A Tentative Vote for Supersymmetry

Do new measurements offer indirect support for an elegant attempt to unify fundamental forces of nature?

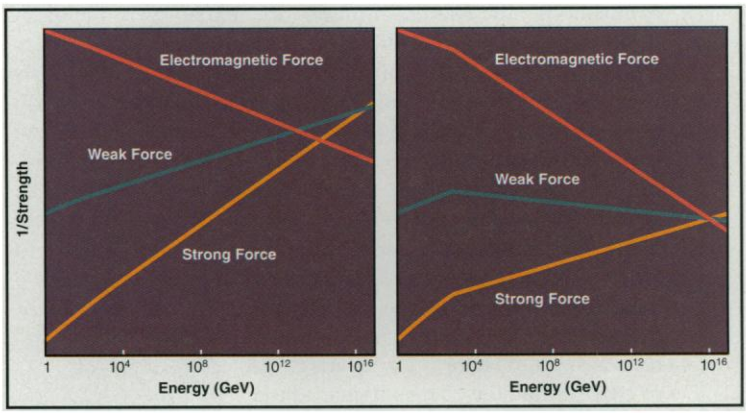
THEORETICAL PHYSICISTS GOT QUITE A JOLT back in 1985, when experimentalists at the European physics laboratory CERN began to argue that some of their anomalous data might actually prove the existence of new particles known as “squarks.” If these particles—proposed counterparts of the more familiar quarks that make up protons and neutrons—had turned out to be real, the discovery would have confirmed a mathematically beautiful theory called supersymmetry (*Science*, 29 April 1983, p. 491), often invoked as one of the grand unified theories (GUTs) that attempt to unite the three fundamental forces that govern particle physics.

Unfortunately for supersymmetry fans, the 1985 results evaporated. But a new series of measurements at CERN has again set some physicists talking about “evidence” for supersymmetry. The findings—measurements of the way the strengths of two fundamental forces change as the energy of interacting particles rises—are in line with the predictions of one version of supersymmetry. What's more, they suggest to some physicists that definitive evidence for supersymmetry might be within reach of the next generation of accelerators. But these claims have also drawn critics ranging from polite to scathing who argue that the new work glosses over theoretical difficulties and that the results could be explained as well by other GUTs.

Any claim about supersymmetry is bound to draw close scrutiny, for the unification it promises is a Holy Grail of particle physics. GUTs are overarching frameworks intended to unify two of physicists' best-established but disparate theories: quantum chromodynamics, the theory of the strong force that binds quarks together, and electroweak unification, a “partial unification” of electromagnetism and the weak force responsible for certain forms of radioactivity.

GUTs generally predict that even though these forces have very different strengths (characterized by so-called coupling constants) under ordinary conditions, they become equal at extremely high energies—somewhere around 10^{14}-10^{16} GeV, more than a hundred billion times greater than energies reached in current accelerators. At those energies the strong, weak, and electromagnetic forces should merge into one. The problem, however, is that when known physics is extended to higher energies, the energy-dependent coupling constant curves don't come close to intersecting (see graph, left).

One of several ways to make the constants converge is to postulate a set of new particles that are “symmetric” to those already known. Such “superparticles” would resemble existing quarks, electrons, and so forth but for two things: Their spins would differ by one-half, leading, for instance, to a spin-1/2 “photino” (a photon counterpart) and a spin-0 “selectron” (an electron counterpart); and their masses would be greater than those of any particle yet discovered. Heavy superparticles, if they exist, would “break” the graphed slopes of the coupling constants and aim them toward convergence at a single unification energy.



Coming together. *Although known physics doesn't predict a unification of forces* (left), *supersymmetry can do the job* (right).

With the exception of the abortive 1985 results, there's been no evidence that such superparticles exist. Recently, however, three physicists led by CERN's Ugo Amaldi analyzed data gathered last year at CERN's Large Electron Positron collider (LEP). The LEP produces massive Z^0 particles—electrically neutral “mediators” of the weak force—in abundance. With an extremely accurate measurement of the Z^0 mass in hand, the researchers were able to pin down the coupling constants for the weak and electromagnetic forces with unprecedented precision. Then they began to “fit” various GUT models to the coupling constant data, only to find that the simplest—and hence most plausible—form of supersymmetry leads the curves to their most elegant convergence (see graph, right).

Other physicists have performed similar analyses over the past 6 years. But because of the new, precise coupling constants, Amaldi and his colleagues were able to limit the masses of the superparticles required for unification to an especially narrow range—between 100 GeV and 2 TeV. Those figures represent energies that lie within reach of the next generation of particle accelerators. That alone is enough to get some experimentalists, such as Boston University physicist Larry Sulak, excited. These “spectacular” results, he says, imply that it will be possible to find supersymmetric particles at the Superconducting Super Collider (SSC).

But the results, reported this spring in *Physics Letters B*, leave theorists like Ken Lane of Boston University cold. “This in no way supports supersymmetry or anything else,” he says. “The best one can say is that some [GUT] models are consistent with these measurements.” Other skeptics, such as Michael Peskin, a theorist at the Stanford Linear Accelerator Laboratory, find Amaldi's results “interesting” but complain that his analysis failed to take into account the “nontrivial” problems that plague any attempt to model the superparticle mass range. “This question is just finessed,” Peskin says. Still, Amaldi gets a cautious vote of confidence from William Marciano, a theorist from Brookhaven National Laboratory: “It should be encouraging for those who believe in supersymmetry,” he says.

GUTs in general have fallen on hard times over the past decade, as none has made exclusive predictions that could be tested at existing accelerators. By implying that supersymmetry might soon be testable, Amaldi's analysis should be heartening not just to supersymmetry proponents but also to lab directors eager to see new machines built. *CERN Courier*, a glossy laboratory publication, highlighted Amaldi's work in several issues earlier this year, and one U.S. physicist even suggests that CERN director-general Carlo Rubbia hyped the findings in order to make a case for building the planned Large Hadron Collider. So far, though, there's no sign that SSC management is jumping on this particular supersymmetry bandwagon. ■ DAVID P. HAMILTON