The Universe in Depth

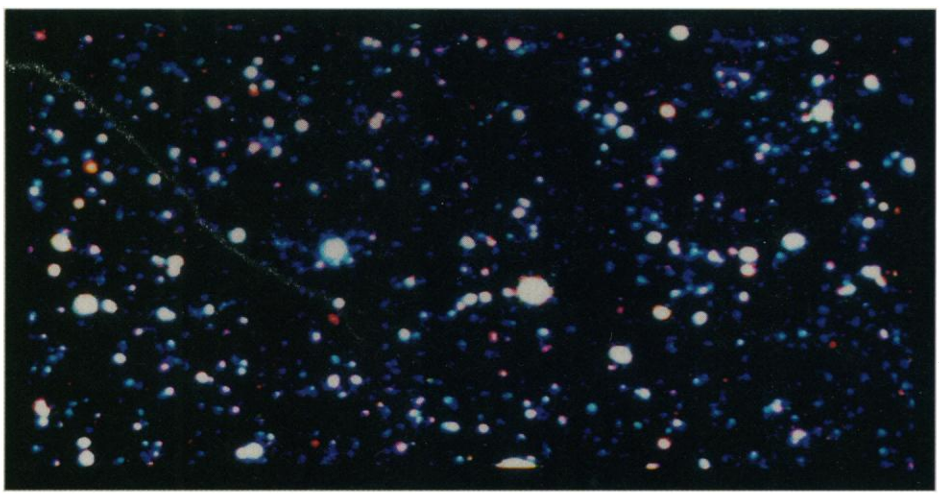
Very long time exposures provide some intriguing hints about the evolution of galaxies, the curvature of the universe, and why the night sky is dark

THE image shown here, which resembles nothing so much as a blackboard spattered with paint, is in fact one of the deepest views of the universe ever obtained. It encompasses a patch of sky barely 1% the size of the full moon. Yet virtually every point of light in it is a galaxy. Moreover, the faintest galaxies are 27th magnitude—about a billion times fainter than can be seen with the naked eye—and are more than 10 billion light-years away.

This particular view is one of a series of 12 such images produced over the past 3 years by J. Anthony Tyson of Bell Laboratories and Patrick Seitzer of the National Optical Astronomy Observatories, working on the 4-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. Tyson discussed it in some detail at a recent workshop on galaxies.*

To minimize the number of foreground stars, he explained, he and Seitzer pointed the telescope at the South Galactic Pole, which lies in the southern constellation of Sculptor; their line of sight was thus perpendicular to the plane of the Milky Way. To maximize the depth of the search, they exposed the image for a total of 6 hours, using a very sensitive charge-coupled device (CCD) detector to collect the light. And to get color information—which Tyson called a poor man's redshift—they repeated the process using filters for three different wavelength bands.

The resulting image is remarkable for several reasons, not the least of which is the sheer number of galaxies it contains. "If you look at the faintest galaxies you can see that the sky is filling in," explained Tyson. In this image the coverage is already approaching 30%; moreover, the coverage will only increase as longer exposures probe even deeper. (Tyson and Seitzer hope to improve their sensitivity by a factor of 10 during the next few years, which will allow them to see 30th magnitude galaxies.) But a sky coverage that approaches 100% is a recipe for disaster, as first pointed out by Johannes Kepler in 1610: if stars (or galaxies) were scattered at random in an infinite universe, then an observer's line of sight would eventually intersect a star no matter where he looked. The night sky would be as bright as the surface of the sun. (This argument was rediscovered in 1823 by the German astronomer Heinrich Olbers; it is now known as Olbers' paradox.)



A portrait of the universe at the 27th magnitude.

Obviously, said Tyson, the night sky is a good deal darker than the sun. And the reason is that we do not live in an infinite universe—at least, not of the kind envisioned by Kepler and Olbers. In the real universe we not only look outward in space but backward in time, toward the Big Bang. Beyond a certain point, the galaxies have to thin out because they are still in the process of forming. The significance of the image shown here is that magnitude 27 may be very close to that point.

To see why, said Tyson, consider that the light from all the galaxies in the universe blends into a diffuse background light on the sky, in much the same way that the sound of individual raindrops blends into the diffuse sound of a rainstorm. Astronomers have even been able to set upper limits on that background: it is roughly equivalent to the light of a single tenth magnitude star spread over a square degree of sky. And yet the integrated light of all the galaxies in the 27th magnitude image is already some 70% to 80% of that limit. "In a sense, we've almost gotten to Olbers' paradox already," said Tyson. "So the galaxy counts had better start bending over pretty soon."

Another intriguing hint comes from looking at the very faintest galaxies in the image: on the average one might expect them to be quite a bit smaller than the not-so-faint galaxies, said Tyson, since they are presumably farther away. But in fact they are not much smaller. Moreover, this is a real effect, since the galaxy images are several times bigger than the blurring caused by atmospheric turbulence. "What this tells us is that we really are in a non-Euclidean universe," explained Tyson. Beyond a certain point, it turns out that Einsteinian curvature actually causes images to get larger with distance. The 27th magnitude galaxies seem to be near that point.

Still another intriguing feature of the 27th magnitude image is the color of the faint galaxies, said Tyson: they are very, very blue compared to the brighter galaxies, despite the fact that they are presumably further away and have a larger redshift. "Since the effect is competing with redshift," he said, "these galaxies must have an enormous ultraviolet enhancement." This suggests in turn that the galaxies are producing hot, massive young stars at a very high rate—exactly as one would expect in galaxies that are themselves quite young.

"If you take the number counts and colors, and fold them in with models of galactic evolution," said Tyson, "you find that you need to start the galaxies at a redshift of 6 to 10 in order to get the colors we see." That is, the faintest galaxies in this image are roughly 1 billion to 2 billion years old, which in cosmic terms is practically newborn. Tyson is the first to admit that such conclusions need a lot of refinement before they are reliable. Nonetheless, it is clear that with deep images such as this one, astronomers can address one of the central questions of cosmology: When did the galaxies form? ■

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* "Workshop on Nearly Normal Galaxies," 21 July to 1 August 1986, University of California, Santa Cruz.