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Information Flow, Causality, and the Classical Theory of Tachyons

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Abstract

Causal paradoxes arising in the tachyon theory have been systematically solved by using the reinterpretation principle as a consequence of which cause and effect no longer retain an absolute meaning. However, even in the tachyon theory, a cause is always seen to chronologically precede its effect, but this is obtained at the price of allowing cause and effect to be interchanged when required. A recent result has shown that this interchangeability of cause and effect must not be unlimited if heavy paradoxes are to be avoided. This partial recovery of the classical concept of causality has been expressed by the conjecture that transcendent tachyons cannot be absorbed by a tachyon detector. In this paper we analyze the directional properties of the flow of information between two observers in relative motion and its consequences on the logical self-consistency of the theory of superluminal particles. We show that the above conjecture does not provide a satisfactory solution to the problem because it implies that tachyons of any speed cannot be intercepted by the same detector.

1. *Introduction*

It is well known that the theory of superluminal particles has been periodically called into play by problems related to supposed causality violations; this gave rise to the formulation of countless paradoxes that have been discussed and apparently resolved on the basis of the reinterpretation principle. For interesting review articles see, for example, Barashenkov (1975) and Recami and Mignani (1974).

It happened, however, that the application of this principle to the solution of causal paradoxes (especially those involving loops between observers exchanging tachyons) failed to recognize the role of the directional properties of information flow, in a sense which will be investigated in more detail in the following sections.

In this paper we shall attempt to clarify the meaning of exchanges of information between observers in relative motion within the frame of the classical theory of tachyons (Recami and Mignani, 1974). It will be shown that one of

the most conspicuous assumptions of this theory, i.e., the interchangeability of cause and effect, is to be at least partially revisited and corrected; it will also turn out that it is difficult to give a definition of the flow of information consistent with the theory of superluminal particles.

2. *Unambiguous Directional Properties of Information Flow*

There seems to be a basic difference between an elementary process (e.g., the exchange of a photon between two atoms) and the flow of information from a source to a receiver, namely, that the first process may admit of time reversal while the second does not. The importance of this point may be appreciated if we recall that the classical theory of tachyons has given up the "old conviction that judgement about what is 'cause' and what is 'effect' is independent of the observer" (Recami and Mignani, 1974).

Now, the flow of information from an observer A to another observer A', by the very meaning of this term, implies that (a) A' becomes aware of something he did not know before receiving the signal; and (b) this knowledge may influence his own future decisions. If one does not accept these implications, it will be useless even to talk of information exchanges or think we can meaningfully discuss them in the frame of any theory.

In the light of the foregoing we would like to revisit the interchangeability of assignments such as source and detector or cause and effect, as maintained by the theory of superluminal particles. To begin with, it should be made clear at the very outset what we actually mean by saying that 'A has supplied information to A'.' Several definitions may be given a priori. We may mean the following:

> *Definition* (1). A has *emitted* and A' has *received* a signal and *all* inertial observers agree on this statement. This is the orthodox view of ordinary relativity; there is no need to say that it is simply ruled out by the supporters of the tachyon theory.

The opposite position is the following:

> *Definition* (2). It is meaningless to distinguish between "real emitter" and "real receiver" since this is only a matter of reference frame.

This is the view expressed by the classical theory of tachyons; we believe that, if carefully analyzed with an eye to information exchanges, this position leads to serious paradoxes.

For the present we shall only mention a logical inconsistency which arises using programmable tachyon exchangers, as suggested by Kirch (1975) in a very interesting paper which deserves much more attention than it has received so far.

We present here a modified version of one of Kirch's arguments as a useful introduction to the present work.

Observer A uses a tachyon machine which at a certain time will emit one tachyon, following an autonomous decision of the operator. Another observer

A' operates a tachyon exchanger which he programmed as follows: It *emits* two tachyons if and only if it *receives* one; in all other cases it emits no tachyons. A' is moving at subluminal speed u with respect to A.

We shall call *transcendent* a tachyon that moves, relative to A, at speed v such that $uv > 1$, where the natural unit $c = 1$ has been used.

At a certain time, A decides to send one transcendent tachyon to A' and then expects A' to reemit the programmed two tachyons in response to the one received. But A' will never do that because, from his point of view, it *received no tachyon*; instead, according to A', a "spontaneous" (i.e., non-programmed) tachyon seems to *leave* A' himself, directed towards A where it will be absorbed. Let us also explicitly note that this oddity occurs with *transcendent* tachyons only.

It must be emphasized at this point that the paradox is not in the fact that A' did not behave as A expected him to do; the true paradox is that A' has been somewhat mysteriously "induced" by A to emit a "spontaneous" tachyon against his own program (we must apologize for the verbal conflict between "induced" and "spontaneous" but there is really no way to avoid it).

The way out of this paradox is not unique.

For example, it may be that, within a consistent tachyon theory, one should not assume the existence of *programmable* tachyon exchangers. This conjecture would easily explain the spontaneous emission described above but it would also rule out any possibility of exchanging information.

A simpler explanation, which saves the possibility of assuming programmable machines, follows from the observation that A', from his own point of view, *will actually emit no tachyon*, in accordance with his preselected program. Then, shifting back to the frame of observer A, we discover that A' will be seen by A *to not have absorbed the tachyon at all.*

The situation may now be recapitulated as follows. Definition (1) denies the very existence of tachyons. Definition (2) is not consistent with the existence of programmable machines unless, due to some as yet mysterious reasons, A' *is unable to absorb transcendent tachyons emitted by* A.

This incapacity of A' to intercept *transcendent* tachyons fired against him by A is just the new important result recently announced by Pavšič and Recami (1976). These authors have shown that this is a consequence of four-momentum conservation.

From our point of view, it is easy to see that this result follows from a definition of the flow of information which is intermediate between definitions (1) and (2) given above. To this end we shall assume that the meaning of the proposition "A has supplied information to A'" is the following:

> *Definition* (3). A has *emitted* and A' has *received* a signal; *not all* observers are required to agree with this statement but the involved observers A and A' will always do so.

This definition automatically rules out the possibility that information be carried from A to A' via transcendent tachyons.

The most interesting consequence of the Pavšič-Recami result or, equivalently,

of Definition (3) above is that it partly reestablishes an unambiguous distinction between emission and reception of information, contrary to what the classical theory of tachyons has been maintaining for years. By "partly" we mean that this distinction holds for the information exchangers A and A' but not for all observers.

In our opinion, the incapacity of A' to intercept transcendent tachyons, which at first sight seems to provide a convenient means of escape from a serious difficulty, is likely to produce exactly as many problems as it is able to solve. In the following section we shall analyze the consequences of this partial recovery of the causality concept.

3. *Logical Paradoxes Again*

As before, let A and A' be two tachyon exchangers moving at relative subluminal speed u. A is supposed to send a certain information to A': According to Definition (3) this implies that both observers agree that A' *receives* the signals emitted by A (i.e., tachyons are seen by both observers to propagate from A towards A').

Operator A, from his point of view, is allowed to send out information by using tachyons of *any* speed. We have learned, however, that if this information is to be intercepted by A', only nontranscendent tachyons should be used to convey the signal.

Now, we observe that transcendence is not an intrinsic property of a tachyon, nor is it a property of a tachyon with respect to a given reference frame. As can be seen from the transcendence relation itself: $uv > 1$, transcendence is a property of a tachyon with respect to a *pair* of frames A *and* A'. Moreover, it is symmetrical in A and A': It can be readily shown that $uv > 1$ implies $uv' > 1$, where v' is the speed of the tachyon with respect to A'. A and A' will always agree that a given tachyon is or is not transcendent.

Now, from the Pavšič–Recami result or from Definition (3) it follows that, according to observer A, a transcendent tachyon emitted by A himself cannot be intercepted by A'. This tachyon, then, *will proceed past* A' *out to infinity* (we assume that only two exchangers A and A' are involved in the process). It will be interesting now to shift to the frame of observer A' and see how the same process is seen to develop.

According to A' a superluminal particle comes in from infinity and travels past A' towards A, where it will be absorbed. And now the paradox.

According to A' the tachyon approaching from infinity cannot be intercepted "because" this tachyon "must" proceed towards A, where it will be eventually absorbed. Now, what is so peculiar with this tachyon that A' is unable to intercept it? Simply that this tachyon is transcendent with respect to the pair A' and A. But a moment of reflection shows that *any* tachyon (whatever its speed) approaching A' from infinity may be considered to be transcendent with respect to a suitable pair A' and A, provided the speed of A with respect to A' is adequately chosen.

The conclusion is that A' should not intercept tachyons of *any* speed

because he does not know beforehand whether the incoming particle will or will not be *later* absorbed by some observer A! Thus, the causal paradox pointed out by Kirch appears to have been only delayed by the trick of assuming that transcendent tachyons cannot be absorbed. At present we do not see any reasonable way out of this difficulty.

4. *Final Remarks and Conclusions*

It may be interesting to spend a few words on the fact that transcendence is symmetric but not transitive, in a sense that will be illustrated below. Suppose that A sends information to A' (by means of nontranscendent tachyons, in accordance with the preceding discussion). Immediately upon receipt of these signals, A' decides to pass that same information on to the collinearly moving observer A'', also by means of nontranscendent tachyons. There is then a flow of information from A to A' (on which both A and A' agree) and another flow of information from A' to A'' (on which both A' and A'' agree).

Then it would be nice to discover that the overall process corresponds to a flow of information from A to A''. But this is not always the case, since the speeds of the tachyons and frames intervening in this example can be so arranged that A'' may not agree with A that the latter is the original source of information.

In the kinematically simplified situation where the speed of A' relative to A is the same as the speed of A'' with respect to A' (let us call these speeds u), and if A and A' both emit tachyons of speed v (speed of each tachyon with respect to *its own* emitter) it can be shown by straightforward calculations that when

$$v > \frac{u}{1-(1-u^2)/(1+u^2)^{1/2}}$$

A and A'' do not agree that A is the primary source of the flow of information.

This is another example showing how difficult it may be to define consistently the flow of information within the frame of the tachyon theory.

The results of this paper seem to be in agreement with a previous work (Basano, 1976), where it was pointed out that macroscopic processes (which are characterized by concepts such as statistical behavior, entropy increase, information exchanges, time arrow) cannot be treated on the same foot as elementary processes, to which time reversal usually applies. This surmise, however, has been criticized by Pavšič and Recami (1976) in their interesting paper referred to above.

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