magnitude too large.

Moreover, the plain-vanilla cosmological constant would have been stretching all of space throughout the lifetime of the cosmos. As a result, a large lambda should affect such observable features of the universe as the frequency with which distant galaxies happen to fall directly behind foreground galaxies, allowing the nearer galaxy to act as a gravitational lens and bend the distant light. A powerful lambda would also begin to overpower gravity as the universe expands, setting limits on the formation of large-scale structure. To some cosmologists, these features are setting uncomfortably tight limits on a cosmological constant.

So theorists are playing with alternatives. "People have started to realize that there are lots of good models that may even be more physically motivated," says Martin White of the University of Illinois, Urbana-Champaign, who updated earlier work on what he and Turner call X-matter. X-matter would permeate the universe with a uniform density of energy, fueled by sources that could range from exotic wrinkles in the fabric of space-time, called textures or light cosmic strings, to some mysterious scalar field. Unlike the cosmological constant, it could change as the universe expanded, ramping down the "pressure" through which it affects matter and evading the gravitational lensing constraints, for example.

Like ordinary matter, however, such an energy reservoir would form denser and more rarefied regions over time as gravity acted on it. Paul Steinhardt of the University of Pennsylvania and his collaborators have explored that behavior in a physically consistent candidate for a variable background energy, which they call quintessence. Quintessence, says Steinhardt, might not only flesh out the universe to an omega of 1 but, by evolving a structure of its own, might also have influenced the formation of giant gatherings of galaxies.

Any form of background energy would also have shaped how ripples grew in the primordial sea of matter soon after the big bang, says Steinhardt. And because those ripples left their mark on the cosmic microwave background—the afterglow of the big bang—the high-resolution maps of the cosmic background that are expected from spacecraft early in the next century could point to the true nature of the universe's hidden energy. Meanwhile, physicists and cosmologists have plenty to speculate about. Strange as every possibility may sound, it's a strangeness that cosmologists may have to live with.

–**James Glanz**

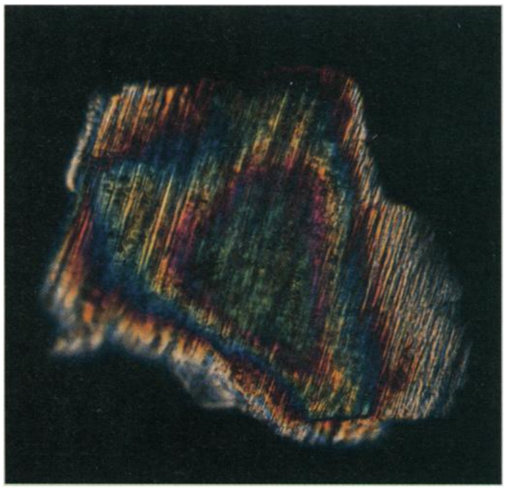
EARTH SCIENCE

Comet Shower Hit, But Life Didn't Blink

SAN FRANCISCO—Back in the 1980s, when researchers were piecing together the story of how a great impact killed the dinosaurs, comet showers were all the rage. Tantalized by hints that mass extinctions like the one that swept away the dinosaurs might have recurred every 30 million years or so, researchers proposed that regular swarms of comets have battered Earth, devastating life. But little evidence has emerged for even a single comet shower, much less periodic ones. Now, researchers tapping a new sort of geologic record find solid evidence that at least one comet shower did pelt Earth—but without apparent effects on life.

Last month at the annual fall meeting of the American Geophysical Union here, geochemist Kenneth Farley of the California Institute of Technology in Pasadena and his colleagues reported finding a high level of comet dust in 35-million-year-old ocean sediments—evidence that the inner solar system was aswarm with comets for some 2 million years. Farley's work "sounds very good," says comet specialist Paul Weissman of the Jet Propulsion Laboratory in Pasadena. It "supplies more evidence that there was a flood of comets into the solar system"—at a time when at least two major impacts struck the planet. But unlike the comet showers envisioned in the 1980s, this one left life unscathed and apparently was not part of a series.

A comet shower could begin far beyond Pluto if a wandering star gravitationally nudged some of the trillion or so comets dwelling there into orbits passing near the sun. Because comets passing through the inner solar system spew dust, some of which eventually settles to Earth, a pulse of dust should indicate a comet shower. Farley's team searched for this signal by measuring the amount of helium-3—the lighter, rarer isotope of helium—and its ratio to helium-4 in ancient sediments. Because the solar wind is rich in helium-3, the ratio of helium-3 to helium-4 in comet dust is more than 3000 times higher than in terrestrial sediment.



GLEN IZETT

Shocking shower. An impact during a comet shower 35 million years ago shocked this quartz grain (parallel striations) but didn't cause an extinction.

The most likely place to find the helium traces of a shower, Farley and his colleagues decided, was at Massignano in the Italian Apennine, which preserves sediments from 35 million years ago, late in the Eocene epoch. Two of the largest impact craters of the past billion years—northern Siberia's Popigai, 100 kilometers across, and the 85-kilometer Chesapeake at the mouth of Chesapeake Bay (*Science*, 22 September 1995, p. 1672)—formed at that time, hinting that these impacts might be part of a shower. Sure enough, the Massignano sediments yielded a 2-million-year-long surge in helium-3. It peaked about 35.5 million years ago, right at the time of the two major impacts, at six times background levels.

As comets flooded the inner solar system, the amount of dust filtering into Earth's atmosphere would be expected to climb sharply over a few hundred thousand years, and the helium-3 did so "in almost perfect agreement with predictions," says Farley. Then helium-3 levels slowly fell for almost 2 million years, the same time span needed for planetary gravity to sling these comets back out of the inner solar system. "His results seem to be consistent with everything" predicted for a comet shower, says geochemist and helium-3 analyst Sean Higgins of the Lamont-Doherty Earth Observatory in Palisades, New York.

What's missing is any sign that the shower affected life. The fossil record shows that species came and went at about the usual rate during the shower, although there was a major extinction more than a million years later (*Science*, 18 September 1992, p. 1622). It seems that only truly giant impacts, like the one that left 180-kilometer Chicxulub crater and did in the dinosaurs, can trigger a major extinction, says geologist Wylie Poag of the U.S. Geological Survey in Woods Hole, Massachusetts.

Also missing is any evidence that comet showers come in 30-million-year cycles. Farley measured helium-3 across the debris layer left in the Apennines by the Chicxulub impact, 30 million years before the Late Eocene event, and found "no indication of a shower," he says. It seems that the Chicxulub impactor—the only known extraterrestrial killer in the planet's history—was a lone rogue.

–**Richard A. Kerr**