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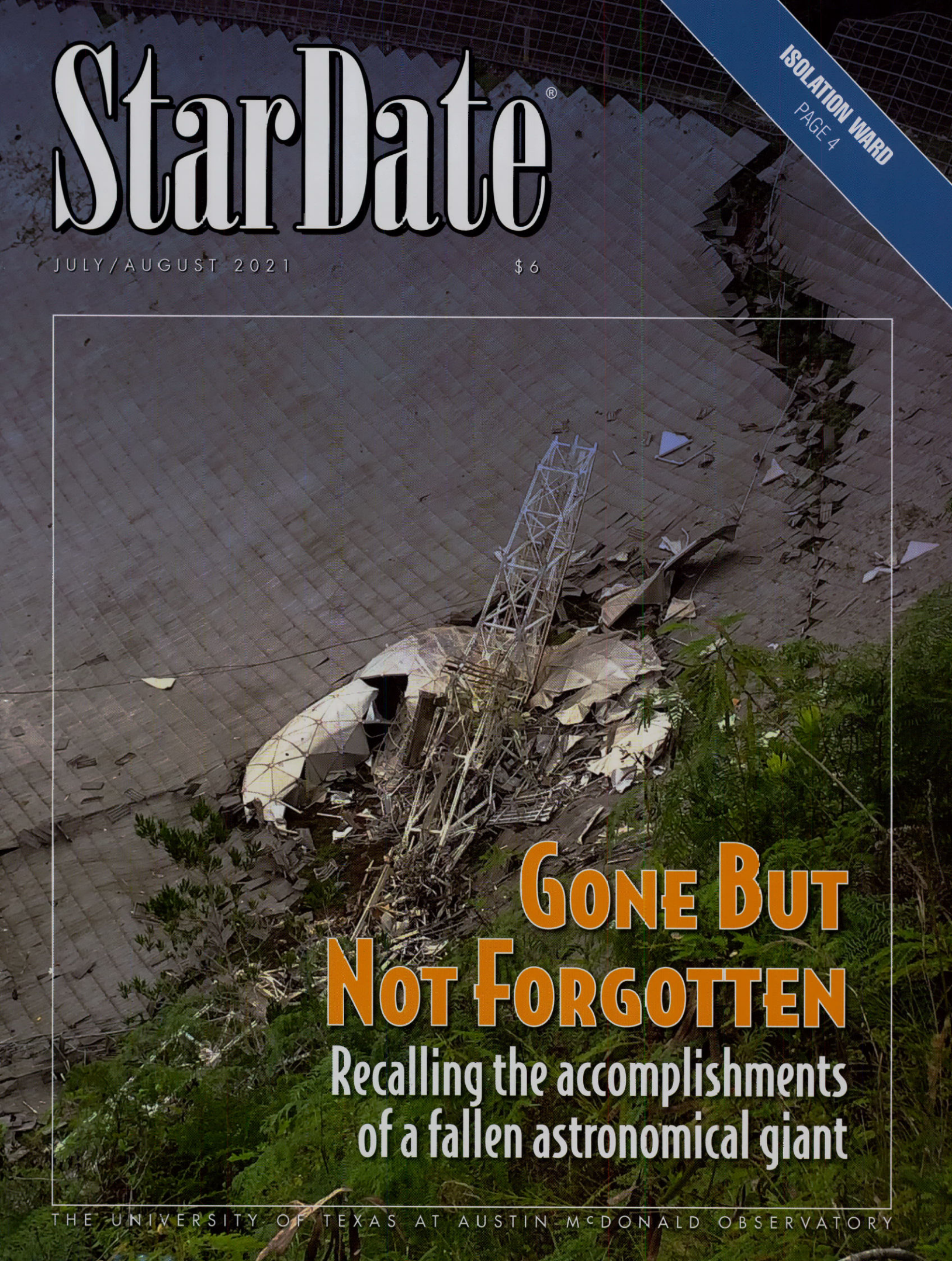
ISOLATION WARD
PAGE 4



Gone But Not Forgotten

Recalling the accomplishments of a fallen astronomical giant

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

StarDate®

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Features

Departments

MICHELLE NEGRON/NSF

On The Cover

Part of the Arecibo radio telescope's receiver has crashed into its giant dish in this December 2020 image. Find out about the telescope's demise and its accomplishments in our feature on page 16.

This Page

Hundreds of galaxies populate the cluster ACO S 295 in this recent Hubble Space Telescope image. The gravity of some of the galaxies acts as lenses, distorting the view of other galaxies behind them.

Coming Up

Expectations are high for the James Webb Space Telescope, the most expensive space science mission to date, which is scheduled for launch late this year. We'll fill you in on its mission, its technology, and the hopes of astronomers around the world. We'll also explain how Earth's changing climate is beginning to have an impact on astronomical observations.

ESA-HUBBLE/NASA/F. PACAUD/D. COE

MERLIN

Dear Merlin,

Given that the Moon is gradually moving away from Earth, how long until the Moon is far enough away to no longer provide us with the occasional total solar eclipse?

Robert Mullinax
Katy, Texas

That's hard to know, even for Merlin. However, a couple of studies in recent years have said the final total eclipses should occur anywhere from about 600 million to more than one billion years from now.

All of this is set up by the tides. As the Moon orbits Earth, its gravity creates ocean tides. As a tide sloshes against the continents, it causes Earth's rotation to slow down. The newborn Earth, for example, probably rotated once every six hours or so, versus today's 24-hour period. To keep the books in order, as Earth slows down the Moon moves farther away. Today, it's receding at roughly 1.5 inches (3.8 cm) per year. (To obtain that number, scientists shot laser beams from McDonald Observatory and other sites, which bounced off special reflectors left on the Moon by Apollo astronauts and Soviet robotic probes.)

So in the past, with the Moon much closer to Earth, total eclipses were more common and lasted longer. Even today, when the Moon is farther from Earth than its average distance, it creates "annular" eclipses, which leave a thin ring of light around the lunar disk. Such eclipses will become more common in the future. Eventually, when the Moon moves about 15,000 miles (25,000 km) farther than its current average distance, it will appear too small to ever completely cover the Sun.

Dear Merlin,

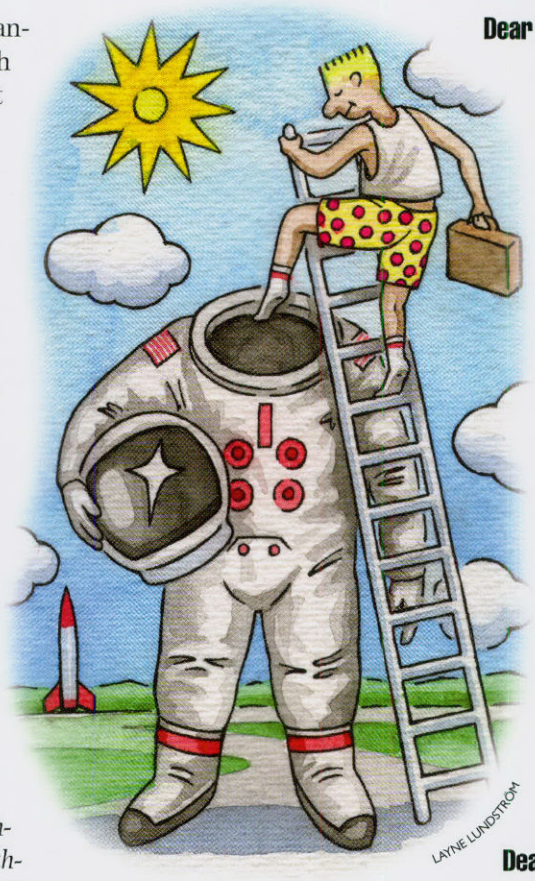
I understand how diving to the bottom of the oceans puts immense pressure on a diver or sub. But as I understand it, outer space is referred to as an infinite vacuum. I keep wondering how we can venture out in fabric suits without being ripped apart. How does that work?

Tommie Smith
Portland, Oregon

The suits that astronauts and cosmonauts wear when they venture into the vacuum of space aren't just flimsy rompers. They're like miniature spacecraft, with their own power supplies, oxygen, radios, and everything else needed to keep the inhabitants alive.

Suits worn by American astronauts when they venture outside the International Space Station consist of almost 20 layers, many of which are stitched together to make a single garment. Some of the layers are filled with tubes that carry cold water to keep an astronaut from overheating, while others provide insulation against heat. One layer contains oxygen to maintain the proper pressure on the wearer's body, which is about one-third of atmospheric pressure. The suit's outer layers are made of a combination of materials, including the material that's used in bullet-proof vests. And the top half of the suit is enclosed in a rigid fiberglass shell, which provides plenty of protection against the vacuum of space.

On Earth, the entire rig weighs more than 300 pounds, so it's a good thing the astronauts are almost weightless when they wear it in space!



Dear Merlin,

When we are born, do our zodiacs make our personality or is it just a zodiac?

Lee Cleveland
Austin

The zodiac is nothing more than a series of constellations that trace the Sun's path across the sky. It has nothing to do with your personality. Some people decide to live their lives according to the tenets of astrology, so in that sense the zodiac influences them. But that's a personal choice, not a scientific inevitability.

Dear Merlin,

Since Earth is not a uniform sphere, does this warp the spacetime that satellites pass through, causing their velocity to vary? If it does cause a change in velocity, does this impact GPS satellite data?

Charles Burke
Farmingdale, New Jersey

Yes and yes.

Because Earth is slightly pear shaped, orbiting satellites experience a slightly changing gravitational pull as they go around. The atomic clocks aboard Global Positioning System satellites have built-in correction factors to compensate for the change in gravity and velocity as they orbit the planet. Without those corrections, satellites would provide incorrect position and timing data to devices on the ground, so the entire system would fail in a matter of hours.

Merlin is unable to send personal replies. Answers to many astronomy questions are available through our web site:

stardate.org/astro-guide

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THE LONELINESS OF THE LONG-DISTANCE ASTRONAUT

ONE OF THE BIGGEST CHALLENGES OF SENDING ASTRONAUTS TO MARS WILL BE HELPING THEM COPE WITH THE STRESS OF ISOLATION AND CONFINEMENT

BY RACHEL FAIRBANK

Viewed from inside a lander, an astronaut prepares to explore Mars. Inset: A concept of a possible Mars habitat.

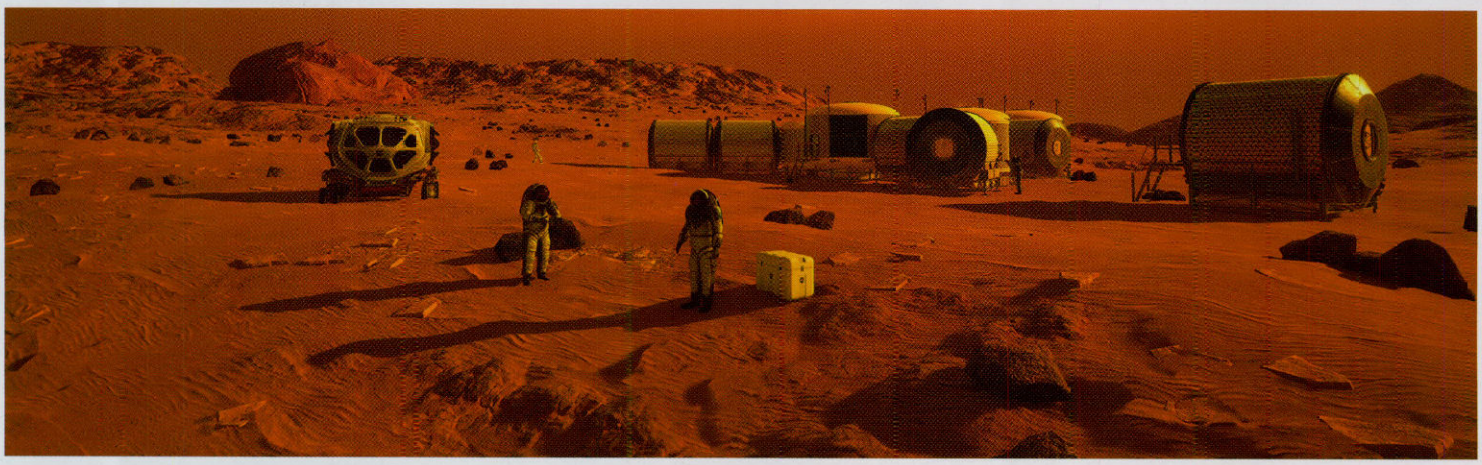
NASA/JPL (2)

On the slopes of Mauna Loa, in a desolate spot 8,200 feet above sea level, sits a small white dome. The Hawai'i Space Exploration Analog and Simulation (HI-SEAS) habitat has been home to six experiments, ranging from four months to a year, in which participants simulated the experience of living on Mars. One question the experiments were designed to answer is, "What happens when people are confined and isolated in a small space for a long time?"

HI-SEAS is one of many experiments set up to study the question. Others have included Mars500, where six volunteers simulated a year-and-a-half journey to Mars; Human Exploration Research Analog (HERA), where volunteers are confined to a small, windowless capsule, with only limited contact with the outside world, for up to 45 days; and the recent Deep Time mission, in which volunteers spent 40 days in a cave in France.

Sending astronauts to Mars would be an incredible technological feat, putting fragile humans in a spaceship that has to provide every necessity for life, travelling hundreds of millions of miles through the vacuum and radiation of space, then landing on a planet that is hostile to human life, where the air isn't breathable, there is no protection from the Sun's radiation or galactic cosmic rays, and the average surface temperature is 80 degrees below zero Fahrenheit (–62 C). Then, once astronauts have lived and walked on the surface of Mars, they would have to make the six-month journey home again.

For all of the science and engineering, one of the most vulnerable parts of the expedition may be the minds of the astronauts. As currently outlined by NASA, a trip to Mars would squeeze six astronauts into a space approximately the volume of a two-bedroom apartment, a space they cannot leave, with a communication delay that will widen as the distance to Earth increases. There will be no Zoom meetings, just pre-recorded videos and emails that can take up to 20 minutes to arrive. There will be no walks around the neighborhood, no



visits with friends and family, no jaunts to pick up a pizza or a carton of yogurt.

That will challenge the crew, requiring, in essence, a rewiring of their expectations for daily life. "We are a social species," says Alexander Stahn, an assistant professor of psychiatry at the University of Pennsylvania, who studies the neurobehavioral effects of extreme environments. "We want to be with family, we want to be with friends, we want to talk to each other, we want to see each other."

Coping with the isolation and confinement of a round-trip mission to Mars will be a task for which no one can be fully prepared.

"There is no superman or superwoman," says Mathias Basner, a professor of psychiatry at the University of Pennsylvania who studies astronaut behavioral health. All of the astronauts will struggle with the isolation, as well as the stress of living in a small, confined area with five other people. Some will handle the stress better than others, but experts say it's likely they all will feel depressed, lonely, and irritable.

Sheyna Gifford, a rehabilitation physician and participant in a year-long HI-SEAS mission, from 2015 to 2016, says the philosophy is to "assume that there is going to be some amount of mission breakage, and build that into your system." Rather than assuming everything will work as intended, NASA and its astronauts must expect the unexpected.

To better understand the "unexpected" and the practical solutions, researchers are relying on a mixture of experiments and real-world analogs. Experiments have the advantage of offering a controlled environment, where researchers can test specific aspects of isolation. The drawback is that experiments are time consuming, expensive to conduct, and can't always simulate the unexpected.

So the experts also draw on accounts of expeditions to places such as Antarctica, where people spend months cooped up with small groups of colleagues during the long winter night. They also study the experiences of others who spend long periods separated from their normal routines, such as crew members on submarines and astronauts and cosmonauts who have spent months in space.

One of the tenets of space exploration is that, before anyone is sent into space, every possible scenario must be tested on the ground. This has made for some odd experiments, such as a series performed in 1964-65 to evaluate the effects of "minimal hygiene." Participants weren't allowed to bathe, shave, or change clothes, and their oral hygiene and use of wipes were restricted, for two to six weeks. Afterward, to quantify the level of filth, participants were rinsed in a portable shower so researchers could collect the runoff, while other researchers were asked to assess the relative levels of odor. The question was how would astronauts hold up, mentally and physically, under a scenario in which an emergency made basic hygiene impossible.

Electrodes are attached to the scalp of the Mars500 commander to monitor brain activity. ESA

For Mars500, which was conducted in Russia, six volunteers were sealed in an isolation chamber for a total of 520 days, beginning in June 2010. The crew simulated all aspects of a Mars mission, including a landing and marswalk. A communication lag with the mission's control center was built in to simulate actual flight conditions.

Wearable tech measured aspects such as sleep timing and duration, while weekly surveys and other assessments helped researchers understand participants' physical and emotional well-being.

One major issue the "marsonauts" faced was with their sleep patterns. One of the crew members started sleeping on a 25-hour cycle (just a few minutes longer than the length of a day on Mars), which often meant he was awake when everyone else was asleep, while the other crew members dealt with issues ranging from too little sleep to too much.

"Sleep is fragile," says Basner, who was part of the team that monitored sleep patterns during the experiment. One problem was inadequate lighting. Bulbs burned out, the color of the light wasn't right, and giving control of the lights to the crew meant the normal daily cycle was prone to disturbances. One of the major conclusions from Mars500 was that astronauts will need high-quality lighting that is kept on a set schedule to reduce the risk of sleep deprivation.

Sleep disturbances also reduced interactions among the crew. If there's ever a major emergency, which would require working together as a cohesive team, a lack of connection among crew members could mean the difference between success and failure—or even life and death.

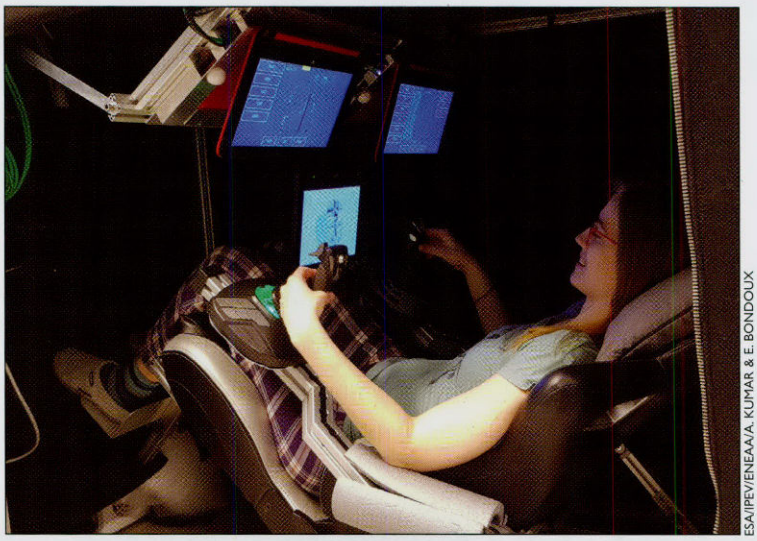
Changes in sleep patterns also have been observed in experiments in caves. A mission sponsored by NASA in the early 1960s found that, without sunlight or clocks to help them track the passage of time, cave dwellers adopted much longer

day-night cycles—up to twice the normal 24-hour period.

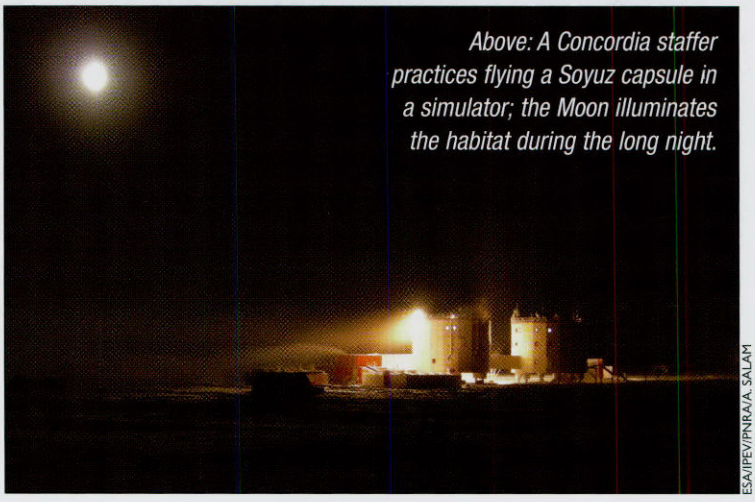
That lesson was strengthened earlier this year with Deep Time. A crew of 15—eight men and seven women, ages 27 to 50—spent 40 days and nights in Lombrives Cavern in France. They lived in tents, generated electricity with a stationary bicycle, and drew water from a well. Scientists monitored their sleep patterns, social and behavioral reactions, and other parameters for later analysis.

Team members eschewed clocks, instead letting their bodies find their own rhythms. When the team emerged, on April 24, some members said they were astonished that their time was up. Based on their sleep cycles, one man said he thought they were only 23 days into the expedition, while other participants put the duration at 30 days. The team leader said it was difficult to coordinate tasks and projects because everyone followed a different "clock."

"NASA scientists closely study astronauts' sleep when we are in space," astronaut Scott Kelley, who spent almost a year aboard the International Space Station (ISS), wrote last year in *The New York Times*, "and they have found that quality of sleep relates to cognition, mood, and interpersonal relations—all essential to getting through a mission in space or a quarantine at home."



ESA/IPEV/ENEAA/A. KUMAR & E. BONDOUX



ESA/IPEV/PNRA/A. SALAM

Above: A Concordia staffer practices flying a Soyuz capsule in a simulator; the Moon illuminates the habitat during the long night.

While controlled experiments offer important lessons, researchers learn even more by studying expeditions to remote locations. Among other things, they've learned the value of strong, steady leadership in surviving dangerous situations.

One major historical example is the Belgian Antarctic Expedition of 1898-1899, where physician Frederick Cook helped the crew of the Belgica survive a year trapped in the ice. As the long, dark winter dragged on, the crew's mental health deteriorated in alarming ways. A general melancholy devolved into a depression so deep that men found it difficult to concentrate or even eat. One crew member died of a heart ailment that Cook believed was exacerbated by the man's fear of the dark, another developed a paranoid delusion that his crew mates wanted to kill him, while the others all experienced disturbances of one kind or another.

During that long period of confinement, Cook prescribed daily exercise, which consisted mainly of walks around the ship's deck in what came to be known as the "madhouse promenade." Cook also had the most-afflicted men sit in front of the fire for a "baking" treatment. These rudimentary measures have been shown to be effective, as research has since demonstrated that light therapy and exercise are helpful for treating depression.

What happened to the crew of the Belgica was the first documented case of what is now called winter-over syndrome, which happens during the seven or eight months when people living in Antarctic bases are shut off from the rest of the world. Symptoms can include depression, anxiety, increased irritability and hostility, and difficulties in concentration and memory, as well as the "Antarctic stare," which is a mild trance-like state.

Researchers continue to study the winter-over syndrome in present-day Antarctic expeditions. "[Antarctica] is considered the most ideal Earth-based analog for space, just because there are so many stressors that are similar across both environments," says Candice Alfano, a professor of psychology at the University of Houston. Similarities include inhospitable environments, extreme confinement, lack of privacy, social isolation, and extended periods of darkness.

Every year, for example, the European Space Agency (ESA) sends a physician as a member of the 13-person winter-over team at Concordia, a French-Italian research station about 1,040 miles (1,670 km) from the south pole. The team spends nine months at the station and experiences 100 days of continuous darkness. Because of the extreme cold, there's almost no chance of rescue if something goes wrong—just like a Mars expedition.

In addition to tending to the health of the other crew members, the doctor studies how they react to what researchers call ICE: isolation, confinement, and environment. One year, for example, the doctor studied how the isolation affected motor skills. Each month, crew members practiced docking a Russian Soyuz capsule to the ISS in a specially designed simulator. The study found that reaction times tended to get worse as the winter dragged on.

Researchers also keep an eye on winter-over staff at American Antarctic bases. In a study led by Alfano, for example, researchers measured changes in health and attitude among 110 vol-

unteers. The subjects included 22 at Amundsen-Scott South Pole Station, which hosts roughly 40 to 80 winter-over staff. They conduct astronomical observations, atmospheric studies, and other experiments, and hunker down for six full months of darkness, with spotty Internet and no hope of evacuation in case of emergency. The other subjects were at McMurdo Station, the largest Antarctic base, which houses about 250 staff members during the winter.

Volunteers filled out monthly questionnaires about their health and mental state. Researchers also looked at stress markers in the participants' blood.

During the nine-month study, participants reported a continuous decline in their positive emotions—satisfaction, enthusiasm, and awe, among others. "Positive emotions are critically important, particularly in stressful environments," says Alfano. "They're known to buffer against stress." Negative emotions increased, but to a smaller degree.

Savoring—thoughts and actions that boost the intensity, duration, and appreciation of positive feelings and experiences—declined as well. "The best way to think about savoring is 'stop and smell the roses,'" Alfano said. The concern is that the monotonous environment will have an effect on the overall mood during a Mars mission. Aboard the International Space Station, astronauts have the luxury of viewing Earth from space, whereas on a Mars mission, this pastime will vanish. As the researchers wrote, "Over time, as the novelty of one's surroundings and experience lessens, savoring may also diminish."

"If we can teach individuals how to utilize savoring, particularly as it becomes more difficult over time, this may help increase the experience of positive emotions, but also decrease negative emotions," Alfano says.

Russian cosmonaut Valery Ryumin once wrote that "all the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 feet and leave them together for two months."

So selecting the right crew—one that can work together even under extreme conditions—is difficult. "It's hard enough to select a single astronaut, but it's 10 times harder to select the crew of astronauts that will actually work together well," Basner says.

HI-SEAS principal investigator and University of Hawaii faculty member Kim Binsted says there must be a balance within the team. "It's really good to have a range of experiences and a range of psychological approaches to conflict, in addition to a range of technical skills," she says.

Binsted also points out that being the only member of any category can make a person feel isolated—the only woman, the only American, the only non-native English speaker, or any other major factor. Although it's not possible to screen for every factor—a crew could end up being made up of five New York Yankees fans and a single Boston Red Sox fan, for example—the crew probably will need to consist of a balanced mixture of people of varying backgrounds and experiences.

Scientists and mission managers also will look for coping mechanisms to help astronauts remain healthy, happy, and productive during the Mars voyage.

For Gifford, although spending a year in the HI-SEAS habitat was stressful at times, such mechanisms helped alleviate the stress. "I would have my moments when I'd say, 'My God, I am the only medical provider up here,'" Gifford says. "My mechanism for dealing with those moments would be to reach out to somebody," which was usually in the form of emails to friends and families.

Crews in Antarctica and in space stations have relied on contact with friends and family as a coping strategy as well, although that will be less of an option with a Mars trip. Other strategies will be open to them, though.

Winter-over crews in Antarctica rely on food, ceremony, and group activities, for example. They stage banquets on key dates, such as sunset, the middle of winter, and sunrise. They sometimes dress up for the occasion and exchange gifts.

Astronauts who have spent months aboard ISS have adopted group activities as well. "I met up with crewmates for movie nights, complete with snacks, and binge-watched all of 'Game

SCOTT KELLY/NASA

NASA (2)

Astronauts have used several coping mechanisms during long flights. From top left: flowers grown in space; Friday night pizzas; Tracy Caldwell Dyson watches Earth go by.

of Thrones'—twice," wrote Scott Kelly.

After growing flowers and other plants during his mission, he noted that those reminders of the great outdoors helped him and others cope with the separation from Earth. "I actually started to crave nature—the color green, the smell of fresh dirt, and the feel of warm Sun on my face," he wrote in the *Times*. "My colleagues liked to play a recording of Earth sounds, like birds and rustling trees, and even mosquitoes, over and over."

Previous experience at dealing with isolated conditions may help Mars explorers as well.

Gifford says she was better able to cope with her HI-SEAS experiment because she had previously participated in a HERA study. NASA has conducted more than a score of HERA experiments in a habitat at Johnson Space Center in Houston. Each crew of four has remained aboard for up to 45 days, studying everything from sleep cycles to habitat lighting.

After the more-isolated experience of HERA, Gifford found herself constantly busy during the year aboard HI-SEAS. "All of our spare time was spent answering emails, talking to Mission Control,

responding to media. We were involved in a lot of projects. There was not a lot of spare time," she says.

"A lot of our crew members went in saying, 'I'm going to learn a language, I'm going to learn to play an instrument,' and that typically didn't happen," says Binsted, another HI-SEAS participant. "They thought they would have a lot of time, but they actually didn't."

A mission also may extract a physical toll on an astronaut's brain, and scientists are studying the possible effects.

Stahn and his colleagues recently published a study in the *New England Journal of Medicine* in which they imaged the brains of expeditioners who spent 14 months in Antarctica. They found a decrease in the volume of areas of the brain that are critical for daily functioning. The majority of the changes were in the hippocampus, which is important for learning and memory formation, as well as social relationships. "We also showed that the crew members performed worse on certain cognitive tests that are associated with the hippocampus," Stahn says. These expeditioners had lived in a small area, traversing the same paths and seeing the same people day in and day out. "The hippocampus is not stimulated much anymore," he says.

In a similar study, Basner, Stahn, and colleagues performed cognitive function tests in participants who spent 60 days in head-down bedrest, which simulates some of the conditions produced by the microgravity of space. The longer the participants spent in those conditions, the harder it was for them to identify facial cues. "They needed more and more time to identify the correct emotion," Basner says. "That could be really relevant for a mission to Mars, because if you're no longer able to read your fellow astronaut's face, then that is not a good situation."

The brain is highly plastic, though. It makes new connections every minute, growing dendrites and creating new synapses, in response to the stimuli around it. Although a lack of stimuli is certain to be an issue for astronauts spending months locked in the equivalent of a two-bedroom tin can, there will be strategies for helping them maintain full cognitive function. Researchers are testing the use of virtual-reality systems to provide additional stimulation to crew members during the long cruises between Earth and Mars, for example.

Gifford says returning to the outside world after the HERA experiment, where there were no windows and limited contact with the outside, was jarring. For example, she remembers the shock when she first saw the Sun again. "We hadn't seen the Sun in weeks," she says. "It was blinding and disorienting."

Gifford says one of her favorite moments from HI-SEAS was during a nighttime venture outside. She was ready to conduct astronomical observations when fog rolled in. As Gifford turned around, she saw a crewmate. He had a light on his suit, making him glow against the backdrop of the mountain and the habitat behind them. "It was this perfectly alien landscape," Gifford says.

One day, if all of the planning and testing and preparation pays off, astronauts will stand on Mars, set against the backdrop of an alien landscape. To get there, we will have to conquer not only great engineering challenges, but human ones as well. But if everything goes to plan, as the marswalkers stand on that alien landscape, we will have learned a little bit more about the human condition.

Rachel Fairbank is a science writer based in West Texas, where the stars shine bright at night.

Resources

Internet

HI-SEAS
www.hi-seas.org

Mars500
www.esa.int/ESA_Multimedia/Videos/2012/01/A_look_back_at_Mars_500

Deep Time
deeptime.fr/en/expedition

Belgian Antarctic Expedition (1897-1899)
library.osu.edu/site/frederickcook/belgian-antarctic-expedition

Concordia Station
blogs.esa.int/concordia

South Pole Station
www.nsf.gov/geo/opp/support/southp.jsp

HERA
www.nasa.gov/analogs/hera

Podcast: What's It Like Pretending to Live on Mars
eos.org/articles/podcast-whats-it-like-pretending-to-live-on-mars

Social Isolation and Space
www.nasa.gov/hrp/social-isolation

NASA Stories and Videos
www.nasa.gov/hrp/elements/hfbp/stories-and-videos

by Alan MacRobert

Big Pictures, Bold Planets, Bright Shower

Summer's signature star pattern, the Summer Triangle, stands well up in the east on July evenings, and even higher in August. At the same time, the curving body of Scorpius and the teapot of Sagittarius scuttle low across the south, anchoring the summer Milky Way. The planets Jupiter and Saturn, the giants of the solar system, are at their best in August, while Venus highlights the western sky shortly after sunset as the dazzling Evening Star.

JULY 1-15

The very different gods of love and war conjoin low in the west-northwest after dusk in the first half of July.

Big, macho Venus and tiny, delicate Mars are closing in on each other there as July begins. On July 1 they are still seven degrees apart, about four finger-widths at arm's length, with Mars to the upper left of Venus. Venus stands out in easy (though low) view by 30 minutes or so after sunset, but Mars won't be plain until the sky darkens further. Mars is only magnitude 1.8 compared to Venus's minus 3.9. That difference of 5.7 magnitudes is a difference of 190 times in brightness.

Each day, Venus and Mars move in on each other by a little less than one degree. They come to conjunction on July 12 and 13, just one-half degree apart. On the 12th, you'll find Mars to the left of Venus, and on the 13th, under it. Bring binoculars! The two planets are quite low by then, but on those dates a beautiful thin crescent Moon points the way to them from higher to their upper left.

And on the 12th, spot twinkly Regulus five or six degrees to the left of the Moon. Regulus actually outshines Mars.

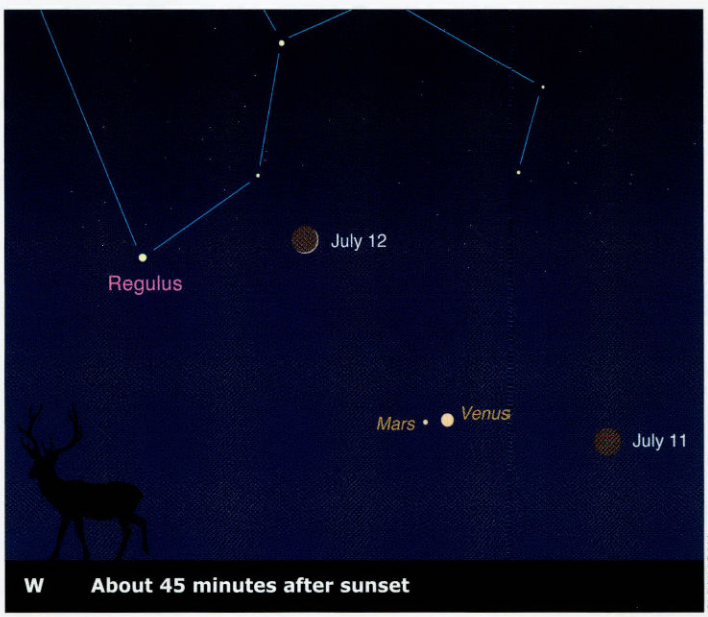
Why is Mars so faint now? There are several reasons: It's on the far side of its orbit from us, it's a small planet to begin with, and its rusty brown surface doesn't reflect much of the weak sunlight that reaches it.

Venus, on the other hand, is almost twice as big in diameter, it's only half as far from the Sun so it gets lit four times as intensely, it's currently closer to Earth, and it's covered with highly reflective white clouds.

Once the night is dark, you'll find the big Summer Triangle dominating the high east. The brightest star on that whole side of the sky is Vega, the triangle's top. Deneb is a couple of fists at arm's length to Vega's lower left, and Altair is farther to Vega's lower right.

If you have a dark enough sky, you'll witness the vast summer Milky Way arching across the east, from low in the north-northeast, up and across the lower part of the Summer Triangle, and down through the Sagittarius star clouds to the south-southeast. The Milky Way will rear ever higher in the hours and weeks to come.

The Big Dipper hangs by its handle in the northwest. Follow the curve of the dipper's handle out by a little more than a dipper-length, and there's Arcturus, Vega's equal in brightness. Right after dark, Arcturus and Vega are also equally near your zenith.



CJ DUNCAN

JULY 16-31

Venus remains very low in the west in twilight. From July 13 to 21 it passes from just above Mars to just to the upper right of Regulus. This is why you have binoculars.

Later in the evening, the two largest planets enter the opposite side of the sky. Saturn glows steady pale yellow low in the southeast as soon as it's dark. Not much later, Jupiter rises into view 20 degrees (about two fists) to Saturn's lower left. By midnight, they dominate the sky in the south. Late on the night of July 24, the bright Moon shines below their midpoint.

Mercury, the last bright naked-eye planet, is buried deep in the dawn.

Once Saturn is in good view, look about three fists above it for Altair. Just a finger-width above Altair is little orange Gamma Aquilae or Tarazed, third magnitude but bright enough to show through most moonlight or light pollution.

A little farther below Altair, you may have more trouble spotting Beta Aquilae, fainter than Gamma by a magnitude (2.5 times). But it's definitely there. Binoculars can bring it out even through full moonlight from the heart of a city. (It's about half a binocular field-of-view below Altair and perhaps a touch to the right.) The row of Gamma, Altair, and Beta form the top of the eagle's head, his bright eye, and his beak the way his stick figure is often drawn.

If you can make out Gamma and Beta Aquilae you're good to go for the whole Northern Cross, the brightest part of Cygnus, the swan, with his outstretched wings. The cross is lying on its side. Its head is Deneb, nearly four fists left of Altair. Its foot is third-magnitude Albireo, which stands almost between Altair and bright Vega. The cross lies right along the Cygnus Star Cloud of the Milky Way.

Follow the line of the Northern Cross from foot to head, extend that line almost twice as far on, and you're at low-lying Cassiopeia, currently in its tilted "W" orientation.

Look south. The second half of July is when bright, curly Scorpius, "the Orion of summer," sparkles at its highest in the south right after dark. Its brightest light is orange Antares, Scorpius's equivalent of Betelgeuse; these are the sky's two brightest "red" (actually yellow-orange) supergiant stars, spectral class M.

Antares is the scorpion's heart. Two fainter white stars flank it. A row of three stars to the upper right of Antares, standing nearly vertical, marks the creature's head. I think of them as the Orion's Belt of summer.

The rest of Scorpius extends down to the lower left from Antares, then finally curls up a bit to include the pair of stars called the Cat's Eyes (also known as the scorpion's stinger), magnitudes 1.6 and 2.6, in the scorpion's tail. The Cat's Eyes are about a pencil-width at arm's length apart.

AUGUST 1-15

Oh so slowly does Venus inch up in the western twilight as summer proceeds. Not until late October will Venus stand even modestly high by full dark.

Saturn and Jupiter, on the other hand, proudly hoist themselves up ever earlier after dusk for southeast-facing viewers. But the best telescopic views of them will be around the middle of the night, when they're highest in the south. Saturn is at opposition on the night of August 1, Jupiter on August 19. They light different sides of dim Capricornus.

Low in the east, the Great Square of Pegasus, starry emblem of autumn, is creeping up as we begin the second half of summer. It's balancing on one corner. The square is not particularly "great" for brightness; its four stars are second and third magnitude. It earns the name by its size, about 15 degrees on a side. That's enough for your fist at arm's length to fit inside.

Off to the square's left, in the northeast, Cassiopeia is also gaining altitude toward its own high autumn showing.

In the west, Arcturus now is only about halfway up the sky. From Arcturus, the narrow, bent kite pattern of the constellation Boötes extends two fists to the upper right.

And in the northwest, the Big Dipper is dipping as if to scoop something up.

This should be a good year for the Perseid meteor shower. It's due to reach its peak late on the nights of August 11-12 and 12-13. The sky will be free of moonlight once the waxing crescent sets in late evening. Meteor rates will be low then but will increase steadily through the night until dawn, as the shower's radiant point (between Perseus and Cassiopeia) rises higher in the northeast. The higher a shower's radiant—its perspective point of origin—the more directly your side of Earth faces into the oncoming meteors.

Bring a reclining lawn chair to a spot with an open view of the sky and no nearby lights. The farther you are from city skyglow the better.

Lie back, let your eyes adapt to the darkness, gaze into the stars overhead, and be patient. Under a fairly good sky, by midnight you might be seeing nearly a meteor a minute, on average.

Lesser numbers of Perseids will appear for a week or two before the peak, and for a few nights after.

Meteor Watch

The Shower

Perseids

Named for the constellation Perseus, the hero, which climbs into view in the early morning hours.

Peak

Nights of August 11, 12

Notes

The Moon is a thin evening crescent, so it sets early and won't interfere with the summer fireworks.

AUGUST 16-31

Venus and Jupiter are the two brightest "stars" of evening: Venus is still low in the west in twilight, soon to set, and Jupiter is in the southeast, on its way up to rule the night. Saturn glows nearly two fists to Jupiter's upper right. The bright Moon shines below Saturn on August 20, and near Jupiter on the 21st.

When the stars come out now, bright Vega is already close to the zenith, approaching it from the east.

Whenever Vega is near the zenith, Altair stands high as the brightest star toward the southeast or south. Look to the lower left of Altair by a little more than a fist and a half at arm's length for dim, compact Delphinus, the dolphin.

If you succeed with Delphinus, can you make out fainter, smaller Sagitta, the arrow? It's above or to the upper left of Altair, a little closer to Altair than Delphinus is. The arrow is flying leftward. Its four main stars range from magnitude 3.5 to 4.4.

Due south, between Scorpius to its right and Jupiter and Saturn to its left, another sky landmark now reaches its greatest height right after dark: Sagittarius. No bright star marks this important group, but eight second- and third-magnitude points form the unique Sagittarius Teapot. It's a little larger than your fist at arm's length, with its triangular spout on the right and its handle on the left. The teapot is currently tilting as if pouring.

Just above the spout is, appropriately, a big puff of steam — the Large Sagittarius Star Cloud, one of the brightest patches of the summer Milky Way.

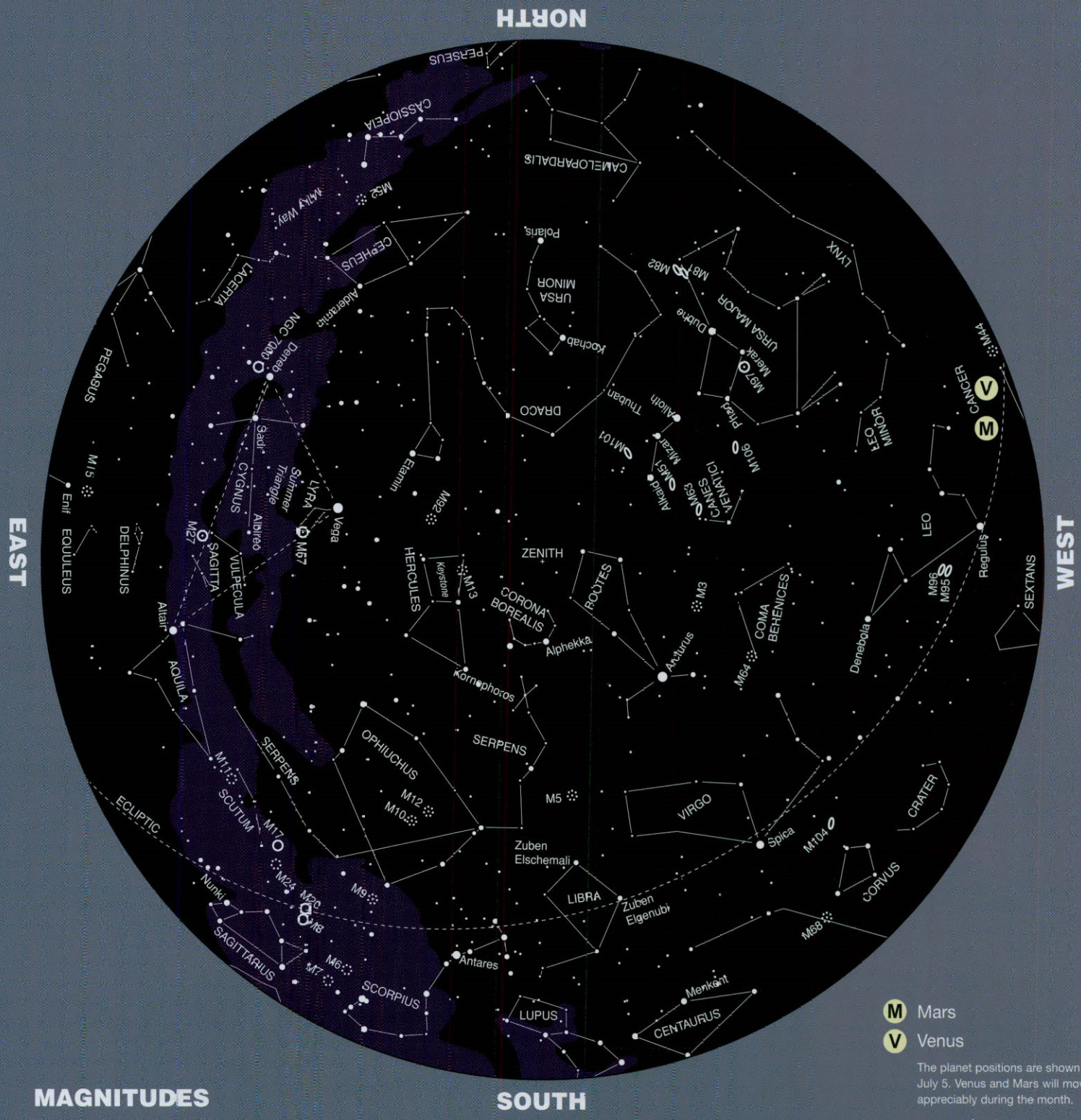
Alan MacRobert is a senior editor of Sky & Telescope.

JULY

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

June 20	**11 p.m.**
July 5	**10 p.m.**
July 20	**9 p.m.**



MAGNITUDES

- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

- Mars
- Venus

The planet positions are shown for July 5. Venus and Mars will move appreciably during the month.

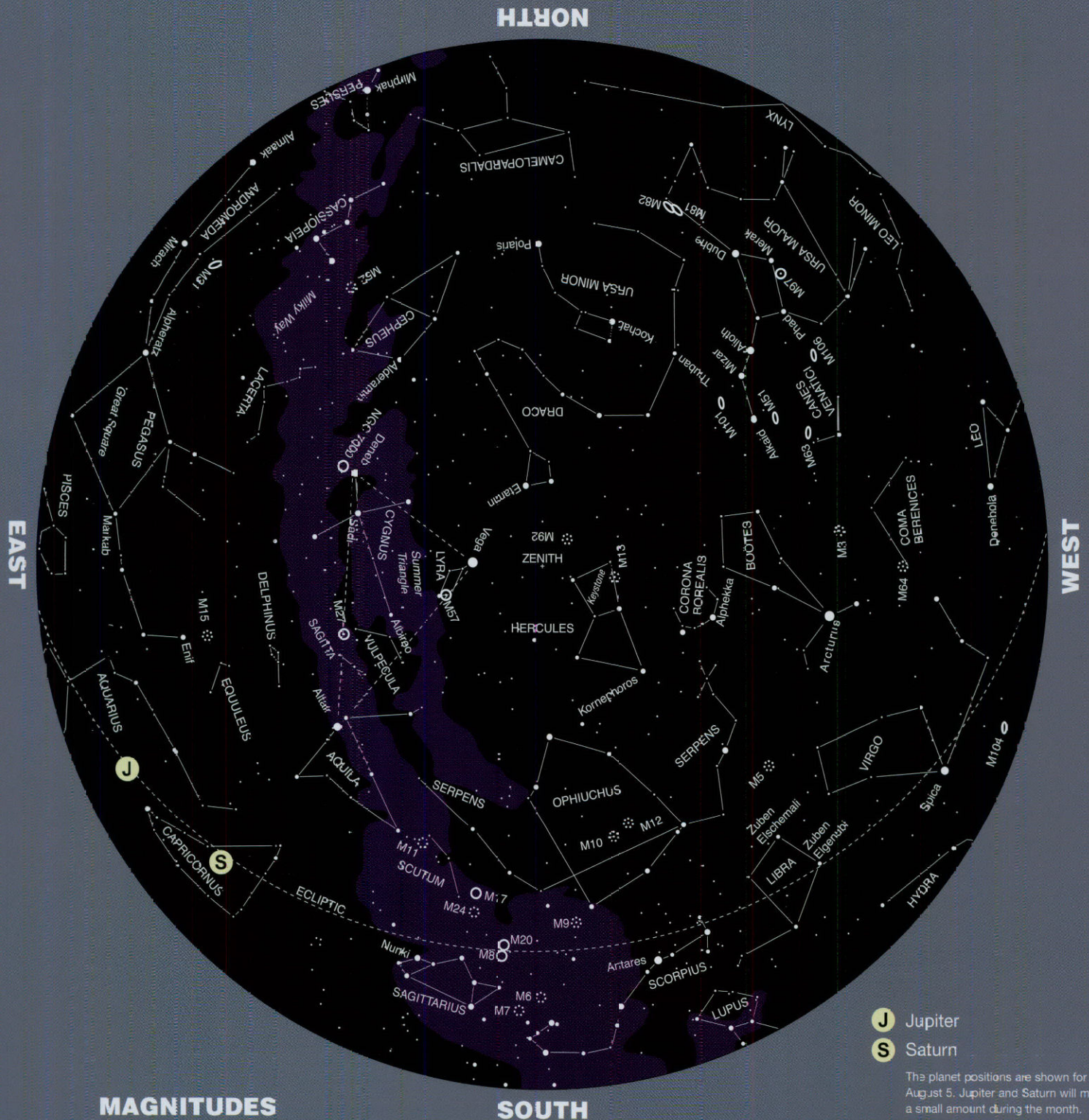
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

AUGUST

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

July 20	11 p.m.
August 5	10 p.m.
August 20	9 p.m.



MAGNITUDES

- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

J Jupiter

S Saturn

The planet positions are shown for August 5. Jupiter and Saturn will move a small amount during the month.

- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

Flying Solo

A long trip to space for the first human satellite

Bruce McCandless II was the first human satellite. Every spacewalker who preceded him had remained firmly tied to the mothership. On February 7, 1984, though, McCandless floated free of space shuttle Challenger strapped to a Buck Rogers-like contraption known as the manned maneuvering unit (MMU). He moved out to about 100 yards from the shuttle, then used the unit's thrusters to gently push him back.

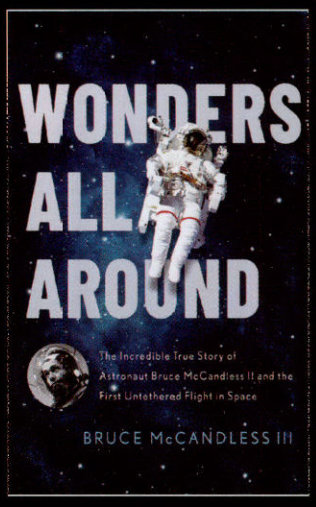
McCandless and his exhilirating trip are the focus of *Wonders All Around*, a combination biography and memoir by the astronaut's son, Bruce McCandless III, a lawyer, author, and environmentalist in Austin. The book mingles the accomplishments of McCandless *père*—second in his Naval Academy class (after John Poindexter, future national security adviser to President Ronald Reagan), carrier-based naval aviator, engineer, astronaut, inventor—with the life and recollections of McCandless *fils*.

The author describes his father as brilliant and driven—a tinkerer who fixed his own household appliances while inventing rocketpacks. He was something of a loner, though, which may have hurt his chances at flying in space. Although he was picked as an astronaut in 1966—the youngest selected to that time, at age 28—he was passed over for both the Apollo lunar missions and the Skylab space station.

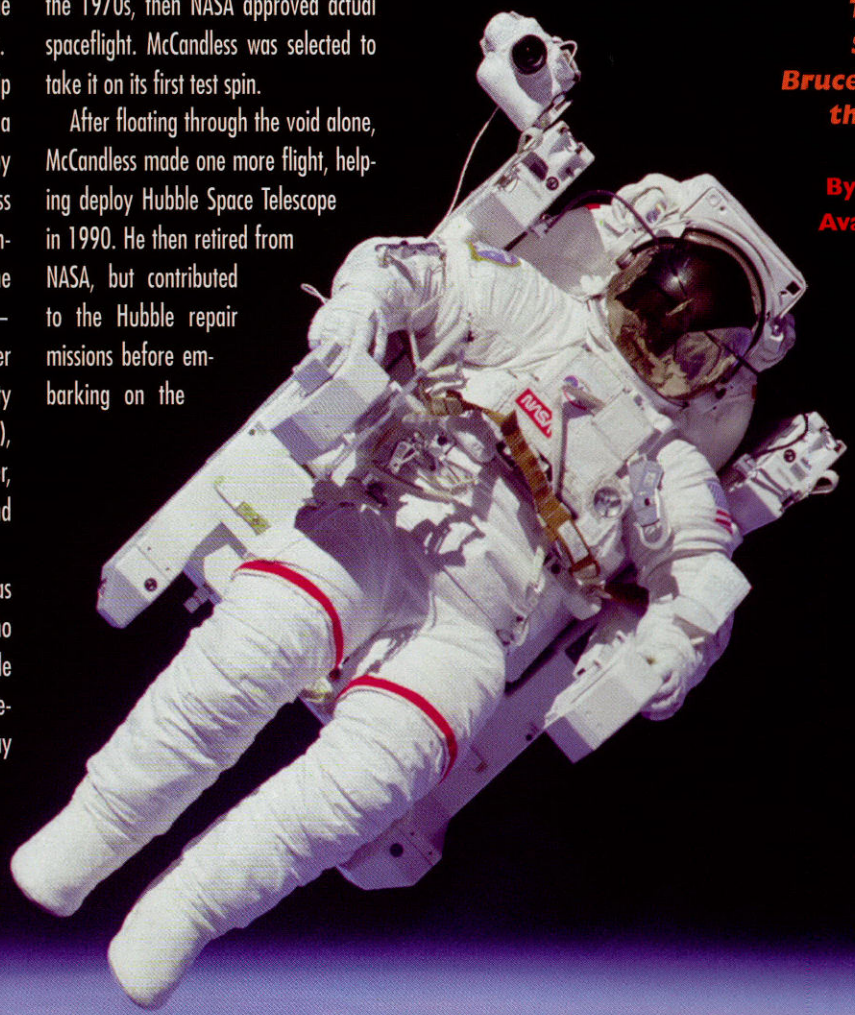
McCandless persevered, though, and helped design and perfect the MMU. One version was tested inside Skylab in the 1970s, then NASA approved actual spaceflight. McCandless was selected to take it on its first test spin.

After floating through the void alone, McCandless made one more flight, helping deploy Hubble Space Telescope in 1990. He then retired from NASA, but contributed to the Hubble repair missions before embarking on the second half of his career, as lead engineer for a space contractor.

McCandless's MMU flight hasn't led to rocket-powered astronauts zooming through space; the rocketpack was retired after just a few flights. It did, however, provide a new way for astronauts to travel—as human satellites.

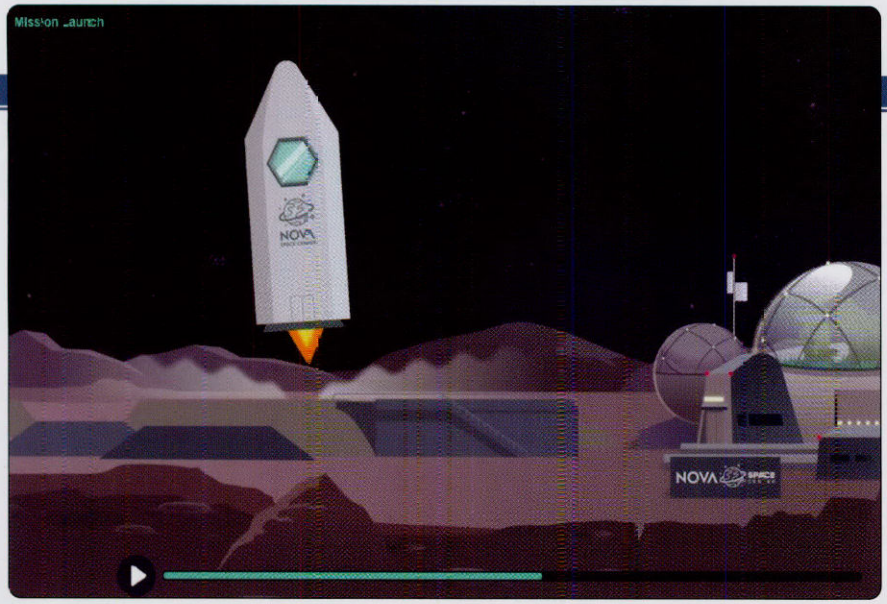


Wonders All Around
The Incredible True Story of Astronaut Bruce McCandless II and the First Untethered Flight in Space
By Bruce McCandless III
Available July 13; $24.95



McCandless floats free of space shuttle Challenger.

NASA (2)



Galactic House Hunters

Game players find homes for displaced extraterrestrials

A new online game from the PBS Nova program takes players into the hunt for exoplanets—planets that orbit stars other than the Sun. In Nova Exoplanet Lab, players become scientists for the galactic resettlement team, which has received a distress call from aliens in need of new home worlds. To help, players must follow the processes used by scientists to discover and understand other planets.

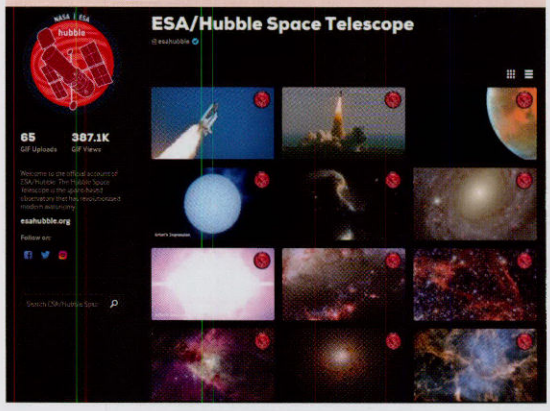
The game is aimed at students in junior high and high school, and includes a teacher's guide and other materials. It's designed to teach students how astronomers find other planets; determine key characteristics of those worlds, such as their size and mass; and measure the composition of their atmospheres, which reveals their suitability for life. With that information in hand, the player then assigns a "habitability number" to a target world, telling the aliens whether it's a world worth checking out.

www.pbs.org/wgbh/nova/labs/lab/exoplanet

Experience Hubble View on GIPHY

Each April, the European Space Agency's Hubble Space Telescope office marks the anniversary of Hubble with a public project. The project celebrated its thirty-first anniversary this year by launching an account on GIPHY, an online database and search engine. The account features animated GIF files compiled from images from or of the telescope. The public can contact info@esahubble.org to suggest a video or animation from the ESA/Hubble website to include. Among many other discoveries, Hubble has delved deep into the early years of the universe, supported the discovery that the expansion of the universe is accelerating, and probed the atmospheres of planets around distant stars.

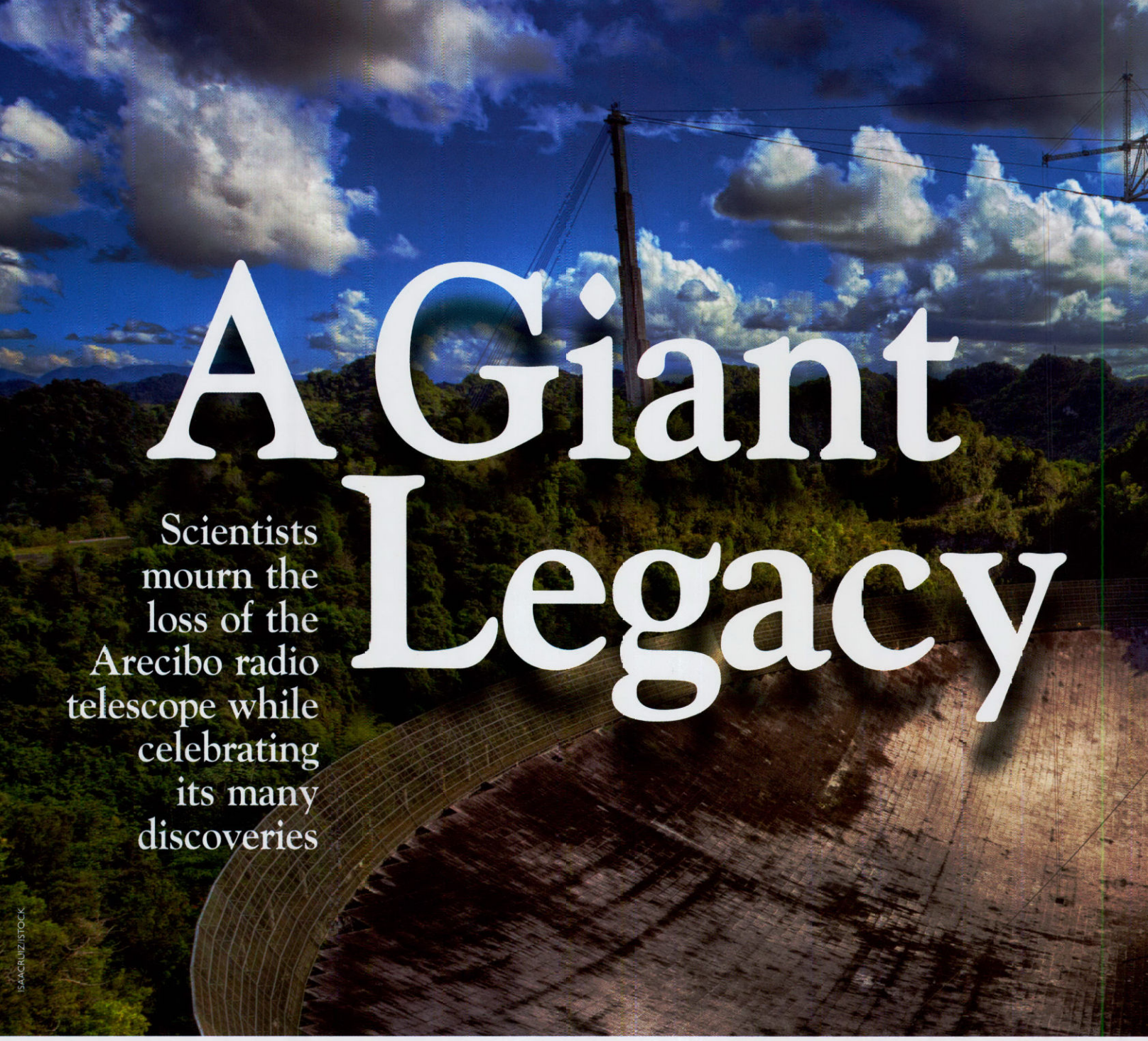
giphy.com/esahubble



Making Summer Nights a Little Less Fun

Fireflies are among the more pleasant features of a summer evening. Children chase them across the yard, and adults enjoy their beautiful flashes. But our own nightlights could be chasing them away. Recent work has found that artificial lights can interfere with the flashes, which are part of the mating ritual. That means there could be fewer of these twinkling lights for future generations of children to chase.

JUD MCCRANIE/WIKIMEDIA



A Giant Legacy

Scientists mourn the loss of the Arecibo radio telescope while celebrating its many discoveries

ISAACRUZ/ISTOCK

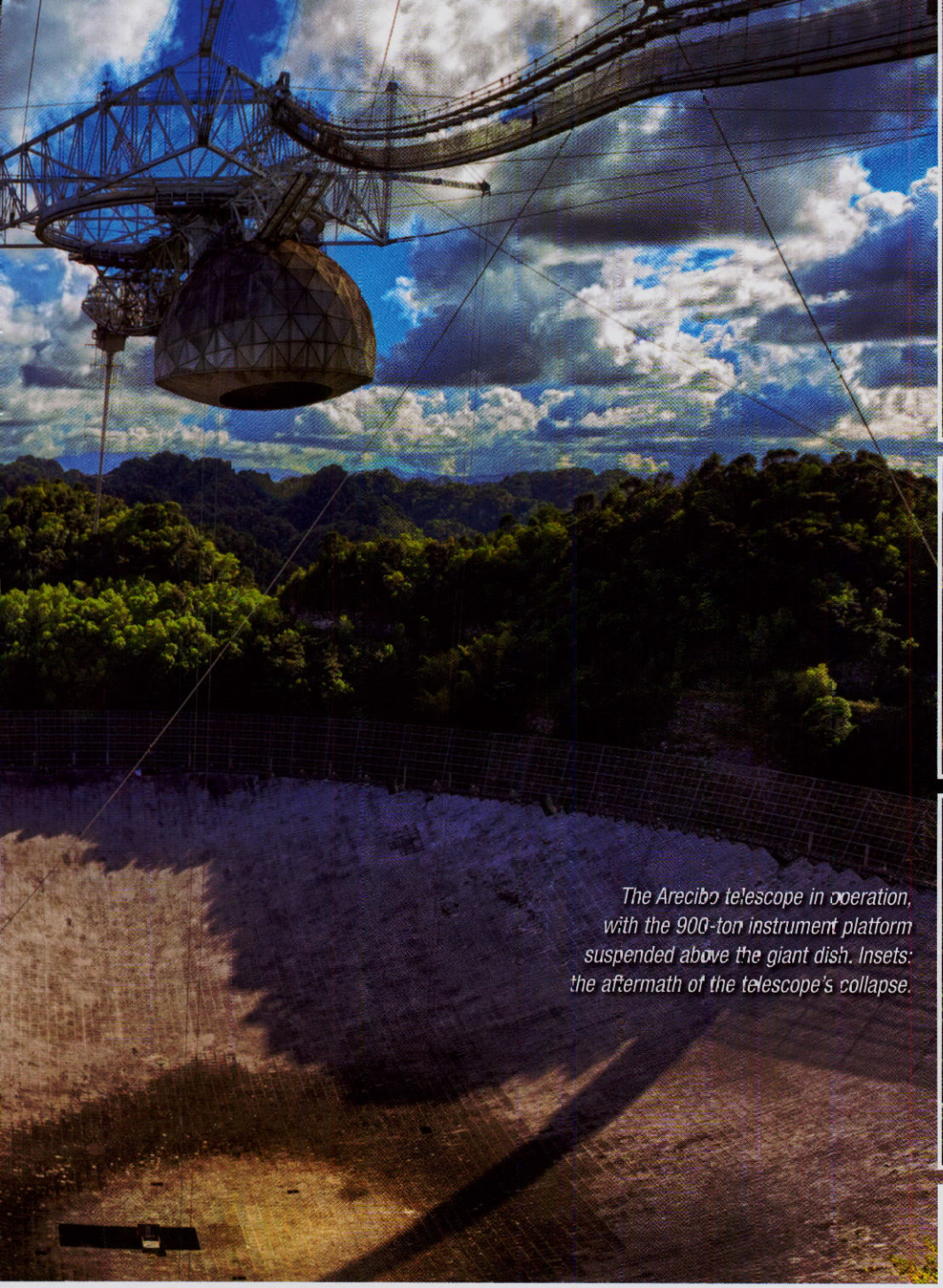
Chris Salter and Tapasi Ghosh joined several colleagues at Arecibo Observatory in Puerto Rico late one night as they used the observatory's giant radio telescope to scan Arp 220, a galaxy 250 million light-years away that's giving birth to many new stars. They saw evidence of the molecules methanimine—its first possible detection in another galaxy—and hydrogen cyanide. The compounds can combine with water to create glycine, the simplest amino acid and one of the basic building blocks of life. "Finding glycine in astronomical sources would be a holy grail of astronomy," Ghosh says.

Salter and Ghosh, who have been married for decades, fondly recall that night as one of the highlights of their 26 years working at Arecibo Observatory. "It also was a great example of Arecibo feeling like a family," Salter says, "because it was the first time every member of the astronomy department at Arecibo had ever collaborated on one single experiment, and that was a great feeling of togetherness."

Their finding—and the collaborative teamwork that led to it—showcases just one of the many groundbreaking discoveries produced by the observatory over the years. Tragically, though, most of its work ground to a halt late last year when its 1,000-foot (305-meter) telescope collapsed after 57 years in operation.

Sravani Vaddi, a postdoctoral fellow at Arecibo, was working from home on August 10 when an auxiliary cable snapped. She was observing one of her target galaxies and checking on the data. "I noticed that my target was somewhere, and the telescope was pointing somewhere else," Vaddi says. When she went to investigate the next day, she learned about the cable.

The cable was one of many supporting a 900-ton platform suspended above the bowl-shaped dish, which was built in a sinkhole in the limestone hills. The



The Arecibo telescope in operation, with the 900-ton instrument platform suspended above the giant dish. Insets: the aftermath of the telescope's collapse.

MICHELLE NEGRON/NSF (3)

BY KRISTEN POPE

structure contained antennas that collected radio signals reflected from the dish, along with highly sensitive receivers that fed the signals to scientific instruments.

The observatory planned to repair the cable and resume operations. While engineers assessed the problem, though, a main load-bearing cable snapped, in November. This one broke at approximately 60 percent of its rated capacity, so the engineering teams determined that it was simply too dangerous to make repairs, so the telescope's owner, the National Science Foundation (NSF), decided to tear it down. "Unfortunately, it got so unstable that we could not do anything—we just had to let it go," says Angel Vazquez, Arecibo's head of telescope operations.

Then, on December 1, the entire structure collapsed, with cables and support towers swinging wildly, causing damage to other facilities on-site though no injuries were reported.

Vaddi's data were some of the last the iconic telescope collected. She was able to look at five of the 30 galaxies she had hoped to sample before the collapse. "The reason why Arecibo was chosen for these observations is because of its size and sensitivity," Vaddi says. "You have a large collecting area. I was looking at very faint sources, and so Arecibo played a very crucial part in looking at these faint galaxies." She says now it will take longer for her to collect data, estimating she will need three to four hours on another telescope for each hour she would need on the Arecibo telescope.

Vaddi is just one of many scientists mourning the loss of the telescope while also looking back and celebrating Arecibo's many discoveries over the decades.

Arecibo's giant telescope was the brainchild of William E. Gordon, an electrical engineer and astronomer at Cornell University, who wanted to study the ionosphere—an electrically charged layer of the upper atmosphere. He selected a site in Puerto

Rico, about 12 miles (19 km) south of the city of Arecibo.

The U.S. military was interested in detecting incoming ballistic missiles as they passed through the ionosphere, so it funded the telescope as a way to learn more about the ionosphere's properties. Yet the telescope also served as a general-purpose radio telescope from the beginning.

Gordon conceived the telescope in the late 1950s and it opened, as the Arecibo Ionospheric Observatory, in 1963. The dish was the world's largest and most-sensitive radio telescope for more than 50 years, until China's Five-hundred-meter Aperture Spherical Telescope was completed in 2016.

The giant telescope covered 20 acres, was 167 feet deep, and was surfaced by almost 40,000 aluminum panels, which reflected radio energy to the receivers, supported by steel cables. The instrument platform was suspended 450 feet overhead from cables connected to three concrete towers.

NSF took over the observatory in 1969, and in 1971 renamed it the National Astronomy and Ionosphere Center. NASA and NSF soon agreed to share costs on a major upgrade, resurfacing the dish reflector and adding new equipment. Another significant upgrade was completed in 1997.

The world-famous telescope was popular not just among scientists, but also in pop culture. It served as the villain's lair in the James Bond thriller "GoldenEye," and it detected signals from an extraterrestrial civilization in the movie adaptation of the Carl Sagan novel *Contact*.

Arecibo also has faced a number of challenges over the years, including Hurricane Maria in 2017, which caused extensive damage, and earthquakes in 2014, 2019, and 2020.

Through it all, the observatory has focused on astronomy, planetary science, and space and atmospheric sciences, and was home to a rich legacy of discoveries, with more than 3,500 scientific publications based on the telescope's observations.

Much of the work was focused on our own celestial neighborhood, the solar system. For that research, the telescope functioned as a giant radar gun. It beamed out powerful pulses of radio waves, then listened for the reflection from the Moon, Venus, or other targets. The returned radio waves revealed how the target objects were moving, and eventually allowed scientists to image their surfaces.

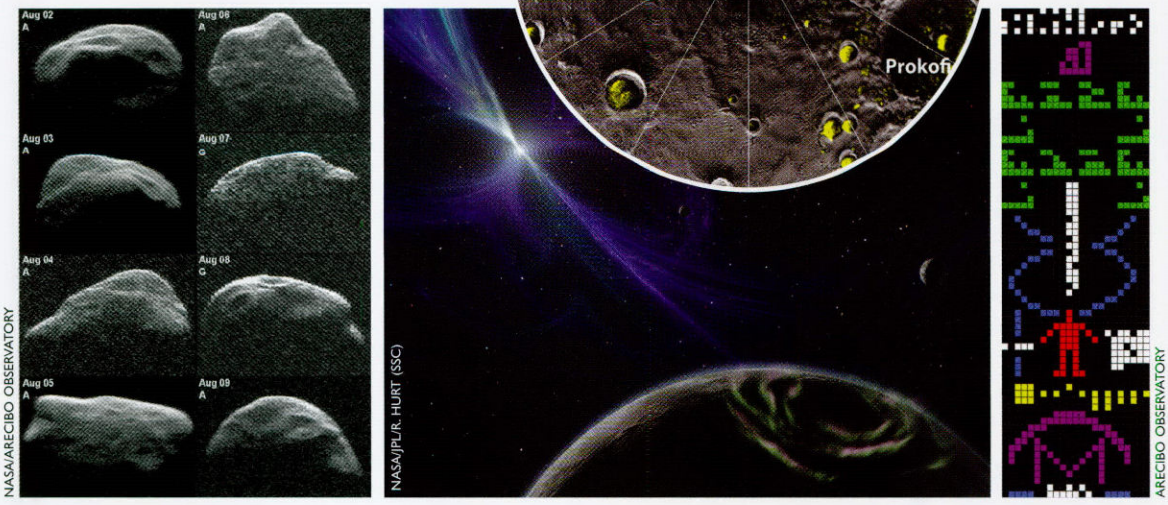
In 1965, for example, scientists learned that Mercury rotates once every 59 days (with two orbits around the Sun for every three turns on its axis) rather than the 88 days (and one rotation per orbit) previously believed. About the same time, researchers used the telescope to peer through Venus's clouds, discovering that it rotates backwards from the other planets, completing one turn every 245 Earth days.

Arecibo's work also led to some of the first radar images of the Moon and Venus, which were published in 1970. As the technology improved over the years, the telescope made sharper and more extensive images of the Moon, Venus, and Mercury, eventually producing maps of their surfaces. And it discovered possible deposits of water ice buried in deep craters near the poles of the Moon and Mercury. Confirmation of the lunar deposits by orbiting spacecraft has led NASA to target future missions to the south polar region, where ice could provide oxygen, rocket fuel, and other resources for explorers.

The telescope also mapped many asteroids, including several that have passed close to Earth. The observations help scientists understand the threats that such asteroids could pose to our planet.

Ed Rivera-Valentín worked at Arecibo from 2014 to 2018 as a staff scientist in the planetary radar group. Now, he works at the Lunar and Planetary Institute studying planet formation, habitability, and planetary defense. Rivera-Valentín points out how Arecibo's extremely sensitive radar systems could detect vital information about objects in space—including their size, shape, speed, surface geology, and moons. Combined with observations from other telescopes, it could tell scientists where the objects would be in 50 or 100 years, alerting us if such an object was on a collision course with Earth.

"Arecibo provided all of the data that NASA would need in case it needed to mitigate this impact," Rivera-Valentín says. "If you want to develop a mission to actually stop a potential impactor, you want to know its size, shape, density, all the stuff, which I think that Arecibo was able to provide. I always call it 'the Nos-



A giant legacy, clockwise from top: A radar image of Mercury, overlaid on images from the Messenger spacecraft, shows possible deposits of ice (yellow); the Arecibo message to a star cluster; artist's concept of planets orbiting a pulsar; a series of radar images of an asteroid.

tradamus,' because it helped tell us when there was potential impending doom."

Arecibo's planetary studies haven't been limited to the solar system, though. In 1992, based on Arecibo observations, Aleksander Wolszczan and Dale Frail announced the discovery of the first planets ever discovered in another star system. The two worlds orbited PSR 1257+12, a pulsar about 2,300 light-years away. The pulsar is the corpse of a star that exploded as a supernova. The dead core rotates 161 times per second, beaming "pulses" of radio waves at Earth with each turn. Tiny variations in the timing of the pulses revealed the gravitational pull of the orbiting planets, while continued observations revealed a third. The planets must have formed from debris left over after the supernova explosion.

The following year, Joseph Taylor and Russell Hulse won the Nobel Prize in Physics for a discovery they made at Arecibo in 1974: a binary pulsar, in which two pulsars orbit each other. Timing the pulses from the two bodies showed that the orbit was shrinking as they emitted gravitational waves, providing the first indirect confirmation of the existence of these tiny "ripples" in space and time. (At the time of its collapse, Arecibo was part of a collaboration that was using pulsars to make more-direct detections of gravitational waves.)

And in 2019, Gregory Desvignes, with the Max-Planck-Institut für Radioastronomie and the Paris Observatory, and his colleagues published a paper on the binary pulsar J1906+0746. They monitored it with the Arecibo telescope for more than 10 years, recording variations in radio pulses. In 2005, they observed two pulses per rotation, but by 2018 one was gone; it had moved away from our line of sight due to a "wobble" in one of the pulsars.

"The source started to decrease in luminosity after a few years," Desvignes says. "It's only with the Arecibo telescope that we were allowed to continue the monitoring of this source. Due to Arecibo's fantastic collecting area, we were able to achieve detection even after we were no longer able to observe it with other radio telescopes."

The telescope was even used as a long-distance telephone. In 1974, it transmitted the first message from humans to extraterrestrials—1,679 bits of data that can be arranged to show a picture of the telescope, a human being, the solar system, and other details. No one is expecting a reply soon, though, because the message was aimed at the Hercules star cluster, which is about 22,000 light-years away.

For Rivera-Valentín, Arecibo is far more than an observatory; since he was born in the city of Arecibo, it's also his home. His proximity to the observatory growing up inspired him, as well as many other students, to take an interest in scientific careers. "My family took me there and inspired me as a child to even think science was a potential career for me," Rivera-Valentín says. "It hasn't just been inspiring for people that go into astronomy, planetary science, atmospheric science, engineering—it's been inspiring for the entirety of my island."

Salter and Ghosh also know the impact Arecibo can have on children because they raised their daughter there. When she was 4 or 5 and running around the observatory grounds, one of the facility's longtime gardeners told Salter, "She's your daughter, but she's not just your daughter. She's the daughter of the observatory," Salter fondly recalls.

Salter describes the wonder of visiting the telescope at night as "one of the experiences that will be with me until my final days." Ascending in the cable car for five minutes in near-total darkness, he says "you would rise above the levels of the hills… and suddenly the whole of the plateau of Puerto Rico is revealed to you, and the lights of the villages all around wink into view like a set of fairy lights, and it's an absolutely magical experience." Salter says.

Science is continuing at Arecibo despite the void left by the loss of the telescope. Scientists are using other facilities on-site, and the observatory is continuing public outreach and education efforts. "The observatory is still operational," says Angel Vasquez. "We are still doing science at the observatory, [but] not at the scale we did before."

Scientists are planning for what's next. While crews repair damaged buildings and remove debris, a team of scientists and engineers has prepared a white paper with plans for a potential Next Generation Arecibo Telescope.

From a list of projects they would like to explore—including planetary defense, solar system science, climate change, radio astronomy, space weather forecasting, gravitational-wave detection, pulsars, and searching for extraterrestrial life, among others—the researchers described the equipment they would need to accomplish these aims.

The proposed telescope would allow for new and expanded science, with a much wider field of view than that of the collapsed telescope. It would cover three times the frequency range and be almost twice as sensitive, while increasing the transmission power by four times. It has a projected price tag of $450 million.

"We do have plans to rebuild, obviously with a different type because of the technology available now," Vazquez says. "It will be much different than what we had before, but nevertheless, we want to get something back up on the air." He notes that NSF will make the final decision, but, he says, "We are gung-ho going forward, and we'll see where this takes us."

Resources

Books

To See the Unseen: A History of Planetary Radar Astronomy, by Andrew J. Butrica; 1996
history.nasa.gov/SP-4218/sp4218.htm

The Invisible Universe: The Story of Radio Astronomy, by Gerritt Verschuur; 2015

Internet

Arecibo Observatory
www.naic.edu

Next-Generation Arecibo Telescope
www.naic.edu/ngat/NGAT-Summary_v2.0_03042021.pdf

Final Report on the Collapse
www.nsf.gov/news/reports/AreciboReportFINAL-Protected_508.pdf

Video of Collapse
apod.nasa.gov/apod/ap201209.html

Molecules in Arp 220
www.sciencedaily.com/releases/2008/01/080114110715.htm

National Register of Historic Places
www.nps.gov/nr/feature/weekly_features/IonosphereCenter.pdf

Kristen Pope is a freelance writer and editor who lives near Jackson Hole, Wyoming.

by Damond Benningfield and Melissa Gaskill

Light(n)ing the Darkness

The darkest matter in the universe could reveal its presence in a flash

If you ever see a straight lightning bolt, please get a picture of it. It could be one of the most important discoveries in the history of physics: confirmation of the existence of dark matter.

Dark matter appears to account for about 85 percent of all the matter in the universe. Astronomers see its effects on cosmic scales. It exerts a gravitational pull on the "normal" matter around it, so it holds together clusters of galaxies and causes stars in the outer regions of spiral galaxies to move faster.

Dark matter produces no detectable energy, though, so no one knows what it is. The leading theory says it consists of subatomic particles—heavy, light, or somewhere between, depending on the model. Physicists have created big experiments to try to catch these particles ramming into particles of normal matter, to no avail. Dark matter has remained stubbornly dark.

One possible reason for its absence is that dark matter particles are much bigger and heavier than most models suggest—weighing a few grams to a few ounces—so there would be far fewer of them. Fewer particles means fewer encounters with Earth, so there's almost no chance that any of them would pass through any of the detectors designed to find them.

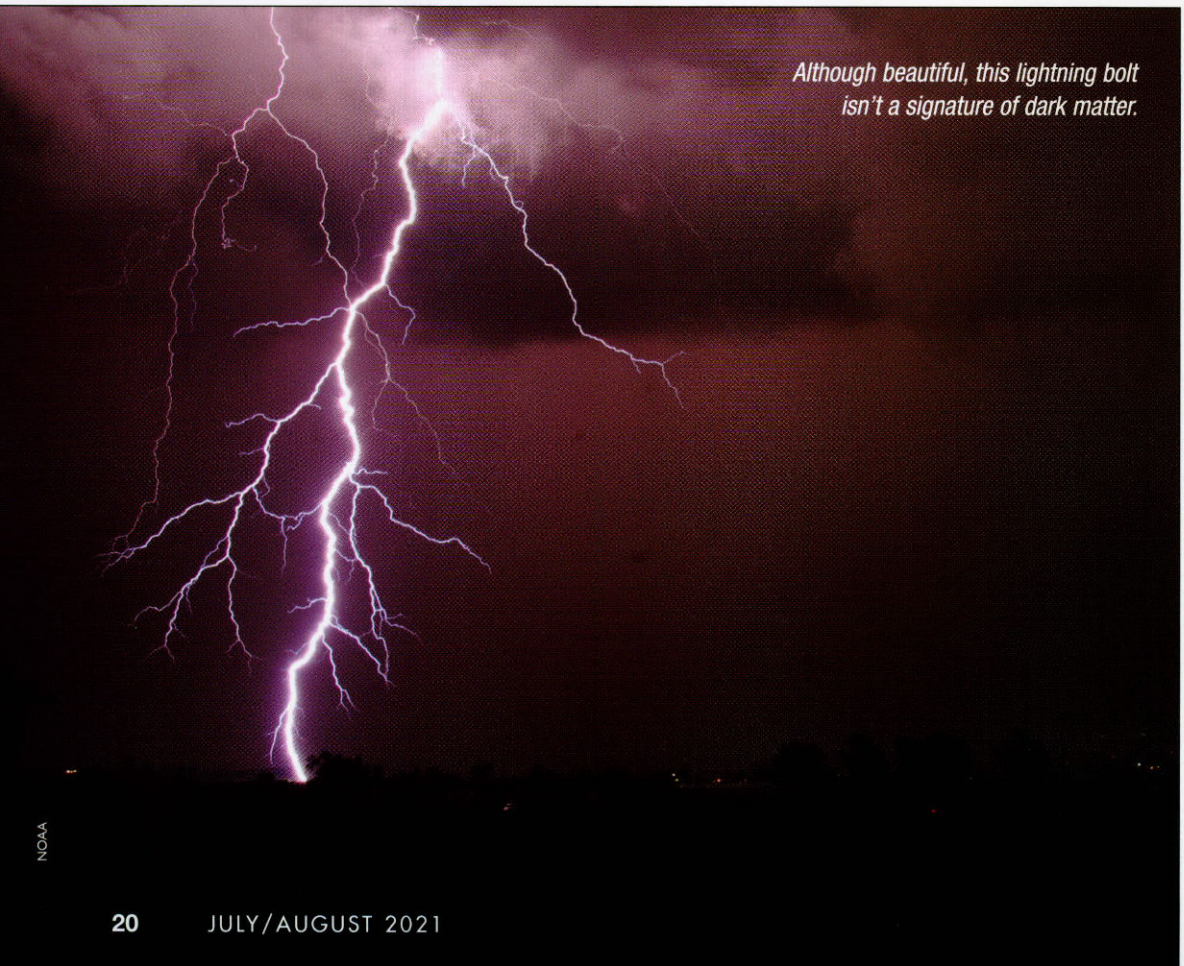
In a study published in March, researchers at the University of Toronto and Case Western Reserve proposed an alternate way to detect jumbo dark matter particles: lightning. As such a particle zipped through Earth's atmosphere, it would ram into atoms and molecules, giving them an electric charge. If it plowed such a pathway during a thunderstorm, the particle could trigger a lightning bolt.

Normally, lightning follows a jagged path across the sky because it's the path of least resistance. Air currents, changes in temperature and water vapor, and other factors trace out a trail that twists across the sky, creating a natural pathway for the electric discharge. A macro dark matter particle would be heavy enough and move fast enough to zip straight through the atmosphere, however, clearing a straight pathway for lightning.

Macro dark matter impacts during thunderstorms would be extremely rare, though. And so far, researchers have found no record of any straight lightning. The research team suggests that could be because no one has looked for it. Networks of lightning-watching cameras might be set up to try to catch such a bolt, or a probe might be sent to Jupiter, which has far more powerful thunderstorms than those on Earth, to look for straight lightning there.

Macros also could have carved trails in granite, the researchers say. A macro's energetic plunge would melt a pencil-thin trail in the rock. When it resolidified, it would form obsidian, a darker rock that would be easily visible in a cut granite slab. (The researchers plan to set up a web site later this year to collect images of possible dark-matter signatures in granite features.)

Atmospheric researchers have already suggested that lightning can be triggered by cosmic rays, which are heavy particles from exploding stars and other cosmic events. Heavier particles of dark matter would simply trigger a different form of lightning—perhaps revealing the presence of a form of matter that otherwise has remained in the dark. **DB**



Although beautiful, this lightning bolt isn't a signature of dark matter.

NOAA

A recent explosive volcanic deposit on Mars

NASA/JPL/MSSS/THE MURRAY LAB

Is Mars volcanically active?

Researchers from the University of Arizona have discovered an eight-mile-wide deposit around a large volcanic fissure on Mars that indicates volcanic eruptions may have taken place as recently as 50,000 years ago. The material matches that expected from a pyroclastic eruption—an explosive eruption of magma driven by expanding gasses, similar to opening a shaken can of soda.

Most volcanism on the Red Planet occurred between three billion and four billion years ago, with a few isolated, smaller eruptions as recently as three million years ago. Most of the planet's volcanoes have produced slow, thick flows of lava like those that built the Hawaiian islands.

The current hotspot of Martian activity, discovered in images from Mars orbiters, seems to be in the Elysium region, a mostly featureless plain that is also the epicenter of present-day quakes and recent floods of water and lava.

This adds to a growing body of evidence that Mars is still relatively active. Other evidence includes seismic rumbling detected by NASA's InSight lander and possible evidence of methane releases sniffed out by American and European orbiters. Eruptions on Mars could be spaced much farther apart than those on Earth—one every few million years. **MG**

Clearing Out the Underbrush

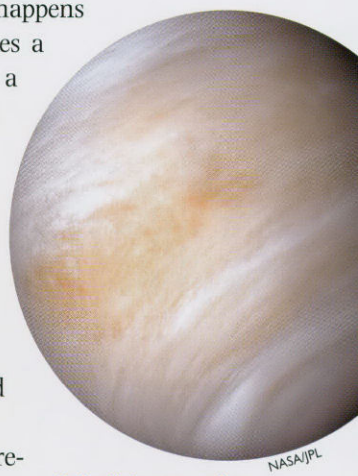
The lush Amazon rainforest grew from the ashes of the cosmic impact that killed off the dinosaurs, according to recent research. An asteroid hit Earth 66 million years ago, near the present-day Yucatán peninsula. The impact created a firestorm and a giant tsunami and blasted enough debris into the atmosphere to block out the Sun for months. That probably killed the dinosaurs and much of the other life on Earth. The new study says it also destroyed almost half of the vegetation in the Amazon rainforest, which took millions of years to redevelop. Trees with thin canopies, allowing dense vegetation at the surface, were replaced by flowering trees with much thicker canopies, transforming the rainforest's appearance.

Venus's 'Wobbly' Days

The length of a day on Venus varies by as much as 20 minutes, according to research recently published in *Nature Astronomy*. Because the planet's rotation rate constantly changes, the research team took 21 radar measurements over a 15-year period and estimated the length of a day from each. The average length is a smidge more than 243 Earth days.

That variation likely explains disagreement among previous estimates of the Venusian day. It may be caused by motions in the planet's dense, heavy atmosphere. As the atmosphere moves across the surface, it may drag or push the planet, changing its rotation rate.

This same effect happens on Earth, but makes a difference of only a millisecond or so per day. The atmosphere on Venus is about 93 times more massive than Earth's, so it has much more momentum to trade with the solid planet.



NASA/JPL

Scientists use radar to study Venus because its surface is hidden below thick clouds.

The paper also reports that Venus tips precisely 2.6392 degrees on its axis (versus Earth's 23-degree tilt). Changes in Venus's spin and orientation reveal how mass spreads out within the planet, providing insight into its formation and volcanic history and how time has altered its surface. Precise data on how Venus moves are critical to any future landing attempts.

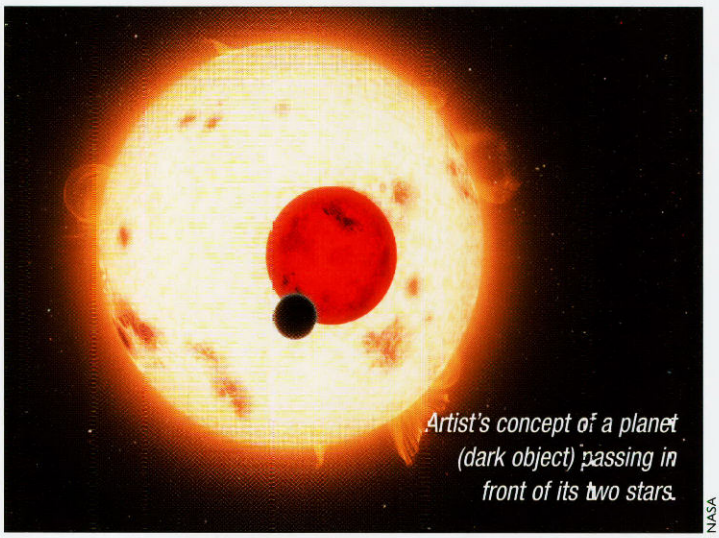
The measurements were made by bouncing radio waves from the 230-foot (70-meter) Goldstone antenna in California off of Venus. Goldstone and the Green Bank Observatory in West Virginia picked up returning waves. Scientists use radio telescopes to study the planet's surface because Venus is coated by an unbroken layer of clouds, which hides the surface from view. **MG**

Multi-Star Systems May be Suitable for Life

New evidence suggests that five known systems with multiple stars—Kepler-34, 35, 38, 64, and 413—may host planets capable of supporting life. Each of these systems, which lie roughly 2,700 to 5,900 light-years from Earth, in the constellations Lyra and Cygnus, supports a habitable zone—a region around the star where conditions are relatively comfortable for life. Kepler-64 has at least four stars, while the others have two stars. All of them have at least one planet the size of Neptune or larger.

Binary systems are common, representing between half and three-quarters of all star systems in the galaxy. Many of these systems, however, don't provide the right conditions for life.

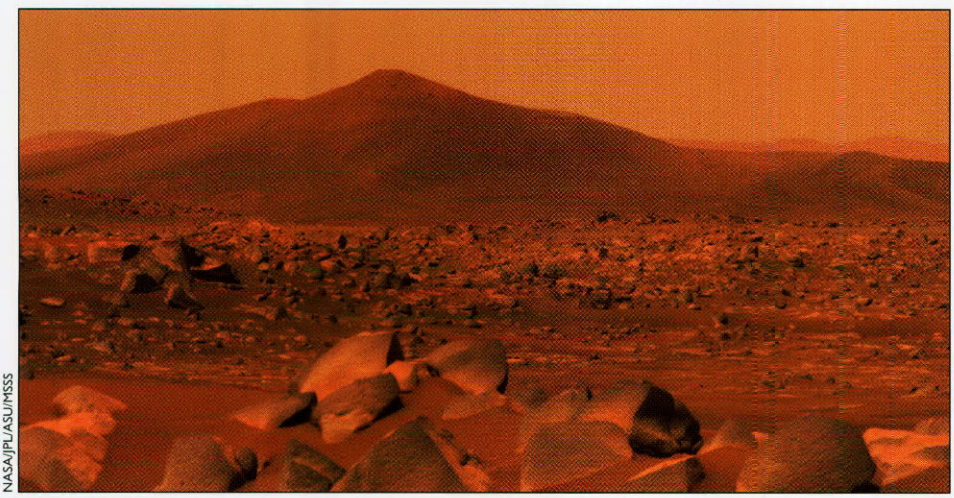
Researchers at New York University Abu Dhabi and the University of Washington used the concept of "dynamically informed habitable zones" to predict where to look for multi-star systems with favorable conditions. The concept has been applied to investigating the habitability of planets that orbit only one star in a binary system, as well as systems with giant planets. This work extended the concept to potentially habitable worlds with orbits that are circumbinary, or around both stars in a close pair. The method demonstrated that the presence of giant planets in the majority of those systems does not preclude the existence of habitable worlds.



Artist's concept of a planet (dark object) passing in front of its two stars.

NASA

So far, only giant planets have been discovered in binary systems, but smaller Earth-like bodies simply may have escaped detection. **MG**



NASA/JPL/ASU/MSSS

Getting the Lay of the Land

The Perseverance rover snapped this view of a hill, informally dubbed Santa Cruz on April 29, the rover's 68th day on Mars. The hill is roughly 1.5 miles (2.5 km) away. Perseverance is surrounded by large rocks, which were deposited by a roaring river when Mars was much younger. The rover will poke through the ancient sediments for evidence of microscopic life. The rim of Jezero Crater, where the rover landed, is visible in the distance.

Severe 'Space Weather' Could Zap Airliners

Bad weather can make a flight across the ocean unhealthy. Space weather also can cause health problems, by exposing flyers to high levels of radiation. A recent study found that powerful storms could increase radiation levels by a factor of more than 100 on some flights.

Space weather is produced by the Sun. Violent eruptions on its surface send radiation and particles streaming through space. When they hit Earth, they can damage or knock out orbiting satellites, disrupt power grids, and cause other problems.

During strong solar storms, airlines divert flights from high latitudes because they're zapped by higher levels of radiation.

The new study, by researchers at the University of Toulouse, modeled the possible effects of powerful storms on 25,000 flights that took place in March 2019. The models considered altitude, ground track, jet streams, and other factors. They looked at dosages passengers and crew would have received during two especially strong storms in the modern era, plus two even stronger ones more than a millennium ago.

The study showed that, in some cases, such as flights between Paris and Los Angeles, the radiation dose could be more than 100 times stronger than the typical background radiation. Flight crew members could receive a significant fraction of their annual radiation limits in a single flight.

Airlines and governments provide real-time updates on space weather, allowing pilots to adjust their routes. Even so, especially strong storms still could inflict uncomfortably high levels of radiation. **DB**

A combined X-ray and radio view shows star clusters and giant gas clouds in the heart of the Milky Way Galaxy. The center of the galaxy is in the bright region near the center of the image, with the galaxy's central supermassive black hole near the right edge of that region. Flows of hot gas, perhaps accelerated by exploding stars, stream above and below the center. Magnetic fields sculpt some of the gas into long, thin filaments.

NASA/CXC/UMASS/Q.D.WANG; NRF/SARAO/MEERKAT