INTERTIAL FORCES IN DIRAC'S VACUUM

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In Dirac's version of classical electrodynamics with the gauge $A_\mu A^\mu = k^2$, the vector potential may, following Dirac's suggestion, be interpreted as the velocity 4-vector of an electromagnetic ether. It is shown that the inertial forces generated by this ether are identical with the Lorentz force acting on a charged particle.

Key words: Dirac's vacuum, inertial forces, Lorentz force, Mach's principle.

Ever since the advent of the special theory of relativity in 1905 [1] the idea of a universal ether as a possible explanation for the propagation of electromagnetic phenomena has been considered a very suspicious one, to say the least. Even today, most physicists think that the ether hypothesis is not only obsolete, but incompatible with the relativity principle. A more precise statement, however, would be that it is impossible to detect motion at constant velocity through the ether. What use, then, is an ether which cannot be detected? The answer lies in the above statement itself: Without an ether, what does the expression "at constant velocity" mean? (constant relative to what?).
On the other hand, the ether has come back with a vengeance, albeit under a different name: the vacuum - logically enough, in the quantum version of electrodynamics. The fact that this new ether cannot be detected through any state of uniform motion of the observer - covariance, of course, does the trick - does not mean that it should always go unnoticed. The Lamb shift of the hydrogen atom is one of the most precise measurements in physics. One could argue that this is only a side effect of the vacuum, a ripple on Dirac's electron sea. Moreover, the true vacuum is plagued with an infinite energy density which is taken care of by the procedure of normal ordering. Is not the new ether, therefore, condemned to the same fate as the classical one? Even the more suggestive example of the Casimir effect, after all, can be viewed as a direct interaction between boundary elements. And, apart from such subtle side effects, the quantum (covariant) version of the vacuum is very similar to its classical model. Indeed, as a consequence of the Doppler effect, a charged particle moving at constant velocity through an isotropic (in some reference frame) electromagnetic radiation undergoes friction, unless the power spectrum of the radiation is identical with the zero temperature black-body spectrum \( \rho(\omega) \sim \omega^3 \). The suggestion that the universe might contain zero-point radiation with this interesting property was first made by Nernst [2] in 1916, after Einstein and Hopf [3] gave the expression of the frictional force - a typical case of a perfect fluid: no viscosity, the friction being proportional to the acceleration (as with the inertial force in Newton's law). All this is very suggestive of a physical medium, but how could one proceed from this? Where does this strange vacuum come from? Can it flow like a genuine fluid or undergo deformations like a solid? Could it be the subject of direct experiments? It should be clear from the above that the central problem here is the origin of inertia. This is where Mach's principle comes in: Inertia here is the result of mass there (the "universe") [4]. Some kind of retarded action (fields) would then build up the ether throughout space. The idea strongly motivated Einstein. Paradoxically enough, his starting point, the equivalence principle, led him