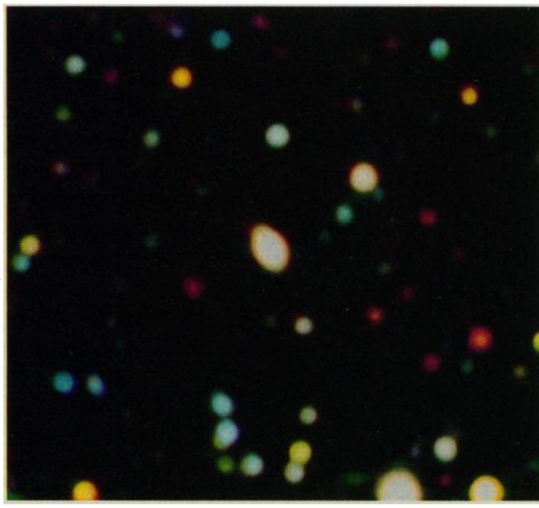
A Window Looking Out on Creation

Cosmology has always been one of those fields where solid facts are scarce and where theorists are forever floundering in a bog of *ifs* and *maybes*. But not for much longer—not if astronomers' latest "New Technology" telescopes and instruments fulfill their promise. Witness the image shown below: an infrared portrait of galaxies some 20 times more distant than any seen before at these wavelengths.

"We're opening a whole new window onto cosmology," declares University of Hawaii astronomer Lennox L. Cowie, a member of the team* of observers who have just published the image in *Astrophysical Journal Letters*. "And it's the one we always wanted." Astronomers have indeed been trying to peer through this infrared window for a long time now, not least because they expect it to provide an unparalleled view of the time of the galaxies' birth. The very first stars in the very first galaxies flared into life so many billions of years ago that their light has long since been redshifted into the infrared. So if astronomers want to understand that epoch, this is the best place to look.



Lennox L. Cowie

The universe in depth. *A portrait of distant galaxies in visible light (blue), near infrared (green), and 2.2 micrometers (red).*

Until recently, however, their view has been a murky one: the available infrared detectors could measure radiation from just one position on the sky at a time, so that images had to be built up point by point in an excruciatingly slow mosaic. Only in the mid-1980s were astronomers able to fashion infrared array detectors: semiconductor chips that cram several thousand miniaturized infrared sensors into a grid that can produce an image directly. And only in the past year or so have they become skilled enough in the use of these arrays to go after very faint, cosmologically distant sources.

Cowie and his colleagues produced this image last year at the 3.8-meter United Kingdom Infrared Telescope atop Hawaii's Mauna Kea, using a 62 by 58 element indium antimonide array camera built for the telescope in 1986 by team member Ian McLean of the University of California, Los Angeles. The image shows a tiny patch of sky in the constellation Aquarius as seen by the camera after 22 hours' exposure time spread over five nights.

Even with the array, says McLean, this was an extremely tricky image to obtain: the infrared heat emissions from the sky over Mauna Kea and from the telescope itself were far brighter than the faint sources he and his colleagues were searching for. "It was like looking for a firefly crawling across a searchlight," he says. Among other things, says McLean, they were able to accomplish that feat only by calibrating the response of every sensor in the array to a precision of better than one part in 10^5.

In the end, however, their reward was a field of distant galaxies scattered so densely on the sky that the full moon would cover some 40,000 of them. The dimmest sources are about the 21st to 24th magnitude at a 2.2-micrometer wavelength, which means that this image attains approximately the same sensitivity as very long exposures of the sky made at optical wavelengths by observers such as Bell Laboratories' J. Anthony Tyson.

Even this is by no means as faint as the observers ultimately want to go. But their achievement is nonetheless being hailed as a significant step toward a better understanding of what actually triggered the formation of the galaxies and what grouped them into a gargantuan pattern of clusters, superclusters, and voids. "It's beautiful work," says Tyson.

Indeed, this particular image raises some intriguing questions already—even though, as team member Simon Lilly points out, "It's only one image of one field, so you have to approach it rather cautiously."

When, for example, did the very first galaxies burst into life? Suppose they appeared very early, says Cowie, within a billion years or so after the Big Bang. (In technical terms this would correspond to galaxy formation at redshifts of 5 to 10.) Then the first blazes of star formation ought to be just barely visible in this image, he says. By the same token, however, any galaxy forming that early in the universe ought *not* to appear in the corresponding optical images since it would be redshifted into invisibility at those wavelengths. And that requirement rules out virtually every blob in sight, says Cowie: all of them do have optical counterparts.

Unfortunately, he says, these objects are much too faint for anyone to calculate their age by getting a real spectroscopic redshift. But one tentative conclusion is that galaxy formation didn't start early, that instead it started comparatively late—and that the blobs we see here are actually among the first galaxies to form. This would certainly please the advocates of what is currently the most prevalent theory of galaxy formation, which envisions the process being controlled by the ebb and flow of an invisible haze of elementary particles known as "cold dark matter." Computer simulations suggest that galaxies wouldn't form in a cold dark matter universe until 2 or 3 billion years after the Big Bang, corresponding to a redshift of about 2.

But if these infrared blobs are indeed newborn galaxies, says Cowie, then why are there so many of them, especially in the optical images? Depending on which wavelengths you look at and how you do your estimates, he says, these blobs are as much as ten times more abundant than galaxies are today. So does that mean that 90% of all the galaxies that ever formed have somehow blown themselves apart?

The answers to such conundrums won't be easy to get. But there will soon be a lot more data to work with. Already, Cowie and his group at Hawaii are taking data with the first working infrared array to have 256 by 256 sensor elements, not to mention a good deal more sensitivity than existing models. Within a few years, these arrays should be widespread. "Finally," says McLean, "we're starting to do some real observational cosmology."

■ M. MITCHELL WALDROP

* Lennox L. Cowie, J. P. Gardner, and Simon J. Lilly of the University of Hawaii and UKIRT and Ian McLean of University of California, Los Angeles.