

# Non-Locality, Causality and Aether in Quantum Mechanics

J. P. VIGIER, Paris

Laboratoire de Physique Theorique, Institut H. POINCARÉ

With 16 figures (Received 1981 July 20)

## Introduction

Since MICHELSON's experiment, EINSTEIN has acquired, (in the general public) the reputation of being the destroyer of the Aether concept. This is a misconception: he only buried the "absolute" classical aether models. Indeed in a little known paper (EINSTEIN 1924, i.e. published after the discovery of general relativity) he describes the curved spacetime as a changing real material field (i.e. as a covariant aether) which carries gravitational interactions along the light cone.

This astonishing paper (entitled "Über den Äther") remained largely unnoticed due to EINSTEIN's defeat in the BOHR-EINSTEIN controversy and his subsequent isolation in the physics community. It anticipates by a few years EINSTEIN's well-known attempt to unify matter and gravitational field by considering particles as singularities in the  $g_{\mu\nu}$  field. This description, which implies the geodesic trajectories, constitutes (to my knowledge) the only materialistic explanation of the objective nature of the laws of motion which now naturally result from the local continuity of the gravitational field. This description of matter as part of extended fields evidently conflicts with the irreducible unsurpassable statistical character attributed by BOHR to the waves of quantum theory. This is natural. Already EINSTEIN's description of probability as limit of distributions induced by subquantal stochastic processes had led (after 1927) to the famous epistemological divorce between Relativity and the Copenhagen Interpretation (CIQM) of Quantum Mechanics.

The aim of the present report is to revisit EINSTEIN's 1924 ideas in the light:

- a) of recent developments in the Stochastic Interpretation of Quantum Mechanics (SIQM)
- b) of the growing experimental evidence in favor of non-local interactions in recent experimental tests of the EINSTEIN-PODOLSKY-ROSEN (EPR) paradox.

In other terms we are going in successive sections

- A) to add to the usual  $g_{\mu\nu}$  terms stochastic  $\tilde{\delta}g_{\mu\nu}$  terms and describe spacetime as a real subquantal covariant random medium, which implies subquantal fluctuations at the velocity of light,
- B) to show that the corresponding Brownian like motions of the classical extended model of spinning particles satisfy the relativistic generalisation of NELSON's form of NEWTON's law i.e.:

$$m(D_c v_a - D u_s) = F^+ \quad (0-1)$$

where  $D_c$  and  $D_s$  represent drift and stochastic derivatives,  $v_a$  and  $u_s$  drift and stochastic four velocities,  $F^+$  the external force.

- C) To demonstrate that the non-locality recently connected with quantum mechanics in the theoretical analysis and experimental tests of the EPR paradoxon can be interpreted in this extended gravitational model since one can deduce from it the SIQM, the superluminal propagation of the quantum potential and the causality (in EINSTEIN's sense) of quantum phenomena.

Indeed this new possible unification of gravitation and quantum theory at the microscopic level

- 1) interprets the non-local interactions predicted by wave mechanics and describes the EPR paradoxes as action at a distance between spacelike separated particles.
- 2) implies possible new experimental tests which would help to choose between CIQM and SIQM.

## 1. EINSTEIN'S Random Aether Model

A) The idea to use random fluctuations of the  $g_{\mu\nu}$  field (considered by EINSTEIN himself (EINSTEIN 1924) to be a possible representation of a real all pervading material field) as the origin of the real quantum forces which justify the stochastic interpretation of quantum mechanics is not new in the literature. Indeed EINSTEIN's ideas on the question were reactivated by JANOSSY (1972) who considered the cosmological term  $\Lambda g_{\mu\nu}$  in:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = X T_{\mu\nu} \quad (1-1)$$