A basic problem in the theory of special relativity

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Abstract

We show that the invariance of the velocity of light by frame change leads to a mathematical contradiction.

Key words: light, photon, velocity, moving frame, Lorentz factor.

1 Introduction

One of the basic assumptions of special relativity is that the velocity of light in the vacuum is frame independent. This assumption is a special case of the relativistic composition formula of velocities. Since it represents a scientific revolution compared to the classical addition formula which directly follows from the absolute character of time in Newtonian mechanics, it was from the beginning the main point of discussion for the opponents to Einstein's theory of special relativity. This invariance property of the speed of light is supposed to have been confirmed by the Michelson-Morley experiment and subsequent verifications of the same type (cf. e.g. [3, 4]) and, more indirectly, by its consequences. In physics papers, the velocity of light in the vacuum is denoted by c, and the value of c is supposed to be known with a great precision nowadays. However some physicists went on criticizing the basic axiom of special relativity, among other things claiming that the Michelson-Morley experiment does not really prove the constancy of c, cf. for instance [2] for a critical discussion of the interpretation of that experiment. In [1, 5], rather complicated examples were given to disprove several basic axioms of special relativity. It would be a very difficult task to cite all papers or books in which the theory of relativity is in question. But the author could not find until now in the literature a simple example showing a mathematical contradiction in special relativity. Such a contradiction, developed in Section 2, is the main object of the present short note. Sections 3 and 4 are devoted to the consequences of the counterexample and a few remarks.

2 A simple one dimensional contradiction

This counterample was suggested to the author when trying to understand the observations of Olaf Römer concerning the apparent revolution time of the satellite Io of Jupiter in 1676, recorded in many textbooks, cf. e.g. [5], subsections 4.1 and 4.2. Let us consider a luminous source which will be taken as spatial origin denoted by O. All objects considered here will belong to the positive half-line $[0, \infty)$. At time $t = 0$, the source emits a photon in the right direction which, according to usual assumptions in relativity, travels with the velocity c in the space-time frame with origin $(0, 0)$, considered the fixed frame. We can forget about the two other spatial dimensions which play no role here. A punctual object $M = M(t)$ is travelling with a constant negative velocity $-v$, $0 < v < c$. The intial position on the half-line is given by $OM(0) := D > 0$. We shall study the relative motion of the photon with abscissa

$$Op(t) = ct$$

and the point $M(t)$ given on the positive axis by

$$OM(t) = D - vt.$$

In the spatial frame of the fixed source O, it is clear that as long as the photon $p(t)$ does not reach $M(t)$, we have

$$dist(p(t), M(t)) = OM(t) - Op(t) = D - vt - ct = D - (c + v)t. \tag{1}$$

In particular, the photon collides with M at the exact time

$$T_1 = \frac{D}{c + v} \tag{2}$$

On the other hand, in the spatial frame moving with $M(t)$, according to special relativity, there is a contraction of the time by the factor

$$\alpha = \sqrt{1 - \frac{v^2}{c^2}} < 1$$

which is the inverse of the Lorentz factor $\gamma > 1$. Taking the time origin 0 corresponding to the initial configuration, we can define the proper time τ in the moving frame by

$$\tau = \alpha t.$$

In order to avoid any notation confusion let us introduce

$$\mathcal{M}(\tau) := M(t) = M(\gamma\tau); \quad \pi(\tau) := p(t) = p(\gamma\tau)$$

The **relativistic hypothesis on constancy of light velocity** implies here that

$$\frac{d}{d\tau} dist(\pi(\tau), \mathcal{M}(\tau)) = -c \tag{3}$$

as long as the photon $\pi(\tau)$ does not collide with $\mathcal{M}(\tau)$). In addition, in the spatial frame moving with $M(t)$, according to special relativity, there is a spatial contraction by the same factor α for objects in the fixed frame, so that in that frame, the initial distance between the photon and M is not D, but αD. From (3) we infer that as measured in the moving frame

$$dist(\pi(\tau), \mathcal{M}(\tau)) = \alpha D - c\tau$$

from which it follows that the collision time evaluated in the moving frame is equal to

$$\tau_2 = \frac{\alpha D}{c}$$

Finally, coming back to the time in the "fixed" frame, we find a collision time equal to

$$T_2 = \gamma \frac{\alpha D}{c} = \frac{D}{c}, \tag{4}$$

a contradiction with formula (2) giving $T_1 = \dfrac{D}{c+v}$ for the *same* event in the *same* frame.

3 Conclusion

In the various papers dealing with criticism of the absolute character of light speed, it is often concluded that the true composition rule for velocities is the simple vector addition. The example of Section 2 of course also suggests that, but at the level of the present note we shall not go that far, since the exemple that we considered is special, involving the collision between a photon and a material point. What we obtain is that the three following properties are logically incompatible:

- The invariance of velocity of light by uniform translation.
- The relativistic time contraction.
- The relativistic space contraction.

4 Some remarks

Remark 4.1. *A contradiction would also appear with M moving in the opposite direction.*

Remark 4.2. *If it turns out, as a consequence of the various objections published in the literature, that Special Relativity must be forgotten and that we have to recover absolute time as in Newton's framework, the simple composition rule of velocities by vector addition will follow automatically. In this case the velocity of light is no longer a limit and this is a very good news for spatial exploration.*

Remark 4.3. *An often invoked confirmation of time contraction for moving objects is the behavior of cosmic muons which are able to cross a distance that they should not be able to cover as a consequence of their short life span. But, as mentioned for instance in the book [5], an alternative explanation would be that cosmic muons are supra-luminic, with a speed exceeding c by several orders of magnitude.*

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