Causality Effects of Particles That Travel Faster Than Light

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This paper comments on a recent paper by Feinberg and describes an experiment in which an effect would precede its cause if there were particles that travel faster than light.

In a recent paper, Feinberg[1] studied the possibility of constructing a Lorentz-invariant quantum field theory describing particles (which he called "tachyons") that travel with a velocity greater than that of light in vacuum. He discussed several of the rather unusual properties of such particles, if they existed. One most important consequence of their existence, however, was discussed with insufficient thoroughness: the possibility of reversing the temporal order of cause and effect.[2]

As Feinberg pointed out, the existence of tachyons would permit the following experiment. At time t_0 in the laboratory, atom A is in an excited state at rest at x_1 and atom B is in its ground state at x_2. At time t_1 atom A descends to the ground state and emits a tachyon in the direction of B. Let e_1 be this event at t_1, x_1. Subsequently, at $t_2>t_1$, atom B absorbs the tachyon and ascends to an excited state; this is event e_2, at t_2, x_2. At $t_3>t_2$, atom B is excited and A in its ground state. Now for an observer traveling with an appropriate velocity (less than that of light) relative to the laboratory, the events e_1 and e_2 appear in the opposite order in time. He describes the experiment by saying that at t_2' atom B spontaneously ascends from the ground state to an excited state, emitting a tachyon which travels toward A. Subsequently, at t_1', atom A absorbs the tachyon and drops to the ground state.

It is clear from this that what is absorption for one observer is spontaneous emission for another. But if quantum mechanics is to remain intact (and we hope to be able to detect such particles) then there must be an observable difference between them: The first depends on a *controllable* density of tachyons, the second does not. In order to elucidate this point, let us repeat the above experiment many times over.

Let atoms A and B be shielded from one another, except at randomly selected time intervals. Then the laboratory observer will measure a statistical correlation between events e_1 and the subsequent events e_2. To be specific: If he opens a shutter on a box containing excited tachyactive atoms A at times chosen by consulting random tables, he will find a correlation between these times and the times at which recoil measurements on atoms B show significant deviations from background. He concludes that events e_1 and e_2 are causally related, with e_1 as the cause because it is controlled by the random tables.

The traveling observer must detect the same correlations, and on the basis of the same reasoning he must also conclude that e_1 is the cause of e_2. The statistical correlation of e_2's with e_1's selected at random, rules out that all along e_2 occurred spontaneously. But for him the correlation in time is such that the e_2's occurred *before* the e_1's. Hence he is forced to the conclusion that in this experiment the effect preceded its cause.

My purpose in pointing out this consequence of the existence of tachyons is not to argue that their existence is either impossible or logically contradictory. Nor would their existence destroy causality. It would simply produce occasions on which the temporal order of cause and effect is reversed. It would, in principle, make precognition experiments possible. But contrary to some discussions in the literature,[3] such an eventuality, although contrary to the accepted generalizations based on all our past experience, is not *logically* contradictory. The notion of cause and effect is defined by invariant (or statistical) correlation of the latter with the former. We distinguish the cause from the effect by its independence, e.g., by randomizing its occurrence or nonoccurrence. The temporal order of the two is an *observational* fact. We may not believe that new experiments will ever find effects that precede their causes, but if they do causality itself is not thereby endangered.[4]

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[1] G. Feinberg, Phys. Rev. **159**, 1089 (1967).

[2] Such a phenomenon is sometimes called "sending a signal backwards in time." Whether this is an appropriate phrase in the present instance of statistical correlations only, is a question of semantics.

[3] See, e.g., D. Bohm, *The Special Theory of Relativity* (W. A. Benjamin, Inc., New York, 1965), p. 158.

[4] It is therefore not really correct to label the canonical arguments for dispersion relations simply "causality." They refer to the experimentally established property of causality that causes always precede their effects.