The most ambitious program is now under way at the 305-meter Arecibo radio telescope in Puerto Rico. With a sensitive new compound detector, built in Australia, the Arecibo team plans to image hydrogen emissions over 1/6 of the sky within 4 to 5 years. The survey officially began in February, but the team had already detected 165 galaxies and other objects during a commissioning run last fall.

"If a galaxy has any hydrogen gas in it, we will see it," says radio astronomer Martha Haynes of Cornell University in Ithaca, New York, who leads the survey with Cornell colleague Riccardo Giovanelli. Among the survey's main quarries are dwarfs in or near our Local Group that have retained their gas by virtue of avoiding interactions with big galaxies.

Indiana University's van Zee found one such object serendipitously with the Very Large Array of 27 radio telescopes in Socorro, New Mexico. Among five galaxies in van Zee's study was UGC 5288, a nondescript dwarf about 16 million light-years away. Radio emissions revealed an extraordinary disk of gas, extending seven times farther into space than the galaxy's stars. "It's a huge amount of hydrogen, but it's spread out like a pancake," says van Zee. She described the dwarf in January at a meeting of the American Astronomical Society in San Diego, California.

According to van Zee's analysis, the hydrogen is rotating peacefully. That suggests the gas was not expelled by supernovas or captured during a merger. She suspects the hydrogen is a relic of the galaxy's birth, making the disk a potentially rare sample of the gas from which galaxies arose—and relatively uncontaminated by nuclear fusion in stars.

UGC 5288 is "density-challenged," Haynes says. "It did not have enough gravity to form in a normal way. These galaxies have a much slower process of converting their gas into stars, if at all." Van Zee notes that UGC 5288 does contain a lot of dark matter, but some process—perhaps rapid spin at birth—spread most of its gas too diffusely.

Astronomers have long hoped to find an even more extreme object: a galaxy consisting only of gas, in which stars have never burst forth. A team led by astronomer Robert Minchin of Cardiff University in the United Kingdom made just such a claim in the 20 March *Astrophysical Journal Letters*. Using radio data from the Jodrell Bank Observatory in the U.K., the team found a "dark hydrogen cloud" about 1/10 as massive as the Milky Way on the margins of the heavily populated Virgo Cluster of galaxies. The starless cloud shows evidence of galaxylike rotation, Minchin says.

The observations drew worldwide attention, but few other astronomers were convinced. Nottingham's Merrifield noted that the pattern Minchin's team ascribed to a rotating disk—closely tied regions of hydrogen, some moving away from us and others toward us—could also arise from smaller blobs of gas moving in different directions. Haynes also is skeptical: "The Virgo Cluster is a tricky place to work. It's a dynamic environment," she notes, with galaxies milling about and perhaps casting off shreds of gaseous debris.

New detailed images might settle the issue. Minchin's team used the Westerbork Synthesis Radio Telescope, an array of 14 antennas in the Netherlands, to zero in on the mystery object in late April. The team has not yet settled on an explanation for the patterns it sees. "We're working on what it means," Minchin told *Science*. "It's certainly more complex than just a [dark] galaxy on its own. I still think it's a bona fide galaxy," he says, although it may have interacted with a neighbor.

The astronomers also will use the Hubble Space Telescope later this year to scour the dark patch for hints of stars. "Watch this space," Minchin says with a chuckle. His slogan applies equally well to those who scan the depths between giant galaxies, looking for feeble companions to help complete the tale of cosmic assembly.

–ROBERT IRION

Nonproliferation

A Radioactive Ghost Town's Improbable New Life

The city of Pripyat, abandoned after the Chornobyl explosion 19 years ago, offers a unique trove of data for modeling a dirty bomb attack

PRIPYAT, UKRAINE—A rusted Ferris wheel groans in a stiff breeze, the only sound in Pripyat's central square. In April 1986, this attraction and the adjacent bumper cars were newly built and preparing to open for the First of May holiday. Then on 26 April, reactor number four of the Chornobyl Nuclear Power Plant exploded, spreading radionuclides across Europe. Most of the 50,000 residents of Pripyat, within eyesight of the reactor, were power plant workers and their families; everyone was evacuated. They were told to pack for a 3-day trip, but their relocation to other parts of Ukraine ended up being permanent. Nineteen years later the abandoned town is frozen in time, the dilapidated little amusement park still waiting for opening day.

Dead end. Entry to the city of Pripyat, near the Chornobyl nuclear plant, has been barred since the evacuation of 1986.

In a bizarre twist brought about by the 11 September 2001 terrorist attacks, Pripyat is getting a new lease on life. People will never move back into the deteriorating Soviet-era apartments. Instead, scientists are planning to use the radioactive ghost town as a unique laboratory for modeling the dispersal of radionuclides by the detonation of a dirty bomb or an attack with chemical or biological agents. "Pripyat offers an unparalleled opportunity to fully understand the passage of radioactive debris through an urban area," says a nonproliferation official with the U.S. State Department. Modeling in Pripyat, he says, also "can be extended to preparing us against biological and chemical aerosols."

The surreal city's resurrection as a test bed for catastrophes gained backing at a workshop on aerosol dynamics held last month at the International Radioecology Laboratory (IRL) in nearby Slavutych, a town built to replace Pripyat. The workshop was sponsored by the U.S. Civilian Research and Development Foundation, an Arlington, Virginia–based nonprofit that funds nonproliferation efforts in the former Soviet Union. There, radioecologist Ronald Chesser of

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Texas Tech University in Lubbock described new models of the radioactive plumes from the burning reactor. In addition to giving a sharp picture of the accident, they can be adapted to predict the spread of aerosols in a hypothetical terrorist attack.

Two years ago, a team led by Chesser, Brenda Rodgers of West Texas A&M University in Canyon, and IRL's Mikhail Bondarkov measured radioactivity at hundreds of spots in the so-called Red Forest, a swath of dead pines west of the reactor that received lethal radiation doses from the first plume, known as the western trace. (It's called the Red Forest because the needles turned an auburn color.) Sampling 17 years after the accident, Chesser had expected a blurry approximation. "To our surprise," he says, "we saw a very good picture of the plume" as reconstructed from particle density and deposition data: a 660-meters-wide, 290-meters-tall bell-shaped column.

Fortunately, the western trace missed Pripyat, which lies about 3 kilometers north of the reactor, but it "probably wiped out most wildlife in the Red Forest," Chesser says. By the time the winds began pushing the plume northward, it was about half as dense, he says. To reconstruct how badly Pripyat was hit, last summer his group measured radioactivity at more than 1700 spots in and around the city. They found that the heart of the northern trace barreled just east of Pripyat (see graphic, right). If the city had absorbed a direct hit, Chesser estimates that the toll would have been roughly 6000 cancer deaths. "The winds were very, very fortunate," he says.

The U.S. Defense Threat Reduction Agency (DTRA) intends to build on this work to forecast what would happen if a dirty bomb were to explode in a city. "We can't directly simulate this kind of attack, so we use various means to obtain representative data," says John Pace, a meteorologist with DTRA's Chem-Bio Defense Program in Fort Belvoir, Virginia. "The advantage of Pripyat is that the radioactivity is already there." In the city's central square, moss growing in cracks in the pavement sends Geiger counters galloping; it will be another decade before half the radiocesium deposited here will have decayed. Although Pace notes that there are "huge differences" in the consequences of a dirty bomb compared to those of the Chornobyl explosion, by focusing on the spread of material, "we can still obtain useful data that we can use to improve our capabilities to respond to urban terror attacks."

Studying surface contamination can give clues to how aerosol deposition is affected by a town's layout, construction materials, and building positions relative to prevailing winds. "What's particularly interesting with Pripyat is that there are a number of rather tall buildings, up to 16 stories, so we can go back and gather exposure data from different levels above the ground," Pace says. Vertical mixing of contaminants in cities, he says, "is an area where we don't have as much data as we'd like."

Realistic model. Simulating a dirty bomb in Pripyat could yield valuable defense information, researchers say.

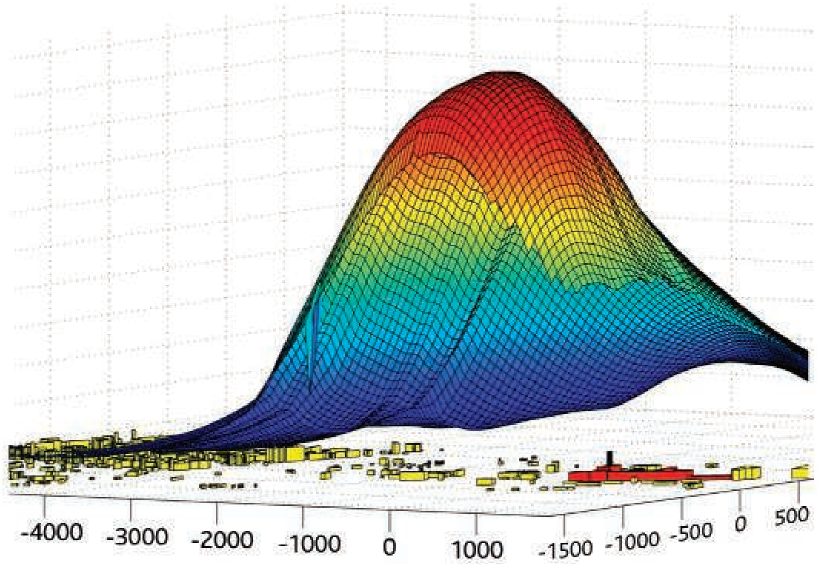
Down the road, benign gases could be released in Pripyat to model dispersal. DTRA has supported similar studies. In 2001, 120 shipping containers were set up to model release scenarios in the Mock Urban Setting Test at the Dugway Proving Ground in Utah (*Boundary-Layer Meteorology*, June 2004, p. 363). In Oklahoma City in 2003, DTRA and the Department of Homeland Security sponsored a study in which an inert tracer gas was released downtown. A similar experiment is planned for Madison Square Garden in New York City this summer.

In living cities, however, constraints on sensor placement and on release locations and times can limit the range of data collected. "A site like Pripyat would offer more freedom in that regard," says Jeremy Leggoe, a chemical engineer at Texas Tech who has modeled the influence of vegetation on aerosol dispersal. Pripyat has disadvantages: For example, vegetation that has gradually been engulfing the city would have to be cut back. "That's particularly important, since in a real event, a large proportion of the exposure that you're concerned about—initial victims and emergency responders—will take place at ground level," Leggoe says.

Faced with such obstacles, DTRA for now would prefer to harvest existing data. "In any other city exposed to radiation, there would have been cleanup efforts that disturbed the exposure patterns, but that's not the case with Pripyat," Pace says. DTRA has asked scientists who work in Pripyat to collect samples and report the results to the agency. Initial studies will not involve tracer gases. "Nor would we intentionally release radioactive materials," says Pace.

A measure of good may yet come out of Pripyat's eldritch fate. "Pripyat is not a mockup. It is not a sterile façade of buildings erected for the purpose of blasting particles through its empty spaces," says Chesser. "Bicycles, pianos, libraries, and baby dolls decaying through 19 winters are there to remind us that learning from this event really matters." Pripyat would be a good laboratory, he says, precisely because it is real.

–RICHARD STONE



"Fortunate wind." A new analysis shows how breezes kept the dense plume of radionuclides from Chornobyl (in red) away from Pripyat's center.

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