that when the light is merged, the resulting bright and dark interference bands sweep back and forth over the intensity detectors at a different rate for each pair of telescopes. The software can then disentangle the separate interference bands from each pair, analyze them to eliminate atmospheric distortion, and merge them to generate the image.

According to Mackay, the hardest part is getting the beams to overlap exactly, then keeping them that way. On the scale of a few wavelengths of light, he says, "all the things we are using in fact are rather wobbly and jellylike." But it all worked well enough for COAST to make the first images ever of the two distinct stars in the Capella star system, which are about 100 million kilometers apart—closer than Earth to the sun.

"This demonstration is extremely important to show that this [technique] will do what it's supposed to do," says Johnston, who with his colleagues is building the Navy Prototype Optical Interferometer near Flagstaff, Arizona, where a six-beam system will generate star images by the summer of 1997. It will be joined by an array of five 1-meter telescopes slated for construction at the Mount Wilson Observatory near Pasadena, California. Still larger systems are in the offing at ESO's Very Large Telescope in Chile, whose four 8-meter telescopes will operate part-time as an interferometer, and at the Keck.

With COAST and its successors, optical astronomy will enter a new era, say proponents of the technique. "Only interferometers have the capability for imaging the surface of stars in any way comparable to what we routinely do for the sun," says Hal McAlister of Georgia State University, who heads the Mount Wilson project. The technology may also offer a view of planets around other stars (*Science*, 2 February, p. 588). "If these planets are pretty warm … there may be a fair chance you can image them," says von der Lühe.

Some optical astronomers are more cautious. Says Charles Jenkins of the Royal Greenwich Observatory, "The question about interferometry has to be not whether it will work, but whether it can be made to work on an interesting number of objects, and that means making it work on much fainter stars." Faint objects require larger telescopes to gather more light, but atmospheric effects can scramble the crucial phase information across a single large mirror.

Antoine Labeyrie of the Observatory of Haute-Provence near Nice, a pioneer of optical interferometry who is currently constructing a prototype for an array of 27 telescopes, has no such doubts. "Large multitelescope systems," he says, "are the unavoidable evolutionary path in optical astronomy."

–Andrew Watson

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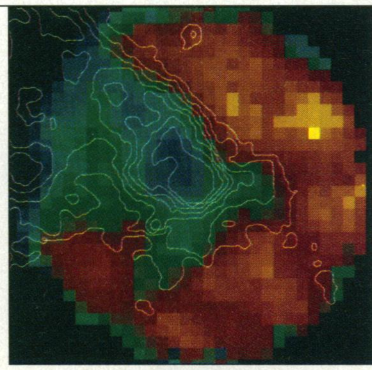
ASTRONOMY

Adding Depth to X-ray Maps

When the Bard wrote that "the floor of heaven/Is thick inlaid with patens of bright gold," he didn't know how right he was. Present-day sky-watchers, who have pushed their observations far beyond the optical wavelengths that inspired those lines, still find the display both dazzling and—yes—floorlike, because their images lack depth. The problem is acute for observers studying x-ray emissions from great bubbles of hot plasma in our part of the Milky Way, whose three-dimensional shapes should hold clues to the history of star formation. Because x-ray photos yield only a projection of these emissions, says Priscilla Frisch, a University of Chicago astronomer, "it's like looking up at the plane of the sky and saying, 'Oh, how beautiful,' but not knowing how far away anything is."

That frustrating lack of depth perception may be ending, however. At the American Astronomical Society meeting in San Antonio last month, Q. Daniel Wang of Northwestern University described a technique he calls "x-ray shadowing" for adding depth to photos like those obtained by the Roentgen x-ray satellite. Wang, who uses cool, dense clouds of neutral gas that waft through our galactic neighborhood as a kind of cosmic range finder, has begun to "put the distance scale on the x-ray emitting regions," says Frisch. His first results have also tossed fuel on a long-simmering debate about the distribution of hot plasma throughout the Milky Way.

All-sky surveys show a giant splotch of "hard" x-ray emission—the signature of a plasma, or ionized gas, at several million degrees kelvin—in the direction of the galactic center. A softer glow from slightly cooler plasma streams in from all directions. The hard emission is thought to come from a "superbubble"—a hot, tenuous region blown up like a balloon by repeated supernova explosions—centered perhaps 500 light-years away toward the constellations Scorpius and Centaurus. The dense gases that pile up around these regions are fertile ground for forming new stars.



Q. DANIEL WANG

Cool shadow. Gas cloud to the left creates dim spot by absorbing x-rays.

The soft emission is more mysterious, although astronomers are certain of one thing: Because x-rays at these wavelengths should be absorbed quickly by intervening gases in the galaxy, they must come from another plasma bubble directly surrounding the solar system. But did this "local bubble" also form from supernova explosions or, as Frisch has suggested, from a breakout, or huge leakage, from the Scorpius-Centaurus superbubble? The answer could be of more than local interest: Competing theories view the gases in the Milky Way either as a warren of hot superbubbles connected by tunnels reminiscent of the breakout scenario, or as mostly cool gas with isolated hot pockets.

The size of the bubble could be a clue: An influx of gas might heat a larger volume than a single supernova, for example. But, says Randall Smith of the Goddard Space Flight Center in Greenbelt, Maryland, "it's like being in a foggy room—we can tell that there is something [hot] right around us, but we have no idea of the distance." Enter Wang. He sought to remedy this problem by correlating patches of infrared emission—indicating the presence of cool gas clouds—with the shadows they leave on x-ray maps as they block x-ray emissions. Then Wang calculated the distance to these gas clouds by noting which stars of known distance along the clouds' sightlines are partially obscured and which aren't.

The final step is to find, say, two clouds along almost the same sightline. By comparing x-ray "colors" based on spectral features of the plasmas between Earth and each cloud, Wang infers the average plasma temperatures out to the near cloud and in the interval between the clouds. Wang's first results along one sightline show plasma at a million degrees extending some 200 light-years into space and plasma at half that temperature pushing out yet another 300 light-years. He thinks a structure of that size is more consistent with "a flood of hot gas from the Scorpius-Centaurus superbubble," possibly expanding into the remnants of a very old superbubble in our region, than with a pocket heated by a recent, local supernova.

Opponents of that view laud Wang's measurements but dispute his conclusions. Says Don Cox of the University of Wisconsin, "I think almost anything that causes heat to be deposited here—whether it's leaking in or from an explosion that happened here—would generate a structure of the kind he's seeing." But as Wang uses more sightlines to piece together a fuller picture, say Cox and others, the emerging shape should reveal golden clues to the Milky Way's structure.

–James Glanz