Quantum Field Theory for a Rotating Observer.

G. DENARDO  
Istituto di Fisica Teorica dell'Università - Trieste  
Istituto Nazionale di Fisica Nucleare - Sezione di Trieste

R. PERCACCI  
Istituto di Fisica Teorica dell'Università - Trieste

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Summary. — In the context of the problem of inequivalent quantizations, we study the case of a real massive scalar field in flat space, as perceived by a rotating observer. It is shown that, in the case of uniform rotation, the creation-annihilation operators are the same as those of an inertial observer, while, in the case of nonuniform rotation, a new vacuum state arises which is a superposition of couples of Minkowskian particles with opposite angular momentum along the axis of rotation. Comparison is made with the case of a linearly accelerating observer.

It is not trivial to say that the vacuum state of ordinary quantum field theory appears such also to noninertial observers. Indeed several papers have been published in the last few years, dealing with Minkowskian models in which typical curved-space-time effects turn out.

Such effects can be grouped into two categories:

I) Mere observer-dependence effects, such as inequivalent quantizations following from the use of different co-ordinate systems (1-4). It turns out that the definition of particle given by a noninertial observer does not agree with the usual one, so that for instance the « Minkowski vacuum » is perceived by

a uniformly accelerating observer as a thermal bath with definite temperature. It is clear, however, that the v.e.v. of the energy-momentum tensor vanishes in this case and this is a covariant, observer-independent statement.

II) «Truly physical» effects, such as vacuum polarization and real particle production. These can be achieved in Minkowski space-time by imposing some Poincaré-symmetry-breaking boundary condition, e.g. the vanishing of the field on a moving barrier (the mirror) (15-8). Both effects are best studied by means of the energy-momentum tensor, however the number of created particles can be computed by means of Bogolyubov transformations when an initial and a final static region exist. There is a particular case, that of a hyperbolic mirror trajectory, for which \( \langle 0 | T_{\mu\nu}| 0 \rangle \) vanishes, though particles are created (7,8).

It is our aim to present here some results concerning the following problem: how does a rotating observer see a quantum scalar field? Only effects of the first kind will be investigated, and in a subsequent paper we wish to extend the calculations to the case in which nontrivial boundary conditions are imposed, so that effects of the second kind might turn out. We will have to confront the normal modes of the field for a rotating observer with those of a nonrotating one and, in order to simplify things, we will not use plane waves but cylindrical waves. Obviously, as long as we restrict ourselves to nonrotating cylindrical co-ordinates, our particle concept is perfectly equivalent to that of the Minkowski particles, except that we use eigenstates of Hamiltonian, momentum along z, angular momentum around z.

The formulae are not given explicitly for the nonrotating case, but can be recovered from those given by simply putting \( \Omega = 0 \) (e.g. the normal-mode functions \( U_{k\xi m} \) appropriate to the nonrotating observer are obtained from eqs. (7), (6) by setting \( \Omega = \dot{\Omega} = 0 \)).

To set up the reference frame which is appropriate to a rotating observer, start from cylindrical co-ordinates \( (t, z, r, \theta) \) and perform the transformation

\[
\varphi = \theta - \int_{\tau}^{t} \Omega(t') dt',
\]

which is slightly more general than that treated, e.g., in ref. (6,10) in that here

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