Acta Physica Academiae Scientiarum Hungaricae, Tomus 37 (3), pp. 283—285 (1974)

TIRED LIGHT, LORENTZ COVARIANCE AND CONSERVATION PRINCIPLES

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(Received 18. V. 1974)

BYRNE and BURMAN have pointed out that the solutions of the Proca equation yield waves that propagate freely at constant frequency, and consequently is incompatible with the "tired light" hypothesis discussed previously by us [1,2]. Their assertion is correct, and our statement that waves propagating with decreasing frequency as a function of time (or distance) were solutions of the Proca equation in the Lorentz gauge was erroneous. This, however, should not be taken to imply that the Proca equation has no tired light solutions, or that the hypothesis necessarily violates Lorentz covariance. This may be illustrated as follows.

Consider the Klein—Gordon equation for a massive, neutral vector boson field:

$$(\Box + \mu^2)\psi_\alpha = (4\pi/c)J_\alpha \,, \tag{1}$$

where $\Box$ is the d'Alembertian operator, μ the rest mass of the transfer particle, and the J_α the sources of the field components ψ_α. This equation, equivalent to the Proca equation, for the free field is

$$(\Box + \mu^2)\psi_\alpha = 0 \,. \tag{2}$$

The standard solutions of Eq. (2) are of the form:

$$\psi_\alpha = (\psi_\alpha)_0 \exp(if_\alpha) \,, \tag{3}$$

where $(\psi_\alpha)_0$ is a constant and f_α is, for the moment, an arbitrary (vector) function of the components of the four vector x_α. To find the constraint on f_α such that Eq. (3) is a solution of Eq. (2), Eq. (3) may be substituted into Eq. (2) and the operations carried out, yielding,

$$\mu^2 = \left(\frac{\partial f_\alpha}{\partial x_\alpha}\right)^2 - i\,\frac{\partial}{\partial x_\alpha}\left(\frac{\partial f_\alpha}{\partial x_\alpha}\right) . \tag{4}$$

When Eq. (4) is satisfied, Eq. (3). will be a solution of Eq. (2) and Lorentz covariant since the real part of Eq. (4) is a scalar.

We now make the usual decomposition of x_α into space and timelike coordinates. Eq. (4) then reads

$$\mu^2 = \left(\frac{\partial f}{\partial x_j}\right)^2 + \frac{1}{c^2}\left(\frac{\partial f}{\partial t}\right)^2 - i\left(\frac{\partial^2 f}{\partial x_{j^2}} + \frac{1}{c^2}\frac{\partial^2 f}{\partial t^2}\right), \tag{5}$$

where the sum over j is understood. For the Lorentz gauge we have

$$f_j = \omega(t - x_j/c)\,. \qquad (6$$

In this case ω is independent of x_α for a given frequency, and

$$c = f(\omega, \mu)\,,$$

where μ is also independent of x_x. This solution is clearly incompatible with the tired light hypothesis. Consequently, either the Klein—Gordon equation, or the Lorentz gauge condition must be abandoned, *if* light is fatigued by the process of propagation. Of these alternatives, eliminating the gauge condition seems to us least unpalatable, so we proceed to construct tired light solutions to Eq. (2) on that basis.

Let us suppose, in conformity with the tired light hypothesis, that the solutions of Eq. (2) are of the form given in Eq. (3), but

$$f_j = \omega_0 e^{-\beta x} j(t - x_j/c)\,, \tag{7}$$

where ω_0 is a constant, c the velocity of propagation of the field, and β the "range" of the field (the distance at which the magnitude of the rest mass of the photon decreases to $1/e$ of its initial value). It should be noted here that, in general, Lorentz covariance of the field equations will be forfeited if solutions of the class of Eq. (7) are insisted upon. This is a consequence of the fact that c (which occurs in the d'Alembertian) may depend not merely on ω, but also on x_α. This situation may be avoided by requiring that c be a constant, that is, independent of *both* ω and x_α. Under this stipulation, Eq. (7) will be a solution of Eq. (2), if the constraint of Eq. (5), which now reads,

$$\mu^2 = \omega_0 e^{-\beta x} j\left\{\left[(t - x_j/c) + 1/c\right]^2 + 1/c^2\right\} - i\omega_0 \beta^2 e^{-\beta x} j(t - x_j/c)\,, \tag{8}$$

is met. Such solutions are Lorentz covariant (by virtue of the constancy of c), and thus the tired light hypothesis is susceptible of self-consistent formulation.

The relinquishing of the Lorentz gauge condition essential to the construction of Lorentz covariant, tired light solutions for Eq. (2) gives rise, however, to predictions of curious and disquieting phenomena. These stem from the fact that the equation of continuity is no longer satisfied for either the free field, or sources. The resulting non-conservation of energy and charge is, in our opinion, unacceptable on conceptual-metaphysical grounds, as it seems to imply creation and/or annihilation of energy and charge *ex nihilo*. If one rejects this proposition, yet wishes to preserve the tired light hypothesis, some sort of "continuous reconstitution" hypothesis, as we already suggested [2] appears inescapable. But the continuous reconstitution hypothesis, too, is not without undesirable properties. For example, it implicitly assumes that charge may be carried by the field in a suppressed, immediately unobservable state, and there is no plausible mechanism known whereby the "reconstitution" could take place. This, to our way of thinking, smacks very strongly of the most unacceptable characteristics of action-at-a-distance.

Nevertheless, repeated attempts to detect the hypothetical missing mass in recent years have all resulted in failure. This being the case, perhaps, despite its novel and disturbing features, the tired light hypothesis bears investigation by means of an experiment resembling that we have described.[2] Although the hypothesis may be conceptually distasteful, it does seem a workable solution to at least the missing mass dilemma. Moreover, unlike the experiments designed to detect the missing mass, it is amenable to direct laboratory falsification.

REFERENCES

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2. W. YOURGRAU and J. F. WOODWARD, Acta Phys. Hung., **30**, 323, 1971.