To be submitted to
Lett. Nuovo Cimento

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-77/52(P)
3 Novembre 1977

G. Dattoli, M. Mattioli and R. Mignani : MASSIVE PHOTONS AND TACHYON MONOPOLES.

Servizio Documentazione
dei Laboratori Nazionali di Frascati
Cas. Postale 13 - Frascati (Roma)

Laboratori Nazionali di Frascati
Servizio Documentazione

LNF-77/52
3 Novembre 1977

G. Dattoli, M. Mattioli and R. Mignani(*): MASSIVE PHOTONS AND TACHYON MONOPOLES.

ABSTRACT

We generalize Proca's equations to the case where both subluminal and superluminal charges are present. The consequent existence of two massive photons raises serious doubts on the possibility of electromagnetic interactions between bradionic and tachyonic charges.

We conclude that the hypotheses of tachyon monopoles and massive photons are inconsistent each other.

(*) Istituto di Fisica dell'Università, L'Aquila and INFN - Sezione di Roma.

The possibility of non-zero rest-mass for photons has been the object of many theoretical and experimental investigations[(1)]. The field equations describing a massive photon are, as well known, Proca's equations, which can be written in the Maxwell-like form[(*)]:

$$
\begin{aligned}
\underline{\nabla} \cdot \underline{E} &= \varrho - m^2 \varphi \\
\underline{\nabla} \cdot \underline{H} &= 0 \\
\underline{\nabla} \times \underline{E} &= - \partial H / \partial t \\
\underline{\nabla} \times \underline{H} &= \partial \underline{E} / \partial t + \underline{j} - m^2 \underline{A}
\end{aligned}
\qquad (1)
$$

with self meaning of symbols.

It was conjectured, some time ago, by Recami and one of the present authors (R. M.) that faster-than-light electric charges behave as magnetic monopoles[(2)]. Indeed, they introduced superluminal Lorentz transformations for the electric and magnetic fields, which allow to generalize Maxwell's equations to the case when both subluminal and superluminal electric charges are present[(2)].

The remarkable feature of the generalized Maxwell equations is that superluminal electric currents play to role of (space-like) magnetic currents[(2)]. The basic tool, in order to extending Maxwell's eqs. to tachyon charges, consists in the introduction of a "self-dual"[(2)(+)] e. m. tensor $T^{\mu\nu}$:

$$T_{\mu\nu} \equiv F_{\mu\nu} - i \overset{*}{F}_{\mu\nu} \qquad (2)$$

where $F_{\mu\nu}$ is the usual e. m. tensor and the dual $\overset{*}{F}_{\mu\nu}$ is defined as:

$$\overset{*}{F}_{\mu\nu} = 1/2 \, \varepsilon_{\mu\nu\varrho\sigma} F^{\varrho\sigma} \quad . \qquad (3)$$

(*) We use the metric (+---). Summation is understood over the repeated indices. Natural units ($\hbar$=c=1) and Gaussian rationalzed units are used.

(+) In the sense of complex-manifold theory: $T^{\mu\nu} = i \, \overset{*}{T}^{\mu\nu}$ see ref. (3).

In terms of $T^{\mu\nu}$, the Maxwell equations valid for both superluminal and subluminal charges read[2]:

$$\partial_\nu T_{\mu\nu} = j_\mu (s) - i\, j_\mu (S) \qquad (4)$$

Where s = subluminal and S = superluminal.

Let us apply a similar procedure to Proca's equations. They can be generalized as follows:

$$\partial_\nu T_{\mu\nu} = \left[j_\mu (s) - m^2 A_\mu (s) - i (j_\mu (S) - m'^2 A_\mu (S)) \right]. \qquad (5)$$

If we confine ourselves to requiring covariance under the proper Orthochronous Lorentz group, eqs. (5) are equivalent to the following ones:

$$\begin{aligned} \underline{\nabla} \cdot \underline{E} &= \varrho (s) - m^2 \varphi (s) \\ \underline{\nabla} \cdot \underline{H} &= \varrho (S) - m'^2 \varphi (S) \\ \underline{\nabla} \times \underline{E} &= - \partial \underline{H} / \partial t - \underline{j}(S) + m'^2 \underline{A}(S) \\ \underline{\nabla} \times \underline{H} &= \partial \underline{E} / \partial t + \underline{j} (s) - m^2 \underline{A}(s). \end{aligned} \qquad (6)$$

with clear meaning of the notation.

As one easily realizes, eqs.(6) describe a massive electrodynamics with (spacelike) magnetic charges.

A very appealing and expected result. However, eqs. (6) suffer with some troubles, which are absent in the case of generalized Maxwell's equations with zero-mass photons. The more serious one is that now two photons , one subluminal and the other superluminal,, are put in the theory. Indeed, as it is easy to realize (either by the very "duality principle" (see ref. (2)), or by applying to eqs. (6) the standard procedure to derive wave equations for $\underline{E}$ and $\underline{H}$), m' is the mass of the (faster than light) particle corresponding to the (superluminal) massive photon, and it is : $m^2 = - m'^2$ (as it must be). Obviously, the existence of two massive photons raises serious doubts about the possibility of electromagnetic interactions between subluminal and superluminal charges. Therefore, we are led to conclude that there is a basic incompatibility between the two theoretical ideas of tachyon monopoles, on one side, and massive photons, on the other side.

It is only a matter of experiment to decide whether nature made the one ore the other choice, or none of them.

REFERENCES.

(1) See e. g. : A. S. Goldhaber and M. M. Nieto, Rev. Mod. Phys. 43, 277 (1971); A. Barne and J. D. Scargle, Phys. Rev. Letters 35, (1975); L. Davis jr. , A. S. Goldhaber and M. M. Nieto, Phys. Rev. Letters 35, 1117 (1975); A. S. Goldhaber and M. M. Nieto, Sci. Am. 234, 66 (1976).

(2) E. Recami and R. Mignani, Riv. Nuovo Cimento 4, 209, 398 (1974); Lett. Nuovo Cimento 9, 479 (1974); Phys. Letters 62B, 41 (1976); Lett. Nuovo Cimento 9, 367 (1974); Lett. Nuovo Cimento 11, 417 (1974): Nuovo Cimento 30A, 533 (1975).

(3) E. J. Flaheerty, Hermitian and Kählerian Geometry in Relativity (Springer, 1976), p. 208.