Lost Space

Rising din threatens radio astronomy

By SIRI CARPENTER

Twilight at the Very Large Array radio telescopes near Socorro, N.M.

Dave Finley/NRAO/AUI

The amount of energy collected from space by all the radio telescopes ever used to explore the sky would not light a single lightbulb. This fact, oft stated by radio astronomers, points out the Achilles' heel of their endeavor.

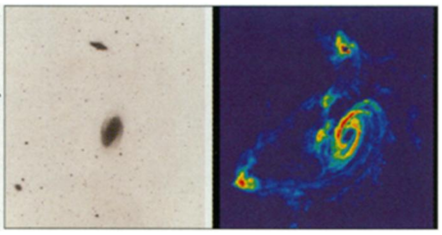
Radio astronomy tracks cosmic events by tuning into weak radio waves that identify the molecules in stars and other celestial bodies. Stronger signals, either from space or earthly sources, can easily overwhelm even the most sophisticated radio telescopes. Today, the sky buzzes with the signals of cell telephones, television and radio broadcasts, military radar, air-traffic-control chatter, and satellites involved in communications, navigation, and meteorology.

Since radio astronomy arrived on the scene in 1932, it has radically transformed scientists' understanding of the universe. Eavesdropping on radio whispers, astronomers detected microwave echoes left over from the Big Bang, discovered compact spinning stars called pulsars, and documented the earliest moments in the formation of galaxies.

Exploration at radio wavelengths has uncovered rich details invisible to optical telescopes. While an optical image of a massive group of galaxies shows only scattered pinpricks of light, a radio image reveals swirling streamers of hydrogen gas that connect the star systems and provide clues to their behavior.

Radio astronomers have been able to make such discoveries because the skies remained free of noise for much of this century. Now, though, the radio environment has grown deafening, by astronomers' standards, and the competition among those who would like a piece of the radio spectrum has become frenzied.

"It's like gold mining," says Paul A. Vanden Bout, director of the National Radio Astronomy Observatory (NRAO) in Charlottesville, Va. "People are scrambling like crazy for spectrum."



Dave Finley/NRAO/AUI

Visible-light image (left) of the M81 group of galaxies shows light emitted by individual stars. Radio image (right) shows hydrogen gas connecting the galaxies.

The organization charged with keeping order is the International Telecommunication Union (ITU) in Geneva, an agency of the United Nations. It meets every 3 years to divvy up radio-frequency bands among more than 40 types of services, from airplane phones to military radar. Since 1959, the agency has tried to protect scientists by setting aside a few small slivers of the radio spectrum. At the low end of the spectrum—the traditional hunting ground for radio astronomers—scientists lay claim to about 2 percent of the territory.

Many other groups share areas of the spectrum, but astronomers can't do that as readily because human-made signals can easily swamp a radio telescope's electronics.

"The rest of the users tend to regard us as kind of a nuisance, because we're the ones that are the most demanding," says Vanden Bout. "But the fact of life is that we're incredibly sensitive to all these other signals, so competing commercial interests can find ways to live with each other that are acceptable to them but are not acceptable to us."

Virtually any strong source of radio waves can cause interference if its signals stray too near the frequencies at which scientists are observing. Even the transmissions from an ordinary cordless telephone, if used close to a radio telescope, would be strong enough to throw off the instrument.

When it comes to making radio astronomers really edgy, nothing works as well as throwing a few dozen satellites into low Earth orbit. There's no escaping satellite systems, because their very goal is to blanket even the most far-flung corners of the planet all the time. To date, several hundred satellite systems have petitioned ITU for frequency allocations. With the rapid growth of wireless communications, radio astronomers fear they may soon have no quiet spots left for their research.

"You can think of the spectrum as a resource, much like timber or government land," says Mark M. McKinnon of the NRAO's Green Bank, W.Va., site. "Some of these things you open to exploitation—

that's fine. But then there are wilderness areas you'd like to preserve."

Even in radio astronomy's youth, scientists understood the importance of a quiet sky. In 1958, the NRAO built its first telescope in Green Bank. In the isolated West Virginia mountains, radio astronomers could largely escape interference from short-wave radio, military radar, aircraft communications, and television transmissions.

To protect the new observatory, the federal government surrounded it with a 13,000-square-mile National Radio Quiet Zone. Within that area, anyone who wanted to install a fixed transmitter had to demonstrate that their signals would not interfere with astronomers' observations. Today, the area around Green Bank remains the only such quiet zone in the world.

Like the Green Bank observatory, most of the world's major radio telescopes are tucked into remote sites that have been relatively uncluttered by ground-based interference. In recent years, however, radio astronomers have found their privacy increasingly violated from above.

For a decade, astronomers have grappled with a constellation of Russian navigational satellites called the Global Navigation Satellite System (GLONASS). When the Soviet Union launched the satellites in the late 1980s, it didn't take part in the ITU allocation process. The satellites' signals seriously interfere with astronomers' observations in a protected radio band at about 1612 megahertz (MHz).

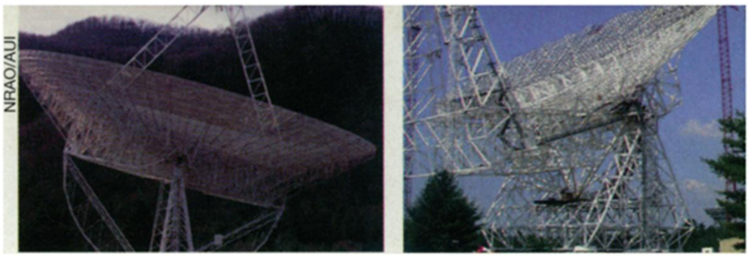
This is the same frequency radiated by hydroxyl (OH)—a substance as central to astronomy as ozone is to meteorology. Radio waves from hydroxyl stream from interstellar dust clouds as they collapse to form stars. The signal hails from the atmospheres of aging red giants, stars that are relatively cool and larger than the sun, and from a type of star, called a Mira variable star, that astronomers use as an indicator of celestial distances.

With hydroxyl serving as such an important tool for studying objects in the Milky Way and beyond, radio astronomers hated having the satellites blur their view of its signal. In 1992, the Russian government agreed to replace aging GLONASS satellites by 2005 with satellites that will not interfere with radio astronomy observations.

Recently, though, another satellite system has worried astronomers. Iridium, a telecommunications company based in Washington, D.C., last year launched a fleet of 66 satellites designed to provide global wireless telephone services, even where cell towers can't reach.

These satellites' main earthbound signals, called downlinks, are just above 1621 MHz. Although this frequency falls outside radio astronomy's protected band, Iridium's downlinks, like GLONASS' signals, include weaker, extraneous signals that sometimes seep into hydroxyl's band. Because the Iridium network covers the entire Earth at all times, such leakage could cripple astronomers' observations anywhere.

In the end, radio astronomers and Iridium reached a compromise. To gain licenses in the United States and some other countries, Iridium pledged that for a few hours each day, it would keep the levels of spurious emissions to levels tolerable to the scientists.



The legs of the tripod supporting the receiver of the 300-foot telescope (left) at Green Bank, W.Va., captured interfering signals. To replace this telescope, which collapsed in 1988, astronomers are building a new telescope (right), whose offset design should minimize interference.

So far, Iridium has kept its promise—although not for reasons the company would have preferred. Because Iridium hasn't sold as many subscriptions to its service as it had hoped, its satellites haven't transmitted at their full capacity.

Even without breaching regulations, however, Iridium has impaired some scientific observations. Most radio telescopes can't avoid picking up emissions in radio bands near the ones they're tuned to, making it hard to deal with Iridium's emissions lurking just outside the protected hydroxyl band.

This problem has particularly plagued NRAO's Very Large Array (VLA), an assembly of 27 radio telescopes, plus one spare, near Socorro, N.M. The array's many antennas make it particularly susceptible to interference, says VLA's Gregory B. Taylor. When the electronic messages between the telescopes mingle with Iridium's downlinks, they become garbled, and the array doesn't function properly.

Since Iridium began transmitting last year, the VLA has discontinued all observations at 1612 MHz. "It's not [Iridium's] fault," Taylor acknowledges. "They're abiding with the agreement. But the VLA wasn't designed with this sort of interference in mind."

Radio astronomers gained a reprieve last month when Iridium declared bankruptcy. "In some sense, it might give radio astronomers a grace period," says McKinnon. "If Iridium had been successful, everyone would want to jump on the bandwagon."

"Iridium's setback has been so widely publicized that there's enormous caution in the financial world about funding new ventures," says John V. Evans of COMSAT Corp. in Bethesda, Md. However, Evans says, Iridium was "a wake-up call to the radio astronomers to discover that there's a huge demand for radio frequencies."

As the wireless-communications industry expands, astronomers expect they'll soon confront interference from a profusion of satellite systems. To cope with such threats, observatories are dedicating more time and effort to combating interference.

Most observatories now have at least one scientist working full-time to deal with radio interference, says Michael M. Davis of the Arecibo Observatory in Puerto Rico. There, a team of 10 astronomers and engineers share the job of advising local transmitters of radio signals how to avert interference problems.

"That's the kind of subtle impact interference has on an observatory," remarks Davis. "Every person you have working on radio frequency interference is a person who isn't spending that time doing something else equally useful to the observatory."

Some observatories are trying to build a degree of immunity into their telescopes. A few sport expensive electronic equipment that filters out frequencies in which human-made signals create interference, allowing astronomers to observe in peace at nearby frequencies.

Even when observatories can afford it, filtering out unwanted signals won't solve all of radio astronomy's interference woes, however. "Each time there's one of those new interfering signals, it means that's another frequency range that's lost for doing astronomy," explains Paul F. Goldsmith, director of the National Astronomy and Ionosphere Center, which operates the Arecibo Observatory. "It's like putting blinders on a horse so it can only look in certain directions."

The currently protected bandwidths don't encompass all the signals of interest to astronomers, either. Scientists have so far detected thousands of radiation frequencies emitted from more than 100 different molecules. At the far reaches of the cosmos, the expansion of the universe causes the radiation from these molecules to shift to lower frequencies, a phenomenon known as the Doppler effect.

At the NRAO's Green Bank site, a new telescope will include a feature that scientists hope will defeat some of the most troublesome interference. On traditional radio telescopes, a receiver that collects radiation is structurally supported by a tripod centered over the dish. A shortcoming of this design is that the legs of the tripod capture interfering signals and bounce them into the receiver, exacerbating problems.

The new Green Bank telescope, scheduled to be completed this year, moves the support structure to the side of the dish, which keeps it from reflecting unwelcome signals into the receiver.

Radio astronomy is fast approaching a crisis, say many scientists. Feats of engineering may help beat back the interference in the short term, but many radio astronomers are reluctant to rely solely on technical solutions to keep their field afloat.

Some scientists argue that more responsibility for curbing spurious emissions—those signals that leak outside their intended frequency range—should fall to the services that generate the problem. Satellite companies can minimize unwanted noise by designing transmitters more carefully or by using filters to block particular signals.

Whether or not companies choose to do this is partly a matter of economics. Filters, for example, add weight to a spacecraft, driving up launch costs. Some satellite makers voluntarily include filters and other precautions against spurious signals, but astronomers are pushing for requirements more stringent than the current rules.

Perhaps radio astronomers' greatest hope is for the use of frequencies above 71 gigahertz, where much of the cutting-edge research is turning. Commercial interest in these higher frequencies is only now emerging, and at ITU's next allocation meeting, in Istanbul, Turkey, next May, scientists will aim to preserve the relatively pristine landscape they now enjoy at such high frequencies.

"It's inevitable that the commercial organizations will continue to put pressure on," comments ITU's Roger N. Smith. "But I think radio astronomers have to draw a line in the sand to make sure the situation doesn't get any worse, because once they lose the spectrum, it's lost."

"We just have to go on fighting," says Goldsmith. "You're never going to say you've won. The best you can do is to say you haven't lost. And we want to hold on to as much as we can for the future."

It's easy to detect a note of resignation when radio astronomers talk about the noisy universe created by expanding wireless technology. Even as they describe ways to maintain a tenuous grasp on their few prized slices of spectrum, radio astronomers almost always add another quiet observation. If nothing else, maybe someday they can hide their telescopes in a place that's likely to remain quiet: the far side of the moon. □

Chemistry

From New Orleans at a meeting of the American Chemical Society

Treatment makes cotton permanent-fresh

A simple and inexpensive treatment makes fabrics lethal to odor- and disease-causing bacteria, says Jeffrey F. Williams of HaloSource Corp. in Seattle. Such antimicrobial textiles could find uses in sportswear, towels, hospital gowns, and bandages.

Williams and his colleagues grafted compounds called *N*-halamines to cotton fibers with a process developed by Gang Sun of the University of California, Davis. The method resembles that used to give fabrics a permanent-press finish by binding resin to cotton. In the new method, the *N*-halamines hold onto chlorine atoms that then kill any microorganisms the fabric contacts. The researchers report that after 2 minutes on treated cloth, the detectable number of microbes on the fibers drops from 1 million to zero.

The team even conducted a smell test with the help of 10 brave volunteers. Williams and his group placed cat urine and bacteria on treated and untreated fabric. This foul combination "generates ammonia in prodigious amounts within minutes," says Williams. After 4 hours, the smell of the untreated fabric caused volunteers to gag and cough, whereas the treated fabric gave off only a light chlorine odor.

The grafted *N*-halamines stay on the fabric for at least 50 washes, Williams says. A dilute bleach rinse refreshes the molecules with chlorine and restores their antimicrobial activity. Such fabrics could help prevent the transmission of disease in hospitals and may be useful for burn victims, who are especially vulnerable to infection. —*C.W.*

Vanishing ink could bolster recycling

An erasable printer ink could offer a better way to reuse and recycle office paper, say scientists at Toshiba Corp.'s Research and Development Center in Kawasaki, Japan. Erasing a printed document would allow workers to use a piece of paper several times before sending it to a central plant for recycling.

The prototype ink developed by Shigeru Machida and his colleagues contains three components: a dye, a developer, and an erasing agent. When the dye is bound to the developer, it looks black. Dripping a solvent over the ink, however, breaks the bond, turning the dye invisible. A new bond then forms between the developer and the erasing agent. That way, "the color never returns," Machida notes.

The researchers have demonstrated the process by running a pen containing the solvent over a document. So far, they've printed and erased each document as many as 10 times. Machida says, "The printing quality doesn't change, but the paper eventually gets mechanically damaged." Then, dog-eared paper could be hauled to a recycling plant, where heat treatment would make the ink colorless. This could result in whiter recycled paper.

Currently, recycled paper made from office waste often appears yellowish because the ink can't be completely removed. Repeating the conventional ink-removal process does result in whiter paper but requires large amounts of electricity and water. —*C.W.*

Low-fat ice cream can still satisfy

A taste test conducted at the University of Missouri in Columbia finds that most people like low-fat chocolate ice cream as much as its full-fat counterpart. Previous tests with vanilla ice cream found that people tended to dislike low-fat versions, complaining of a harsher, less-smooth taste.

"Chocolate is a very complex flavor" resulting from about 500 different compounds, says chemist Ingolf U. Gruen. This complexity probably masks any taste change due to the lack of milk fat, he says. A panel of eight trained tasters, however, could tell the sinful from the saintly desserts. —*C.W.*