unification of electromagnetism and the weak interaction.

In parallel with all this, the accelerator physicists are also using the collider to explore the technology of linear colliders in general, with a view toward pushing electron-positron physics into realms of energy that are simply not practical with conventional, circular machines. "LEP is already 27 kilometers around and it's getting ridiculous," says Hutton. In any given circular machine, a process known as synchrotron radiation will eventually cause the particles to lose energy as fast as the accelerator can supply it. Doubling LEP's 160-GeV energy would therefore require a quadrupling of its size, which would make it larger than the proposed Superconducting Super Collider. (If built, the supercollider's energy will be more than 100 times LEP's because it will use protons, which have much lower synchrotron losses.)

Thus the appeal of a linear collider, says Hutton: eliminate the synchrotron losses by eliminating the circular motion. In particular, he says, if two linear accelerators, each about 10 kilometers long, were pointed down each other's throats like muzzle-to-muzzle rifles, they could achieve a total collision energy of 1 trillion electron volts (TeV). That would be sufficient to bring forth not just Zs, but Higgs bosons, supersymmetry, "technicolor" particles—indeed, much the same kinds of high-energy exotica that the supercollider would be looking for. Moreover, because electron-positron annihilation events tend to be far less complicated than the massive splatter produced by colliding protons, a high-energy linear collider would be able to dissect those phenomena with far greater precision.

Basking in the afterglow of the first Zs, Richter and his colleagues are already thinking hard about how to actually build such a full-scale machine. Known variously as "the Next Linear Collider" or "the TeV Linear Collider," it is in an embryonic state at best, says Richter. In particular, there is still a great deal to learn about building power supplies that can provide sufficient accelerating muscle without an impossible price, and about the focusing of electron-positron beams at TeV energies. (The cross section would be measured in *nano*meters.) "The earliest time we could produce a credible proposal would be 1992 or 1993," he says, "and even then only if everything works well here."

On the other hand, the experience so far with the Stanford collider has already taught everyone involved a crucial lesson for taking that next step: "Be prepared!" says Richter. "For anything!"

■ M. MITCHELL WALDROP

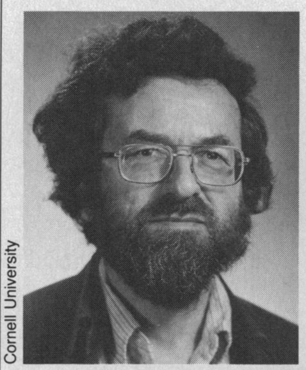
Can You Help the Mets by Watching on TV?

Physicist-philosopher-baseball fan David Mermin uses the Baseball Principle to make a point about the nature of reality

EINSTEIN DIDN'T LIKE IT. He called it "spooky action at a distance" and argued that no self-respecting universe would allow such behavior. But the behavior that Einstein did not like turns out to exist in our universe after all.

In 1981–82, French researcher Alain Aspect and collaborators did a series of experiments that proved that events in one place can be mysteriously correlated with events in a second region so far removed from the first that no direct communication between the two is possible. Right there in the laboratory was Einstein's "spooky action." Physicists are still arguing about the implications of the experiments.

Cornell University physicist David Mermin has a unique way to make some of these abstruse arguments accessible to the nonspecialist. He takes an interpretation of the Aspect experiment offered by Henry Stapp of Lawrence Berkeley Laboratory and rewrites it in baseball terms. The irreverent Mermin, who at one time crusaded to make "boojum" an accepted scientific term, finds that asking "Can you help the Mets by watching on TV?" opens the door to some rather deep questions.



Cornell University

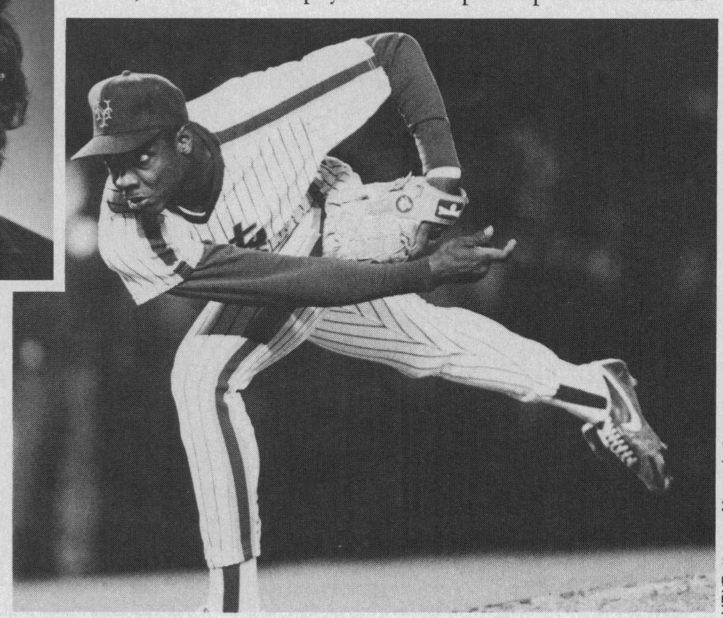
Most fans know in their hearts, Mermin says, that watching the game on TV makes no difference to the outcome. "What I do or don't do in Ithaca, New York, can have no effect on what the Mets do or don't do in Flushing, New York," Mermin says. "This is the Baseball Principle."

A pedant, Mermin says, might argue that what the Baseball Principle really means is that if one examined a large number of games, some of which the fan watched and others he did not, then statistically the team would perform equally well in the watched and unwatched games.

But Mermin means something stronger than a statistical statement. "Tonight, for example, whatever the Mets do will be exactly the same whether or not I end up watching the game." He calls this claim that the Baseball Principle applies to individual games the Strong Baseball Principle.

"Nonsense," says the pedant. You either watch the game or not, and you cannot possibly know what would have happened in the alternate case. It is impossible to test the Strong Baseball Principle, and a statement that cannot be tested has no meaning.

This is where you are wrong, Mermin replies. It is possible to test the Strong Baseball Principle—not in the world of baseball, perhaps, but in the realm of quantum physics. The Aspect experiments offer a



UPI/Bettmann Newsphotos

Mets fan David Mermin *says that what he does or doesn't do in Ithaca, New York, can have no effect on what Dwight Gooden does or doesn't do in Flushing, New York. "This is the Baseball Principle."*

unique chance to compare something that happened with something that did not.

The Aspect work was a laboratory realization of a thought experiment proposed in 1935 by Einstein, Boris Podolsky, and Nathan Rosen. The three actually offered the thought experiment as an argument against quantum theory, because they believed that the predictions of quantum mechanics—as illustrated by the experiment—were too outlandish to accept. Forty-six years later, however, Aspect's data supported the predictions of quantum physics.

In the Aspect experiments, an emitter shoots two photons at a time in opposite directions. The polarizations of the two photons in each pair are correlated—the photons will display identical polarizations if the polarizations are measured along the same direction. On each side of the emitter is a detector that measures the polarizations of the photons.

According to quantum mechanics, neither photon has a well-defined polarization until it is measured at the detector. Before that, the polarization can only be described statistically, in terms of the probability that a measurement will give this value or that one. In layman's terms, measuring the polarization of the photon transforms the photon from one whose polarization is no more than a set of probabilities to one with a polarization of fixed value.

What bothered Einstein about this experiment was that measuring one photon gives more information about the polarization of the other than the other photon could even know about itself. To describe this rather subtle effect in nonphysical terms, Mermin shows how the photons and detectors seemingly violate the Strong Baseball Principle.

In Mermin's depiction of the Aspect experiment, each detector flashes either red or green, depending on the polarization of the detected photon. Further, each detector has two settings, 1 and 2, that determine the angle the polarization readings are made at. The choice of setting at one detector corresponds to the decision of a fan to watch or not watch a game, and the color flashed at the other detector corresponds to the outcome of the game. The Strong Baseball Principle implies that for each individual pair of photons, whatever happens at detector B does not depend on the choice made at detector A.

By aligning the two detectors so that their orientations differ by a certain angle, it is possible to get the following statistics: If both detectors are set at 1, or if one is set at 1 and the other at 2, they will flash the same color 85% of the time; if both are set at 2, they agree only 15% of the time.

Suppose now that one takes many runs of data with both detectors set at 1. The data for the first 25 runs might look like:

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A(1):  RGGGRGRGRRGRRGRGRRRRGRGGR ...
B(1):  RGGRRGGRRRGRRGRGRGRRGGGGR ...
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Note that each detector flashes red and green randomly, each color flashing half the time. Statistically, the data will look the same no matter what the detector setting—the (Weak) Baseball Principle is valid.

The Strong Baseball Principle states that a different choice of setting for detector A would not have affected what happened at detector B, and vice versa, *in each individual run*. Philosophers might argue that this statement is meaningless, but bear with me, Mermin says—we can learn something here.

Imagine that detector A had been set at 2 instead of 1. It is impossible to say what data would have been taken at A, but the Strong Baseball Principle implies the data at B would be unchanged, run by run. Furthermore, even though the hypothetical A(2) data is unknowable, we do have some information about it: It must agree with the B(1) data in 85% of the runs. Similarly, if detector B had been set at 2 instead of 1, we cannot say what colors it would have recorded, but the B(2) data must agree with the A(1) data 85% of the time.

But now we can see that applying the Strong Baseball Principle has got us into trouble. B(2) differs from A(1) by 15%; A(1) differs from B(1) by 15%; and B(1) differs from A(2) by 15%. This implies that A(2) differs from B(2) by at most 45%. However, the detectors were designed so that A and B would differ by 85% if both had really been set to 2. Thus, even though we cannot say what data appeared in the A(2) and B(2) runs (since, after all, they did not happen), we can say there is no possible arrangement of data that could fit. The Strong Baseball Principle cannot possibly be true here—it is testable, but false.

Does this mean that what happens at B does depend on the choice made at A? That watching the Mets on TV does make a difference? Mermin says no. "It merely implies that you cannot apply the Baseball Principle to individual games." But this, says Mermin, is amazing enough: such metaphysical arguments show that living in a classical, deterministic world has not prepared us to think in quantum terms.

■ ROBERT POOL

ADDITIONAL READING

N. D. Mermin, "Can you help your team tonight by watching on TV? More experimental metaphysics from Einstein, Podolsky, and Rosen," in *Philosophical Consequences of Quantum Theory* (Notre Dame University Press, South Bend, 1989); reprinted in N. D. Mermin, *Boojums All the Way Through* (Cambridge University Press, Cambridge, England, 1989).

Cold Fusion: Bait and Switch?

Cold fusion is starting to look like it might become an example of the "bait and switch" technique. Just as almost everyone is bored with the claims of fusion in a jar, the first whispers are out that it may not be fusion at all, but something more mysterious.

At the 8 May meeting of the Electrochemical Society in Los Angeles, a rumor surfaced to explain why Stanley Pons and Martin Fleischmann have been so secretive about the analysis of their palladium electrodes, in which they claim to have produced room-temperature fusion. The two, the rumor said, suspect that the palladium has undergone some unspecified chemical change that causes it to produce a great deal of heat, and they do not want anyone else to discover the nature of the change first.

At the meeting, Pons and Fleischmann said they have arranged for the electrodes to be tested for the presence of helium-4—a hypothesized by-product of the alleged fusion reaction—but they were quite vague about the details. A number of scientists believe that if analysis shows the electrodes have no helium-4, then the claim of cold fusion is dead. Fleischmann himself admitted as much at the meeting.

James Brophy, vice president for research at the University of Utah, where Pons works, said Pons and Fleischmann have given samples of their electrodes to two laboratories. One is Johnson Matthey PLC, the company that supplied the palladium electrodes. Brophy said Johnson Matthey loaned the palladium to Pons and Fleischmann on the condition that they could analyze the metal after it went through the "cold fusion" process. He would not name the other laboratory.

Although Brophy disagreed with the particular variant of the rumor heard at the meeting, he confirmed speculation that something besides cold fusion is being considered as a cause for the heat Pons and Fleischmann report. One reason for the secrecy surrounding the analysis of the electrodes, he said, is that if something besides fusion is going on, the tests could reveal what it is. If that something turns out to be valuable, the discovers of the process want to be the first to know.

Charles Martin at Texas A&M said his group is still convinced of heat production in the palladium, but has never said it was fusion. The Texas A&M group is also having its electrodes analyzed, but would give no details.

■ ROBERT POOL