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Science

Black Hole Hunters

Aiming to make the first portrait of the hungry monster at the center of our galaxy, astronomers built "a telescope as big as the world."

JUNE 8, 2015

Dennis Overbye
OUT THERE

PICO DE ORIZABA NATIONAL PARK, Mexico — Sheperd Doeleman's project to take the first-ever picture of a black hole wasn't going well.

For one thing, his telescope kept filling with snow.

For two weeks at the end of March, Volcan Sierra Negra, an extinct 15,000-foot volcano also known as Tliltepetl that looms over the landscape in southern Mexico, was the nerve center for the largest telescope ever conceived, a network of antennas that reaches from Spain to Hawaii to Chile.

Known as the Event Horizon Telescope, named after the point of no return in a black hole, its job was to see what has been until now unseeable: an exquisitely small, dark circle of nothing, a tiny shadow in the glow of radiation at the center of the Milky Way galaxy. It is there that astronomers think lurks a supermassive black hole, a trap door into which the equivalent of four million suns has evidently disappeared.

Nature, Albert Einstein once said, is not malicious, only subtle. But it loves a good fight.

Lightning greeted Dr. Doeleman and his crew of astronomers late one night as they crested the summit of their outpost in the unfriendly sky.

What little air there was tasted the way you might imagine it would on Mars. Snowflakes swirled around their heads. The Large Millimeter Telescope, a 20-story tower with a 150-foot-wide bowl-shaped antenna sitting like an oversize cocked hat on its roof, was barely visible in the gloom.

The astronomers stepped gingerly out of their cars onto a moonscape of rocks and down a ramp into the telescope's basement, a labyrinth of warmly lit rooms and labs, as if entering the lair of a James Bond villain.

Dr. Doeleman had planned to spend the night working out new techniques to point the telescope, which among its other problems was afflicted by a persistent and annoying electrical hum. By the time the weather had cleared enough, the radio dish was frozen solid underneath an inch of ice. The stars whirled above, past the remains of storm clouds, their secrets unscathed.

"This is par for us," Dr. Doeleman, a fresh-faced 48-year-old researcher from M.I.T.'s Haystack Observatory and the Harvard-Smithsonian Center for Astrophysics, said with a mix of resignation and pride.

If he and his colleagues succeed, the images they capture will be in textbooks forever, as definitive evidence of Einstein's weirdest prediction: that space-time could curl up like a magician's cloak around massive objects and vanish them from the universe. In short, that black holes — objects so dense that not even light can escape their maws — are real. That space and time as we know them can come to an end right under our noses.

Conversely, they could produce evidence that Einstein's theory of gravity, general relativity, the rule of rules for the universe, needs fixing for the first time since it was introduced a hundred years ago.

"We're swinging for the fences," Dr. Doeleman, who has spent eight years putting this effort together, said one afternoon in an office in Serdan, a small town

at the volcano's base.

He was dressed in long johns and layers of sweaters and fleece, and sipped coca-leaf tea to combat the effects of altitude. He was sweaty, and his hair stood on end in an Einsteinian Mohawk after a long night trying to troubleshoot his telescope.

"We have to worry about everything, from soup to nuts," he said, ticking off all the things that make this radio network, stretched like a spider web across the planet, a fragile object. Success hinges on the exigencies of weather on several continents, high-strung technology, altitude, even traffic — two of his colleagues had just been delayed in a car accident on the way from Mexico City.

"I guess spider silk is stronger than steel," he said, "but even spider silk can snap."

The Cosmic Roach Motel

Black holes were one of the first and most extreme predictions of Einstein's General Theory of Relativity, first announced in November 1915. It explains the force we call gravity as objects trying to follow a straight line through a universe whose geometry is warped by matter and energy. As a result, planets as well as light beams follow curving paths, like balls going around a roulette wheel.

Einstein was taken aback a few months later when Karl Schwarzschild, a German astronomer then serving on the Russian front, pointed out that the equations contained an apocalyptic prediction: Cramming too much matter and energy inside too small a space would cause space-time to sag without limit. No force known to science could stop it from becoming a sinkhole from which not even light could escape.

Einstein could not fault the math, but he figured that in real life, nature would find some way to avoid such a calamity. A century later, however, astronomers agree that space is indeed sprinkled with massive objects that emit no light at all. Call them cosmic roach motels. Stars, atoms, wisps of gas that trace their pedigree to the Big Bang — all of them check in, never to check out.

Many of them are supposed to be the remnants of massive stars that have burned out, collapsed and imploded in cataclysms like supernovas or the even more violent gamma-ray bursts visible across the universe.

Generations of theorists, including Stephen Hawking, using the telescope of the mind, have made careers investigating the properties of these objects only barely in the universe. But they are still arguing about just what happens inside a black hole and the ultimate fate of whatever falls in.

Nearly every galaxy seems to harbor one of these dark monsters, millions or even billions of times as massive as the sun, squatting at its center like Dante's devil. The bigger the galaxy, for some reason, the more massive the void inside it. How that happens is a cosmic nature-versus-nurture question, and anyone's guess.

"How does a black hole know how big a galaxy it's in and when to stop growing?" mused David Hughes, the director of the Large Millimeter Telescope, "or, conversely, how does the galaxy know to stop feeding it?"

Left by themselves, black holes lie dormant with their mouths open. But when something — say, a wayward star or gas cloud — does fall toward a black hole, it is heated to billions of degrees as it swirls in a doughnut called an accretion disk around the cosmic drain. Black holes are sloppy eaters, and when they feed, jets of X-rays and radio energy can be squeezed like toothpaste out of a tube from the accretion disks. Astronomers believe this is what produces the energies of quasars, brilliant beacons in the cores of galaxies that far outshine the starry cities in which they dwell. "Paradoxically," Dr. Doeleman said, "that makes black holes some of brightest things in the sky."

Last winter, a team of astronomers from Beijing University and the University of Arizona announced that they had discovered one of the biggest, baddest black holes yet — 10 billion times as massive as the sun, anchoring a quasar that was blazing 40,000 times brighter than the Milky Way when the universe was only a billion years old.

Not all the action is so far, far away.

The center of the Milky Way, 26,000 light-years from here, coincides with a

faint source of radio noise called Sagittarius A*. Astronomers like U.C.L.A.'s Andrea Ghez tracking the orbits of stars circling the center have been able to calculate that whatever is at the center has the mass of four million suns. But it emits no visible or infrared light.

If this is not a black hole, neither Einstein nor anyone else knows what it could be.

"That is the strongest evidence so far for an event horizon," Dr. Doeleman said, using the name for the boundary of a black hole, the edge that is the point of no return.

But that is only a circumstantial argument, assuming that Einstein was right. "If Einstein was wrong, how would we know?" said Avery Broderick, a theorist at the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, noting that general relativity, for all its mathematical beauty, had never been tested under the extreme conditions that would prevail in the Big Bang or black holes, where the full weirdness of Einsteinian space-time would manifest itself.

According to work that goes back to a paper by James Bardeen in 1967, the Sagittarius black hole, if it is there, would appear as a ghostly dark circle amid a haze of radio waves. Its exact shape, the theorists say, would depend on details like how fast the hole is spinning.

The black hole's own gravity will distort and magnify its image, resulting in a shadow about 50 million miles across, appearing about as big from here as an orange would on the moon, according to calculations performed by Eric Agol of the University of Washington, Heino Falcke of the Max Planck Institute for Radio Astronomy in Germany and Fulvio Melia of the University of Arizona, in 2000.

The proof of the pudding for Einstein would be if radio astronomers could determine that the shadow, the graveyard of four million suns, really was that small. They have been whittling its size ever since Sagittarius A* was discovered, in 1974.

In 2005, a group led by Shen Zhiqiang of the Shanghai Astronomical Observatory narrowed the diameter of Sagittarius A* to a cloud of energy less than

90 million miles across, about twice the size of the long-sought shadow, using the Very Long Baseline Array, a transcontinental network of antennas.

“For most people, seeing is believing,” Dr. Agol said at the time. But there was a problem getting measurements any finer. The ionized electrons and protons in interstellar space scattered the radio waves into a blur that obscured details of the source. “It’s like looking through frosted glass,” Dr. Doeleman said.

To see deeper into the black hole shadow, they needed to be able to tune their radio telescope to shorter wavelengths that could penetrate the haze. And they needed a bigger telescope. The bigger the antenna, the higher resolution or magnification it can achieve.

“Our black hole is active but eating on a slow diet, with billion-degree gas around it,” Dr. Doeleman said. The result, at the heart of the Milky Way, is “a puffy cloud,” he said. “You need the right frequency to see through the debris at the galactic center.”

Enter the Event Horizon Telescope.

On the Edge

Dr. Doeleman had taken a wandering path to the edge of infinity.

The son of a science teacher, he grew up in Oregon and studied physics at Reed College in Portland. He applied to attend graduate school at the Massachusetts Institute of Technology, but before he could go, he saw an ad looking for people to do experiments in the Antarctic. He signed up and spent most of a couple of years at the bottom of the world. “It was there that I probably caught the bug for doing science under challenging circumstances,” Dr. Doeleman said. He reapplied to M.I.T. from Antarctica and then wandered around Asia on his way home.

At M.I.T., he first joined a group doing plasma physics, then dabbled in X-ray astronomy and biophysics before joining a radio astronomy group. The technique of choice for radio astronomers is known by the intimidating name of very long baseline interferometry — V.L.B.I. for short — in which separate radio telescopes as far as a continent apart can be joined in a synchronized network that mimics a

single antenna with a very big diameter.

Dr. Doeleman was originally interested in using the technology to monitor movements of the Earth's crust and was hoping to travel to exotic places to install instruments. But it turned out they were already installed. So his eyes turned to the heavens and the mysteries of quasars.

During a talk recently, Dr. Doeleman showed a picture of a galaxy in the constellation Centaurus, a gentle-looking pearly smoosh of starlight with a slash of dust across its belly. Known as NGC 5128, the galaxy can be seen through binoculars from the Southern Hemisphere.

Then he showed a picture of the same galaxy taken through what he called "radio goggles." In this view, the galaxy is being ripped apart by an explosion at its core, shooting lobes of energy thousands of light-years across space.

Dr. Doeleman traced his interest in quasars and black holes to the moment he first saw images like that. "Whatever is powering those jets has to be insanely powerful," he said.

In 2008, Dr. Doeleman had what he calls an "a-ha moment" when he and colleagues yoked together three radio telescopes in Hawaii, Arizona and California into a interferometer system and trained it on the galactic center, using a shorter wavelength. They detected a small blob of energy, "a dot that would not go away."

They were seeing something through the frosted glass. But what?

Since then, he and his colleagues have devoted their energies to building a network big enough to see whether that radio dot harbors signs of a black hole.

In all, the Event Horizon Telescope involves 20 universities, observatories, research institutions and government agencies, and more than a hundred scientists. Among other things, to keep the radio telescopes in their network suitably synchronized, they had to equip them with new atomic clocks accurate to within one second every 100 million years, and new short-wavelength receivers.

Dr. Doeleman recalled having to wear an oxygen tank to test atomic clocks at the new ALMA array, on a 16,000-foot plateau in Chile. Another colleague, Daniel

Marrone of the University of Arizona, spent last winter at the South Pole installing a new receiver. Both of these installations will eventually join the Event Horizon observations.

The March observing run was the first time the group would have enough telescopes — seven radio telescopes, on six mountains — to begin to hope they could glimpse the black hole. They would have five chances over a period of two weeks.

On each night, they hoped to have two black holes in their sights: Sagittarius A*, and one in a giant galaxy known as M87, which anchors the enormous Virgo cluster of galaxies about 50 million light-years away. The M87 black hole has been estimated at six billion times the mass of the sun, and from here, it would appear only slightly smaller than the Milky Way black hole. Moreover, jets of energy shoot like a blowtorch from its accretion disk and across intergalactic space. Astronomers really wanted to get a close look at that.

Hoping for Boredom

"It's beautiful work," Andrew Strominger, a Harvard theorist who has joined the Event Horizon team, said of the telescope.

In practice, it could be gritty or boring, depending on how things were going.

The visit to Sierra Negra in March was Dr. Doeleman's fifth in two years. The commute required a plane ride and five hours in buses, cars and trucks to the small, decidedly untouristic town of Serdan. He sometimes toted a special crystal used to test atomic clocks, which provoked attention from security officers. "It looks just like you would expect a bomb to look — a metal cylinder with wires sticking out," he said.

For his troubles, he often wound up with a headache, the price of working almost three miles above sea level. The telescope control room is outfitted with finger monitors that measure blood oxygen and an oxygen tank and mask for those woozy moments.

Sierra Negra is next door to an even bigger peak, Pico de Orizaba, Mexico's

highest mountain, and the pair combine to create their own weather, which can cause problems for astronomers.

One night, the telescope was being turned to keep it from filling with snow. Dr. Doeleman was in the unheated receiver room, where light from the antenna's focus bounces off mirrors down an open shaft into boxes the size of microwave ovens, when he felt the building shake. Thinking it might be an earthquake, Dr. Doeleman ran for the elevator, only to find his colleagues rushing up from the control room and offices below. "I was pretty freaked," he said.

It was no earthquake. Because of an electrical malfunction, the gargantuan dish, half a football field wide and weighing 1,600 metric tons, had suddenly lurched to a stop, transferring all that momentum to the structure around it.

Later on, a real earthquake sent the astronomers running from their breakfasts down in Serdan.

In late March, Dr. Doeleman's collaborators were camped out on similarly uncomfortable mountains in Chile, Hawaii, California, Arizona and Spain, waiting for his signal, based on weather forecasts and the state of their equipment — all the accouterments of that spider silk — to begin observing. All the telescopes would point in unison at M87, and then at the galactic center.

When it works well, this ganging up on the cosmos is "boring, in a good way," Dr. Doeleman said one night that was anything but boring, explaining that the observations best proceed automatically while the astronomers all hold their breath.

Belying the boredom is the hope that in the subtle interplay of radio waves they will see the signature of one of nature's great calamities. Waves from different parts of the radiation cloud around Sagittarius A* would interfere with one another, producing a complicated pattern that a computer could read as a black hole.

Imagine, Dr. Doeleman said, that someone is dipping a finger into a pond and creating ripples. If there were tidal gauges installed along the shore, you could figure out where the ripples were coming from by recording the arrival of each

wave crest on the shore. One finger would make concentric circles.

If there were two fingers doing the dipping, the ripples would interfere with one another, sometimes amplifying, sometimes canceling out. As a result, some tidal gauges would show crests combining to be extra large; others would show troughs.

“By analyzing this pattern,” Dr. Doeleman said, “we can tell what’s going on far away.” Someone reading the pattern could distinguish whether there was just one finger or many of them in some arrangement dappling the water.

In this case, there are antennas spread along the shore of infinity, synchronized by atomic clocks, recording the radio waves as they arrive.

“This is the way you build a telescope as big as the world,” Dr. Doeleman said.

If everything went right — if all the elements of Dr. Doeleman’s spider web of weather and electronics and superprecise timing held together — they would see that any given wavefront would arrive bearing the marks of interference, a complicated pattern of crests and troughs — “fringes,” in the astronomical vernacular. With enough fringes from baselines going in different directions across the sky from the various observatories, the astronomers could reconstruct a map what was happening out there, thousands of millions of light-years away.

Seeing even one fringe from one baseline would be a triumph — it would mean they were achieving the kind of resolution needed to make a detailed image of Sagittarius A* and see if it looks like a black hole. Making that image, of course, would be another long story indeed. Until they saw that first fringe, the Event Horizon team would simply have to hold their breaths.

That could be months. All that data would be too much to send over the Internet. Nobody would know if the whole telescope had worked until the data recorded from each separate instrument had been correlated in a supercomputer back at M.I.T. As Dr. Doeleman liked to say, “The bandwidth of a 747 loaded with disk drives is phenomenal.”

If they are lucky, sometime later this summer or fall, then, they might see emerging from the computers at M.I.T. the first rough image of a black hole. And

its size and shape could provide a judgment on general relativity, the harshest test yet a century after Einstein dreamed up the theory.

For some theorists, breaking Einstein is the main game. “The least exciting thing would be to find general relativity works beautifully,” said Dr. Broderick, at the Perimeter Institute.

But Dr. Doeleman says he is also excited about what he likes to call the “secret sauce” of the Event Horizon Telescope: the chance to see inside the engine that produces the monstrous energies of quasars.

“We can see a black hole eat in real time,” he said. By following hot spots in the superhot gas swirling toward oblivion, they can even measure the rotation rate of the black hole.

“If something is dancing around the edge of the black hole, it doesn’t get any more fundamental than that,” Dr. Doeleman said. “Hopefully we’ll find something amazing.”

The Plumbers’ Blues

The first piece of Dr. Doeleman’s spider silk to break was the radio telescope in Chile. Its receiver died and had to be sent back to Europe for repairs.

That failure put more of an onus on the Mexican telescope.

Sierra Negra was a natural choice as the fulcrum of the Event Horizon Telescope. Not only is it centrally located, but the new Large Millimeter Telescope, with its giant dish designed for short wavelengths, is also the most sensitive radio telescope in the network. Completed in 2006 by the National Institute of Astrophysics, Optics and Electronics in Puebla state and the University of Massachusetts, Amherst, at a cost of $116 million, it is the largest and most expensive scientific project in Mexico. Its inclusion in the Event Horizon Telescope was a point of great pride to its director, Dr. Hughes, who has spent the better part of the last decade getting the instrument up to snuff.

“People want to bring their equipment and their experiments here now,” he said.

During a dry run, however, the astronomers discovered that the telescope's new receiver was afflicted by a mysterious electrical buzz.

Astronomical history is replete with mysterious hisses and buzzes that turn out to be cosmic breakthroughs. One incident 50 years ago with two Bell Labs astronomers, Arno Penzias and Robert Wilson, turned out to be the signal of cooling radiation from the Big Bang itself, and resulted in a Nobel Prize.

But this was not the cosmos calling. The hum did not interfere with the data, but it did interfere with pointing the antenna. Normally, to lock onto a radio source, the astronomers would rock the telescope back and forth to find the strongest signal, like a cross-country driver trying to tune into a distant Yankees game.

Strong sources like Jupiter still came booming through above the noise. But the buzz was louder than faint sources like Sagittarius A* at the galactic center, meaning that the astronomers could not be sure they were recording data from the right target. As a result, the Mexican telescope had to sit out the first official observing run.

Several days of troubleshooting failed to make the buzz go away. "We're just plumbers here," Dr. Doeleman said one morning.

To make matters worse, the expert on the receiver, Gopal Narayanan of the University of Massachusetts, was called home for a family emergency.

If the astronomers did not solve the problem, they would be down to just four sites in the network. "Every antenna is precious," Dr. Doeleman said, but the prolonged absence of the Large Millimeter Telescope could be crippling. Losing Mexico on top of Chile would leave the astronomers with less than half the information they had hoped for.

"We're on a slippery slope," Dr. Doeleman said.

He and his colleagues hit on a plan. Unable to isolate the noise, they decided to see if they could use a less sensitive but quieter receiver to point the telescope, and then switch over to the new receiver to collect data. They could calibrate the pointing difference between the receivers by aiming each one in turn at a bright

object like Saturn and measuring the offset.

“It’s a lot of handwork,” Dr. Doeleman said. “Once you know the offset, you can lock in with a computer model.”

“What do I feel about this project?” Dr. Doeleman said that afternoon as the team was assembling to go back up to the telescope, raising his voice so everyone could hear. “We’re going to succeed. It’s going to take a lot of innovation, but we have a good team to do it.”

At the time, Dr. Doeleman was not planning on being part of that team. He was scheduled to go home to his family the next morning, having already extended his stay in Mexico once.

Dr. Hughes urged him to stay, saying the team needed his leadership and expertise.

Doing so would require an intense Skype conversation with his family, Dr. Doeleman said.

Dr. Hughes replied that it should be an easy decision, given the scientific consequences.

The Kid Stays in the Picture

Dr. Doeleman packed his bags for the long ride to the airport. But in the morning, looking distraught, he announced he had changed his mind and would stay.

Two of his postdocs were new to observational astronomy, the Mexican scientists who had joined them were new to the Event Horizon procedures, and Dr. Narayanan, the receiver expert, was not back yet. The telescope’s chances of helping to produce a black hole image were hanging in the balance. “If we were going to have any chance of doing it, I had to stay,” Dr. Doeleman said.

His reward was another night of snow in the dish, a real heartbreaker because for the first time, everything else was working.

Twelve hours later, the team made its third try. The atmosphere in the control room was almost giddy as the telescope swung into position, staring at the black hole in the fiery galaxy M87.

Dr. Doeleman, wearing a scarf knitted by his wife, typed into his laptop that the Large Millimeter Telescope was taking data. At last.

“That’s a real moment,” he told Dr. Narayanan, who had just returned from home. “That’s a real moment, Gopal. That’s huge.

“We’re gonna image a black hole,” he said, beaming. “That’s what we’re here for. This is it. We’re doing it.”

The connection established, they settled down to be bored — but an hour later, the weather went bad and they had to stow the telescope to keep the snow out.

Just before dawn, five long hours later, the weather cleared enough for the telescope to rejoin the network, now focused on the Milky Way center.

Laura Vertatschitsch, one of Dr. Doeleman’s postdoctoral researchers at the Center for Astrophysics, said, “My heart was beating a million miles a minute, and I was smiling from ear to ear.”

High-fives were exchanged — but two hours later, the sun had risen too high for them to continue. The black-hole party now became a race against time and weather. The next night, the Mexican telescope was shut out by the weather completely.

As Dr. Doeleman put it later in an email, “There were a couple of nights where the other sites were having an E.H.T. party and we were at home in PJs doing the crossword. Maddening.”

Getting Out of Dodge

Dr. Doeleman did finally go home, satisfied that his team was in good shape to carry on, while he watched by laptop and Skype. Dr. Narayanan took apart the receiver and traced the troublesome noise to mechanical vibrations, which he treated with duct tape. After all, he said, duct tape had helped save Apollo 13.

Naturally, that was when things started working.

They were now down to their last official chance to spin the silk. The weather was not promising, Dr. Vertatschitsch said later by email, but they went up Sierra Negra anyway. They spent half the night going through their piggyback routine to point the telescope, writing computer code on the spot. “It’s hard to describe,” she wrote, “but there is an adrenaline that comes with this high-stakes problem-solving.”

Then they clicked with the Event Horizon Telescope for good, first for Virgo and then for Sagittarius, collecting data until dawn. Afterward, some of the astronomers ran out and took a selfie in front of the telescope, celebrating, Dr. Vertatschitsch said in an email, “the sweat, the lack of sleep, the exhaustion and the pure joy of an experiment. It’s the moments you live for.”

From afar, Dr. Doeleman had his own moment. “I wasn’t there,” he said later. “Sometimes, the best thing you can do is get out of Dodge.”

That night marked the end of the Event Horizon Telescope’s official observing run, but as it happened, there was an encore. California, Arizona and Mexico were available for an extra night. That, said Dr. Vertatschitsch, was the best night of all.

“It was the best weather we had seen all trip,” she said. Dr. Narayanan’s taped-up receiver was able to do the pointing by itself.

“All I had to do was go,” Dr. Doeleman said later. “On the final two nights, the clouds parted. Everything comes out biblical in the Event Horizon Telescope.”

A Sneak Peek

Two weeks later, Dr. Doeleman, looking relaxed and 20 years younger, with his wife and two children in tow, traveled to New York to give a talk in the Hayden Planetarium at the American Museum of Natural History. He said in a separate conversation that some 200 terabytes of data — about as much as is contained in the printed material in the Library of Congress — were then on the way to M.I.T., the bandwidth of that metaphorical 747 in action.

This year, the 100th since Einstein presented his Theory of General Relativity,

the calendar is chock-full of meetings and celebrations devoted to the theory. Perhaps during this yearlong party, astronomers may finally know if the dark shadow of eternity is smiling at us through the star clouds of Sagittarius.

The computers are already running.

At the end of April, an email went out to the Event Horizon collaboration, dense with graphs, the result of correlating the observations from one night between two mountains — Sierra Negra and Mauna Kea, in Hawaii.

They showed striking signs of an interference pattern. The fringes were there. The spider silk had held.

“I had no idea I could hold my breath that long!” Dr. Doeleman said.

Correction: June 11, 2015

A capsule summary on Tuesday for an article about efforts to take the first picture of the black hole at the center of the Milky Way misidentified what one scientist calls a “telescope as big as the world.” It is a network of telescopes around the world, not just a telescope on the dormant volcano Sierra Negra in Mexico.

Correction: June 16, 2015

An article last Tuesday about efforts by scientists to take the first-ever picture of the black hole at the center of our galaxy by using a worldwide network of telescopes misstated, in some copies, a task that Sheperd Doeleman, the head of the project, once completed at the ALMA telescope array in Chile. He was testing atomic clocks, not installing receivers. And a chart with the article misidentified one of the telescopes in Hawaii that is part of the network. It is the Submillimeter Array, not the Small Millimeter Array.

A version of this article appears in print on June 9, 2015, on page D1 of the New York edition with the headline: Hunt for the Star Eaters.

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