IC/71/144

International Atomic Energy Agency
and
United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

TOPICAL MEETING
ON GRAVITATION AND FIELD THEORY

13 - 16 July 1971

(SUMMARIES)

MIRAMARE - TRIESTE
November 1971

SOME RECENT DEVELOPMENTS

R. Penrose

Birkbeck College, London, UK.

Some recent work by Newman and his collaborators has led to an alternative approach to the question of asymptotic symmetry groups for asymptotically flat space-time. Although at first sight this new approach seems physically obscure, there are reasons for believing that it may ultimately have deeper significance than the BMS group approach. It involves choosing "canonical cross-sections" of $\mathcal{I}^+$ for which $\sigma^0 = 0$. However, this can only be achieved in general with <u>complex</u> cross-sections. The resulting asymptotic symmetry group which naturally arises appears to be the complex Poincaré group. This requires physical interpretation: for example, a complex displacement corresponds to the addition of an intrinsic angular momentum per unit mass.

These ideas find natural expression within the theory of twistors and allow that theory to be extended from flat to asymptotically flat space-times. The use of complex numbers and holomorphic functions plays a vital role in twistor theory. The geometrical manifestation of complex structure emerges in connection with Kerr's construction of the shear-free null congruences in flat space-time and in Newman's generalization of this to asymptotically flat space-time. The shear-free condition has importance for the question of clear-cut wave propagation and to the nature of scattering by gravitational waves. One of the main aims of twistor theory is to provide a new formalism for quantized gravitational theory. The formalism is not based on points but on null lines. Consequently, quantization should result in the "smearing" not of light cones but of space-time points.

Flat space twistors are the spinors for SO(2,4) which is locally isomorphic to the conformal group. A twistor Z^α (and its complex conjugate $\bar{Z}_\alpha$) describes the momentum and angular momentum structure of a zero rest-mass particle with intrinsic spin $\frac{1}{2}\hbar Z^\alpha \bar{Z}_\alpha$, but Z^α involves an additional phase factor which can be interpreted as polarization. These eight real degrees of freedom are represented by the four complex components of Z^α. Orthogonality $Z^\alpha \bar{Y}_\alpha = 0$ corresponds to collision between the particles. The geometry of twistor space is, in a sense, dual to that of space-time. Zero rest-mass fields (spin $\frac{1}{2}n\hbar$) are described by contour integrals of holomorphic functions of Z^{α} (or of $\bar{Z}_{\alpha}$) which are homogeneous of degree -n-2. Quantum scattering amplitudes for wave packets described by such functions may be evaluated by performing contour integrals in many twistor variables. Each such contour integral may be represented by a graph. Quantum electrodynamics in the high-energy limit can apparently be correctly described in this way, but rest mass and gravitational interactions (which break conformal invariance) have yet to be incorporated correctly. It is hoped that the generalization, suggested by Newman's work, of twistors to asymptotically flat space-time may provide the necessary clue. Asymptotic twistors form a four-complex-dimensional Kähler manifold of signature (++--).

REFERENCES

B. Aronson, R. Lind, J. Messmer and E. Newman, "A note on asymptotically flat spaces" (preprint 1971).

E.T. Newman, E. Couch, K. Chinnapared, A. Exton, A. Prakash and R. Torrence, J. Math. Phys. 6, 918 (1965).

I. Robinson, J. Math. Phys. 2, 290 (1960).

R. Penrose, J. Math. Phys. 8, 345 (1967).

R. Penrose, J. Math. Phys. 10, 38 (1969).

R. Penrose, Int. J. Theoret. Phys. 1, 61 (1968).

R. Penrose, article in a Festschrift dedicated to J.L. Synge (to be published).

R. Penrose, article in a Festschrift dedicated to J.A. Wheeler (to be published).

R. Penrose and M. McCallum, "Twistor theory: an approach to the quantization of fields and of space-time" (preprint 1971).