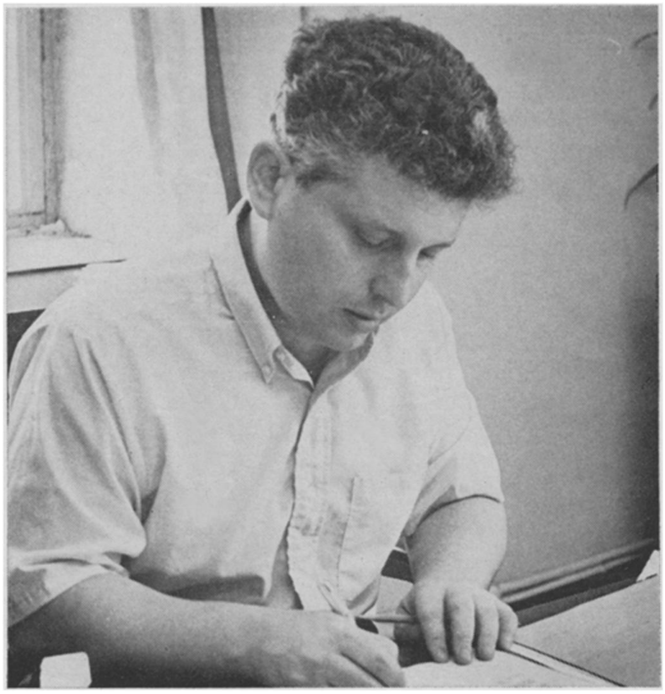
Princeton University

Wheeler: History determines particle properties.



Yeshiva University

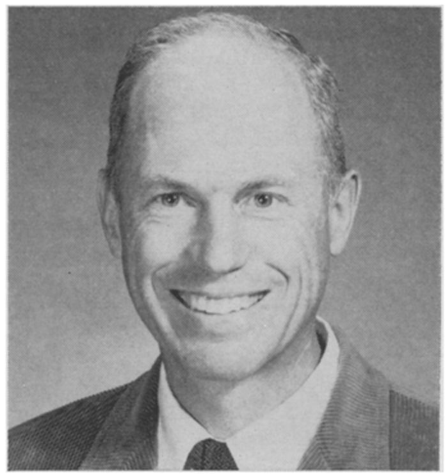
Komar: Almost forty years in the wilderness.

THEORETICAL PHYSICS

Particles and geometry

A concept called superspace may help to unite cosmology and particle physics

by Dietrick E. Thomsen



University of North Carolina

DeWitt: A lot of work ahead.

"Particles are nothing but geometry," said Einstein. The task that he left to his successors was how to make this apparent, how to fit his theory of the geometry of the universe, called general relativity, into the world of subatomic particles, and to show how the geometry relates to the characteristics of elementary particles.

Such a procedure is called quantization of general relativity. Among the subatomic particles important physical quantities cannot vary smoothly but must do so in discrete jumps called quanta and this is the most striking way in which the subatomic world differs from the macrocosm.

Over the last 50 years physicists have worked out successful quantum theories of mechanics and electrodynamics that reconciled those two branches of physics to the properties of the microcosm. A similar effort has been underway for general relativity, but it has not yet reached its goal.

Achieving the goal could unite cosmology and particle physics, bringing a deeper understanding of both.

A major problem is that general relativity is basically a different kind of theory from the two others. With both mechanics and electrodynamics, theorists could regard space and time as having a definite geometrical structure in which the activities concerned took place. In general relativity, however, the gravitational forces, which are the ones the theory mainly deals with, do not merely act in space and time; they determine its geometry as well. Thus space and time cannot be so easily used to order and label the events that take place. They are part of the action themselves, and theorists must always have an eye out for possible changes in the geometry as gravitational events go forward.

"Nearly 45 years after the introduction of quantum theory and nearly 40 years after the quantization of fields," says Dr. Irwin Goldberg of Drexel Institute of Technology, "almost no two people can agree on what is the proper approach" in the case of general relativity.

Therefore, when some 100 experts on general relativity, ranging from senior professors to a high school student, Lane Hughston of Dallas, who was first in this year's Science Talent Search, gathered at Cincinnati a few weeks ago for the Relativity Conference in the Midwest, quantization and how to achieve it were a major focus of interest and vigorous debate.

One approach to linking geometry

and particle physics leads to a mathematical concept called superspace, says Dr. John Wheeler of Princeton University. The concept aroused a great deal of discussion at the meeting, drawing about half the participants to an unscheduled afterhours seminar.

Superspace, says Dr. Wheeler, has an infinity of dimensions. In it all possible three-dimensional spaces are merely points. Einstein's theory admits that space can be curved but doesn't define the curvature. As soon as curved space is admitted, any number of three-dimensional spaces, with all manner of different curvatures, can be imagined. The problem is to sort these out to find which represents the actual universe.

In superspace, theorists can order these different three-dimensional geometries and study them. Seeing how the equations of Einstein's theory act in each of the three-dimensional spaces, theorists can sort out geometries that could apply to the known universe. Temporal sequences of these can be built up, and each sequence represents a different possible history for the universe.

Dr. Wheeler suggests that the characteristics of subatomic particles depend on these histories. "Particles in this universe," he says, "have properties unique to this history. If you look for another, you get different particles." In support of this, he points out that if you believe in an expanding universe, you can imagine a time near the beginning when the universe was too small to contain an object the size of a subatomic particle. Therefore one can argue that the so-called elementary particles are not something that was put in at the beginning, but that they developed out of the history of the universe the same way as more complex structures, atoms or molecules for instance, have developed.

But "how could one think of so ridiculous an idea?" asks Dr. Wheeler. "Why even think of different histories?" The answer lies in a basic characteristic of quantum physics. In a classical theory a given set of initial conditions can lead to only one definite result. In quantum physics it often happens that a given starting condition can lead to several results. An atom, for example, that has received some energy from the outside may have several ways available to get rid of that energy; which one a given atom happens to take is a matter of statistics and probability and cannot be predicted exactly in advance.

Likewise, says Dr. Wheeler, when one applies quantum mechanics to the history of the universe, one can have different outcomes. Study may show which one we have.

What actually is, says Dr. Wheeler, may be determined by some structure in the universe that is "submerged below our ordinary level of view, but carries all of particle physics." An analogy to this is the structure of atoms, which explains chemistry. Atomic structure was submerged below the level of view of chemists throughout the 19th century so that the chemists knew that certain chemical combinations took place, but did not know why these were possible and not others.

Knowledge of the substructure that Dr. Wheeler postulates may explain why an electron or a proton, for example, has a certain amount of mass and not some other amount. It could give meaning to some of the more abstruse characteristics of subatomic particles, which are so far really only names, and it might help physicists to understand the structure of the universe, answering such questions as why the space we perceive has three dimensions and not some other number.

Thinking along these lines has not gone far, says Dr. Wheeler. "The idea may be entirely wrong," he says, "but it's an encouraging concept."

Somewhat less encouraged is Dr. Arthur S. Komar of Yeshiva University. "Since 1930," he says, "we have been almost 40 years in the wilderness already." He wonders whether the special nature of general relativity may make it impossible to get a quantum theory that is any use. He insists on answers to such questions as: "What does it mean to quantize a classical theory?" and "Why is the game being played?"

Dr. Komar's caution arises in some measure from his study of the mathematical form of the theory. Classical general relativity expresses the relationships among physical quantities in certain ways. The question is whether the forms of these relationships can be conserved in going from the continuous world of the classical theory to the jumpy one of quantum theory, and whether a meaningful theory results if they are. All the relationships found in the classical theory need not be conserved, he says, but then the problem becomes which ones to conserve in order to arrive at a useful theory.

A more optimistic view is taken by Dr. Bryce S. DeWitt of the University of North Carolina, who has also done much work with superspace. He complains that "We have heard so often that we do not have a satisfactory quantum theory of gravity that outsiders have the idea there is no satisfactory quantum theory of gravity." Not so, he says. "We have already quite a lot and are no worse off than any other field theory." But to allegations that he thinks the job is already done, he replies: "Who doesn't think we have a lot of work ahead?" ◇