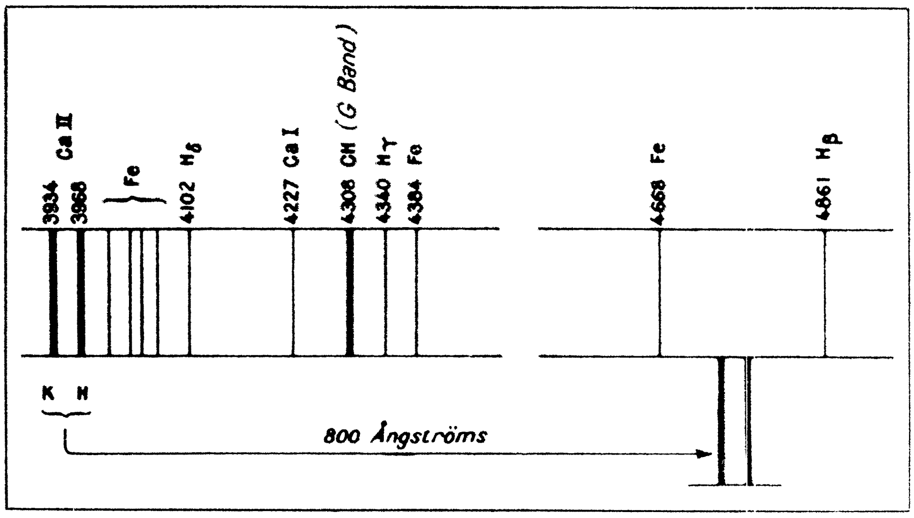
THEORETICAL PHYSICS

Gravity and infinity

An infinite gravity creates theoretical difficulties

by Dietrick E. Thomsen



When Sir Isaac Newton gave the world his universal theory of gravitation, he thought he had solved a problem. In a way he had, but in doing so he created several others that have been plaguing physicists ever since.

For 300 years physicists have discussed the nature of gravitation, its relation to cosmology and its place among other kinds of natural forces.

Up to now, all of Newton's successors, however much they have altered his theory, have agreed with him that gravitational forces have an infinite range. That is, no matter how far one body may be removed from another, they will still experience some gravitational influence from each other. It may be so small as not to affect their behavior in any measurable way, and it may make some theories hard to accept, but in principle it still is there.

One scientist troubled by inconsistencies attending infinite gravitational ranges is a professor at the University of Chicago, Dr. Peter O. G. Freund. He and two of his students, Aman Maheshwari and Edmund Schonberg, are contributing to the debate a theory—really two slightly different theories—in which gravitational forces have a limited range. Such a theory, if true, would lead to important consequences in cosmology, namely a pulsating universe, and some changes in theoretical if not experimental particle physics.

Dr. Freund cites two reasons for proposing such a theory. They relate to Albert Einstein's revision of gravitational theory, which currently has the most general acceptance.

In the first place, Einstein's theory gives reason to believe that the extent of the universe is finite. But Einstein's retention of the infinite range of gravitational forces creates a problem. "If you have an infinite gravitational range and the universe were finite," says Dr. Freund, "you can't ever convince yourself of the correctness of the theory."

So he proposes to limit the range of gravitational effects to the effective size of the universe, the extent of space that contains the bulk of the gravitating matter.

Dr. Freund is careful to ensure that in his theory the parts of the universe can all affect each other gravitationally, by making the range of gravity coincide with the size of the universe. In this way the actual effects of gravitational forces are not changed very much, but troublesome infinities go out of the calculations.

If the universe expands, the range of Dr. Freund's gravitation keeps up with it. But this extension of the range reacts back on the universal expansion in such a way that mathematically, at least, periods of expansion alternate with periods of contraction, and over eons one would see a pulsating universe.

The second reason has to do with difficulties encountered in quantizing Einstein's theory. In order for gravitational theory to take its proper place in particle physics, it must be worked out so that gravitational quanta exist, that is, particles that act as embodiments and carriers of gravitational forces, just as light quanta, or photons, carry electromagnetic forces. In quantizing Einstein's theory, says Dr. Freund, exceptions to mathematical rules occur.

Newton and his immediate successors developed a way of looking at the space around a gravitating body as if it were inhabited by an array of potential forces. These would become actual if another body were brought into the neighborhood.

This, the so-called force field, became a successful method of calculating the effects of gravity and later electromagnetism, although it begged the question of how the forces were mediated across empty space. In Einstein's theory space is the mediator of gravitational forces instead of simply the empty arena in which the forces appear. Einstein's space is a physical entity that can be bounded and curved. The presence of a gravitating body causes space to curve, and the curves govern the motion of other bodies that come near.

But Einstein's curvaceous geometry is hard to see. "In experiments," says Dr. Freund, "we measure the motion of matter rather than triangulate the universe." His theory dispenses with Einstein's geometry, makes gravity finite and contents itself, as Newton's did, with field equations to determine the forces and equations of motion to determine the dynamics of the bodies involved.

Modern particle physics gives Dr. Freund another approach to the force-mediation problem.

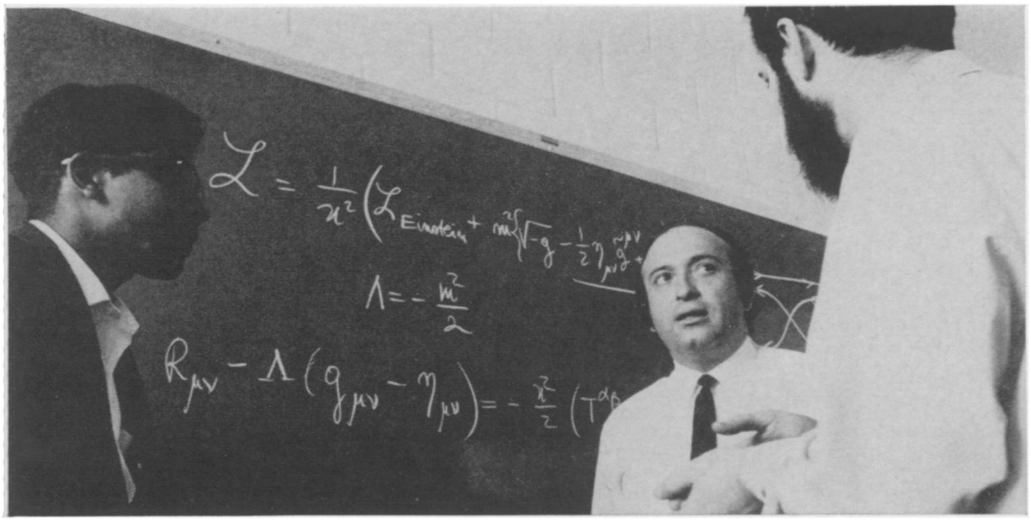
Certain particles, the so-called field quanta, embody natural forces such as electromagnetism, the strong nuclear force and, physicists believe though they have not seen its quanta, gravitation.

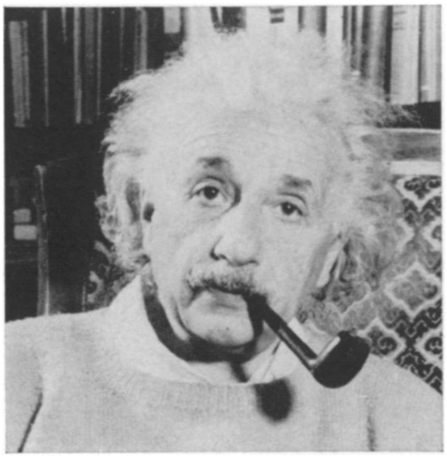
Forces are mediated in particle physics by having these quanta fly back and forth between the bodies concerned. In a somewhat similar way a Ping-Pong ball mediates a force between two paddles.

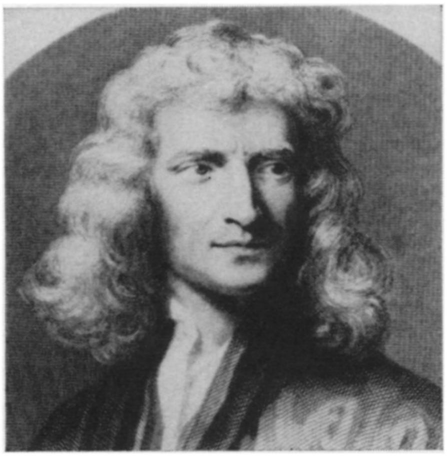
Theories of natural forces have had to be reworked to include these quanta. This can be done for Einstein's gravitation theory, but not without the mathematical problems Dr. Freund complains of when giving his reasons for submitting another.

The field quanta go by a rule that says that those that represent forces of infinite range, the photon for electromagnetism and the graviton for gravity in Einstein's theory, may not have a rest mass. The ones that represent short range forces—the only one now known for certain is the pion for the strong nuclear force—may have a rest mass.

But, says Dr. Freund, "in a finite universe the statement that the graviton mass is zero cannot be checked."







Spectrogram (left) shows shifts in a galactic spectrum; Maheshwari, Freund and Schonberg discuss equations for a finite gravity; Einstein's curved space and Newton's action at a distance meet in theory.

Univ. of Chicago

So Dr. Freund and his students give gravity a finite range and change theoretical particle physics by introducing a graviton which has mass. Since the range they give it is astronomical, their graviton's mass is small, on the order of 10^{-14} (one hundred-thousand-billionth) of a proton's. By comparison the mass of a pion is about one-eighth that of a proton.

All of this dos not change experimental particle physics very much. Dr. Freund's or any one else's graviton would be just too small to be recorded by present experimental techniques.

To find experimental evidence to decide among gravitational theories is very difficult.

The predictions about forces and visible effects in Dr. Freund's theory come out very close to those of Einstein. "No experiment that could be done within our galaxy," says Dr. Freund, "could distinguish between the two." But he has hopes for such distinction from studies of the red shifts of distant galaxies.

That the light reaching the earth from distant galaxies is reddened is considered by cosmologists to be evidence that they are all flying away from us. Everything flying away from everything else means the universe is expanding.

Each of the different gravitational theories makes a different prediction about the red shifts that should be seen, because the manner of expansion or contraction varies from one to the other. Dr. Freund's theory says, in fact, that at times the red shift should turn blue. A blue shift would mean the galaxies are coming together, and, Dr. Freund says, this alternation of red and blue shifts can be taken as a prediction of a pulsating universe.

Red shift data are still not good enough to select among gravitational theories. But, says Dr. Freund, "we think the next 100 years will tell." ◇

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