Doppler Effect in Absolute Spacetime: Proposal for a New TDE Experiment

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The new Doppler effect formula is derived within the framework of the recently proposed privileged system theory (PST). Comparing this formula with its SRT equivalent reveals a characteristic difference as to the expected value of the transverse Doppler effect (TDE). Namely, for the angles of observation different from $\theta = 0^\circ$ and $\theta = 180^\circ$ the PST Doppler effect formula predicts a blueshift component with the maximum value at $\theta = 90^\circ$. This prediction enables to perform a test of special relativity (against the theory based on the assumption of a privileged system) in a 'true' TDE experiment.

Keywords: transverse Doppler effect, special relativity, privileged system, privileged system theory

1. Theoretical background of previous TDE experiments

The TDE experiments are widely considered as one of the most important empirical confirmations of SRT. A theoretical basis for the presence of TDE was formulated in Einstein's 1905 paper [1], and subsequently specified in his paper of 1907 [2]. An original TDE experiment, executed by Ives and Stilwell in 1938 [3], in spite of its attribution to the considered phenomenon, does not consist in direct transversal (lateral) observation. Instead, it makes use of the fact that, according to SRT, the redshift effect caused by time dilation superimposes on the 'usual' longitudinal Doppler effect. The idea of the Ives-Stilwell experiment lies in separation of these two effects with the aid of detectors aimed at $\theta = 0^\circ$ and $\theta = 180^\circ$. The results obtained for these two angles indicate a characteristic offset in relation to the results predicted by the classical (*i.e.* non-relativistic) formula. Such an approach seems to have an advantage over the direct transversal observation (at $\theta = 90^\circ$) since it eliminates the aberration problem with all its references to different theories. The recently executed TDE tests [4], [5], besides their considerably increased precision, duplicate (with one exception [6]) the general scheme of the Ives-Stilwell experiment.

In fact, the distinction between the longitudinal and transversal way of observation does not have any fundamental significance in TDE experiments since they are conceived as a test of special relativity against the 'classical' theory. Since both in the SRT Doppler effect formula:

$$f = \frac{f_0}{\gamma\left(1 + u\cos\theta/c\right)} \tag{1}$$

and its 'classical' equivalent:

$$f = \frac{f_0}{1 + u\cos\theta/c} \tag{2}$$

the presence (or absence) of the Lorentz factor $\gamma = \left(1 = u^2/c^2\right)^{-1/2}$ does not depend on the θ value, then the choice of the observational method is the sole matter of convenience and intended precision of the obtained result.

2. Derivation of the Doppler effect formula from the privileged system assumption

There are a number of theories that assume the existence of a privileged system (the preferred frame of reference) and, at the same time, do not neglect such phenomena as length contraction and time dilation. They all originate from the idea proposed by FitzGerald and Lorentz, undertaken in the face of difficulties connected with the null result of the Michelson-Morley experiment. According to the approach presented in [7] and then developed in [8], all of the so-called ‘relativistic’ phenomena have absolute reference, which means that, in opposition to SRT, they are conceived as ‘real’. This assumption, if consequently fulfilled and expanded, leads to a new type of transformation (‘inertial transformation’) [9], [10], [11] and determines both the kinematics and dynamics of the resulting theory. It is worth mentioning here that dynamical predictions (concerning energy) of the proposed privileged system theory (PST) [10] differ from the SRT predictions. Besides, introducing PST is not the sole matter of ontological preference but rather a question of necessary replacement of SRT, following from the exact formal reasons [12].

In the case of the Doppler effect considered in this context, the following questions should be taken into account:

1) The speed of the light signal in the observer’s frame;

2) The velocity of the emission source in the observer's frame;
3) The relation of the time rates between the emitter and receiver.

We shall take the settlements concerning the above-mentioned points in their 'ready-made' shape (derived in [10]), defining them as follows:

- The speed of light in the general case is given by

$$c' = \frac{c - u\cos\theta}{1 - u^2\cos^2\theta/c^2} \tag{3}$$

  with u the velocity of the observer as related to the privileged system, and θ the observed angle of emission. For $u = 0$ we get $c' = c$, which entails the constant speed of light in the privileged system. Also, for $\theta = 90^\circ$ it follows that $c' = c$.

- The reciprocal velocities of the two systems with one of them privileged, relate to each other as

$$u' = u\gamma^2 \tag{4}$$

  with u and γ both related to the privileged system.

- The time rates of the two systems with one of them privileged are, due to inertial transformation, inversely proportional to each other:

$$\begin{aligned} t' &= t/\gamma \\ t &= t'\gamma \end{aligned} \tag{5}$$

  with t the time measured in the privileged system.

Let us consider the Doppler effect under the privileged system assumption, for the cases when either the observer or the source of emission is at rest in the privileged system. These two cases correspond with the basic form of inertial transformation [10] (though they do not comprise all possibilities described by 'general inertial transformation' [11]).

Let us denote by γ_{source} the Lorentz factor for the source of emission, and by $\gamma_{observer}$ the Lorentz factor for the observer, both defined as related to the privileged system. Then the mutual relation of the source and observer against the privileged system can be written as

$$Q_\gamma = \frac{\gamma_{observer}}{\gamma_{source}} \tag{6}$$

This quotient describes the relation between the time rates of the systems fixed to the source and to the observer, as well as determines the relation of their mutual velocities. For the extreme cases considered here, we obtain either: $Q_\gamma = 1/\gamma_{source}$ (for the observer at rest in the privileged frame), or $Q_\gamma = \gamma_{observer}$ (for the source of emission at rest in the privileged frame). In the second case, the Lorentz factor (γ) responsible for time dilation moves from denominator to numerator in the Doppler equation.

Considering the above settlements, we can easily arrive at the conclusion that, in the case when the observer rests in the privileged frame and the source is in absolute motion, the PST Doppler effect formula conforms to the usual SRT formula (1). Instead, in the opposite case, we have to take into account (3), (4) and (5). In consequence, the Doppler effect formula takes the form:

$$f = \frac{\gamma f_0}{1 + u\gamma^2 \cos\theta \Big/ \dfrac{c - u\cos\theta}{1 - u^2\cos^2\theta / c^2}} \tag{7}$$

3. Predictions derived from the PST Doppler effect formula

At first, let us examine the PST Doppler effect formula (7) considering two extreme cases, *i.e.* with $\theta = 0^\circ$ and $\theta = 180^\circ$. For $\theta = 0^\circ$ we get

$$f = \frac{\gamma f_0}{1 + u\gamma^2 \Big/ \dfrac{c-u}{1-u^2/c^2}} \tag{8}$$

Rearranging gives

$$f = \frac{\gamma f_0}{1 + \dfrac{u\gamma^2 - u^3\gamma^2/c^2}{c-u}} = \frac{\gamma f_0}{1 + \dfrac{u\gamma^2\left(1-u^2/c^2\right)}{c-u}} = \frac{\gamma f_0}{1+u/(c-u)} =$$

$$= \frac{f_0}{\sqrt{1-u^2/c^2}\left[1+u/(c-u)\right]} = \frac{f_0}{\sqrt{1-u^2/c^2}\left[c/(c-u)\right]} = \frac{f_0(c-u)}{\sqrt{c^2-u^2}} =$$

$$= \frac{f_0\left(c^2-u^2\right)}{\sqrt{c^2-u^2}\,(c+u)} = \frac{f_0\sqrt{c^2-u^2}}{(c+u)} = \frac{f_0\sqrt{1-u^2/c^2}}{1+u/c} = \frac{f_0}{\gamma(1+u/c)}$$

Analogously, for $\theta = 180^\circ$, from

$$f = \frac{\gamma f_0}{1 - u\gamma^2 \Big/ \dfrac{c+u}{1-u^2/c^2}} \tag{9}$$

it follows that $f = \dfrac{f_0}{\gamma(1-u/c)}$.

We may then conclude that, for these two cases, the PST Doppler effect formula conforms to the SRT formula. However, the equivalence between (7) and (1) does not constitute a general rule. One can easily demonstrate this by considering the special case of $\theta = 90^\circ$. By substituting $\cos 90^\circ = 0$ in (7), we obtain

$$f = \gamma f_0 \tag{10}$$

Meanwhile, the same value applied to (1) gives

$$f = f_0/\gamma \tag{11}$$

Thus, for the observational angle $\theta = 90^\circ$, PST predicts the blueshift effect in opposition to the redshift effect predicted by SRT. For the source of emission at rest in the privileged system, the blueshift effect amounts to the value determined by Lorentz factor. This outcome points to the possibility of a new TDE experiment.

4. The framework of the SRT *vs.* PST test in the TDE experiment

Though it is not a matter of formal proof, it is however reasonable to assume that, if the privileged system exists, it coincides with the frame determined by isotropic background radiation. The revealed dipole anisotropy of this radiation, caused by the Doppler effect (the 'great cosinus in the sky'), points to the mean velocity of Earth against this background, of the value *ca.* 390 km/s, in the direction described by the galactic coordinates $l = 207^\circ$ and $b = 50^\circ$. This enables to project a 'true' (*i.e.* lateral) TDE experiment with the velocity of the emission source against the Earth's laboratory corresponding to the assumed state of absolute rest of this source. The considered velocity gives the quotient $\beta = \frac{u}{c} = 0,0013$, with u the velocity of the observer in the Earth's lab. This gives the value of the Lorentz factor $\gamma = 1 + 8,45 \times 10^{-7}$. In turn, the rate of (10) and (11) gives $\gamma^2 = 1,00000169$, which describes the difference between expectations of PST and SRT. This value, though obviously small, yet does not seem to be beyond the reach of the possibilities of modern experimental setups.

We have mentioned above the TDE experiment [6] that consisted in the direct transversal observation. It is clear, however, that the question of direction of observation does not fulfill all of the requirements put on TDE by the assumption of a privileged system. Besides this one, the other two conditions are: the right spatial orientation of the experimental setup due to the above-mentioned galactic coordinates, and the right velocity of the emission source (or, at least, regarding the right value in calculations). Meanwhile, the velocities of the emission source (hydrogen atoms) that were the subject of observation in the considered experiment exceeded the Earth's velocity against the background radiation from 6.5 to over 23 times. Secondly, the spatial orientation of the apparatus was purely accidental. These two reasons make this experiment not useful for our purposes.

We suggest, therefore, to perform a test of special relativity in an experiment that fulfills the requirements described in this paper.

References

[1] A. Einstein, "On the Electrodynamics of Moving Bodies", *Annalen der Physik*, 17: 891 (1905)

[2] A. Einstein, "Über die Möglichkeit einer neuen Prüfung des Relativitätsprinzips", *Annalen der Physik* Ser.4, 23 (1907)

[3] H.E. Ives, G.R. Stilwell, "An Experimental Study of the Rate of a Moving Clock", *J. Opt. Soc. Am* 28, 215-226 (1938)

[4] R. Grieser *et al.*, *Appl. Phys. B* 59, 127 (1994)

[5] G. Saathoff *et al.*, *Phys. Rev. Lett.* 91, 190403 (2003)

[6] D. Hasselkamp, E. Mondry, A. Scharmann, "Direct Observation of the Transversal Doppler-Shift", *Z. Physik A*, 289, 151-155 (1979)

[7] G.F. FitzGerald, “The Ether and the Earth’s Atmosphere”, *Science* 13, 390 (1889)

[8] H.A. Lorentz, “The Relative Motion of the Earth and Ether” (1892), in *Collected Papers*, vol. IV, 219-223 (The Hague, 1937)

[9] F. Selleri, “Theories Equivalent to Special Relativity”, *Frontiers of Fundamental Physics*, 181-192 (Plenum London / New York, 1994)

[10] M. Rybicki, “An Alternative to SRT: a Theory Based on the Idea of a Privileged System”, *Galilean Electrodynamics* 18, Special Issues 2, GED-East, 31-34 (Fall, 2007)

[11] M. Rybicki, “Inertial Transformation Extended to the General Case”, *Galilean Electrodynamics* (in press)

[12] M. Rybicki, “Transformation of Work Reveals the Incoherence of SRT (Correspondence), *Galilean Electrodynamics* 18, Special Issues 1, GED-East, 31 (Spring 2007)