COBE Sows Cosmological Confusion

The discovery of unevenness in the background radiation at first promised to winnow theories of the early universe. But the shake-out now seems farther off than ever

Contrary to newspaper accounts last April, NASA's Cosmic Background Explorer (COBE) satellite did not find traces of God, nor did it rescue a supposedly ailing Big Bang theory from imminent demise. At Princeton University 2 weeks ago, during the first major meeting assembled to discuss last April's report of "bumps in the Big Bang," the heady headlines reporting the discovery became a long-running joke among the assembled cosmologists. Even the rather less lofty claims made by the principal investigators—that the finding had given a major boost to ideas about how galaxies and other structures took shape in the early universe—were up for grabs at Princeton as attendees launched into a heated debate.

AP/WIDE WORLD

Startling claims. COBE team leader George Smoot.

When the COBE team announced by press conference—they have yet to publish the work—that they had for the first time spotted unevenness in the background of microwaves pervading the universe, the researchers went on to claim that their discovery would thin out the multitude of competing models for how cosmic structures formed from such primordial lumps. Eight weeks later, close to the opposite has happened, as the Princeton gathering showed. Instead of thinning out, the models have proliferated, with previous leaders falling from favor and unlikely long shots entering the fray. "The interpretations are all over the place," says Princeton astrophysicist Edwin Turner. "Now there is less agreement than before."

Not that anyone doubts the COBE finding. Turner and his colleagues in the field do agree that, as he puts it, "The observations are fairly secure." Unchallenged is COBE's discovery of faint, part-per-million variations in temperature—barely perceptible but vast warm and cold splotches—in the pervasive microwave background. The microwaves themselves, discovered in the 1960s, supposedly sprang from the Big Bang itself, and cosmologists agree that—if they are real—COBE's splotches are the spread out remainder of tiny primordial bumps of the type that seeded the formation of galaxies and sculpted the even vaster starry sheets that arch across the skies. But that's as far as the agreement goes.

Some notable researchers were startled, for example, by one of the COBE team's claims, as stated by team leader George Smoot of the University of California, Berkeley: "Now we can get serious about the Big Bang theory." If COBE had failed to see these ripples in the cosmic background radiation, he explained, the Big Bang theory would have fallen into disrepute. Not so, said cosmologists at the Princeton meeting: Other evidence for the Big Bang is so overwhelming that it would have survived, bumps or no bumps. Says Berkeley's Marc Davis, "The Big Bang didn't need this proof."

For Paul Steinhardt of the University of Pennsylvania, the Big Bang theory was clinched in the 1960s by the discovery of the microwave background. Further support followed, he recalls, when measurements of the relative amounts of hydrogen, helium, and lithium in the cosmos matched the proportions theorists say would have emerged from nuclear reactions in the hot, dense aftermath. "This [the COBE result] is another brick in a solid foundation," he says.

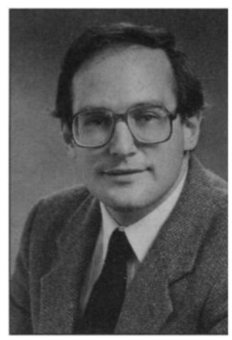
Even some members of COBE's own team agree. "Saying that now we know the Big Bang theory is correct is like saying now we know cancer is a disease," says Rainer Weiss of the Massachusetts Institute of Technology. Some of Weiss's fellow team members suggest that the claim that COBE results bolstered a shaky Big Bang had been tailored for a doubting public. "Some people questioned the Big Bang theory," points out COBE team theorist Ned Wright of the University of California, Los Angeles. When pressed for names, though, he comes up only with "*The New York Times*."

No Boost for Inflation?

And that was but the beginning. At their press conference and in a widely circulated preprint, the team argued that the pattern COBE detected lends crucial support to a controversial Big-Bang variation called inflation, which posits a dramatic growth spurt in the newborn universe (*Science*, 1 May, p. 612). To the press, members of the COBE team also suggested that by supporting inflation, their results indirectly bolster cold dark matter, a favorite model of structure formation that builds on inflation and relies on slow-moving (cold), elusive particles to give a head start to cosmic structures.

Both assertions, say some other researchers, were premature. "There was some useful enthusiasm and joy following the results, but they hadn't done their full homework in the interpretation," asserts Princeton theorist James Peebles. Several people pointed out that the hasty interpretations observers attach to new data often turn out to be wrong. "My view is you should state the facts and let the theorists have a chance to figure out what they mean," says Berkeley astronomer Andrew Lange, himself an observer. Turner got a good round of laughs at the meeting with a slide of what he called the firmest conclusions to be drawn from COBE: on the list, that the Big Bang happened and that experimentalists tend to overinterpret their results.

At the Princeton meeting, the COBE team's claim about inflation served as the prime example of the latter. Support from COBE would have amounted to a major boost for an already-popular scenario. In the 10 years since its invention, many theorists have embraced the idea because it explains the observed uniformity of structure across the universe and the relative smoothness of the cosmic background radiation. Inflation would have ironed out any big unevenness in the fabric of the early universe, at the same time leaving subtle ripples—the seeds of galaxies and structure. In-



The Big Bang was solid. Paul Steinhardt.

Cosmic God Squad Comes Under Fire

In the 24 April press conference unveiling the first results from NASA's Cosmic Background Explorer (COBE) satellite, team leader George Smoot uttered the words, "If you're religious, it's like seeing God." The hint of divinity—if it existed—was certainly subtle: COBE had spotted millionth-of-a-degree variations in the temperature of the microwaves left over from the Big Bang—traces of the earliest structures in the universe. But Smoot and God were soon sharing print space around the world under headlines including such words as "the mind of God," "the theory of creation," and even "grand unification of religion and science." Team member John Mather added to the fervor when he told *The Washington Post* that he saw a parallel between the biblical version of creation and the NASA satellite's version.

Cosmology has a way of getting confused with religion because they confront similar questions about the beginning and the end of the universe. So perhaps it's no surprise that Smoot's comment struck a chord with some of science's communicators. But for the same reason, it struck a nerve with his fellow scientists. "That's poison," says COBE team member Rainer Weiss about the religious connection. "I wish to hell they'd never gotten near it."

Weiss and other cosmologists insist that their flock should make an extra effort to guard against suggesting that they can provide the same kinds of answers as religion. "It gives people the wrong idea about what it means to be a scientist," says Princeton University cosmologist Edwin Turner (Turner thinks the God references were at best a mistake, at worst an abuse of scientific authority). Smoot team member Charles Bennett agrees: "Science is about things you can measure," he says.

Conveying the limitations of cosmology to an eager public can be a struggle, say researchers. Weiss and COBE researcher Phillip Lubin, veterans of other surveys of the cosmic background radiation, recall that they often got questions about God from local people when they launched balloon experiments in remote spots around the world. But the public's desire to see God's hand in cosmic data, say other researchers, makes it all the more important to be clear about what findings like the COBE results do and don't mean.

Smoot, in his defense, says he never meant to connect his data to God but only to illustrate the importance of his work. "You have to give some cultural context," he says. "Some people compare a result to finding the Holy Grail." Besides, he adds, "Language has gotten so inflated, with superbowl and supercollider and all that." And he's not sure the religious connection is altogether inappropriate. "Science is replacing the role of religion as an authority," he says.

But when pressed, he admits there are limits to what even COBE can deliver. Even when cosmologists figure out where galaxies and other cosmic structures came from (something they're still far from doing), Smoot agrees that "you never answer the religious questions. You still have 'what came before?' and you can ask 'who designed it all?' " Which is why University of California, Berkeley, astronomer Andrew Lange thinks that "our Big Bang picture is [unsatisfying] to human beings. It doesn't serve our emotional needs in terms of a creation myth."

–F.F.

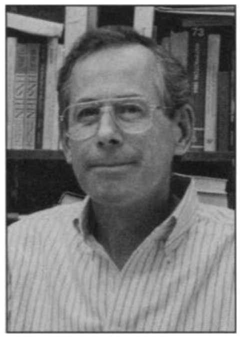
deed, the concept has been so appealing that researchers have come up with a raft of models that use those inflation-sown seeds as the starting point for the formation of galaxies and clusters of galaxies. These models, cold dark matter among them, generally rely on armies of invisible particles, or dark matter, to reinforce the fluctuations and help then gather up clumps of ordinary matter.

But inflation has been by no means the last word. Competing with those inflation-based models are scenarios in which structure formation was seeded by huge "defects" that marred the cooling universe like flaws in an ice cube. Far-fetched as all the scenarios sound, they are derived from predictions of particle physics.

With all this uncertainty, cosmologists have needed data to help them thin out the field—and that's exactly what COBE's putative boost for inflation was supposed to have done. At first glance, the inflation claim looked plausible, and COBE team members Smoot and Charles Bennett of the NASA Goddard Space Flight Center still stand by it. Inflation does predict the kind of pattern the COBE team detected in the microwave background: a so-called scale-invariant power spectrum, in which similar fluctuations show up at different size scales—spots within spots within spots. But opponents haven't switched camps because they say the results also support alternative models of the early universe. "The power spectrum (from COBE) agrees with inflation and all other theories as well," says inflation-doubter Neil Turok, a cosmologist at Princeton University who advocates cosmic defects.

Blowing Hot and Cold

That leaves as much doubt as ever about whether the seeds of structure came from inflation or some other process. And the COBE measurements actually made the zoo of models for the subsequent growth of structure more crowded, by allowing some formerly unpopular models to re-enter the fray and weakening earlier favorites. Far from getting a boost from the COBE results, cold dark matter took a hit. Theorists combined the COBE results with sky surveys that show the distribution and velocities of galaxies—the structures that resulted from primordial bumps like those traced by COBE. They found that the observations don't match cold dark matter's predictions. While backers still hold out hope, Berkeley's Davis, who has worked on one of the large sky surveys, puts it bluntly: "Cold dark matter doesn't work."



Applying a corrective. James Peebles.

Also hard hit was hot dark matter theory, an alternative that replaces the mysterious cold dark particles by known particles called neutrinos (hot because they move close to the speed of light). Pulled through the test of sky surveys and COBE data, Princeton astronomer Michael Strauss concludes, hot dark matter fares no better than cold.

And these inflation-based models aren't the only ones to suffer from the COBE findings. Rival models that take cosmic defects as their starting point also fare poorly. Even though the pattern of fluctuations COBE traced doesn't rule them out, as Turok is quick to stress, these models do predict stronger temperature fluctuations than COBE saw. "We are in a very difficult stage, and we don't know where we are going," says a frustrated Masatake Fukugita, a cosmologist from the University of Kyoto.

Few of the models are fatally wounded—at least in the eyes of their creators. Between the possible errors in the COBE results and the room for adjustment in the models, there's enough wiggle room for even the most hard-pressed cases to squeeze by. "One thing I was surprised to see was that COBE has not ruled out huge classes of models. People can force them to fit," says Dick Bond of the Canadian Institute for Theoretical Astrophysics, Toronto.

But some cosmologists, unwilling to force existing models to work, have started getting serious about models they previously considered ungainly, such as a mixture of hot and cold particles or a combination of these and a mysterious antigravity factor called the cosmological constant. "These are not the most elegant models," says Davis, "but the data have gotten so good that you have to consider these theories on the merit that they fit the data."

New Ferment

The combination of new data and unsettled theories should make for some exciting times in cosmology. "This is one of those breakthroughs that turn the field red hot," says University of Pennsylvania's Steinhardt. The heat may increase another notch with results from other microwave experiments. COBE can only measure the very biggest "bumps" in this microwave background. Detectors at the South Pole, for example, can trace finer scale details. And so far, says Steinhardt, the South Pole instruments see only perfect evenness. This lack of structure, he says, "is getting a little painful." Reconciling COBE's broad-scale map with the finer scale results from the South Pole, says Steinhardt, may call for one of the complex explanations of the cosmic background—possibly the one he's been developing, in which the "lumps" COBE has mapped contain the signature of gravitational waves generated by the Big Bang.

Before such strange beasts can be either banished or welcomed into the fold of competing theories, there's also more work to be done on the calculation side, says Bond. He adds that cold dark matter appeared to suffer such a blow from the COBE results only because it was the best thought-out model, with the sharpest predictions. "It's easy to say something is possible when not enough calculations have been done," he says.

The one thing Bond and his colleagues are sure of is that a theoretical shake-out is coming, and the COBE results will help drive it. But they aren't holding their breath. Says Princeton's David Spergel, "I don't know whether we're really close to an answer or nowhere near it."

–Faye Flam

MEETING BRIEFS

Biologists Trace the Evolution of Molecules

An unusual mix of 300 molecular biologists, population geneticists, and evolutionary biologists came together from 11 to 14 June at Pennsylvania State University for the International Conference on Molecular Evolution. Though their disciplines go by different names, all use the tools of molecular biology to sort out evolutionary history–whether they are trying to decipher the evolution of molecules such as RNA and DNA or reconstruct the family ties of humans and other organisms (see story on page 32, for example). Though the meeting was rife with disagreements about findings and even about methods, the participants did cover more than 3 billion years of evolution in 3.5 days. What they missed, they'll pick up on next year: They agreed to form a new Society for Molecular Biology and Evolution, which plans to meet annually.

Creation of the Exon Universe

When Nobel–Prize winning molecular biologist Walter Gilbert glanced at the program at the start of last week's conference on molecular evolution, he got a surprise: There, in the abstracts, was a description of a poster confirming a key prediction Gilbert had made in 1986—one that had been based on a highly controversial theory about how genes were put together in the earliest cells. "It's just what the doctor ordered," exclaimed Gilbert as he met the Canadian graduate student presenting the poster.

The student, molecular biologist Claus Tittiger of Queen's University in Kingston, Ontario, has discovered a piece of apparently senseless DNA, called an intron, in exactly the spot in the mosquito genome where Gilbert had forecast it would be. Like a piece of tape splicing together sections of movie film, the intron falls where Gilbert's "exon shuffling" hypothesis suggests two protein-coding modules called exons were joined together early in the evolution of the gene for the enzyme triosephosphate isomerase (TPI). But even as Gilbert delightedly embraced the new evidence, some scientists at the meeting were unconvinced: "This is just one example that supports his theory," says Indiana University evolutionary biologist Jeffrey Palmer, who criticized the hypothesis in an invited talk and in lively discussions that spilled out into the hallways during the conference.

Gilbert has had to get used to sniping ever since he argued in *Science* (7 December 1990, p. 1377) that genes were constructed from a surprisingly small number of genetic building blocks that have been around for 3 billion years. The Harvard University biologist proposed that several thousand of those blocks—the ancestors of exons—were shuffled and recombined in new ways over the millennia by introns, whose role has puzzled scientists for decades. By separating the protein-coding exons, he hypothesized, introns made it easier and faster for the exons to move about through recombination, thereby permitting rapid evolution of novel forms.

But that proposal put Gilbert at the center of an ongoing controversy. If introns played the role he described, they would have to be as old as the genes they are found in. As early as 1978, W. Ford Doolittle of Dalhousie University in Nova Scotia had proposed that introns were always part of the ancestral genome. Supporting that view, Gilbert found introns in identical locations in the genomes of distantly related organisms, such as corn, chickens, and humans. This, the "introns-early" school argued, provided evidence that the introns must have been inherited from a common ancestor of plants and animals.

Wrong, insist doubters, including Palmer. The trouble is that examples of introns showing up in identical locations in the genomes of plants and animals are the "exception, not the rule," says Palmer. The vast majority of the hundreds of thousands of introns in animal genomes are found in different positions than the introns in plant genomes. Moreover, introns are missing from the protein coding genes of many ancient organisms, including all prokaryotes (organisms with nonnucleated cells) and all of the earliest known eukaryotes (which have nucleated cells).

Gilbert responds that introns would have been lost from some genes after their assembly as they were "streamlined" for more efficient transcription of the genetic message. And now he can point to Tittiger's poster for support. In a 1986 article in *Cell*, Gilbert had noted that in such distantly related organisms as corn, the fungus aspergillus, and chickens, the TPI gene has a total of 11 exons and 10 introns—although not all appear in any one creature. He proposed that the ancestral gene had included all of those introns, plus one extra, to break up one of the exons that