

Although the historical priority of this proposal undoubtedly is due to FitzGerald, Lorentz systematically employed and elaborated the idea in his theory of electrons; he also attempted to provide a theoretical basis for the contraction [8].

Lorentz made suggestions that since the forces between the molecules of solid bodies are of the electromagnetic origin and these forces change when the bodies move, the distances between the molecules and, consequently, the sizes of bodies change in proportion to the factor $\sqrt{1 - v^2/c^2}$. However, since Lorentz could not know how a structure of solid bodies is formed into a crystalline lattice he was unable to explain *how* moving bodies should be contracted. Therefore, his supposition is only the hypothesis. But Lorentz's main idea - the physical origin of the moving bodies contraction is change in the EM forces acting between ions - is used to derive the mechanism of contraction described in Sec.

It is useful to note that the author of the experiment, Prof. Michelson shared Lorentz-FitzGerald point of view on treatments of his experimental results. As Lodge writes in 1921 in Nature journal [9], 'I was interested, when visiting the University of Chicago last winter, to find that Prof. Michelson himself was perfectly satisfied with this sort of view of his experiment, and did not consider that its interpretation necessitated any revolutionary considerations. The FitzGerald contraction is a peculiarity which could scarcely have been detected in any other way, since it is really an affair of the ether- the connecting medium in which all molecules are embedded-and affects every kind of matter to the same extent.'

Again, let us repeat that the weak point of the Lorentz-FitzGerald hypothesis is that their authors could not give the scientific background for it. Moreover, correctness of this hypothesis cannot be confirmed by calculations of the forces acting between molecules in a moving body.

Nevertheless, some analysis shows that the explanation of the Lorentz contraction by special relativity also contains some questionable points. According to the special relativity, the null result of the MM experiment is beyond doubt, since the speed of light is the same in any inertial frame. Motion of the Earth in the space can be treated as motion of some inertial frame with respect to the microwave background radiation frame (recent time this frame is sometimes treated as a preferred one because of its extension to the whole universe). However, the explanation of the moving bodies contraction, which is given by the special relativity, is somewhat vague. In Einstein's theory, length contraction is an apparent, kinematic effect that depends on the definition of simultaneity, or the procedure of measurements of moving bodies. Einstein mentioned [10] that, 'The question as to whether length contraction really exists or not is misleading. It does not "really" exist, in so far as it does not exist for a comoving observer'. As it is noted in the textbook of Møller [11], 'according to relativistic conceptions, the notion of the length of a stick has an unambiguous meaning only in relation to a given inertial frame, this length being different for the different systems of inertia'. Thus, a question on possible existence of a physical effect is changed to the question on interpretation of some phenomenon in different inertial frames.

This fact alone translates the discussion on the cause of the bodies contraction into the field of scholasticism - actually any measurements of moving bodies whose velocity is comparative to the speed of light are technologically impossible. Correspondingly, the main obstacle to determine within the special relativity whether the length contraction is a real or apparent effect is an impossibility to come to agreement on correct synchronization between objects being in two inertial frames.

Meanwhile, this obstacle can be overcame. Let us show that in the Michelson–Morley experiment the contraction of the rod should be real. It is achieved because we have 'universal tool' to measure the lengths in different frames. But before some explanations should be given. The only accessible inertial frame is the frame rigidly linked with the Earth. In this frame the MM interferometer is always at rest. When one considers (uniformly) moving interferometer, it means that this is an abstract consideration. But in this abstract consideration, one can associate some physical properties with the moving device.

Let us compare the events occurring with the light beams passing in the Michelson interferometer, but in two inertial frames. In one of them the interferometer is at rest, and in the other it is moving with velocity $v$. The registration of events cannot depend on the frame; if an event with the device occurred in one frame, the same event must occur with the same device in any other inertial frame. In the reference frame of an interferometer at rest, the experimentally recordable event is the absence of a fringe shift. The same event must also be recorded in the frame of reference in which the interferometer is moving. The occurrence of this event means that the traveling times of light beams in the arms of the interferometer must be equal,

$$t^{\perp}_{rest} = t^{\|}_{rest}\,; \quad t^{\perp}_{mov} = t^{\|}_{mov}\,.$$

Since the speed of light is $c$ in any inertial frame - we prove a reality of the effect within the special relativity - the optical paths of the light beams for moving device are equal for both transverse and longitudinal directions,

$$\ell_{\perp} = ct^{\perp}_{mov} = \ell_{\|} = ct^{\|}_{mov}\,.$$

But the *calculated lengths* of the optical paths are different (sec. III). Thus to ensure equal lengths of $\ell_{\perp}$ and $\ell_{\|}$ one should assume that the arm oriented along motion of the device must contract.

This conclusion is made without reference to any measurement or synchronization procedures. But the result obtained cannot be explained by the special relativity since even the question on a physical cause of the contraction is nonsense in this theory. On the contrary, the contraction described by Eq. (17), is real and is derived from the equations of electrodynamics. It can be assumed that since the electromagnetic phenomena predicted on the basis of these equations are realized, then this compression of moving bodies should also be realized.

## 5. Conclusions

It is shown in this article that all three types of the moving bodies contractions are able to explain the null results of the MM and KTh experiments. It is caused by the fact that all experiments are made in the internal frame linked with the Earth.

More detailed analysis shows that that only a type of contraction derived from the interatomic potetnial is able to explain all aspects of these experiments. The Lorentz-FitzGerald contraction cannot give the minimum of the energy of the crystalline lattice when its ions displace. The relativistic contraction is 'apparent' and cannot serve to explain reality of this effect.

One may object that a subject of this work - the analysis of the experiments made about 150 years ago - is only of historical interest. It is not so. A knowledge on this type of contraction allows to predict difficulties in planning interstellar flights. Such flights are feasible only if a spaceship can be accelerated to velocities comparative to the speed of light - the distances between the stars are too great. But if a structure of the material changes with acceleration the electronic processes in this material will change since deformation of the solid state causes the change of its properties. For comparatively low velocities, for example, of the order of $0.1c$, only electronic processes can change although this can lead to failure of the electronics. For higher velocities, even destruction of the material can occur.

Such an realization is indirectly confirmed by astronomical data. We never detected some macroscopic body which enter the solar system with very high velocity, and even the molecules. The only objects which come with subluminal velocities from deep space are elementary particles.

Thus, this contraction can be a very high barrier in the way of the interstellar flights. It is a reason to study this contraction more scrupulously.

## References

[1] Michelson, A. A., Morley, E. W.: On the relative motion of the earth and the luminiferous ether, *Am. J. Sci.* $3^{rd}$. Series. **34**, No 203, 333 (1887)

[2] H.Lorentz. De relatieve beweging van de aarde en den aether, Amsterdam, *Zittingsverslag Akad. v. Wet.*, **1**, p. 74 (1892)
The Relative Motion of the Earth and the Aether. English translation:
https://en.wikisource.org/wiki/Translation:The_Relative_Motion_of_the_Earth_and_the_Aether

[3] Kennedy, R. J.; Thorndike, E. M. Experimental Establishment of the Relativity of Time. *Physical Review.* **42**(3), 400 (1932)

[4] V. Onoochin and S. von Weber, On the Size of Moving Rigid Bodies Determined from Conditions of Equilibrium of Ions in a Crystalline Lattice. *Einstein and Poincare : the physical vacuum* / edited by Valeri V. Dvoeglazov. Published by C. Roy Keys Inc. (2006)

[5] C. Kittel. *Introduction to solid state physics.* Wiley and Sons, Inc. $8^{th}$ ed. (2005). Ch. 3.

[6] W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism*, $2^{nd}$ ed. Addison Wesley, London (1962).

[7] Ziman, J. M.: *Electrons and Phonons. The Theory of Transport Phenomena in Solids.*, Clarendon Press, Oxford, 1960.

[8] Dieks, D. The "reality" of the Lorentz contraction. Zeitschrift für Allgemeine Wissenschaftstheorie **15**, 330–342 (1984)

[9] Lodge O., The Geometrisation of Physics, and Its Supposed Basis on the Michelson-Morley Experiment. *Nature***106**, No. 2677. 795 (1921)

[10] Einstein A. Zum Ehrenfestschen Paradoxon. Eine Bemerkung zu V. Variĉaks Aufsatz. Physikalische Zeitschrift. **12**, 509–510 (1911)

[11] Møller C. *The theory of relativity.* Oxford, $2^{nd}$ ed. (1955) p. 45

[12] Hunt B.J. The origin of the FitzGerald contraction. *British J. Hist. Sci.*, **21** p. 67-76 (1988)