one or two intentional mismatches. They they find that mismatches hinder the binding of PNAs as much as (or possibly more than) they do that of the natural molecules.

But even if PNA turns out not to be the best DNA analog for biomedical purposes, says Georgetown's Cohen, its discovery has opened the eyes of the research community to the possibility of radically different synthetic versions of the DNA and RNA. Egholm says he and his colleagues are now considering other variations. "PNA took us away from the natural backbones," he says.

It also shattered his notions about the uniqueness of life's genetic machinery, he says. "Why did nature settle on DNA as the universal genetic material?" he asks. With radically different possible alternatives, it may be we got DNA in our chromosomes by blind chance. In fact, in spite of the success that nature seems to have over a couple of billion years with DNA, it might have had even more with PNA.

–Faye Flam

ASTROPHYSICS

Pattern Emerges in Cosmic Ray Mystery

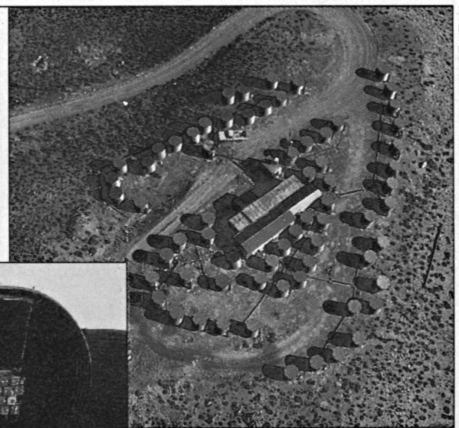
Anyone who thinks that physics is in danger of running out of mysteries should contemplate high-energy cosmic rays, particles that arrive from space at energies millions of times higher than ever achieved in an earthly particle accelerator. There are plenty of candidates for the sources of cosmic rays that arrive with relatively modest energies: the sun, the shock wave at the edge of the solar system, or supernovae within our galaxy. But at energies thousands and even millions of times higher—above a quadrillion electron volts (10^{15} ev)—it has been anyone's guess what manner of heavenly accelerators are launching these particles toward Earth.

Now a collaboration of physicists working with the University of Utah's Fly's Eye cosmic ray detector reports a series of clues that may narrow the search. At energies of about 10^{19} ev, they report in the 22 November issue of *Physical Review Letters*, one kind of cosmic ray source that generates mainly heavy nuclei seems to peter out and a new source, specializing in protons, takes over. That top-end source, the researchers say, seems to lie outside the galaxy—but not too far afield. That, at least, is the implication of the most energetic cosmic ray ever detected, a single particle that the Fly's Eye registered at an extraordinary 3 x 10^{20} ev—a wallop, says University of Utah physicist Pierre Sokolsky, that is equivalent to "a brick falling on your toe."

The Fly's Eye detector is a swarm of phototubes spread over two hillsides at the Dugway Proving Grounds, an hour's drive from Salt Lake City. The devices look upward into the night sky for the bluish fluorescence from the nitrogen ionized when a cosmic ray plows into the atmosphere and triggers a shower of secondary particles. The altitude of the fluorescence provides a hint of composition—heavier nuclei should trigger air showers at higher altitudes—and its intensity gives a measure of energy.

High-energy events are so rare that the Fly's Eye had to be run for more than a decade before the collaboration could say much about them (*Science*, 8 January, p. 177). By last January, however, the researchers knew enough to say that at 10^{17} ev, several steps below the highest energies, most cosmic rays seemed to be heavy nuclei such as iron. Now, they find that the pattern changes dramatically at higher energies. Their latest results suggest that by 10^{19} ev the heavy nuclei vanish, leaving only protons.

That compositional change, together with a change in the slope of the energy spectrum at the same energy, seems to mark the upper limit of one source, which the Fly's Eye researchers speculate lies within the galaxy. An energy of about 10^{19} ev is where you would expect galactic cosmic rays to become less abundant, says Tom Gaisser of the Bartol Research Institute at the University of Delaware and a Fly's Eye collaborator, because at that point "the particles will be so energetic that they can no longer be contained" by the galaxy's magnetic fields. Moreover, lighter nuclei would have an easier time escaping the magnetic field than heavier ones. Thus it would make sense, if the source is galactic, that most of the cosmic rays reaching Earth would be heavy nuclei.



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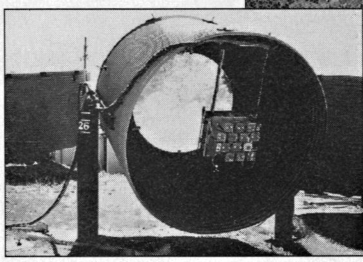

DAVID KIEDA

Eye on the sky. The Fly's Eye array and the photomultiplier tubes inside one detector.

The evidence of a galactic origin for these cosmic rays is necessarily indirect, because the same magnetic fields that can trap cosmic rays also bend their paths, making it impossible to trace their origins. At the highest energies, however, where iron nuclei give way to protons, the bending should be small enough that the trails of the protons should still point roughly toward their origins. A galactic source would be readily apparent, as Sokolsky explains: "If these particles were coming from the galactic disk, where most of the matter in the galaxy is located, we should begin to see striking anisotropies in arrival directions." But the ultra-high-energy protons seem to come from all directions, suggesting that they originate beyond the galaxy.

Not too far beyond the galaxy, however—at least in the case of the falling-brick event, recorded by the Fly's Eye on 15 October 1991, and discovered by Hong Yue Dai, a postdoc on the experiment. That event had three times the energy of any other cosmic ray ever detected, and at that energy, say theorists, a proton couldn't have made it very far before interacting with the photons of the cosmic microwave background radiation that pervades the universe. According to Sokolsky, at 3 x 10^{20} ev, the particle would only travel perhaps 10 megaparsecs, the distance of the local supercluster of galaxies, before it lost energy.

So where did the blockbuster ray come from? Because of its extraordinary energy, the particle "should point back to its source," says Sokolsky. But, he adds, "the interesting point is there's nothing there. No obvious hot galaxies, radio galaxies, any of the standard models for extragalactic particles."

David Schramm, a University of Chicago astrophysicist, suggests one exotic explanation: The particle was accelerated by the decay of an object left over from the earliest moments of the universe. "It may be the result of the decay of some grand unified thing," says Schramm, "maybe even a topological defect" such as a cosmic string, a kind of hypothetical fracture in the fabric of space time formed during the earliest moments of the Big Bang. "When those remnants decay," he adds, "they give you very, very energetic particles. If that was the case, then these particles would be a probe of extraordinarily fundamental conditions."

Schramm's notion is intriguing, but, as is so often true with high-energy cosmic rays, the evidence is too thin for anything more than speculation. "It's only one event, and you need more," says Sokolsky. "It's an exciting thing, but you don't know what to do with it." Aside, that is, from fueling cosmic mysteries.

–Gary Taubes