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LETTER TO THE EDITOR

A new approach to the problem of superluminous velocity

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Abstract. The problem of superluminous velocity is studied by means of the generalised Galilean transformation of the space–time coordinate.

The possibility of motion at superluminous velocities has been studied since the early 1960s (Bilaniuk *et al* 1962, Feinberg 1967). However, those previous studies based on special relativity meet with a fundamental difficulty; according to special relativity, if the phenomenon of superluminous velocity appeared, there would exist the possibility of breakdown of causality (Rdnick 1972). Recently, the radio data from some quasars and strong compact radio galaxies have shown an apparent expansion faster than the velocity of light (Cohen *et al* 1977); this phenomenon has attracted physicists' attention. Here I shall study the problem of superluminous velocity by means of the generalised Galilean transformation (GGT).

In Chang (1979), I have written a form of GGT:

$$\begin{cases} \boldsymbol{r} = \boldsymbol{r}_0 + [(\Upsilon - 1)/v^2](\boldsymbol{r}_0 \,.\, \boldsymbol{v})\boldsymbol{v} - \Upsilon \boldsymbol{v} t_0 \\ t = \Upsilon^{-1} t_0 \end{cases} \tag{1}$$

where $\boldsymbol{r}$ is a three-vector of space in an inertial frame Σ; $\boldsymbol{r}_0$ is in a privileged frame of reference Σ_0; t and t_0 are the time coordinates in Σ and Σ_0 respectively; $\boldsymbol{v}$ is the velocity of Σ with respect to Σ_0; c is the velocity of light in Σ_0; $v < c$, and $\Upsilon = (1 - v^2/c^2)^{-1/2}$. It is easily seen from equation (1) that the notion of simultaneity of distant events is absolute: independent of the choice of reference frame. This means that the existence of a signal with infinite velocity is allowed.

In Chang (1979) I also wrote the expression for the four-line element of space–time, viz

$$ds^2 = (d\boldsymbol{r})^2 - c^{-2}(\boldsymbol{v} \,.\, d\boldsymbol{r})^2 + 2(\boldsymbol{v} \,.\, d\boldsymbol{r})\, dt - c^2\, dt^2. \tag{2}$$

Here ds^2 is an invariant. Making use of equation (2) and the expression

$$ds^2 = g_{\mu\nu}\, dx^\mu\, dx^\nu \tag{3}$$

we can get the expression of the metric tensor $g_{\mu\nu}$, with the Greek indices $\mu, \nu = 1, 2, 3, 4$. The sign of ds^2 is connected with three different kinds of particles. The corresponding relations are as follows:

$$ds^2 \begin{cases} < 0 & \text{(bradyon)} \\ = 0 & \text{(photon)} \\ > 0 & \text{(tachyon).} \end{cases} \tag{4}$$

For the photon $ds^2 = 0$, we can get the expression for the velocity of light (Chang 1979). As for the tachyon, it should have some peculiar properties. We shall see that, because $ds^2 > 0$, the local time ($d\tau = c^{-1}\sqrt{ds^2}$) would become imaginary. This means that the concept of the rest system of the tachyon makes no sense. However, we can introduce the four-momentum of the tachyon referring to the case of the particle of subluminous velocity (bradyon). It is

$$P^\mu = \mu_0 c \, dx^\mu / ds \tag{5}$$

where $P^\mu = \boldsymbol{P} = (ds/dt)^{-1}\mu_0 c^2$; the parameter μ_0 is called the proper mass of the tachyon; the $\boldsymbol{P}$ is the three-momentum of the tachyon, which can be written as

$$\boldsymbol{P} = \mu_0 \boldsymbol{u}[(u^2/c^2) - (1/c^4)(\boldsymbol{u} \, . \, \boldsymbol{v})^2 + (2/c^2)(\boldsymbol{u} \, . \, \boldsymbol{v}) - 1]^{-1/2}. \tag{6}$$

Here $\boldsymbol{u}$ is the velocity of the tachyon, whose value must be larger than the velocity of light in the same frame.

Using the metric tensor $g_{\mu\nu}$ expressed by equation (2), and lowering the indices of P^μ, we can obtain the covariant components P_μ of four-momentum for the tachyon. Let the energy of the tachyon $E = -cP_4$; then

$$E = \mu_0 c^2 (1 - \boldsymbol{u} \, . \, \boldsymbol{v}/c^s)[u^2/c^2 - (1/c^4)(\boldsymbol{u} \, . \, \boldsymbol{v})^2 + (2/c^2)(\boldsymbol{u} \, . \, \boldsymbol{v}) - 1]^{-1/2}. \tag{7}$$

In principle, the value of $\boldsymbol{u}$ in equations (6) and (7) is allowed to be infinite, while the values $\boldsymbol{P}$ and E would become minima. If $u \to \infty$, equation (6) becomes

$$\boldsymbol{P}_\infty = \mu_0 x[1 - (1/c^2)(\boldsymbol{v} \, . \, \boldsymbol{n})^2]^{-1/2}\boldsymbol{n} \tag{8}$$

and equation (7) becomes

$$E_\infty = -\mu_0 c(\boldsymbol{v} \, . \, \boldsymbol{n})[1 - (1/c^2)(\boldsymbol{v} \, . \, \boldsymbol{n})^2]^{-1/2} \tag{9}$$

where $\boldsymbol{n}$ is a unit vector given by $\boldsymbol{n} = \boldsymbol{u}/u$.

Furthermore, combining equations (6) and (7), the relation between the energy and momentum of the tachyon can be written as

$$\boldsymbol{P} \, . \, \boldsymbol{P} = E^2/c^2 = \mu_0^2 c^s. \tag{10}$$

In general we can see that, when using the covariance of the generalised Galilean transformation, introducing the view of superluminous velocity is internally consistent. In this way, the direction of the time would not become inverse for the tachyon in any reference frame, and the causality would not be broken down, for the notion of simultaneity is frame-independent.

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