Mach's Principle, Earyon Conservation and Baryon Mass (*)

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Summary. — Mach's principle is viewed as being incorporated into relativity by means of Dicke's scalar field theory. The assumption is made, however, that the scalar field interacts only with baryonic matter. Then it follows that the baryon current obeys an equation of continuity. Furthermore, by adopting the steady-state model of the Universe, the baryon mass becomes determined by the scalar field. Thus, both baryon conservation and the origin of the baryon mass can be regarded as a consequence of Mach's principle. In order to ensure the unrestricted validity of the equivalence principle, one must allow for a pressure in the matter fields. Various cosmological consequences are discussed.

1. — Introduction and generalities.

In recent years the cautious opinion has been repeatedly vociferated, both in public and more often privately, that the clarification of elementary particle theory may ultimately necessitate the recognition of its link with cosmology. Quite apart from such interesting speculations as expressed, for example, long ago by Dirac (1), we may mention the recent attempt (2) to explain the apparent violation of PC-invariance in K° decay. In spite of the unavoidably esoteric nature of such investigations, it may be occasionally permissible to direct efforts in this direction, even though thus neglecting for a short while more pressing, down-to-earth problems. It is in this spirit that this paper has been written.

The idea that local properties of matter (i.e., of elementary particles) are determined by the Universe in the large, has been expressed in modern times

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by Mach (*). The influence of Mach's ideas on Einstein are well known, and it was a surprise that, apparently, Mach's principle did not become really incorporated into the theory of general relativity (**).

When we start to think of possible manifestations of cosmology in elementary particle physics, the two items that come immediately to mind are the mass of baryons and the conservation of baryon number. The first problem, i.e., the enormous mass ratio of baryons and leptons, should be related to Mach's principle. Concerning the second problem, it is clearly necessary to have a field coupled to the baryons in such a way that a locally conserved baryon current ensues. The «natural» candidate for this field would be a long-range (massless) vector field and indeed this has been suggested first by Lee and Yang (3). However, Dicke (4) argued convincingly that isotropy and homogeneity of the Universe is incompatible with the existence of a long-range vector field which has a nonvanishing cosmic average value. This of course does not rule out the possibility that baryon conservation is caused by a short-range (massive) vector field (5), but short-range fields have no cosmological significance.

We believe, and shall demonstrate on a simplified and nonquantized model that both problems mentioned in the preceding paragraph have a common cosmological origin and solution. The necessary starting point for such an investigation is, of course, the incorporation of Mach's principle into the underlying cosmology. Brans and Dicke (6) suggested recently that a gravitational theory compatible with Mach's principle can be constructed by combining a Jordan-type gravitational tensor field with a scalar field. In a subsequent paper Dicke (?) showed that this theory can be cast into a form in which the gravitational field appears as the conventional metric tensor while the scalar field \( \phi \) can be interpreted as a massless matter field. Further consequences of the theory were discussed by Dicke (8) in later publications.

(*) For a lucid historical review see, for example, R. H. Dicke: The many faces of Mach, in Gravitation and Relativity, H.-Y. Chiu and W. F. Hoffmann (editors) (New York, 1964).


