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TACHYONS AND THE SEARCH FOR A PREFERRED FRAME

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Bradyons, Luxons and Tachyons

The theory of relativity arose out of the need for reconciling the electrodynamics of moving bodies[1] with their apparent universal validity in every inertial frame. Since Maxwell's equations were not invariant under Galilean transformations of mechanics one had to replace them by the Poincaré transformations of relativity theory.[2] The transformation of the Galilei group for change to a frame moving in the x direction is

$$x \to x - ut, \quad t \to t, \quad y \to y, \quad z \to z$$

while the corresponding Poincaré transformation is

$$x \to \frac{x - ut}{\sqrt{1 - u^2/c^2}}, \quad t \to \frac{t - ux/c^2}{\sqrt{1 - u^2/c^2}}, \quad y \to y, \quad z \to z$$

where c is the speed of light. This difference in transformation calls for a profound change in our notions of time and of simultaneity since the time depends on the frame in which it is measured. Two events considered to be simultaneous in one frame will not, in general, be so seen in another.

The relativistic transformations imply a velocity addition law: if an object moves with a velocity v and the frame itself is moving with respect to a standard frame with velocity u (in the same direction), then the observed velocity of the object in the other frame is

$$v' = (v - u)(1 - vu/c^2)^{-1} .$$

[If the two velocities are not in the same direction, the transformation law is more complicated; we shall not discuss the more general law here.] From this transformation law we can obtain

$$c \mp v' = (c \mp v)(c \pm u)(1 - uv/c^2)^{-1}$$

Hence if $|v| < c$ we have $|v'| < c$. That is to say in all frames the speed would be less than the speed of light.

We may therefore distinguish three classes of objects[3]: those of the first class called "bradyons" which have speeds always less than c; and those of the second class called "luxons" which have speeds always equal to the speed of light. A third class of objects are those which exceed the speed of light: they must always travel with a speed exceeding the speed of light. The particles which belong to this third class are called "tachyons."

Tachyons have a space-like energy-momentum four-vector so that

$$E^2 < c^2p^2 .$$

Hence the square of the rest mass m_0 defined by

$$m_0^2c^4 = E^2 - c^2p^2 < 0$$

requires the "rest mass" to be imaginary. But both luxons which have zero rest mass and tachyons which have imaginary rest mass never come to rest! The energy and momentum are always real.

Transcendent Tachyons and the Reinterpretation Principle

Under relativistic transformations the energy and momentum of tachyons change according to the familiar law:

$$E' = \frac{E - pu}{\sqrt{1 - u^2/c^2}} \; ; \qquad p' = \frac{p - Eu/c^2}{\sqrt{1 - u^2/c^2}}$$

Since the frame velocity $u < c$ and $c^2p/E = v > c$ there is always a velocity

$$u_0 = c^2/v = E/p$$

of the frame for which we get

$$E' = 0 \; ; \qquad p' = |m_0|c \, .$$

This may be called a "transcendent state" of the tachyon in which it carries no energy but travels with infinite speed.[4] There is an infinity of such states which correspond to the orientation of the momentum. While the tachyon has infinite speed in this frame in almost any other frame it would have a finite velocity.

If we however consider the purely geometric transformation of the energy-momentum, we would be forced to conclude that there are other frames in which it would have negative energy. But a negative energy particle would violate our notions about energy and its flow: Such objects provide us apparently with the possibility of infinite sources of energy! There is a corresponding difficulty with the temporal ordering of events along a tachyon trajectory. If A and B are "events" along the tachyon trajectory, A would precede B if $t_A < t_B$. In some other frame they would have other values t_A' and t_B'. There are even some frames in which $t_A' > t_B'$. In other words the tachyon seems to go backward in time. Both these seem to be difficulties with tachyons being admitted as physical particles. But these are not unrelated problems: one sees that when $t_B' < t_A'$ the tachyon has negative energy. Only negative energy tachyons go backward in time.

But this, in turn, implies that as long as we relate particle emission to loss of energy by a "source" and particle absorption to gain of energy by a "detector" emitted particles always go forward in time. The only novelty with regard to tachyons is that the role of "source" and "sink" are dependent on the observer. This is the "reinterpretation principle" for tachyons.[3] It is related to the ideas of Dirac, Stückelberg, Wheeler and Feynman on positrons as electrons going backwards in time,[5] but here this is a physical occurrence and not a convention. If tachyons carry charge or baryon number the reinterpreted particles will be antitachyons.

The Dazzling Tachyon Sky

The preceding considerations point out that the absence of tachyons in an experimental situation with possible tachyon emitters is a frame-dependent condition. What is emission by a source S in the frame Σ may be seen as absorption by a detector S' in the frame Σ'. This is a startling result: for light, a dark night sky is seen as a dark sky by every observer. But a tachyon-less sky for one observer may be seen as having tachyons by a moving observer!

Let us assume that we have a frame Σ_0 in which we have no incoming tachyons in the space except for any that may be emitted by sources S_1, S_2, etc., at our control. So if we have detectors D_1, D_2, etc., they will not detect ambient tachyons. Let us now consider any moving observer in a frame Σ_1. The observer sees most of the tachyons emitted by S_1, S_2, etc., as being emitted, but those in a preferred cone as being absorbed by S_1, S_2, etc. If the relative velocity between Σ_1 and Σ_0 is u and the tachyons initially had a momentum p and energy E then this cone has a half-opening angle θ' such that

$$\tan \theta' = E^{-1}(1-u^2)^{-1/2}(p^2u^2 - E^2)^{1/2} .$$

This incidentally means that if the observer in Σ_1 had his own perfect detector within this distinguished cone he will see incoming tachyons from space! What is more, the number of these tachyons is limited only by the efficiency of the detector. We have therefore potentially infinite flux of tachyons incident on any detector in Σ_1. There is a dazzling brilliance in the tachyon sky in Σ_1. This is true for any frame other than Σ_0. Hence at most we can have one preferred frame in any locale where the tachyon sky is dark. In every other frame there is an ambient flux.

Search for a Preferred Frame

After many decades of search for motion with respect to a preferred frame we now have the possibility of such an experiment. Let Σ_1 be any frame in which we have suitable tachyon detectors. Then there will be a net momentum transfer to the detector which will, in general, depend on both the direction of the normal to the detector surface $\underline{n}$ and the direction of the relative velocity $\underline{u}$ of Σ_1 with respect to the preferred frame Σ_0. It will acquire a maximum value when $\underline{n}$ coincides with the direction of $\underline{u}$.

Just as in the Michelson-Morley experiment[6] we expect the direction of $\underline{u}$ to change as the earth rotates and revolves around the sun. So we expect to have both diurnal and seasonal variations of the "tachyon stress."

The tachyons contributing to this stress are all soft tachyons: they all have energy less than

$$E_1^{\bullet} = \frac{u}{\sqrt{1 - u^2/c^2}} \, |m_0| c^2$$

and a momentum less than

$$p_1 = \frac{1}{\sqrt{1 - u^2/c^2}} \, |m_0| c$$

in absolute magnitude. So we must devise a method which depends on the tachyon stress rather than the detection of single events.[7] No such experiments have been done so far.

Concluding Remarks

The existence of such a tachyon preferred frame of reference involves no violation of the principles of relativity. This case is no different from the detection of the ambient 3°K blackbody radiation[8] which defines a preferred local galactic frame. There is no definitive reason to expect that these two preferred frames have to be the same.

Once the existence of the saturating tachyon flux in certain cones in any non-preferred frame is accepted it becomes impossible to devise an experiment in which tachyon "signals" in these directions are an essential part. All of the thought experiments that have been devised to demonstrate the incompatibility of tachyons with relativistic physics do employ the possibility of such signals[9]: therefore they are all to be abandoned.

The test for such a preferred frame would be an excellent method of verifying the existence of tachyons; and our notion with respect to this frame would be of considerable interest.

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