Pramāṇa - J. Phys., Vol. 30, No. 6, June 1988, pp. 511–519. © Printed in India.

Spin and mass content of linearized Poincaré gauge theories

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MS received 12 January 1988; revised 22 March 1988

Abstract. A unified gauge theory of massless and massive spin-2 fields is of considerable current interest. The Poincaré gauge theories with quadratic Lagrangian are linearized, and the conditions on the parameters are found which will lead to viable linear theories with massive gauge particles. As well as the 2^+ massless gravitons coming from the translational gauge potential, the rotational gauge potentials, in the linearized limit, give rise to 2^+ and 2^- particles of equal mass, as well as a massive pseudoscalar.

Keywords. Gravitation; gauge theories; teleparallelism; rotons.

PACS No. 11·15

1. Introduction

There has been considerable interest in gauge theories of massless and massive spin-2 fields, in the recent past (Sinha 1984). Here we investigate the spin-two gauge fields of Poincaré gauge theory (Hehl 1980). In this theory the gauge potentials are a tetrad e_i^{α} and an anholonomic connection $\Gamma_i^{\alpha\beta} = -\Gamma_i^{\beta\alpha}$. The gauge field strengths are torsion and curvature, defined by

$$F_{ij}{}^{\beta} = \partial_i e_j{}^{\beta} - \partial_j e_i{}^{\beta} - e_i{}^{\gamma}\Gamma_{j\gamma}{}^{\beta} + e_j{}^{\gamma}\Gamma_{i\gamma}{}^{\beta}, \tag{1}$$

$$F_{ij\alpha}{}^{\beta} = \partial_i \Gamma_{j\alpha}{}^{\beta} - \partial_j \Gamma_{i\alpha}{}^{\beta} - \Gamma_{i\alpha}{}^{\gamma}\Gamma_{j\gamma}{}^{\beta} + \Gamma_{j\alpha}{}^{\gamma}\Gamma_{j\gamma}{}^{\beta}. \tag{2}$$

It is convenient to define the following contractions of the curvature and torsion:

$$F_{\alpha} = F_{\alpha\beta}{}^{\beta}, \quad F_{\alpha\beta} = F_{\gamma\alpha\beta}{}^{\gamma}, \quad F = F_{\alpha}{}^{\alpha}. \tag{3}$$

One can form three invariants quadratic in torsion (i.e. invariant under general coordinate transformations and spacetime-dependent Lorentz rotations of the tetrad):

$$\left.\begin{aligned} &J_1 = F_{\alpha\beta\gamma}F^{\alpha\beta\gamma}, \quad J_2 = F_{\alpha\beta\gamma}F^{\alpha\gamma\beta}, \\ &J_3 = F_{\alpha}F^{\alpha}. \end{aligned}\right\} \tag{4}$$

One can form six invariants quadratic in curvature:

$$\left.\begin{aligned} &I_1 = F_{\alpha\beta\gamma\delta}F^{\alpha\beta\gamma\delta}; \quad I_2 = F_{\alpha\beta\gamma\delta}F^{\alpha\gamma\delta\beta}, \\ &I_3 = F_{\alpha\beta\gamma\delta}F^{\gamma\delta\alpha\beta}; \quad I_4 = F_{\alpha\beta}F^{\beta\alpha}, \\ &I_5 = F_{\alpha\beta}F^{\alpha\beta}; \quad I_6 = F^2. \end{aligned}\right\} \tag{5}$$