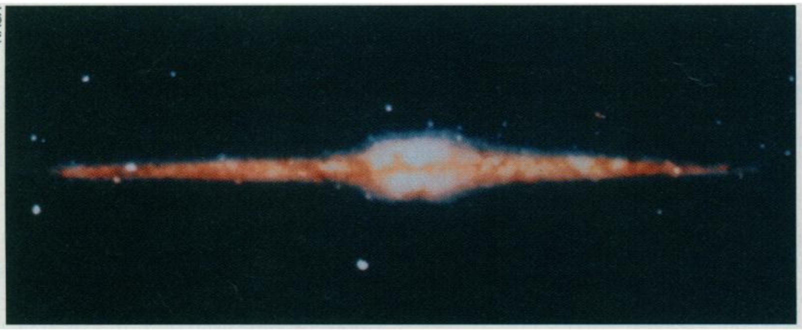

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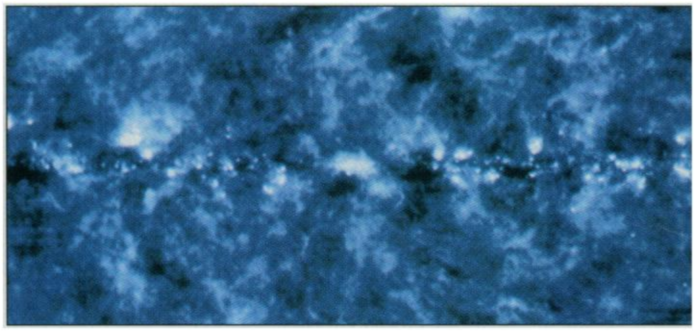


ASTRONOMY

Satellite Images Display the Galaxy's New Colors

When astronomers sent up a string of satellites in the past few years to take pictures of the cosmos in various kinds of light, they expected some surprises. But never did they imagine the views that these satellites would bring back of our own Milky Way Galaxy. Last month, a conference* titled "Back to the Galaxy" brought together the most detailed images yet, and they show a previously uncharted world: a monstrous sponge-like structure of 500 light-year-wide bubbles floating in the galactic gas, as well as hundreds of 300 light-year-long "worms"—wriggling columns of hot gases projecting out of the galactic disc.

Astronomers say these formations record violence and upheaval within the galaxy far beyond anything they expected. They had seen hints of such things before, but nothing like the detailed images, taken in radio, infrared, and x-rays, which became available within the past year, thanks to satellites including the Cosmic Background Explorer (COBE), IRAS, and ROSAT, capable of detecting at those wavelengths. "We have new maps in wavelengths we've never seen before," said Carl Heiles of the University of California, Berkeley, in a summary talk at the close of the meeting. "This is a gold mine," adds the University of Colorado's Richard McCray, describing the wealth of new data. "And it's only begun to be mined."

At this point, astronomers have gone much further in producing the images than in understanding what they mean. But they suspect that the worms and bubbles both spring from hundreds of supernovae going off together like packs of cosmic firecrackers. If they're right, and if they can comprehend the cataclysmic explosions that seem to be percolating the stuff of the galaxy, the work may help answer some long-standing astronomical questions about the galactic forces that sweep gas and dust into stars. As NASA-Goddard astronomer William Waller notes, stars dying in supernovae stir up the galactic gas, and that in turn stirs up new stars. So by studying the images the satellites are producing, astronomers may learn something about how stars are born as well as about how they die. "It's like an ecosystem. It's all so interconnected that astronomers now realize they must understand the interstellar gas to understand the galaxy at all," says Waller.

Although the images produced by the various satellites may look very different, taken together they provide a consistent picture of the galaxy. Some trace out the thin, million-degree gas that fills the bubbles, while others delineate the thick, cooler gases that make up the bubble walls as well as the walls of the "worms."

Goddard's Waller put together maps of the galaxy's "warm gas" with a temperature of 10,000 K, using infrared emissions detected by the IRAS satellite. Overall the galaxy has a sudsy look in these maps, he says, although he admits that individual bubbles are hard to discern. "It's like an ink blot test. My wife picked out this one," he says, pointing to some arcs that may or may not connect into one bubble.

The "worms" also emerged from the IRAS data, in this case in images prepared by another Goddard astronomer, William Reach. Some worms of 10,000 K gas writhe alone, while others—also known as "chimneys" or "fountains"—channel columns of even hotter million-degree gas as it rises out of the galactic plane. There had been hints of these structures before, Reach says, in images made by radio telescopes. But only now are the pictures encompassing the whole galaxy, or huge swathes of it, in striking detail. "Now we can see large structures, whereas people could only see parts before," he says.

The worms probably form, says Reach, when big bubbles of hot gas burst right out of the galaxy. A good-sized worm is about 400 light-years across and stretches 1000 light-years high. They are so immense that even a massive supernova couldn't provide enough power to produce one of these structures by itself, says Reach. It would take hundreds going off within a few million years. That happens quite often, says Reach. "Clusters exist where stars have a similar age," he explains. "If you start out with a cluster, within a million years you have most of them going supernova."

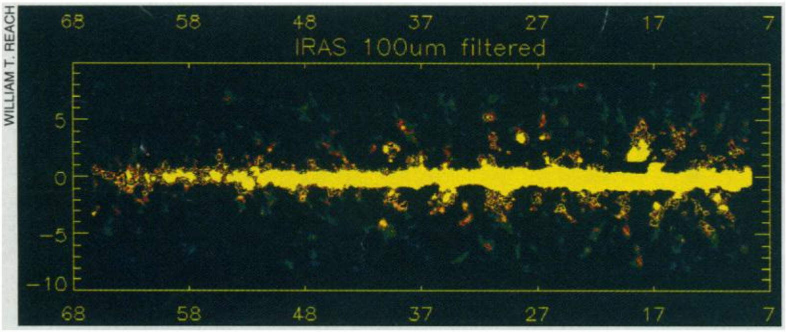
IRAS is not the only satellite turning up images of huge gas bubbles. So is COBE, which is best known for shedding light on the birth of the universe through its observations of the cosmic microwave background radiation. COBE's detectors can also trace the long wavelength infrared radiation coming from within our galaxy, which is emitted as carbon and nitrogen ions cool, explains Charles Bennett of Goddard, who is analyzing the COBE images.

Ionized nitrogen can only exist, Bennett says, in places hot enough to supply the energy needed to knock an electron off a nitrogen atom. In contrast, just a little starlight can knock an electron off a carbon atom, so carbon ions live in the cooler regions, where the gas clumps in thick clouds. Bennett tracks the infrared radiation emitted by these hot nitrogen and cool carbon ions to map out the distribution of both hot and cold regions of the galaxy. The result, Bennett says, is a map showing bubbles of hot gas hundreds of light-years across, especially around a region called the molecular ring toward the center of the galaxy. "They really named that after the wrong piece of jewelry," says Bennett. "It should be the molecular necklace." It's really a bead necklace, he says, strung with the vast bubbles of hot gas.

But you don't have to travel to the molecular ring to find a bubble: Our own immediate neighborhood is right in the middle of one, says University of Wisconsin astronomer Daniel McCammon. His analysis of ROSAT data shows that for 100 light-years out the interstellar gas surrounding the sun is 1 million degrees. Soon after its launch in 1990, ROSAT, which is still exploring the x-ray profile of the sky, detected a mysterious background of x-rays, so smoothly distributed that McCammon says they can't come

*The conference was held on 12 to 14 October at the University of Maryland in College Park.

WILLIAM T. REACH



Three faces of the galaxy. Left: COBE's picture of the galaxy in near-infrared. Center: IRAS infrared showing bubbles. Right: Another IRAS image, which highlights "worms."

from stars or other point sources. "The only thing that works is thermal emission from hot gas," he says. ROSAT, he says, is seeing the emissions of million-degree gas in our bubble. The density of this gas is very low, with less than one atom per 10 cubic centimeters—less than one-tenth the average density over the galaxy. "Temperature tells you how fast atoms are moving, independent of density," McCammon says. Any of these speeding atoms approaching Earth would be deflected by the magnetic field or cooled off by our atmosphere.

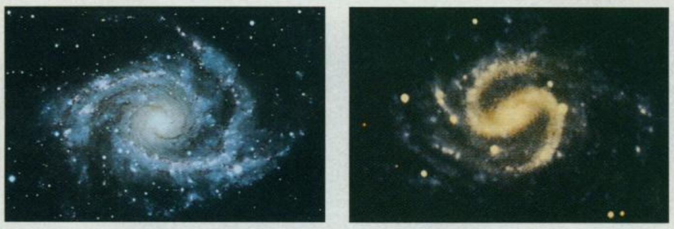
What's more, McCammon can see the cooler gas that borders our bubble with radio telescopes and infrared probes. By comparing its distribution with that of the hot gas, he finds that our bubble bulges out in some places and the cooler gas bulges inward in others. Though he can't directly see bubbles with ROSAT, he says the evidence is mounting that they exist, and that perhaps most of the mass of the galaxy is in the "walls" separating bubbles in the froth.

Together, the latest round of pictures in x-rays, infrared, and radio shows that our galaxy is a more complex environment than anyone imagined, says McCammon. But not all the astronomers like the new terminology that has followed. "I don't like this term 'worms' at all," exclaimed Colorado's McCray after one of the meeting's worm talks. Since it came into use, McCray says, he gets the creeps whenever he looks at a picture of the galaxy. And then there are the chimneys and fountains, bubbles and shells—a real mix of metaphors. "We definitely have a surfeit of colorful terminology," he says. On the other hand, he considers, we can see a tremendous amount happening. The hodgepodge of images is a sign that the field is really moving.

–Faye Flam

What Kind of a Galaxy Is This, Anyway?

PLANETARIUM ARMAGH



KITT PEAK NATIONAL OBSERVATORY

What do we look like? Not the galaxy on the left, which shows a standard spiral, M81. Our galaxy probably resembles the one on the right—a barred spiral, NAC1365.

Earlier this year, when Hawaii-based artist John Lomberg was commissioned by the Smithsonian to paint a mural of our Milky Way galaxy, he sketched out the standard picture of a pinwheel-shaped structure with stars radiating like arms from a spherical core. But to make sure his depiction was scientifically accurate, Lomberg brought his preliminary sketches to an expert—astronomer Leo Blitz of the University of Maryland. Blitz didn't like what he saw. "It was all wrong," he says. A minor problem was that Lomberg's galaxy had too many arms and their shape was wrong. But Blitz was most concerned that the picture didn't illustrate Blitz's own theory—that we live in a "barred spiral" galaxy in which the arms emanate from an elongated, cigar-shaped center.

Lomberg's mistake wasn't so surprising though, because until now, most astronomers shared his guess that the galaxy was a more perfect spiral. "People assumed it was nice and symmetrical," says astronomer Carl Heiles of the University of California, Berkeley. Although Blitz and colleague David Spergel of Princeton had proposed the barred spiral idea in 1990 on the basis of infrared pictures of the galactic center taken by a Japanese balloon-borne experiment, other astronomers didn't find the evidence convincing. But now their views may be changing, thanks to serendipitous observations by the Cosmic Background Explorer satellite (COBE). "The latest results match the [barred spiral] model perfectly," says Heiles. "This is a major advance in our understanding of the galaxy."

Astronomers have had difficulty determining the shape of the galaxy because from where we sit, which is right inside the pancake-thin galactic disc, the spiral arms can't be seen directly. Astronomers have mapped out three of them by plotting the positions of stars and gas that form them. But spirals come in two varieties—barred and the ordinary more rounded type—each of which is about equally common in the cosmos. And the difference is in the shape of the center—which is elongated for a barred type.

Blitz and Spergel have been probing the galactic center by examining its infrared emissions, which penetrate the thick dust better than visible light. Unfortunately, the central bulge seen from our vantage point could be produced by either type of galactic center—ordinary or barred. Blitz predicted, however, that if the center is a bar, one end probably slants toward us and should appear brighter than the end that slants away.

And that's where the new COBE results come in. Although the satellite was sent up mainly to study the cosmic microwave background that many astronomers believe emanated from the Big Bang, it also sports an infrared detector called DIRBE, which is set to map the infrared radiation released by the first generation of stars. When Michael Hauser and his colleagues at the NASA-Goddard Space Flight Center trained DIRBE on the huge flux of infrared radiation pouring forth from the blob of stars at our own galactic center, they found strong evidence supporting Blitz's proposed barred spiral.

Hauser says he and his colleagues went to great pains to subtract out the effects of the galactic dust. If one part of an object appears brighter than another, it could just mean that a cloud of dust is obscuring the darker part, he explains. But in the end DIRBE's map revealed that at one end the bright bulge at the galactic core is brighter than the other, indicating that the core is a bar that tilts at about a 45 degree angle relative to our line of sight. "The galaxy does have an asymmetry to suggest there is a bar with one end closer to us than the other," says Hauser—and that's just what Blitz had predicted. And yes, Lomberg's mural, scheduled to go on display in the Smithsonian's National Air and Space Museum next December, does depict the barred spiral galaxy Blitz and Spergel proposed.

–F.F.