Variable Speed of Light in 3-dimensional Euclidean Space.

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Abstract: The speed of light according to special relativity has the same constant value *c* with respect to a distant star, as it has with respect to the Earth or with respect to a moving source. Special relativity explains this paradox through kinematics. It proposes that space is 4-dimensional pseudo-Euclidean and, hence, the classical law of velocity addition is not applicable. In this work we show that experimental observations of the constancy of the speed of light can be explained remaining in the framework the three-dimensional Euclidean space model and the classical law of velocity addition. But in this case, we have to accept the existence of some 'hidden' dynamics that leads to equalization of the velocity of light (photon) to value *c* within the same frame. We show mathematically that the transverse Doppler Effect can be used in support of such hypothesis (note, that the transverse Doppler Effect is still considered the main arguments in favor of the relativistic kinematics). Astronomical observations of binary stars also support the hypothesis that the speed of light changes within a physical frame of reference.

Keywords: speed of light, Ritz hypothesis, transverse Doppler Effect

1. Light still remains a "dark" issue in physics.

The speed of light according to **special relativity** (SR) has the same value *c* with respect to any inertial frame of reference. Wherein the inertial frames of reference are understood to be such frames of references that are related through the Lorenz transformation. An attempt to build an alternative physical model in 3-dimensional Euclidean space brings us back to a classical problem: in what frame of reference does light travel with speed *c*? More than 100 years passed since the time this problem brought the so-called "crisis in physics" that was settled with the development of SR. During this time new ideas emerged and new experiments were performed among which there were some "problematic" experiments that contradicted the SR. However, in the scientific community it is conventional to consider a phenomenon as established provided it has been confirmed by several well-known independent laboratories. For various reasons the "problematic" experiments were not repeated in these laboratories.

It follows from the model of three-dimensional Euclidean space and independent time that the speed of light in various geometric frames of reference can have different values. However, this conclusion requires a more detailed discussion when the real physical frames of reference are considered wherein experiments are conducted, specifically, those that demonstrate the invariance of the speed of light. For example, if we suppose that propagation of light is a process in a medium (aether) then the motion of the aether itself with respect to a given frame of reference should be taken into consideration too.

It has been established that light transfers energy from one physical body, a source, to another, a receiver, in discrete increments, that is, quanta. However, among physicists there is no unified point of view for the description of the material carrier of the quantum, that is, the photon. There are three types of photon that are usually used in descriptions of the optical experiments demonstrating quantum properties of light [1]. The difference in usage of the term "photon" reflects the difference in interpretation of the results of such experiments.

1. ***C-photon*** is a classical wave packet, that is, spatially localized, quasi monochromatic electromagnetic radiation carrying a quantum of energy $\varepsilon = \hbar\nu$ where ν is the mean frequency of the radiation spectrum. The "corpuscular" properties of *C-photon* reveal themselves only at the moment of detection. There are quantum optical effects, however, such as : the essential quantum effects that have no classical analogues. These effects cannot be described in the framework of the semi classical model based on Maxwell's equations.

2. ***M-photon*** is a hypothetical elementary particle of the light field generating an impulse at the output of the photodetector. Although there is no rigorous definition of *M-photon* in the framework of any consistent theory, this photon, as a particle, with the wave properties of an elementary particle, is used in various optical studies where an attempt is made to go beyond the framework of the Copenhagen interpretation. It is assumed in these studies that any radiation field consists of a set of almost independent *M-photons* with definite *a priori* features to be revealed after a time.

It is interesting that the first corpuscular models of the light field consisting of the elementary particles, each with energy $\hbar\nu$ where ν is the radiation frequency, were developed after A. Compton performed an experiments on X-ray scattering (1922). The observed change in the frequency of scattered radiation was explained by the elastic collision of an electron and a particle possessing energy $\hbar\nu$ and momentum $p=\varepsilon/c$ In 1926, G.H. Lewis called this particle a photon.

Note, that if propagation of light is a nonlinear process in a medium like a soliton (the density inside a soliton can be different than that of the surrounding medium, then the model of C-photon, as a classical wave packet, does not contradict the model of M-photon as a hypothetical elementary particle.

3. *Q-photon* is an objective entity corresponding to the Fock state of the light field with $n=1$ or a superposition of such states with nearly equal energies. This definition can be made in terms of the standard quantum theory of light. However, the statement that 'light consists of photons' (suggesting the definite number n of such constituent elements of light) does not make any sense in the standard quantum theory because the field before measurement has no definite n Of course, a problem of interpreting the quantum formalism still remains. The Copenhagen interpretation forbids asking nature "idle" questions, that is, it has a pragmatic tint. In the framework of this interpretation 'A photon can be called a photon only if it is a detected photon'. Investigations of the characteristics of the pure or combined state of the field are only permitted.

There is a case where all the above mentioned types of photon appear consistent: when the light field is in the one-photon state (photon in the pure state). In this case a priori properties of the photon can be discussed.

2. Equalization of the light's speed to the known value of *C* near the Earth's surface

In 1908 Walter von Ritz suggested that $\overline{c}$ was the velocity of light with respect to the source and the classical law of composition of velocities was valid for the case of the moving source (the so-called Ritz ballistic hypothesis) [2]. Under this assumption the aberration of starlight, as wellas the results of the famous Michelson-Morley experiment, and those of most other experiments aimed at detecting the aether wind come into agreement with each other.

However, the experiment performed at CERN, Geneva, in 1964 was considered to be the most convincing evidence against the Ritz theory.

In this experiment the speed of 6 GeV photons, produced in the decay of very energetic neutral pions, was measured by time-of-flight over paths up to 80 meters in length. The pions were produced by the bombardment of a beryllium target with 19.2 GeV protons having speeds (inferred from the measured speeds of charged pions produced in the same bombardment) of 0.99975 c ... [3]. Within experimental error it was found that the speed of the photons emitted by the extremely rapidly moving source was equal to c. If the observed speed is written as $c' = c + ku$, where u is the speed of the source, the experiment showed

$$k = (0 \pm 1.3) \cdot 10^{-4} \qquad (1)$$

The three hypothesis below are in agreement with the results of the CERN experiment.

<u>The first hypothesis:</u> **the speed of a photon equals c when measured with respect to Earth, and is independent of the velocity of the source.** Indeed, the experiment performed at CERN could be explained by this hypothesis in the frame of the model of 3-dimensional Euclidean space, but it brings other problems that take us back to the “crisis in physics” of the beginnign of the 20th century.

<u>The second hypothesis</u>. This **hypothesis** is the basis of the special relativity**:** t**he speed of light has the same value c with respect to any inertial frame of reference**. That is, from the standpoint of SR the speed of an emitted photon measured with respect to an inertial frame of reference associated with a moving source is equal to c, (this also **agrees with the Ritz hypothesis.)** On the other hand, it follows from SR that the speed of a photon measured with respect to Earth is also equal to c, which agrees with the experiment performed at CERN. SR provides an explanation of the above two statements by discarding the classical law of composition of velocities and the hypothesis of aether as a preferred reference system, and byintroducing a model of four-dimensional pseudo-Euclidian space.

<u>The third hypothesis.</u> **Ritz ballistic hypothesis plus a modified extinction theorem.**

It can be concluded from the fact that the relativistic kinematics correctly describes the results of certain optical experiments that in four-dimensional kinematic formalism of special relativity there are dynamics ‘hidden’ in the geometry of space. This idea was first put forward by E.L. Fainberg in 1997 [4].

In other words, it is possible to explain optical experiments remaining in the framework of the three-dimensional Euclidean space and the classical law of composition of velocities with an assumption that **the speed of light (photon) can change within the same real physical frames of reference.** For example, a photon leaves a source with a velocity $\vec{c} + \vec{u}$ where $\vec{u}$ is a velocity of the source with respect to the Earth, and later the speed of photon acquires the value c near the Earth's surface due to some 'hidden' dynamics.

Note, that there were earlier attempts to prove the consistency of Ritz's theory using the extinction effect {Ewald (1912), Oseen (1915), Fox (1962)}. According to this effect when an electromagnetic wave is incident on a homogeneous medium it is extinguished inside the medium in the process of interaction and is replaced by a wave propagated in the medium with a velocity different from that of the incident.

The experiment performed at CERN demonstrated that the equalization of the photon's speed to the value c occured in vacuum. Because of that the extinction theorem was proven to be wrong and was not accepted anymore by conventional physics.

From our point of view, the idea that the velocity of a photon equalizes its value to c near Earth's surface has not exhausted itself. However the nature of that process is, probably, closely connected with the interaction of the photon with the physical fields associated with the Earth. Here we would like to emphasize that the third hypothesis is in agreement with the majority of optical experiments. We will show below that the transverse Doppler Effect can also be explained on the basis of the third hypothesis. Note that the observation of the transverse Doppler Effect is still one of the main arguments in support of relativistic kinematics.

Using CERN experiment we can estimate the length of the path l on which the speed of the photon emitted by the moving source remains $\vec{c}+\vec{u}$ in compliance with the Ritz theory, where $\vec{u}$ is the speed of the source with respect to Earth. If we take the speed of the source $\vec{u}$ to be approximately equal to $\vec{c}$ and set, according to the formula (1), $k=10^{-4}$ for the experimental error then, within the accuracy of the experiment, the average velocity of the photons emitted by the moving source is $c' = c(1 + 10^{-4})$ with respect to Earth. Then the length of the path l on which the velocity of the photon remains $2c$ (that is the sum of the photon's speed c with respect to the source plus the speed of the source c moving in the same direction) would be $l = 1.6 \times 10^{-2}$ (assuming that all emitted photons traveled 80 meters). This is a large distance even for daylight photons (a photon with energy 0.25 eV has wavelength 0.5×10^{-6} m, that is on the path of length l we have $\sim 3 \times 10^{4}$ wavelengths).

3. The derivation of the formula for the transverse and longitudinal Doppler Effect using the classical mechanics law of velocity addition.

Below, the equation for the transverse and longitudinal Doppler Effect is derived for the case of a photon in the pure state. In which case the properties of the photon such as its energy, momentum, mass[1], and polarization can considered. We assume that the classical law of velocity addition and the law of conservation of energy and momentum are valid.

Case 1: Suppose that a source of light is at rest with respect to the Earth, and an observer is moving with a constant speed $-\bar{u}$ relative to the Earth. In the frame of reference of the Earth, the speed of the photon emitted by the source is equal to c and there is no reason why it should change in the observer's frame of reference prior to interaction of the photon and a detector.

We will work in the frame of reference of the observer. In the observer's frame of reference a source of light with mass M is moving with velocity $\bar{u}$ (Fig.1). The energy of the source is composed of kinetic energy $Mu^2/2$ and internal energy E_0 of the excited atoms. Denote by E' the internal energy of the source after the photon is emitted. In addition the source undergoes recoil due to emission: its speed gains an increment of $\vec{\bar{u}}'-\vec{u}$ (where $\bar{u}'$ is the speed of the source after emission of the photon). It follows from the laws of conservation of energy and momentum of the photon and the source that

$$\frac{Mu^2}{2}+E_0=\frac{(M-m_0)(u')^2}{2}+E'+E_{p\,h} \qquad (2)$$

$$Mu=(M-m_0)\bar{u}+m_0\bar{w} \qquad (3)$$

where m_0 is the mass carried away by the photon emitted with speed c with respect to the source, E_{ph} is the photon energy in the observer's frame of reference, and $\bar{w}=\bar{c}+\bar{u}$ is the photon velocity in the same frame. Note that the vector $\bar{w}$ is directed towards the observer.

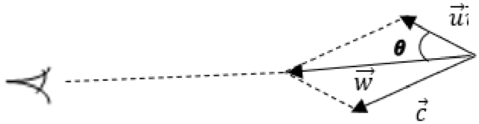

Fig. 1

[1] By the mass of a photon, we mean the dynamic mass of the photon, defined by $m=\hbar\nu/c^2$

From Eq. (3) we obtain for $\bar{u}'$:

$$\bar{u}' = \frac{M\bar{u} - m_0(\bar{c} + \bar{u})}{M - m_0} \tag{4}$$

After emission of the photon, the internal energy of the atom decreases by amount $h\nu_0$, where ν_0 is the frequency of the photon, that is $E_0 - E' = h\nu_0$. Taking this along with Eq. (4) into account, Eq. (2) can be expressed as follows:

$$E_{ph} - h\nu_0 = \frac{Mu^2}{2} - \frac{(Mu - m_0(\bar{c} + \bar{u}))^2}{2(M - m_0)}$$

$$= \frac{m_0 u^2 + 2m_0(\bar{u} \cdot \bar{c}) - m_0^2(\bar{c} + \bar{u})^2 / M}{2(1 - m_0 / M)} \tag{5}$$

If the mass M of the source is much greater than that of the photon, the terms containing m_0 / M can be ignored. In this approximation, Eq. (5) takes the form:

$$E_{pv} = h\nu_0 + m_0(\bar{u} \cdot \bar{c}) + m_0 u^2 / 2 \tag{6}$$

Using relation $m_0 c^2 = h\nu_0$ Eq. (6) can be represented in two equivalent forms:

$$E_{ph} = h\nu_0\left(1 + \frac{(\bar{u} \cdot \bar{w})}{c^2} - \frac{u^2}{2c^2}\right) = \frac{m_0 w^2}{2} + \frac{h\nu_0}{2} \tag{7}$$

Where

$$w^2 = c^2 - u^2 + 2uw\cos\theta \tag{8}$$

Here θ is the angle between the velocity of the source and the direction from the source to the observer, i.e. the angle between vectors $\vec{u}$ and $\vec{w}$.

Consider a special case $u = 0$. In this case Eq. (7) gives:

$$h\nu_0 = \frac{m_0 c^2}{2} + \frac{h\nu_0}{2} \tag{9}$$

An important result follows from Eq. (7) and Eq. (9) that **the energy of a photon, as an entity of mass m_0, can be represented as a sum of two terms, the first of which is the kinetic energy of the center of mass, where we assume all of the photon's mass is concentrated, and the second is the energy associated with the motion about the center of mass, which is**

characteristic of the photon's intrinsic degrees of freedom. Eq (9) was obtained by L.Boldyreva and N. Sotina in 1999. [5].

Assume that all the energy of the photon E_{ph} is equal to the energy detected by a measuring device, that is $h\nu$ (this assumption is no different than that of conventional physics). Under this assumption, we obtain from Eq(6)

$$\nu = \nu_0 \left(1 + \frac{(\bar{u} \cdot \bar{w})}{c^2} - \frac{u^2}{2c^2} \right) \tag{10}$$

If $\bar{u} \perp \bar{w}$, that is, $(\bar{u} \cdot \bar{w}) = 0$, then from Eq. (10) we obtain the expression for the transverse Doppler effect

$$\nu = \nu_0 \left(1 - \frac{\beta^2}{2} \right) \tag{11}$$

Using Eq. (10) and Eq. (8) we obtain the detected frequency of the photon for any value of θ as:

$$\begin{aligned} \nu &= \nu_0 \left(1 + \beta \frac{w}{c} \cos\theta - \frac{\beta^2}{2} \right) = \\ &= \nu_0 \left(1 + \beta \cos\theta - \frac{\beta^2}{2} + \beta^2 \cos^2\theta + O(\beta^2) \right) \end{aligned} \tag{12}$$

Eq. (12) agrees, to within an accuracy of $\beta^2 = (u/c)^2$, with that for the Doppler Effect in special relativity.

Note also that as follows from Eq. (12), the frequency remains the same ($\nu = \nu_0$) in two cases: 1) when the relative speed of the source is zero ($u = 0$), and 2) when $u = 2c\cos\theta$. In these cases $w = c$ and, consequently, the total energy of the photon is the same in both frames of reference. The relativistic equation for the Doppler Effect also has two solutions when the frequency of light remains unchanging. In SR, however, the second solution agrees with our solution only approximately (with an accuracy of β^2 inclusively) and does not have an obvious physical interpretation. The fact that in our apprach the second solution is the **exact** solution of Eq. (12), and has a simple physical interpretation is an additional argument in favor of the theory developed in this work.

Where is the "hidden dynamics" here? In our derivation we take the energy of the absorbed photon to be $h\nu$. In agreement with conventional physics let us use the expression

$$h\nu = mc^2 \tag{13}$$

for the energy of the absorbed photon. It follows from this formula that the mass of the photon changes as the value of the velocity changes and equalizes to the value c in the vicinity of the detector. Then the change of the momentum near the detector is

$$\Delta\bar{k} = m\bar{c} - m_0\left(\bar{c} + \bar{u}\right) \tag{14}$$

Here $\Delta\vec{k}$ equals to the impulse of external forces. In cases when the angle θ between the velocity of the source and the direction from the source to the observer has values from 0 or π formula (14) gives

$$\Delta k = mc - m_0(c \pm u) = \frac{\hbar}{c}\left[\nu - \nu_0(1 \pm \beta)\right] = m_0 c\frac{\beta^2}{2} \tag{15}$$

It can be seen from Eq. (15) that $\Delta k = 0$ **in the first approximation by** β Therefore, in the first approximation by β the **hidden dynamics is in the change of the photon's speed that occurs at the expenses of the change of its mass. That is, as the speed of the photon increases to value** c **its mass decreases, and vise versa: as the speed of the photon decreases to value** c **its mass increases in the vicinity of the detector.** (Note, that here we expand Ritz hypothesis: the speed $\vec{c}$ is the speed of light with respect to both a source and a detector).

Case 2: Now suppose that an observer is at rest with respect to the Earth, and a source is moving with constant speed $\bar{u}$ relative to the observer. In this case the emitted photon has the speed ***c*** and energy $h\nu_0$ in the frame of reference of the source. The speed of the photon with respect to the Earth is different from c when the photon is emitted but equalizes to value c in the vicinity of the source. In this case Eq. (13) for the Doppler Effect remains valid, however, ν in this equation is the photon's frequency with respect to the Earth.

Summary. It is proven above that the relativistic equation for the Doppler Effect can be obtained in the framework of the model of the three-dimensional Euclidean space using the classical laws of conservation of energy.

From the law of conservation of energy it follows that **1)** the energy of a photon, as an entity with mass m_0 can be represented with two terms: the first is the kinetic energy of the center of mass; the second is the energy associated with the motion about the centre of mass; **2)** In the process of absorption of a photon by a moving detector all energy of the arriving photon is absorbed by an atom**.**

4. Light Curve for Eclipsing Binary Stars

We have spoken so far about the change of the photon's velocity near the Earth. A good question is: are there any observations in outer space that can be explained by "hidden dynamics "? That is, observations in which the photon's speed changes in vacuum (without loss of energy) within the same frame of reference? The answer is yes: the astronomical observations of binary stars.

At one time (1913) observations of binary stars was the single objection to the Ritz's ballistic hypothesis. It is generally accepted that the paper by W. de Sitter [6] put an end to the Ritz idea. In his work W. de Sitter pointed out, that if one follows the hypothesis that the speed $\vec{c}$ is the speed of light with respect to each of the stars and the classical law of velocity addition is valid, then light, emitted simultaneously from each star reaches the Earth at different moments. As a result an observer on Earth can observe the discrepancies with Kepler's laws.

De Sitter based his reasoning, however, on a hypothesis that the speed of light is unaffected during its journey to Earth. Our assumption that "hidden dynamics" exists brings Ritz's hypothesis into agreement with the observations of binary stars. Moveover, the known observations of the binary stars can help to estimate at what distances from the stars the speeds of the photons emitted from each of the stars in binary system become equal.

In our analysis we use the same assumptions as SR: speed of light equals c with respect to each star and it also equals c with respect to an observer on Earth. However, from our point of view the key is not in the relativistic law for velocity addition but in a a real change of the speed of light that take place as it propagates thorugh space, that is in existence of a 'hidden'dynamics that manifests itself in the change of the light speed (in vacuum) without energy loss.

Consider the case of eclipsing binary stars, a system of two stars A and B, whose plane of orbit lies in the line of sight of the observer. According to our hypothesis the speeds of photons emitted by star A are equal to c with respect to that star, and similarly the speeds of photons emitted by star B are equal to $\boldsymbol{c}$ with respect to star B (Fig.2). Denote as $\vec{u}$ the velocity of a star in a binary system about the common center of mass (for simplicity considers $\vec{u}$ being the same for both stars). Due to the motion of the stars the speeds of photons moving in the direction of the line-of-sight of the observer should be different. After some time, however, the speeds of the two sets of photons can 'equalize' and acquire the same value c, for example, due to their passing near another celestial body.

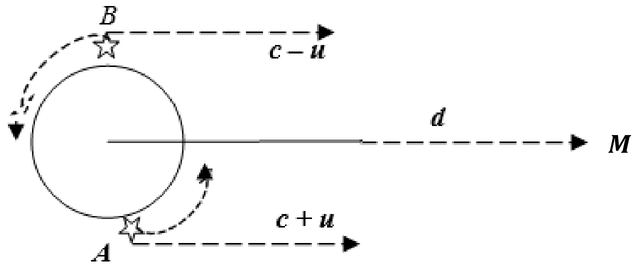

Fig.2

Let d be the distance at which speeds of photons equalize. This way, the light curve plotted by the observer located at a distance d from the binary system (call this point M) is the same as the light curve plotted by the observer on Earth (because the photons travel further with the same speed **).**

The relationship between the current time t and the time of the photon's arrival at point M (for both stars A and B) is given by the following equations:

$$\frac{d}{c(1+\beta\cos\omega t)}+t=\tau_1 \tag{16}$$

for the photon emitted by star A, and

$$\frac{d}{c(1-\beta\cos\omega t)}+t=\tau_2 \tag{17}$$

for the photon emitted by star B.

Let ω indicate the angular speed of the stars' orbital motion about the common center of mass, $\omega=2\pi/T$ where T is the orbital period, and $\beta=u/c$. The position of the stars at the initial moment of time ($t=0$) is shown in Fig.2.

Assume that the number of photons emitted per unit time n *i*s the same for both stars. Let μ_1 be the number of photons per unit time arriving at the point M from the star A**,** and μ_2 be the number of photons per unit time arriving at the point M from the star B. In the time interval Δt each star emits $n\Delta t$ photons. The number of photons arriving at point M is therefore $\mu_1(\tau_1)\Delta\tau_1$ and $\mu_2(\tau_2)\Delta\tau_2$ respectively. Then for star A we have

$$n\Delta t=\mu_1(\tau_1)\Delta\tau_1\approx\mu_1(\tau_1)\frac{d\tau_1}{dt}\Delta t \tag{18}$$

and for star B:

$$n\Delta t = \mu_2\left(\tau_2\right)\Delta\tau_2 \approx \mu_2\left(\tau_2\right)\frac{d\tau_2}{dt}\Delta t \tag{19}$$

where $d\tau_1 / dt$ can be found from Eq. (16)

$$\frac{d\tau_1}{dt} = 1 + \frac{d\beta\omega\sin\omega t}{c(1+\beta\cos\omega t)^2}\,, \tag{20}$$

and $d\tau_2 / dt$ can be found from Eq. (18) as

$$\frac{d\tau_2}{dt} = 1 - \frac{d\beta\omega\sin\omega t}{c(1-\beta\cos\omega t)^2} \tag{21}$$

We are studying the change in light intensity in the reference frame of point *M*. Thus, we have to substitute *t* with τ_1 and τ_2 in Eq. (20) and Eq. (21) respectively. According to Eq. (18) the relative density of photons arriving at point *M* from star A is

$$\frac{\mu_1\left(\tau_1\right)}{n} = 1/\frac{d\tau_1}{dt}\left(t \to \tau_1\right) \tag{22}$$

According to Eq. (21) the relative density of photons arriving at point *M* from star B is:

$$\frac{\mu_2\left(\tau_2\right)}{n} = 1/\frac{d\tau_2}{dt}\left(t \to \tau_2\right) \tag{23}$$

Thus, the total relative density *s* of photons arriving at point *M* is as follows

$$s = \frac{\mu_1\left(\tau_1\right) + \mu_2\left(\tau_2\right)}{n} = \frac{1}{d\tau_1 / dt} + \frac{1}{d\tau_2 / dt} \tag{24}$$

From the viewpoint of SR, *s* = 2, and the graph of *s* versus time (Fig.3) should be constant between eclipses. In our case the graph of the function *s* given by Eq.(25) shows that the curve, which represents the relative photon density *s=s(t/T)* as measured at the point *M,* is a periodic function with the period *T*/2 (where *T* is the orbital period of the star system) (Fig.3).

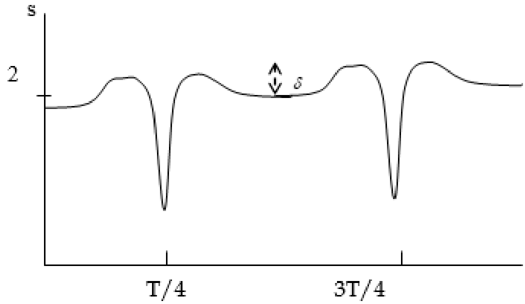

Fig. 3. *Light curve of an eclipsing binary system*

The variations δ from $s=2$ depends on the distance *d* from the star to the point *M* **(**the point where the photons' speeds equalize). Using data for the binary system WW Aurigae, we estimat that at a distance $d=$ 10 AU, $\delta=8.463\times10^{-8}$, and for $d=1000$ AU, $\delta=$ 6.113×10^{-5} **.** In the case of WW Aurigae δ is small and is probably not detectable in observations.

Thus a light curve plotted on the basis of SR with zero δ is different than the curve plotted on the basis of our theory. Light curves showing uneven brightness, however, are often observed. Besides the drops in intensity due to eclipses, there are observed deviations from constant values in the regions of light curves between eclipses. Astronomers have different explanations for these variations, some of which are quite obviously contrived. This topic clearly requires further study to arrive at a credible resolution. And yet the new results of the observation of binary stars might provide new arguments in favor of the existence of a "hidden dynamics", for example caused by the passing of a photon near large masses.

References

1. D.N. Klyshko, *Physics Uspekhi*, **164 (11),** 1187 (1994) (in Russian).
2. W. Ritz, Annales de Chimie et de physique, **8,** 145 (1908).
3. T.Alvager & J.M. Bailey *Phys. Letters*, **12,** 260 (1964).
4. Fainberg E.L., *Physics Uspekhi*, **167** *h* **(11),** 455, (1997) (in Russian).
5. L. B. Boldyreva & N. B. Sotina, A Theory of Light without Special Relativity? (Moscow: Logos, 1999).
6. W. Sitter, *Physikalische Zeitschrift,* **XIV,** 429 (1908).
7. N. Sotina, Reports of the 16th RCCNT&BL Dagomys, city of Sochi, June, 2009, Moscow 179 (2010) (in Russian).