CURRENT SCIENCE — 50 YEARS AGO

POSTULATES IN THE RELATIVITY THEORIES OF GRAVITATION*†

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SINCE Thomson and Tait published their celebrated work which was known at Cambridge, as the Natural Philosophy of T and T′, there have been many theories of gravitation and many relativities. The first noted rebel against Newton was Mach and his clearer conceptions of space, time and inertia have considerably influenced modern research. During the last thirty five years we have had mathematical relativities due to Einstein, Milne, Synge, Page and Sir Shah Sulaiman. To this list may be added the relativities propounded by philosophers like Broad, Levy and others; but these relativities belong to a different region of thought as a remark from Alexander's work will show, *viz*., that 'Space is the Body of God and Time is His Soul'. During the last few years and particularly the last few months much basic work has been done on relativistic gravitation from the mathematical point of view. Important papers have been published by Milne, Robertson, Walker, Hoffmann and Whitrow. Although the treatment in some of these papers is obscured by unfair criticism a few of the conclusions reached go very deep and they explain the interconnections between different theories. One is amazed to see how results proved in the theory of groups more than thirty years ago come out useful in this connection.

In the Newtonian theory gravitation means attraction. In Einstein's theory gravitation is interpreted in terms of Gaussian curvatures for a Riemannian space-time. In Milne's theory gravitation is to be understood from the kinematical consequences of the cosmological principle. The fact is, as Eddington and Milne have stressed, that there is probably no such thing as a law of gravitation: but there are a number of gravitational situations. The gravitational situations are provided by the 'falling apple' and the shapes, sizes and motions of the celestial bodies. The atomic nature of matter is itself a gravitational situation but no theory has so far succeeded in explaining it. The macroscopic aspects of the world-structure provide many interesting gravitational situations such as the red-shift and structure of the nebulae and no modern theory of gravitation can be complete without a cosmology of its own. From the scientific point of view a cosmical situation is as important as the Kepler problem and cosmology can no longer be treated as a speculative attempt to reconcile God with gravitation. A gravitational situation is usually attributed to two sets of causes at work: one is recognised as the set of local causes and the other as that of distant causes. The laws of operation exclusively of the distant causes belong to the domain of cosmology. In the Newtonian theory the effect of the distant causes is summed up in the law of inertia according to which every body, in so far as it can, perseveres in its state of rest or of uniform motion in a straight line. This must be recognised as a law of Newton's cosmology. It furnishes a substratum of bodies in uniform rectilinear motion relative to each other. On the background of this substratum the local causes, which are called forces, are studied to obtain the inverse-square law. In Einstein's theory the flat space of the special theory was found to give the substratum but, later, the theory had to be modified and the substratum was found to be given by a non-static model of the universe of the Friedmann-Lemaitre type. The local causes in this theory are found to be responsible for a curved, Riemannian, space. Even in Milne's theory the classification of causes is made in this manner, the distant causes being responsible for the substratum of particle-observers with kinematical and statistical equivalence while the local causes explain the inverse-square law. The acceleration of a test-particle has been expressly split up by Milne into two parts: one due to the local causes and the other due to the distant ones.

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A gravitational situation may also be analysed, in contradistinction to the procedure of Newton, Einstein and Milne, into macroscopic local causes and

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microscopic local causes. The early attempts by Sir Shah Sulaiman to explain gravitation by means of gravitons and the similar attempt by Synge to explain gravitation by similar particles illustrate this procedure. Synge has evidently not made any progress with his hypothesis and Sir Shah, if I understand right, has now abandoned the gravitons-hypothesis. Any theory whose equations run close to those of Newton's may, in certain cases, give results more satisfactory than Newton's or than those of another theory running close to Newton's. In such a case the superiority of one theory over another can be judged only on the merits of the postulates. One should like to see a clear statement of Sir Shah's postulates so that one may compare them to Newton's. The postulates have got to be very carefully chosen as they are likely to land one into a contradiction. Page's work is an illustration of this. He started on Milne's lines but with particle-observers in a state of uniform acceleration relative to each other and when he found that the line-element of Special Relativity could not be obtained he arrived at the conclusion that his relativity had disproved Einstein's relativity. A mistake was in his postulate that the velocity of light is rectilinear and uniform even in the accelerated frame. The transformation that he claimed to have discovered was known to the students of the theory of continuous groups in 1904.

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Milne has introduced the idea of a particle-observer that is an observer who is located at a point, at any instant, like a particle. Every particle-observer is equipped with a theodolite to distinguish one direction from another, an apparatus for sending and receiving light-signals and a time-sense in order to distinguish whether an event E_1 took place before E_2, after E_2 or simultaneously with E_2. The observer is thus able to represent events by real numbers. It is assumed that such an observer can make observations only at himself. He also associates as a convention a constant c with his signals which enables him to define in a simple manner a space-time frame and also the transformation connecting it with the space-time frame of another observer. It may be noted that in the special theory of relativity laws of nature are supposed to run the same course with respect to observers in uniform relative motion but in the general theory the laws are supposed to be expressible by covariant equations with respect to Gaussian transformations. The Restricted Principle is in keeping with Milne's attitude, but according to him, the invariance with respect to Gaussian transformations and not with respect to particle-observers is a very stringent condition put by general relativity. Milne has therefore proposed the cosmological principle. If A and B are two of the particle-observers they are said to be kinematically equivalent when the totality of A's observations on B can be described in the same form as the totality of B's observations on A. A and B are said to be statistically equivalent when A describes the world including A and B in the same statistical terms as any B. If the observers possessing this two-fold equivalence are called privileged observers the cosmological principle says that corresponding to any moving particle P in the field of a privileged observer A there is another similar particle P in the field of any privileged observer B at the same instant. Milne initially adopted the hypothesis that his observers are in uniform relative motion. But Whitrow has been able to show that with a proper graduation of clocks this assumption can be dispensed with.

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It has been recently shown by Whitrow that Milne's cosmological principle can be replaced by a sample principle and the postulate of spherical symmetry applied by each particle-observer in his neighbourhood and not with respect to the entire universe. It is instructive to compare the content of the sample principle with that of the uniformity postulate used by Robertson. Starting from this postulate and with particle observers such as Milne's Robertson deduces the non-static line-element for the universe and also kinematical and statistical systems similar to Milne's. According to the uniformity postulate 'the description of the whole system as given by A in terms of his immediate measurements is to be identical with the description given by any other fundamental observer B in terms of his measurements.' The sample principle is concerned with observations in the observer's neighbourhood while the uniformity postulate is concerned with world-wide experiences. Walker has also deduced some of the results obtained by Robertson by using the postulate of spherical symmetry. Robertson has particularly stressed the necessity of superposing a law of gravitation on the kinematical system. On the other hand, Milne has proceeded to explain all gravitational situations as essentially kinematical situations. He has argued that it is not right to derive the material content of a non-static universe, as it is done in relativity, by using gravitational equations which account for both the local causes and the distant causes.

One upshot of all these researches is that if Milne is right, a theory of gravitation must be, in the last analysis, divested of conceptional terms and that if there is anything like a law of gravitation it must be tautological with some fundamental uniformity postulate of an observer's measurements in his own neighbourhood; and, if Poincaré is right, a uniformity postulate of this nature should not restrict the geometry of space-time.

Note (*added in proof*). The attention of the reader may be drawn to the recent paper by Milne and Whitrand in *Z. für Astrop.*, **15**, 5, 342 where other important references will also be found.

ANNOUNCEMENT

ALL INDIA SYMPOSIUM ON BIOLOGICAL, MEDICAL AND SOCIAL GERONTOLOGY AND THE IV NATIONAL CONFERENCE OF THE ASSOCIATION OF GERONTOLOGY (INDIA)

(December 19 to 22, 1988, at the School of Life Sciences, Jawaharlal Nehru University, New Delhi)

A symposium entitled "All India Symposium on Biological, Medical and Social Gerontology" will be held during December 19 to 22, 1988 at the School of Life Sciences, Jawaharlal Nehru University, New Delhi. The IV National Meeting of the Association of Gerontology (India) will also take place. The symposium will concentrate on the current researches in all aspects (academic and applied) of the field of ageing (Gerontology-Senescence). This multidisciplinary symposium is intended to make positive attempt to integrate new knowledge about ageing and promote greater communication between the community of individuals engaged in various aspects of ageing research in the country. The focus will be on applications of emerging knowledge and understanding in the field of gerontology for the benefit of human society in which problems of ageing population deserve more attention. The meeting will provide a forum where academic excellence and practical measures can complement each other, and will also make an attempt to make general public aware of the potential of ageing research; to increase the span of healthy productive life and to minimize the social, biological and clinical problems of age (senescence).

Papers for presentation are invited from biological, clinical and social researchers to produce a truly multidisciplinary forum for discussion of a wide range of subjects dealing with any aspects of age and ageing process.

For information, contact the convener, Professor Rameshwar Singh, School of Life Sciences, Jawaharlal Nehru University, New Delhi 110 067, India.