NEWTON's First Law and the Existence of Free Tachyons

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Abstract. NEWTON's first law prohibits the coupling of free tachyons to ordinary matter, if it is interpreted as selection rule interdicting emission without change of the rest-mass of the emitting system.

Das erste NEWTONsche Axiom und die Existenz freier Tachyonen

Inhaltsübersicht. Das erste NEWTONsche Axiom verhindert die Kopplung freier Tachyonen an gewöhnliche Materie, wenn es als Auswahlprinzip angesehen wird, das die Emission von Teilchen ohne Änderung der Ruhmasse des emittierenden Objekts verbietet.

It is well known that emission or absorption of real particles of real rest-mass is tied to a change of the rest-mass of the emitter or absorber, respectively. Two points on a mass shell may be connected by a space-like momentum vector only. In classical special relativity theory this fact ensures that a single electron cannot emit photons, its motion is inert and its momentum constant. On the other hand, the emission of tachyons (i. e. particles with space-like four-momentum) is not interdicted by the conservation of rest-mass. A particle at rest in a chosen inertial frame may start to move by expelling tachyons without spending any rest energy, if it is allowed to emit tachyons. We are bound to wonder if it is impossible to observe NEWTON's first law at all (first paradox of inertial motion). The purpose of the paper is to show that this paradox may not be solved by reinterpretation procedures.

The tachyons in question are directed into the past of the incoming particle. By the so-called reinterpretation principle [1] we are told to interpret the process

$$\begin{matrix}\text{particle}\\ \text{at rest}\end{matrix} \rightarrow \begin{matrix}\text{particle}\\ \text{moving}\end{matrix} + \begin{matrix}\text{tachyon with}\\ \text{negative energy}\end{matrix}$$

not as emission, but as absorption of an antitachyon:

$$\begin{matrix}\text{particle}\\ \text{at rest}\end{matrix} + \begin{matrix}\text{antitachyon with}\\ \text{positive energy}\end{matrix} \rightarrow \begin{matrix}\text{particle}\\ \text{moving}\end{matrix}$$

We are also told to interpret a process as emission only if an energy condition for the tachyon holds. Now there are three possibilities.

1. The emission is an interpretation by the observer. The tachyon is interpreted as emitted, if it has positive energy in the observer's rest frame.
2. The tachyon emission is independent of the observer. Then the tachyon is emitted if it has positive energy in some preferred reference frame (e. g., the cosmological rest-frame of the universe).
3. The tachyon is emitted, if it has positive energy in the rest-frame of the initial state of the emitter.

All three possibilities will be shown to produce inconsistencies or paradoxes.

As to the first possibility, we shall neglect the fact that this form of the reinterpretation principle does not solve the manipulation paradox — if it solves any causal question at all —, we shall merely consider its implication for the inertial motion. Let us choose some inertial reference frame. Any particle in its ground state may emit tachyons of positive energy without changing the rest-mass of the state until it is at rest in the chosen reference frame. Any observer has to see the particle come to rest in his reference frame. That is a clear contradiction: two observers in relative motion cannot observe both the same particle at rest.

The second form of the reinterpretation principle does not lead to this contradiction, but nevertheless we are bound to observe tachyonic dissipation of energy in the preferred frame of reference. Any particle coupled to the tachyons will ultimately come to rest in this frame by ejecting its kinetic energy in form of tachyons. Newton's first law may only be observed for particles at rest in the preferred frame (second paradox of inertial motion).

The third form of reinterpretation allows emission only of tachyons of positive energy in the initial rest frame of the emitter. We postulate the selection rule

$$\eta^{ik}\, p_{i\,(\text{tachyon})}\, p_{k\,(\text{initial state})} > 0\,. \tag{1}$$

But this rule will be no restriction at all, because it depends on the choice of the system considered as emitter. Let us consider a box and a particle inside moving relative to the (massive) box. Let us assume we detect outside a tachyon emitted by the particle in the box. If we interpret the box as emitting system, then the tachyon has to obey (1), if the momentum of the system box + particle is inserted. If we interpret the particle as emitting system, this condition is changed because the momentum of the particle is not parallel to that of the box. To have a condition for the tachyon and not for the procedure of calling a system emitter, we have to fix the meaning of "emitter" — the only possibility being the choice of the elementary process — to condition it with (1).

Let us now take the elementary particle in question. We are left with the necessity of postulating (1) also for bound states, because in a bound state the elementary particles have no definite velocity, (1) is no condition if applied to the elementary particle only Finally we try to define the emitter as the smallest system for which a momentum oan be defined. This can be a free but not necessarily elementary particle. But also in this form the condition (1) gets us into trouble, because it is changed if the particle forms an intermediate bound state with another particle so that the momentum of the bound state has to be inserted in the condition (1):

In the rest-frame of the particle its momentum is

$$p_{(\text{initial})} = (M, 0)$$

and the emission of a tachyon would imply

$$p_{(\text{tachyon})} = \left(M - \sqrt{M^2 + q^2},\, -q\right),$$

$$p_{(\text{final})} = \left(\sqrt{M^2 + q^2},\, q\right)$$

by the momentum conservation. The process may be forbidden by the condition (1). Now we assume a second particle (called catalyzer) with momentum

$$p_{(\text{catalyzer})} = \left(\sqrt{m^2 + p^2},\, p\right),$$

$$p = \lambda q,\ \lambda \geq 1,\ m \leq M.$$

If it forms an intermediate bound state with the first particle, the momentum of the bound state is

$$p_{(1)} = \left(M + \sqrt{m^2 + p^2},\, p\right).$$

Now the process

$$p_{(1)} \to p_{(\text{tachyon})} + p_{(2)},$$
$$p_{(2)} = \left(\sqrt{M^2 + p^2} + \sqrt{m^2 + p^2},\ p + q\right)$$

is not interdicted by (1), $\eta^{ik}\, p_{i_{(1)}}\, p_{k_{(\text{tachyon})}}$ being positive. State 2 may now disintegrate into

$$p_{(2)} \to p_{(\text{catalyzer})} + p_{(\text{final})}.$$

The result is the catalyzer being restored to is original state, but the particle in question managed the emission of the tachyon in spite of the primary interdiction. The effect of the catalyzer lies only in the change of the condition (1). Its state is not changed, so it may be a vacuum excitation particle. In this way any tachyon gets permission without the interference of real particles and we are left with the first paradox of inertial motion. The main problem is the difference between the incoming particle and the emitting particle. We can postulate the interdiction of the emission of tachyons into the past with respect to the emitting particle only, so the emitted tachyons may not be conditioned by the state of the incoming particle.

The difference between incoming and emitting particle does not alter the interdiction of the emission of particles of real rest-mass, if the rest-mass of the incoming particle is restored. It does not alter the interdiction of the emission of particles of real rest mass with negative energy either, because the sign of the energy does not depend on the observer if the rest-mass is real.

Thus the dynamics of special relativity together with the possibility of observation of NEWTON's firts law for any velocity exclude the coupling of real tachyons to normal matter. Nevertheless tachyons may exist as virtual particles representing non-local interactions.

If we consider causal tachyons, then the coupling to these particles marks out a distinct system of reference (case 2). Causal tachyons define a second tachyonic null cone, which is not necessarily a plane as in our discussion. This null cone may be isotropic only in one inertial reference system. If this cone lies in our restframe near enough to the light cone, it may be quite difficult to detect the preferred frame effects connected with its existence. Bimetric theories of gravitation contain this case, and we may consider the gravitons as tachyons of such kind [2]. This question will be the subject of a further paper.

For a detailed list of references to the problem of tachyons see [3].

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References

[1] R. P. FEYNMAN, Phys. Rev. **76**, 749, 769 (1964).
[2] H.-J. TREDER, Ann. Physik, Leipzig (7) **20**, 194 (1967).
[3] E. RECAMI u. R. MIGNANI, Riv. Nuovo Cimento **4**, 209 (1974).

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