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Tachyons and the Arrow of Causality

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Causal cycle experiments are shown to be valid indictments of any tachyon theory which allows all parts of the cycle to occur. This is to be contrasted with claims to the contrary made in a recent paper by Parmentola and Yee. A means of uniquely determining the Lorentz-invariant causal direction of a beam is described.

I. CYCLE EXPERIMENTS

A set of experiments in which a tachyon beam is sent from apparatus 1 to apparatus 2, which is triggered by that beam to send a beam to apparatus 3, etc., can result in a beam arriving back at apparatus 1 *earlier* than the emission of the causally first beam. The causally last beam could then shut off the first apparatus so that it could not possibly emit the causally first beam. Such causal anomalies, which are self-contradictory loops, have been the subject of much discussion.[1] In a recent article,[2] these causal anomalies have been criticized, the authors claiming that there is no anomaly even if the cycle of experiments is performed. It is implied that the observers involved cannot agree that a causal loop resulted, i.e., that the observer who initiated the first emission cannot regard that emission as ultimately *causing* the last absorption in the causal chain (which, in his frame, occurs earlier than the first emission). This line of reasoning seems to rely on the assumption that no unique causal direction exists for tachyons. However, once we realize that, despite the reinterpretation of emission (absorption) as absorption (emission), a well-defined Lorentz-invariant causal direction exists for tachyon beams,[3] then it is obvious that the causal anomalies which have appeared in the literature[1] are indeed valid indictments of any tachyon theory which allows the cycle to be performed. In fact, a Lorentz-invariant causal direction is not even necessary for the anomalies to provide self-contradictory experiments. If each apparatus of any of the anomalies is set to be triggered by the appropriate tachyon event (regardless of the causal connection of that event to any other event), the anomaly will lead to a paradox.[4] In other words, even if an event has a finite probability of being spontaneous, *proceeding at every step as if such an event is a causal reception leads to the contradictory loop.* In any of these anomalies, one may employ the absence of a causally initial beam as the trigger for a cycle of "silence," which produces an earlier (in the first observer's frame) event of silence. This would be a signal to the first observer to send the causally initial beam leading to a contradiction with no ambiguities, as described in detail in Ref. 4 for one such anomaly. It should be noted that the only successful refutations of the causal anomalies have introduced constraints which do not allow emission of some tachyons.[5]

II. CAUSAL POINTERS

We now construct a "causal pointer" which is, in fact, a modification of the causal test suggested in Ref. 3. Suppose an observer "sees" an emitter-absorber A absorbing tachyons. If these tachyons interact with ordinary matter, he can put up a thin screen by which they can be scattered. The detection of scattered tachyons will show that a beam is impinging upon the screen, and the screen may be made thin enough so that the unscattered part of the beam is appreciable. Thus, he could "see" the beam going through his screen and being subsequently absorbed by emitter-absorber A. In particular the tachyon beam may be a pulse of finite temporal duration. During the reception of the pulse, a screen is put in the way and A is subsequently closed and reopened, or a thick shield is placed on the A side of the screen. (The latter may be kept "closed" for a time which is short compared to the temporal duration of the pulse.) If the screen goes blank during this procedure, then the observer knows that the cause of the tachyon beam was the event at A, even though it was an absorption in his frame. (If the screen does not go blank then the event at A resulted *from* the tachyon beam.) We employ a thin screen and detector which are at rest in this observer's system and which are in tachyon ground states. This apparatus has a negligible effect on the beam, so a beam travelling between emitter-absorbers A and B will be found, by cutting the beam alternately on the A and B sides of the screen, to be caused by *either* the event at *A* *or* the event at *B*. Thus, a definite, well-defined, and Lorentz-invariant causal connection between the event at *A* and that at *B* will be determined, the tachyon beam being the causal agent. Every observer, in each of the proposed anomalies, can be supplied with such a "causal pointer" making the causal direction unambiguous and Lorentz-invariant.

III. CONCLUSION

In conclusion, the reader should be reminded that tachyons, as physically realizable entities capable of carrying information across spacelike intervals, are the subject of the anomalies. The "virtual" particles or exchanges which arise in series-type solutions of interaction problems as well as any waves obeying a Klein-Gordon equation may have spacelike four-momenta, however they cannot carry *information* across spacelike intervals. Thus, they do not yield any new conclusions about rigid bodies, action at a distance, etc.[1] *Tachyons can exist only if certain experiments cannot be performed, i.e., only if certain of the emitters will not work.*[5] Finally, I wish to remark that only if tachyons (which interact with tardyons) exist may the arrow of causality point in the opposite direction to the arrow of time. Under such circumstances the arrow of causality is well defined by use of a "causal pointer" for tachyon beams. (Naturally occurring events, connected by tachyons, will indeed result in tachyon beams if we take a large enough sample of tachyon-active material, cf. natural radioactivity.)

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[1] See O. M. P. Bilaniuk and E. C. G. Sudarshan, Phys. Today 22 (No. 5), 43 (1969), for a compilation of both published and unpublished arguments, and Ref. 5.

[2] J. A. Parmentola and D. D. H. Yee, Phys. Rev. D 4, 1912 (1971). The claim made in the literature (which they summarized here) that the reinterpretation principle rules out all anomalies which involve only one space dimension is simply not true; see Refs. 1, 3, and 4.

[3] The Lorentz invariance of causal direction was pointed out and a method of determining that direction was derived by R. G. Newton, Phys. Rev. 162, 1274 (1967). Also see G. A. Benford, D. L. Book, and W. A. Newcomb, Phys. Rev. D 2, 263 (1970).

[4] W. B. Rolnick, Phys. Rev. 183, 1105 (1969).

[5] O. M. P. Bilaniuk and E. C. G. Sudarshan, Phys. Today 22 (No. 5), 43 (1969); P. L. Csonka, Phys. Rev. 180, 1266 (1969); A. F. Antippa and A. E. Everett, Phys. Rev. D 4, 2198 (1971); and R. Fox, *ibid.* 5, 329 (1972).

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Nonlinear Duality Calculation of the Width of the $\pi\pi$ Diffraction Peak*

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We insert Regge-exchange amplitudes into the unitarity relation at intermediate energies. The resulting $\pi\pi$ absorptive part is then required to be dual to one with Pomeranchukon (P), ρ, and f^0 exchange. By assuming ρ and f^0 residue functions consistent with the dual-absorptive model, we can then calculate the P residue near $t=0$.

In previous papers,[1,2] a form of nonlinear duality, abstracted originally from the multiperipheral model,[3,4] was used to calculate the Pomeranchukon residue at $t=0$. In the present paper, we consider $t\neq 0$. In $\pi\pi$ scattering below the 3ρ threshold, our duality condition takes on the form[2]

$$\int_{s_0}^{s_1} ds \left[\sum_i b_i(t)\nu^{\alpha_i(t)} - \sum_{c=\pi,R} a^c(s,t) \right] = 0 , \quad (1)$$

where s, t, u are the usual Mandelstam variables, $\nu = \frac{1}{2}(s-u)/m_\pi^2$, and $b_i\nu^{\alpha_i}$ is the contribution of the Regge trajectory α_i, while a^π and a^R are the contributions of Figs. 1(a) and 1(b) to the absorptive part A. Here R stands for any accessible $\pi\pi$ resonance, and s_0 and s_1 are taken to lie at channel thresholds. In what follows we take $(s_0, s_1) = (4m_\rho^2, 6m_\rho^2)$, which coincide with the $\rho\rho$ and $N\bar{N}$ thresholds, respectively.[2]