cosmic background really do vary drastically from place to place, then the universe is a very lumpy place at this angular scale, more consistent with the defect models then with the inflationary scenarios.

But then there are clues that don't fit either of the two main models—in particular, a report by the MSAM collaboration that they observed two point-like hot spots in the cosmic background. "We expected to see a random pattern of variations," says Meyer, "but in fact we saw in two regions what appeared to be point-like sources. They're reasonably bright, and they are consistent with a thermal fluctuation in the cosmic background radiation." Meyer and his collaborators believe they can rule out galactic dust as the culprit, and the emissions don't seem to come from any known distant galaxies. "We still could be seeing something garbagey, but we haven't thought of what it might be," says Meyer. This May, Meyer and his colleagues will go back to Palestine to search the same positions for the point sources.

That sort of replication, everyone agrees, is exactly what's needed for even the less startling measurements. Cambridge University's Anisotropy Telescope has already provided the first such replication by confirming that three of the MAX results couldn't be due to interference from galactic radiation. In the coming year, Princeton's Saskatoon experiment will be looking at the same patch of sky as MSAM, and the Santa Barbara South Pole experiment will try to replicate observations by Python. To improve its data, Python will also make observations throughout the winter, stretching its observing time by a factor of 10. The downside is the need for someone to go out every day in temperatures of -60° C to tend the instrument. "The guy who's going to do it is really tough," says Dragovan.

Balloon-borne measurements—now limited to flights of 10 hours or so—will also get longer. A collaboration from the University of Chicago, MIT, and NASA Goddard is planning to build a balloon experiment called TopHAT, in which the telescope will sit on top of the balloon—"one of the big problems with ballooning," says Meyer, "is you always have this crazy balloon above you." By flying the balloon in the vortex of winds swirling around the South Pole, the investigators hope to keep it aloft for as long as 2 weeks. Teams at Berkeley and Santa Barbara are developing similar projects.

And if winterlong vigils and long balloon flights don't start to produce consistent maps of the bumps in the cosmic background, says Smoot, salvation may come from a satellite called COBRA, for Cosmic Background Radiation Anisotropy. The object of the satellite, which has been proposed to the European Space Agency, would be to "get an angular resolution of half a degree or better and map a large area or all of the sky."

COBRA wouldn't fly until the turn of the century, but the cosmic background mappers aren't put off. "This is a long haul," says Wilkinson, "I've been at it for 30 years, and it's not an easy experiment. There are lots and lots of ways to go wrong when you're trying to measure signals of 30 microkelvin. It's just going to be a while before the experiments become absolutely convincing, and everybody's working to do that."

–Gary Taubes

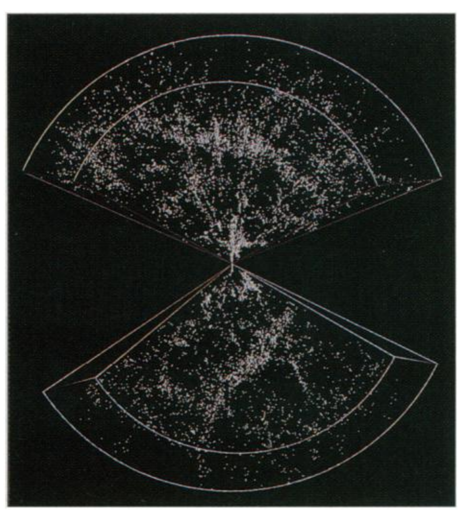
ASTRONOMY

Cosmic Structures Fill Southern Sky

In the mid-1980s, working together at the Harvard-Smithsonian Center for Astrophysics, Margaret Geller and John Huchra shook the astronomical community when they discovered gigantic curving sheets of galaxies, voids hundreds of millions of light-years across, and other large-scale structures filling the sky over the Northern Hemisphere. Conventional models of the cosmos, which had predicted a much more homogeneous universe, could not explain these surprising conglomerations. Perhaps, theorists suggested, the two astronomers had surveyed an unusual part of the sky, and matter in the rest of the universe was more evenly distributed.

No such luck. As part of an international collaboration led by Luis Nicolaci da Costa of the Brazilian National Observatory, Geller and Huchra have now taken their brand of cosmic cartography to the southern sky. And their latest map of galaxy distribution, reported in the 20 March *Astrophysical Journal (Letters)*, looks just like the one in the north: There are lengthy arcs of galaxies, puzzling voids, even a southern counterpart to the "Great Wall"—a continuous stretch of galaxies that had covered the field of view in their northern survey. "Every measure we can find shows they're similar, remarkably so," notes Geller.

After this latest survey, such features can no longer be viewed as cosmic rarities, says da Costa. Just as important, he adds, researchers are beginning to get a handle on the typical sizes of these large-scale structures. The voids, for example, tend to run 150 light-years in diameter. Faced with such data, cosmologists must now develop models of the universe that can yield structures of that size. "There are certainly important constraints coming from these galaxy maps," says Princeton theorist James Peebles, who has wrestled with the thorny problems of large-scale structures for years.



M. GELLER / J. HUCHRA

Structured sky. A new map of the southern sky *(bottom)* shows large clumps of galaxies, as does its northern counterpart *(top)*.

To construct their southern chart, astronomers selected an area of sky, and then located the position of every galaxy, up to a specified level of brightness, within it. To add depth to the picture, they estimated each galaxy's distance by observing its "red shift," the adjustment of its emitted light toward longer (redder) wavelengths. The redder a galaxy, the farther away it is. For this latest chart, which took more than 3 years and observations from telescopes on three continents to complete, the cosmic cartographers recorded positions and red shifts for more than 3600 galaxies. Combined with the northern map, that totals some 14,000 galaxies and covers one-third of the nearby universe.

The structures revealed by this celestial coverage are certainly sowing confusion. "We see these large-scale features and we don't know how to make them. We don't know how to make the structure of the universe," says Geller. For instance, minor energy fluctuations that cosmologists argue existed in the early universe appear to be insufficient seeds to give rise to such prodigious clusters of galaxies. "Gravity can't, over the age of the universe, amplify these irregularities enough," Geller explains.

The puzzle of large-scale structure is likely to get even tougher in the future. A number of still more ambitious red shift surveys, some that will peer out much farther away from Earth and chart perhaps a million galaxies, are either under way or planned. And with them, says Geller, comes an expectation of discovering even greater clumps of galaxies. And those larger structures should give theorists even bigger headaches.

–John Travis