physical sciences

Gathered at the Midwest Relativity Conference in Cincinnati, Ohio

QUANTUM GENERAL RELATIVITY

The requirements of theory

Discoveries of the early part of the 20th century forced upon physicists the necessity of quantizing physical theories. In the older physics the possible variations of important quantities such as mass and energy were smooth and continuous; a body could have any energy and its energy could vary by any amount. In the modern physics of the microcosm, this turns out not to be so. Important qualities vary by discrete amounts called quanta, and changes come by jump instead of smooth progression.

Among the things a quantum theory of gravity should have, says Dr. Bryce S. DeWitt of the University of North Carolina, are a description of gravitational interactions among microscopic particles and a description of gravitational waves and their interactions. It should resolve difficulties of the classical theory concerning discontinuous processes and it should have the classical theory as a limit in the situation where things get so large that quanta are too small to matter any longer.

Though he feels there is still a good deal of work to be done, Dr. DeWitt feels that theorists are well on their way to such a theory. He sees major difficulties in problems involving probabilities and the solution of the difficulties of the classical theory. Others are not so sanguine. Dr. A. S. Komar of Yeshiva University asks, for instance, whether there are not reasons of physical principle to make the task extremely difficult if not hopeless.

SUPERSPACE

For general relativity

Einstein's general relativity allows space to be curved. As soon as curved space is allowed, it is possible to imagine any number of spaces, each with a different curvature. Which of them corresponds to the actual universe and whether the universal space had the same curvature throughout its history are serious theoretical questions.

Efforts to quantize general relativity have led some theorists, says Dr. John Wheeler of Princeton University, to the concept of superspace. Superspace is a mathematical construction that allows physicists to order all the possible three-dimensional spaces in such a way that they can be compared with one another in the way physical theories apply to them.

Superspace has an infinity of dimensions and contains within itself all possible three-dimensional geometries in a manner analogous to the way a three-dimensional cube can be imagined to contain within itself an infinite number of differently shaped two-dimensional surfaces.

Using superspace to study the basic geometrical principles of the cosmos may lead, says Dr. Wheeler, to an explanation of why the ordinary space we perceive has three dimensions and not some other number.

He compares this to the historical situation regarding the density of materials. The density of gold is 18.9 and in past centuries physicists just had to take that number for granted. With modern knowledge of atomic structure, one can calculate the density of gold or any other element. Likewise, says Dr. Wheeler, "we look forward to the day when we can calculate three-dimensionality and not take it as put in from the beginning."

COSMOLOGY

The mixmaster universe

Cosmologists of the last two generations have most often presented theories in which the universe expands. Now Dr. Charles Misner of the University of Maryland presents a model in which the universe bounces and wobbles as it expands.

If the universe is imagined as a kind of sphere centered on three mutually perpendicular axes representing the three dimensions of space, Dr. Misner's calculations lead him to suggest that as it expands over-all, the universe also flattens itself and rebounds in the direction of each of its dimensions in succession. That is, it goes to a pancake shape in one direction, rebounds to a sphere and then pancakes in a direction perpendicular to the original motion.

Dr. Misner describes the over-all motion, which takes eons of time, as "rather like kneading bread" and he calls this model the "mixmaster universe."

TIMEKEEPING

Back to infinity

In theories of the evolution of the universe, a grave difficulty is the so-called singularity, the point from which everything began. If one traces backwards the history of the expanding universe, one can come to a situation where the universe was very small and exploded, or one where the size of the universe was equal to zero.

Either of these situations is mathematically singular. It introduces abrupt breaks into the continuous variation of mathematical quantities and is, therefore, hard for calculation to deal with.

To avoid some of the trouble, Dr. Charles Misner of the University of Maryland has devised a time-counting method that effectively puts the singularity an infinite distance back in time and, therefore, beyond the range of time his calculations deal with.

Reasoning that no matter what timekeeper one used, either the rotation of the earth or the vibration of an ammonia atom, for two examples, there was a time in the history of the universe when these objects did not exist so their value as universal timekeepers is questionable. He proposes, therefore, to use the universe itself as a clock, counting time by the changes in its size. He uses the radius of the universe as his time gauge. Counting by the reciprocal of the radius, he achieves the result that the time when the radius was zero is an infinite distance in the past.