A Giant Step Toward Unified Field Theory

The use of field theory, which connects forces to characteristics of space and describes them by means of equations with geometrical content, is an old tradition in physics. We speak of the earth as being in the gravitational field of the sun. In school most people have seen the demonstration of a magnetic field using iron filings; textbooks represent electric fields with bundles of lines in the manner of Michael Faraday.

This geometrizing tendency has yielded many dividends from philosophy to practical technology. Among theoretical physicists it has aroused the long-standing hope of a unified field theory—essentially one description uniting all kinds of force. At the moment there are four known kinds of force (or interaction, as physicists prefer to say): gravity, electromagnetism and the weak and strong interactions of the subatomic domain.

The modern unified field theory, often called the Weinberg-Salam model after Steven Weinberg of Harvard University and Abdus Salam of Imperial College, London, begins with the weak and electromagnetic interactions. An experiment recently done at the Stanford Linear Accelerator Center has confirmed some key predictions of the Weinberg-Salam model, suggesting that there are not four forces in nature but three: gravity, the strong interaction and the one for which there is no name yet, the weak interaction *cum* electromagnetism. (The historical parallel is the union of electricity and magnetism into electromagnetism as completed in James Clerk Maxwell's theory in 1876.) The significance of the experiment could be seen in the reception of its results—which had been eagerly awaited and even wagered on by physicists. The results, announced at SLAC on June 12 by experimenter Charles Prescott, are reported to have been met with an unusual degree of sustained and enthusiastic applause. As the June 22 NEW SCIENTIST reminds us, citing the august opinion of the philosopher of science Karl Popper, no single experiment can prove a theory, but the preponderance of evidence more and more favors Weinberg-Salam.

The experiment deals with a particularly important aspect of the proposed unified force, its behavior with regard to parity or left-right symmetry. Many things are either left-handed or right-handed. Reflect them in a mirror, and they become their opposite. Other things have no handedness; they look the same reflected in a mirror. It used to be thought that nature was even-handed, showing no preference for left or right. This principle of space-reflection symmetry or parity was one of three symmetry principles — the other two are time-reversal symmetry and symmetry of positive and negative electric charges or matter and antimatter — that all physical processes had to respect.

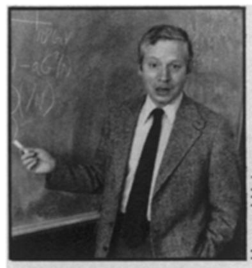
It is now known that for parity at least, some respect it and some do not. Processes governed by the weak interaction are particularly notorious for disrespect to the principle of parity, and what is relevant for the present case is that the formulations of Weinberg and Salam increase the possibilities for such violations and make them a likely means of testing whether this theory is a good description of what's going on. The Weinberg-Salam formulation provides a whole new class of weak-interaction processes, the neutral-current processes.

A neutral-current process is one in which two particles interact without exchanging a unit of electric charge. If a neutrino strikes a proton and bounces off, and the neutrino remains a neutrino and the proton remains a proton, that's a neutral-current interaction. (Before Weinberg and Salam the weak interaction had only charged-current interactions, those in which a unit of charge was exchanged. In that case the proton becomes a neutron and the neutrino becomes a positron.) To test the Weinberg-Salam theory, a search for neutral-current processes was undertaken, and they were discovered in 1973 (SN: 9/15/73, p.164).

The neutral-current interactions are predicted to violate parity, and the experiment mounted at SLAC by Prescottt and a large number of co-workers now seems to confirm that prediction. The experiment strikes high-energy electrons (accelerated to between 16 and 21 billion electron-volts) against proton targets. The electrons' handedness appears in the relation of their spins to the direction of flight. Some will be equivalent to right-handed screws, some to left-handed screws. The question is whether the protons prefer one over the other.

The protons turn out to have a slight preference for the left-handed, and the number is just the same number as predicted.

Physicists would generally assume that electromagnetic forces were dominating any interaction between an electron and a proton, but the appearance of parity violation requires the conclusion that another force is operating. As far as anyone knows, the electromagnetic interaction always respects parity. Physicists assume the



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The ten-year-old unified field theory of Weinberg and Salam (bottom) gets an experimental shot in the arm.

other force is the weak interaction. "That's an assumption," says Richard Taylor, one of the experimenters, but it's a plausible one. The weak interaction exists; nothing else is known that might be causing the effect. If it is the weak interaction, then it is a neutral-current process, because no charge is exchanged between the electron and the proton. So it must be a neutral-current effect that is doing the parity violation between electron and proton. And that pleases the theorists, because it is an important result of the way the theory orders the basic structure of matter that the electron and the neutrino be equivalent to each other in this kind of activity.

Some previous experiments have failed to find this parity-violating effect and caused much unhappiness among the theorists. But they were done with atoms and had complications that are being hotly debated. Meanwhile, a group at Novosibirsk in the USSR claims to have found the electron parity violation, but they have not published enough information to allow Western physicists to judge. Now comes the SLAC experiment, which is described as clear, clean and confirmatory. The great excitement, says Taylor, is that it tends to support the theory as Weinberg and Salam originally conceived it, not as it has been tinkered with over the years. That conception is simple in structure and extremely broad in concept. It does not intend to stop with the electromagnetic and weak interactions. Its basic mathematical feature, the so-called gauge principle, can encompass the strong interaction and may be able to reach gravity, too. If it does that, it will become a theory that explains why everything goes. □