COSMOLOGY

Conformally Invariant Theory of Gravity

from a Correspondent

MOUNTING evidence against the simple steady state theory seems to have caused its last defenders, Hoyle and Narlikar, to abandon it. But their taste for controversy seems to be undiminished, and in two recent articles (*Mon. Not. Roy. Astron. Soc.*, **155**, 305 and 323; 1972) they show how to express the familiar Friedmann models in terms of their conformally invariant gravitational theory. This modification of the conventional approach has the effect of removing the big-bang from the models; in addition, Hoyle and Narlikar propose a new cosmological model.

The conformally invariant gravitational theory on which Hoyle and Narlikar's work is based was constructed in 1964 and is a generalization of general relativity. It is one of a class of theories into which the classical concept of a field—exemplified by the electromagnetic and gravitational fields —is not allowed to enter. The only variables admitted into theories of this type represent positions of interacting particles so that there is an economy of hypotheses. Supporters of direct particle theories, as they are called, claim also that it is illogical to have field theories which in principle admit source-free fields in view of the fact that reality is never ascribed to such fields. When the black-body background was discovered, for example, some cosmologists sought its origin in the creation of the universe whereas others looked for explanations in very distant objects; nobody took the background radiation to be a source-free field. This exhibits the redundancy of a field theory such as electromagnetism in which charged particles are thought of as consisting of nothing more than singularities which happen to exist in the fields, as against direct-particle theories in which the particles are fundamental and the field a mere mathematical device for assisting in calculating their mutual interaction. Direct particle theories can be constructed to correspond to all field-theoretic interactions. Frequently the change is largely formal; but the non-linear nature of general relativity gives rise to a greater difficulty of computing the corresponding direct particle interaction and to a theory which coincides with general relativity only when the number of particles involved is large.

This is an attractive feature of direct particle gravitation. It is in line with the ideas of Mach, who was struck by the fact that inertial frames in which Newtonian mechanics works, such as the Earth's surface (approximately), move uniformly or are at rest relative to the distant stars. He sought to ascribe the phenomenon of inertia to the influence of distant matter. Einstein's general relativity can be thought of as an unsuccessful attempt to formulate a theory of inertia and gravitation in which the coincidence between inertial frames and the distant stars (or better the distant galaxies) is inevitable. Hoyle and Narlikar's direct particle gravitation succeeds here, for it is only the large number of particles whose interaction is considered, including distant galaxies, which makes local inertial and gravitational properties take their familiar form.

The phrase "conformally invariant" in the title of the theory refers to the fact that the form of the theory is unchanged, not only when the coordinate system is changed so that the frames are not necessarily at rest (as is allowed by general relativity) but also when scale factors analogous to changes of units are introduced into the geometry of the world, and these scale factors are allowed to vary with position and time.

Advances in understanding often reveal the most cherished beliefs to be mere conventions. For example, the invariance under non-constant scale factors admits the possibility that the trenchant arguments which cosmologists sometimes use to emphasize the puniness of the solar system and the short time scale of evolution may not apply in our universe. Some conformal frames are of course far more convenient than others. Hoyle and Narlikar show that the conventional frame is that in which all protons have the same mass and in which general relativity is a good approximation to their theory.

All direct particle theories are time symmetric, because interaction takes place between particles separated by time as well as space. This seems to disagree with the experimental observation that retarded interactions maintain causality and that waves emanate from sources in an unsymmetrical fashion. Direct particle theories can nonetheless be reconciled with causality provided that the absorption properties of the universe satisfy certain conditions. Until the new developments the only cosmology which satisfied these requirements (among the models usually considered) was the steady state theory. A belief in direct particle interaction was Hoyle and Narlikar's published reason for continuing to work with the steady state cosmology in spite of the growing evidence against it from source counts.

The first of their two new articles develops these ideas and shows how the conventional big-bang models can be made to appear in a different conformal frame. They show that the big-bang is an artefact of the conventional theory which (if conformal transformation is valid) can be made to disappear. One effect of this is to allow conformal invariance to be tested experimentally. If the homogeneity and isotropy of the black-body background radiation are accepted as incontrovertible evidence of its primaeval origin, the big-bang will have to be accepted as a physical occurrence and conformal invariance will have to be abandoned.

Hoyle and Narlikar naturally follow a different plan. They reject the conventional cosmologies as models of the universe, although they are admissible as pictures of what goes on on a smaller scale, and develop a new cosmology altogether. They point out that a new model is needed because of the failure of conventional cosmologies to explain the tendency of matter to clump together in a large scale in galaxies. Moreover, they maintain that the failure of conventional non-steady state cosomologies to meet the absorber requirements, referred to earlier, is a fatal objection. This point is extremely contentious.

In their second article Hoyle and Narlikar point out some features which would be desirable in a new cosmological model and show how they are allowed by conformally invariant gravitational theory coupled with continual creation. In order to get the absorber properties which they find desirable, while allowing the evolution of the universe for which there is such a wealth of evidence, they show how to revive an idea which was discussed in the 1930s by Dirac and by Eddington. This idea relates the strength of the gravitational interaction constant to the number of particles in the observable universe. This number decreases as the expansion takes particles over the limits of interaction imposed by the finite velocity of light faster than new ones are created. Thus the strength of gravitation diminishes. This is of interest to geophysicists for it would allow the resolution of some of the difficulties of understanding the drift of continents as an effect of diminishing gravitational cohesive force.

It will be of interest to see how the details of the proposed new model work out, and whether they follow in detail from a complete gravitational theory which includes a mechanism for the continual creation. But it is already of great interest to record that even the recent modified forms of the steady state cosmology seem to have been completely and formally abandoned by their two foremost protagonists.