StarDate®

SEPTEMBER/OCTOBER 2021 $6

CLOUDING THE VIEW?
PAGE 16

GOLDENEYE

Giant space telescope almost ready to cast its gaze upon the stars

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

StarDate

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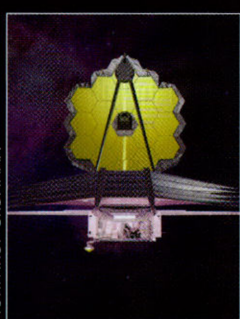

NORTHROP GRUMMAN

On The Cover

James Webb Space Telescope stares into space in this artist's concept. The telescope is the biggest, most expensive, and most eagerly awaited space telescope in history. Page 4.

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A moon appears to be taking shape around a planet in the PDS 70 star system, which is about 400 light-years away. The planet (bright dot to the right of center) is encircled by a disk of dust, much like the larger disk that encircles the star. The planetary disk could be giving birth to a moon. This is the first indication of any moon—even an embryonic one—outside our own solar system.

ALMA (ESO/NAOJ/NRAO)/BENISTY ET AL.

Coming Up

NASA and other space agencies are getting ready to deploy a wave of robotic probes to the Moon, and we'll tell you all about them. We'll also talk about a rarely discussed class of black holes that could be left over from the birth of the universe.

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MERLIN

Dear Merlin,

Why do planets, especially Venus and Jupiter, shine so brightly? It's as if they were stars producing their own light rather than reflecting the Sun's. Why isn't the light more diffuse, like that of a comet?

Gunnar Martone
Sea Cliff, New York

The five easily visible planets—Mercury, Venus, Mars, Jupiter, and Saturn—appear so bright for several reasons. For one thing, they're all close enough to Earth to appear as more than mere pinpoints of light, as the true stars do. Although you don't recognize them as such with the eye alone, they're tiny disks, so they are bigger targets than the stars, which are millions of times farther. And unlike a comet, which has a tiny nucleus surrounded by a cloud of gas and dust that can be millions of miles wide, a planet is dense, so it appears as a solid object.

Another reason for the brightness is that several of the planets—especially Venus and Jupiter—are covered by clouds that reflect a lot of sunlight back into space.

Venus is especially close to the Sun, so it's illuminated by much stronger sunlight than the other planets, so it reflects more light in Earth's direction. And Jupiter is the largest planet, so it's a big presence in the night sky.

The combination makes Venus and Jupiter the brightest lights in the night sky after the Moon.

Dear Merlin,

How close are we as humans to getting proof or evidence of other life in the universe?

Frank Gomez
San Luis Obispo, California

As an all-powerful wizard, naturally Merlin knows whether life exists elsewhere in the universe, but he's forbidden from sharing the answer. Besides, much of the fun is in the hunt.

And the hunt is expanding. Astronomers have discovered hundreds of planets in the habitable zones of other star systems, where conditions are comfortable for life. A few dozen are fairly similar to Earth (out of an estimated 300 million such habitable-zone planets in the Milky Way Galaxy). Others are giants, which are less likely to host life, but they could have moons that would be more hospitable.

New telescopes and instruments are making it easier to examine the atmospheres of such worlds. Certain chemicals in the atmosphere, such as oxygen and methane, are possible signs of life. James Webb Space Telescope (see page 4), scheduled for launch this fall, could provide atmospheric profiles of some planets, while future space telescopes are being designed to make the task easier.

SETI (the search for extraterrestrial intelligence) has ramped up in the last few years as well, with astronomers hunting for both radio signals and laser beams from other civilizations.

The hunt for life in the solar system is ramping up as well. Three current Mars rovers are looking for signs of ancient microscopic life on the Red Planet, and both orbiters and landers have detected methane in the atmosphere (one of those it-might-be-produced-by-life compounds). Future missions may examine Jupiter's moon Europa, Saturn's moon Enceladus, and other worlds that are possible homes for life.

None of these steps guarantees that humans will find life elsewhere. It's possible that Earth is the only planet with life, or that inhabited planets are too far away for current or near-term technology to detect. Yet it wouldn't surprise Merlin if scientists announce solid evidence of extraterrestrial life in the next few decades.

Dear Merlin,

Does the matter bombarding Earth from space—meteors, comet dust, and so on—add enough matter to change Earth's mass and gravity?

Cliff Murphy
Reno, Nevada

Absolutely! Don't try to measure the change, though, because compared to the total mass of Earth, it's minuscule.

Estimates of how much material falls to Earth vary by quite a bit. A good middle ground is somewhere around 50,000 tons per year. That includes everything from tiny grains of dust to asteroids the size of a house or bigger.

Earth's total mass is something like a million billion times greater than that annual influx, so the extra stuff is like adding a cherry on top of a city-sized sundae—it's hard to notice.

Keep in mind that Earth also *loses* mass. Sunlight breaks apart molecules at the top of the atmosphere and whisks them off into space. Again, estimates vary, but figure on a loss of at least 35,000 tons per year.

So if you regularly put Earth on the scales, you just wouldn't notice the difference from one year to the next.

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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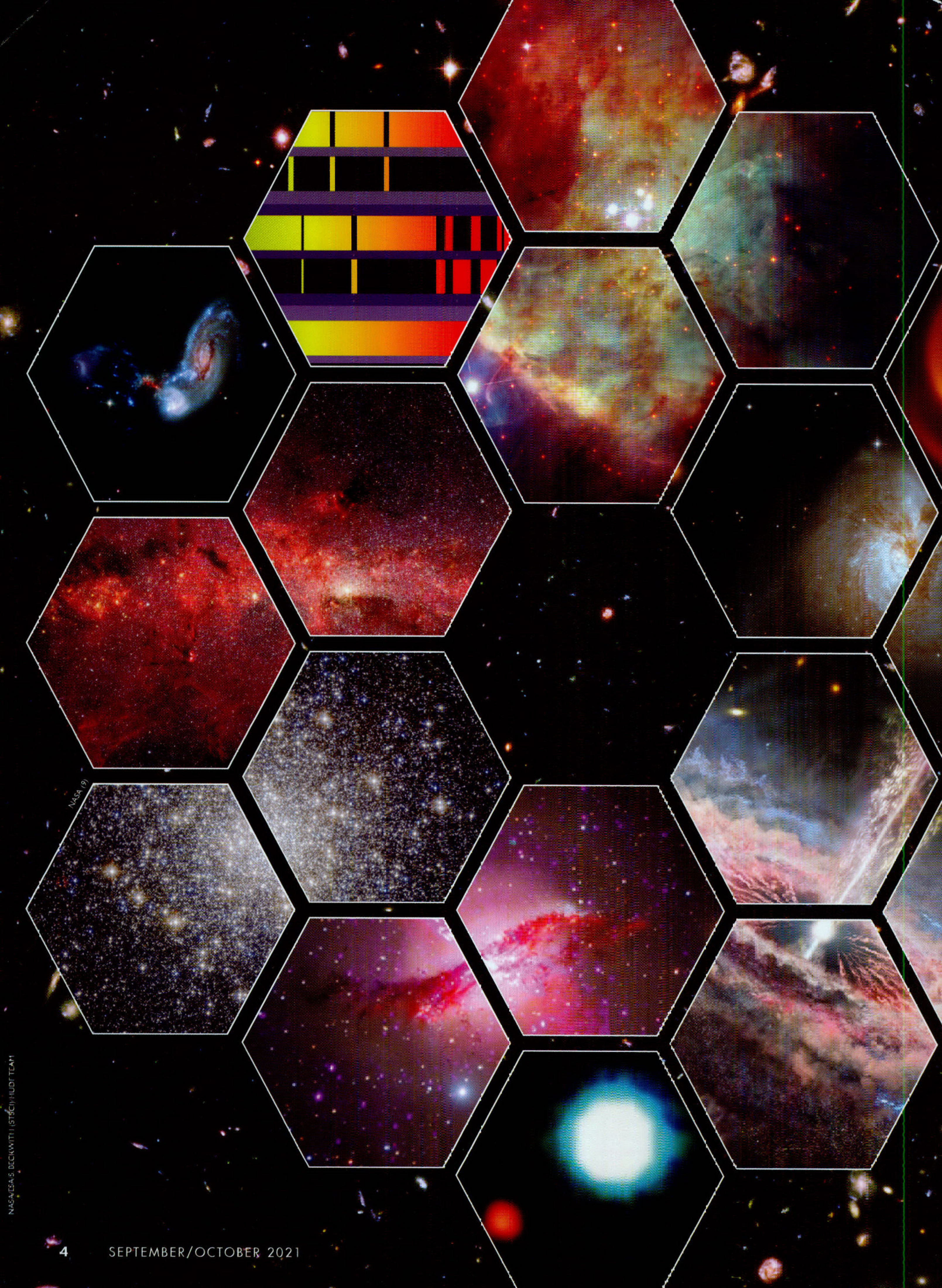


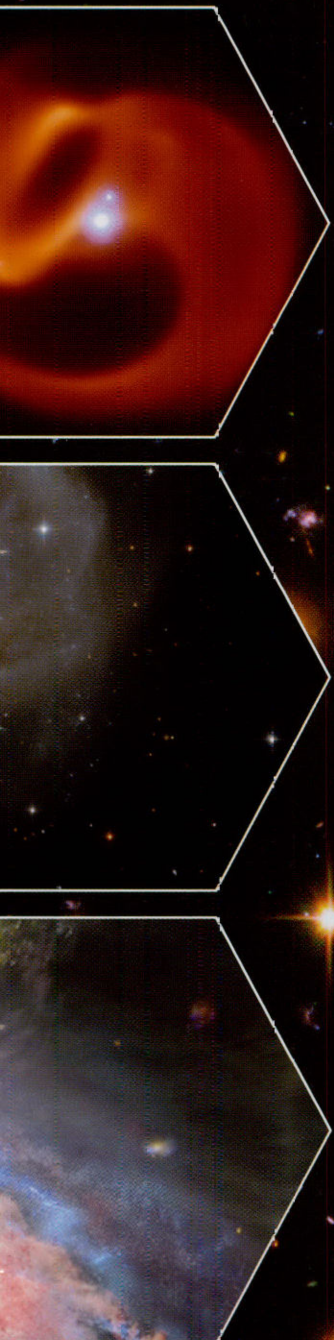
NASA (9)

NASA/ESA/S. BECKWITH (STSCI)/HUDF TEAM

Hopes, Dreams, and Beryllium Hexagons

The largest space telescope in history will study everything from methane on Mars to the origins of the first stars and galaxies

By MELISSA GASKILL



James Webb Space Telescope will explore many types of astronomical objects, including (clockwise from top), stellar nurseries, galaxies, quasars, exoplanets, star-forming galaxies, star clusters, our own galaxy, and colliding galaxies. Many discoveries will be made with spectroscopy, which splits light into a rainbow of colors. Background: The Hubble Ultra-Deep Field contains myriad galaxies, some of which JWST will reexamine.

When James Webb Space Telescope (JWST) lifts off from French Guiana sometime this fall, it will weigh in at about seven tons. It carries a far heavier load, though: the expectations of a generation of astronomers. The scientists plan to use the biggest, most expensive space telescope ever to study every phase in the history of the universe, from shortly after the Big Bang to the modern era; probe the formation of galaxies and planetary systems; and analyze planets in other star systems in search of signs of life.

"The Webb can stare very deeply and study in exquisite detail," says Caitlin Casey, an assistant professor of astronomy at The University of Texas at Austin. "It takes us so much farther back in cosmic time to shed light on an era of cosmic history that we haven't seen before."

An international program led by NASA, the novel telescope is scheduled to settle into an orbit a million miles from Earth, where it will peer deeper into the cosmos than any other space telescope.

The key to any telescope is its primary mirror—the curved surface that gathers and focuses starlight. And JWST's mirror is unlike anything that's flown in space before. In fact, it's not like any mirror deployed on Earth, either. It consists of 18 hexagonal segments that fold up like a piece of Space Age origami. The segments are made of beryllium, a lightweight metal used to make parts for supersonic jets, and coated with a whisper-thin layer of gold.

The mirror was designed to meet the unique requirements of the mission. It has to be big enough to capture the light of distant stars, galaxies, and planets, but not too heavy to launch with existing booster rockets. It has to observe the universe at infrared wavelengths, which are invisible to the human eye, and it has to withstand the cold of space for at least 10 years.

JWST's mirror will span 6.5 meters (more than 21 feet). That's roughly three times the diameter of the main mirror on Hubble Space Telescope (HST), allowing JWST to collect almost seven times more light, which makes it possible to see objects that are fainter and farther away.

But size also is a disadvantage. Current boosters aren't big enough to launch a single mirror that's 6.5 meters in diameter, so engineers split JWST's mirror into 18 hexagonal segments. A pair of "wings," each containing three segments, are folded for launch, but will deploy once they reach space to create the mirror's proper shape. Operators then expect to spend several months tweaking the positions of the individual mirror segments, using small motors on the back of each to form the proper curvature of the overall mirror, which must be accurate to less than one ten-thousandth the width of a human hair. (The same technique is used on large segmented-mirror telescopes on the ground, including Hobby-Eberly Telescope at McDonald Observatory).

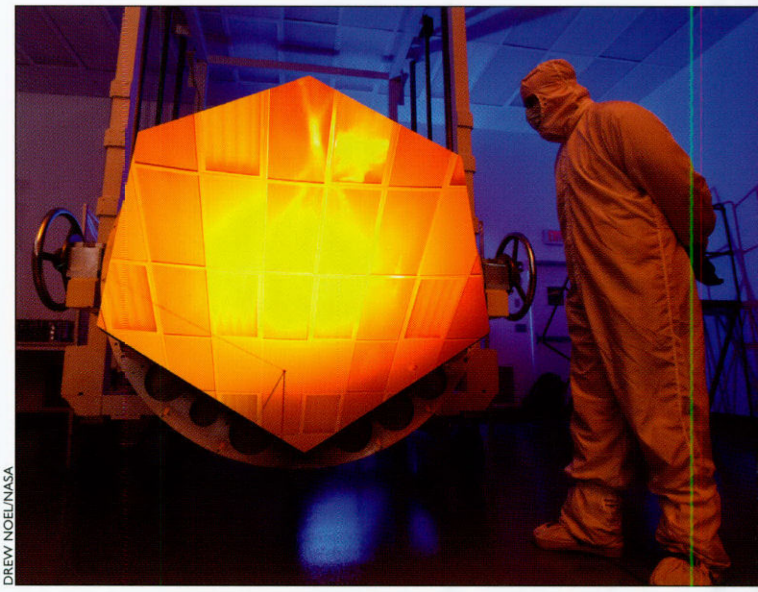
"We have to phase 18 individual mirror segments to act as a single telescope," says Jonathan Gardner, deputy senior project scientist at NASA. "[Many] of the large telescopes on Earth are similarly made up of individual mirror segments, but Webb is in space and has to be operated remotely."

To make the mirror light enough to launch yet strong enough to survive once it gets to space, engineers fashioned the mirror segments from beryllium. This lightweight metal is strong, and it maintains its shape regardless of the temperature (any bending or warping changes the mirror's precisely figured curvature, blurring its view.) In addition, the backs of the mirror segments have a honeycomb structure that keeps them strong but reduces weight—each segment will weigh just 45 pounds (20 kg).

The segments are coated with gold, which reflects the infrared wavelengths the telescope is designed to study. The coating is about 100 nanometers thick—roughly the size of the virus that causes COVID-19. To apply the super-thin coating, designers placed the mirrors inside a vacuum chamber and vaporized a small amount of gold.

The primary mirror will reflect the light it gathers to a secondary mirror, which will pass the light to the scien-

Below: A technician inspects one of the mirror segments. Right: The full telescope mirror before it was packed for launch



DREW NOEL/NASA

tific instruments, including cameras and spectrographs, which break the light from a star or other object into its individual wavelengths. "The instrumentation is all very exciting," says Casey, a principal investigator on COSMOS-Webb, one of the studies selected for Webb's early observations. "We'll get some of the highest resolution images ever and see incredibly deep into space. That combination is unique."

Protecting the mirror is a five-layer, tennis-court-sized sunshield made of Kapton—a thick film that can hold up under the harsh conditions of space. That creates a structure that makes JWST look like a high-tech battleship cruising the space lanes.

One side of the shield will protect the telescope from the intense light and heat of the Sun, as well as reflected sunlight from Earth and the Moon. The telescope will sit atop the other side, facing deep space, where temperatures could reach a nippy minus-394 degrees Fahrenheit.

The sunshield is critical to telescope operations. "To work in the infrared, it needs to be very cold," Gardner says. "Everything that has a temperature radiates in the infrared. The colder it is, the less light comes out. Webb is going to be at 50 degrees above absolute zero, not emitting any infrared light. That makes it possible to see the faint galaxies that we're trying to detect."

To further minimize interference from Earth and the Moon, JWST's destination is the second Lagrange point (L2), a region roughly one million miles (1.6 million km) beyond Earth where the gravitational pull of Earth and the Sun are balanced. This will lock the telescope into perfect unison with Earth. It also will offer extreme cold, an unimpeded view into space, and constant communication with the ground through NASA's Deep Space Network.

NORTHROP GRUMMAN

Astronomers plan to use JWST to address key questions in just about every aspect of astronomy. The 286 research projects selected for Webb's first cycle of observations range from galaxy surveys to studies of quasars, star-forming regions in our Milky Way, and objects in our solar system.

Research papers published or submitted for publication in recent months say the telescope should be a good platform for studying exoplanets (including artificial lights, if they exist, on one of the planets orbiting Proxima Centauri, the closest star); the weather on the "failed stars" known as brown dwarfs; a class of dwarf galaxies ("a free lunch for JWST," according to the paper's title); and regions that are giving birth to stars and planets.

A key goal—and perhaps *the* key goal—is to probe the early universe, and particularly the era when the first stars and galaxies were born.

As part of that, astronomers will conduct the first JWST Deep Field, an especially deep look into the early universe. The telescope will spend days staring at a single small region of the sky. The viewing area will overlap the Hubble Ultra-Deep Field, a project in which HST found and studied as many as 10,000 galaxies. Some of these galaxies are quite far away, which means we see them as they looked when the universe was young. Even so, they're not far enough to help astronomers understand how the earliest stars and galaxies took shape and how they evolved.

"We need to go farther back than Hubble to find the oldest galaxies," says Steven Finkelstein, another University of Texas astronomer and a leader of the new deep field project. "With James Webb, we'll go back to about 280 million years after the Big Bang. With

Hubble, we only went back to about 500 million years. The difference might not sound too impressive, but it's key to identifying the epoch when the first galaxies were forming."

COSMOS-Webb will spend more than 200 hours surveying and mapping half a million galaxies in 0.6 square degrees of the sky—about the area of three full moons—using one of the observatory's cameras, and a smaller area with a second instrument.

"We're excited because we are surveying a patch of sky that is pretty big compared to most telescope fields of view," Casey says. "We'll be able to find some of the most distant galaxies in the deep field and map where they live in the cosmos. Are they clustered together, or stretched out and evenly distributed, like towns scattered across the countryside? We'll be comparing their environment, some basic concepts in cosmology, and how we expect the universe to assemble in the first billion years after the Big Bang."

Exoplanets are another significant area of study for Webb. Exoplanets—planets orbiting stars other than the Sun—were a relatively new discovery when scientists started working on the observatory, in the late 1990s. During JWST's 20 years of development, it become clear that a large, infrared-optimized telescope would be an immensely powerful tool for studying them.

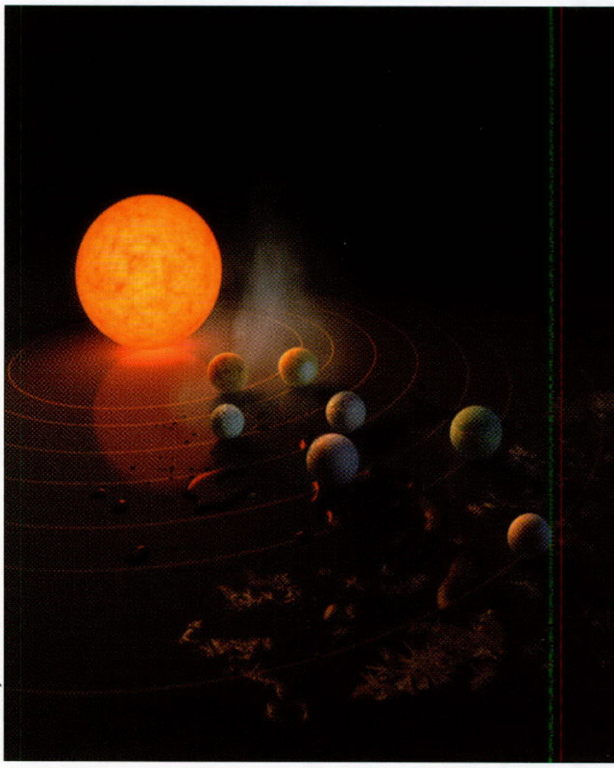
"One area is transiting exoplanets—those that go between their star and our telescope," Gardner says. "When a planet transits, the star's light goes through the planet's atmosphere and into the 'scope. We can measure the constituents of the atmosphere of that exoplanet and look for things, like water vapor or methane, that could be indicative of appropriate conditions for life."

While even JWST probably isn't big enough to find conclusive evidence of life on other planets, it could, for example, reveal whether a small rocky planet has water on its surface, a key step in finding habitable planets.

Astronomers rarely use mid-infrared wavelengths to image distant worlds because Earth's atmosphere absorbs them. Yet free of the interference from that protective blanket of air, JWST can collect light at those wavelengths. Astronomers say that will allow the telescope to make seminal contributions to understanding the chemistry and properties of exoplanet atmospheres. Its observations can build on and expand what ground-based observatories have done in a way that would not be possible otherwise.

JWST won't be limited to studying the worlds in other stars systems. Although it can't look toward the Sun, it is expected to provide robust observations from Mars outward—including Mars itself.

One observing project will measure organics—the chemical building blocks of life—on the Red Planet. The telescope will scan atmospheric and surface chemistry across Mars at high resolution, creating global maps to provide context for the rovers and orbiters exploring the planet. And it may shed some light on the mystery of methane on Mars. The Curiosity rover and some ground-based telescopes have detected the compound, which, on Earth, is produced primarily by living organisms. Mars orbiters, however, have detected little to no methane in the upper atmosphere. Planetary scientists say they hope JWST helps resolve the issue.



TRAPPIST/E. JEHIN/ESO

And if the unexpected happens in our own celestial neighborhood—an interstellar asteroid passes through, a bright comet streaks across the sky, or something slams into Jupiter, for example—the telescope should be ready to turn its golden eye toward it.

JWST has traveled a long and convoluted route to the launch pad. First proposed in 1995 as the Next Generation Space Telescope and projected to cost between $500 million and $1 billion, it saw steadily increasing costs due, in part, to its complexity and novel design.

NASA says technical issues caused nearly seven years of delays. Testing some parts of the hardware took longer than expected. Hardware mishaps caused some schedule delays; at one point, too much slack in cables that pull the sunshield into place created a snagging hazard and several small tears formed within the shield.

In July 2018, based on a March 2021 launch date, NASA announced a total expected cost of about $9.66 billion, including launch and five years of operation. Then, in July 2020, it blamed an additional seven-month delay, to October 31, partly on COVID-related safety precautions, reduced on-site personnel, and shift-work disruption.

The delays and cost overruns irked some members of Congress, who tried to kill the project in 2011 (and almost did). And because the rapidly inflating cost deprived other space projects of funding, in 2010 the journal *Nature* described JWST as "the telescope that ate astronomy."

The delays have continued. The space agency announced yet another, more vague, delay this June, citing issues with shipment of the telescope—a journey by boat (with details not revealed due to piracy concerns)—and readiness of the rocket and spaceport in Kourou, French Guiana, on the northeastern coast of South America. A payload fairing issue grounded the Ariane 5 booster, the telescope's ride into space, in August 2020. COVID-19 also limited operations at the spaceport; as of the June announcement, vaccines were still not widely available in French Guiana.

Even without a global pandemic, building, preparing, and launching the space telescope is a complex process, Gardner says.

For one thing, the team tested each component both individually and as part of the assembled spacecraft. "Take a detector in a camera," Gardner says. "We put the detector in a vacuum chamber and test it. Then we build it into the camera, put that in the chamber, and test it again. Then we put the camera into the instrument compartment, and test that again." In addition to vacuum chamber testing, components were subjected to vibration and acoustic testing to simulate launch. Once all of the pieces were tested and assembled, the instruments were installed on the back of the telescope and the full assembly was tested again.

During this process, bits and pieces of the observatory ping-ponged around the country, with stops in Ohio, Alabama, New Jersey, Maryland, Colorado, California, and Texas. Once assembled, the telescope traveled in its own specially designed portable clean room.

NASA/JPL/CALTECH

Left: JWST will look for atmospheres around the planets of Trappist-1, all of which are about the size of Earth. Above: If a bright comet swings by, JWST will take a look.

Its peripatetic journey occasionally put JWST in the path of trouble.

During vibration testing at Goddard Space Flight Center, in the winter of 2016-2017, for example, Maryland experienced record-breaking snowfall. In the summer of 2017, the telescope rode out Hurricane Harvey during low-temperature testing at Johnson Space Center in Houston—the only thermal vacuum chamber large enough to hold the entire thing (and the same one used to validate Apollo spacecraft components half a century ago).

Starting in midsummer, engineers sealed the telescope in the chamber, removed the air, and brought the temperature down to space-like levels. The plan was to keep the chamber cold for about 30 days before warming it back to room temperature, pumping air back in, and unsealing the door. The hurricane arrived about a third of the way through this process, though. The space center closed so staff could evacuate, and the JWST team had to get permission to remain and keep their fingers crossed that the lights would stay on.

"There was quite a bit of heroics, with people continuing to keep the telescope safe and the testing going," Gardner says, including an emergency shipment of the liquid nitrogen used to keep the chamber cold.

"One of the reasons we did so much testing is that we just have one shot at it," Gardner says. Unlike Hubble Space Telescope, JWST will be too far away for much of any kind of help from home—no astronauts can drop in for repairs or upgrades. Thanks to its L2 destination, though, it does enjoy almost unlimited launch windows (unlike, say, probes to Mars, which have to wait for the proper alignment between Earth and Mars).

The spacecraft carries a 10-year supply of the propellants needed to keep it in place and stable. And if the launch goes well, putting the telescope into the right trajectory without the need for fuel-consuming tweaks, the supply could last much longer.

Gardner says failure modes mostly involve parts just wearing out: "Things don't last forever. Webb will operate as long as it's scientifically productive." "We wish Webb could have the longevity of Hubble," which recently hit 31 years, says Casey. "But it won't."

Astronomers say they hope to use the Webb and Hubble telescopes together. "Webb can follow up on Hubble discoveries, and when we find something new with Webb, we might get some [ultraviolet] pictures with Hubble," Gardner says.

Once JWST launches and deploys its mirrors and shield and operators align the mirrors, turning on and checking all the instruments will eat up an additional five months, so the first images won't arrive until several months after launch.

The scientists eagerly awaiting their arrival see Webb's long journey into orbit as simply the cost of doing the job right. "The delays are disappointing, of course, but at some level, the vast majority of astronomers would much rather it take a couple of extra years or whatever is needed to make sure it works," Casey says. "It has such groundbreaking potential across astrophysics."

Melissa Gaskill is a freelance writer in Austin.

Resources

Internet

James Webb Space Telescope
www.nasa.gov/mission_pages/webb/about/index.html

Space Telescope Science Institute
www.stsci.edu

Hubble Space Telescope
www.nasa.gov/mission_pages/hubble/main/index.html

COSMOS-Webb
www.stsci.edu/jwst/science-execution/program-information?id=1727

JWST Advanced Deep Extragalactic Survey
webbtelescope.org/contents/news-releases/2021/news-2021-004

by Alan MacRobert

Bright Planets Bookend the Early Evening

The stars of autumn begin to push those of summer out of the way as the nights grow longer and cooler. Pegasus is in view in the east as night falls, with several related constellations following the flying horse into the sky over the next few hours. Venus and Jupiter, the brightest objects in the night sky other than the Moon, bookend the early evening sky, while Mercury stages its best morning appearance for the year in October.

SEPTEMBER 1-15

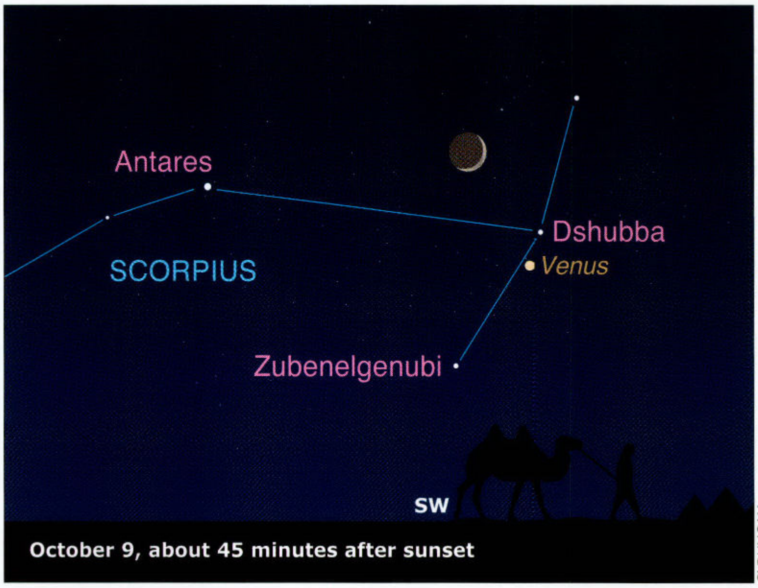
As the first stars begin to come out in the September twilight, the two brightest planets shine from opposite sides of the sky.

The first to look for is Venus, low in the west-southwest, perhaps 45 minutes to an hour after sunset. Venus is the first to try for because it's sinking lower by the minute and sets by the end of twilight. Venus has been hanging tantalizingly low in the twilight for several months now. It will inch higher during the fall.

Look also for fainter Spica near Venus. Even at 1st magnitude, Spica is only a hundredth as bright. It starts September to Venus's left (by two or three finger-widths at arm's length) and passes closest by Venus on the 4th and 5th (a finger-width to Venus's lower left). Binoculars will help you pick it out.

Turn around to Jupiter, the second-brightest planet, in the southeast, a little higher than Venus. As twilight deepens, you'll find dimmer Saturn to Jupiter's upper right.

Like Venus, Jupiter and Saturn glow with a rock-steady light. That's almost always a giveaway for planets. Planets are tiny extended disks, even if too small to resolve with the naked eye, while stars are more truly point-like. That means that all the very slight atmospheric heat waves that are constantly shimmering across your line of sight are likely to send some of a star's light dancing onto and away from the pupil of your eye, making the star "twinkle." The separate shimmerings of all the points on a planetary disk tend to average out, resulting in a steadier glow.



October 9, about 45 minutes after sunset

After dark, Jupiter and Saturn climb higher and shift toward the south. They're both in dim Capricornus, so unless you have a fairly dark sky, they don't have much in the way of background stars. But high above them shines first-magnitude Altair, with, a finger-width above it, its eternal little sidekick, Tarazed.

And to the left of Altair soon after dark, by slightly more than a fist, look for the starry outline of little Delphinus, the leaping dolphin.

It's late summer, so right after dark look low-ish in the south—far to the lower right of Altair—for the Teapot of Sagittarius. It's as big as your fist at arm's length, and it tilts to the right to pour from its triangular spout. Just above the spout is the brightest patch of the Milky Way: the Large Sagittarius Star Cloud. By no coincidence, this is the direction toward the dense center of our galaxy.

To the lower right of the spout's tip, find the pair of stars known as the Cat's Eyes. They're dissimilar (a winking cat?), and they currently tilt from upper left to lower right.

Halfway between the spout's tip and the Cat's Eyes, binoculars will resolve the big, dramatic open star cluster Messier 7, one of the best in the sky.

Look to the upper right from there, by less than a binocular field of view, and you find M7's smaller and dimmer partner cluster, Messier 6.

SEPTEMBER 16-30

Venus is just a trace higher now in the southwest at dusk, but Jupiter and Saturn are making bolder strides upward. They now reach their greatest heights in the south in the convenient mid-evening. The two giants are roughly a month past opposition, which means they're still nearly at their closest to Earth and nearly their telescopic largest. Even without a telescope, Jupiter will show two, three, or even all four of its big moons in binoculars—tiny specks lined up close to either side of the brilliant planet. Their pattern changes from night to night. You'll do better with them if you can brace your binoculars firmly against something solid, like a tree trunk or window frame.

As for the other two naked-eye planets, Mars and Mercury, they're both out of sight, deep in the sunset.

Summer turns to fall, astronomically speaking, on the afternoon of September 22 at exactly 2:21 p.m. CDT. No natural fireworks commemorate this moment; the center of the Sun simply crosses Earth's equator as the Sun heads south for the season.

Visible changes in the sky, as in nature, are much less abrupt as the seasons change. For instance, you may notice Deneb gradually taking over from Vega as the zenith star at nightfall (for those of us at mid-northern latitudes). And the Autumn Star, Fomalhaut, becomes a little more insistent about showing itself over your tree line to the southeast.

And if you situate yourself under a dark sky, soon after dark, you'll find the Milky Way standing straight up from the south-southwestern horizon. From there it runs across the zenith and straight down to the north-northeast. Counting up from the south-southwest, the Milky Way's brightest parts run through the tail of Scorpius (with the Cat's Eyes), the spout of the Sagittarius Teapot, through dim little Scutum, along the backbone of Aquila, across Cygnus at the zenith with the rich Cygnus Star Cloud, then down between Cepheus and Lacerta, through Cassiopeia, and on to rising Perseus.

OCTOBER 1-15

Venus has seemed to remain almost stationary in the southwestern twilight as the weeks go by, but actually it is hurtling eastward with respect to the background stars. However, with respect to your skywatching viewpoint—in which Earth and your western landscape seem motionless—the background stars seem to slide westward behind Venus, moving toward the lower right.

The brightest of these stars is Antares, now approaching Venus from the upper left, along with the other stars of upper Scorpius. On October 9, Venus passes three-quarters of a degree below Delta Scorpii, the second-brightest star in the area after Antares, with the crescent Moon just above them! Then, on October 16, Venus will shine 1.5 degrees above Antares itself.

And while we are considering planets' meet-ups with stars, in October you'll find third-magnitude Delta Capricorni a couple of degrees to the left or lower left of Jupiter, and third-magnitude Beta and Alpha Capricorni farther to the upper right of Saturn. Alpha Cap, the upper of those two, is easily split as a fine double star in binoculars. Some sharp-eyed people can even resolve it with the unaided eye.

Elsewhere in the sky, there's no mistaking that fall has arrived. Cassiopeia stands high in the northeast, its flattened W shape almost standing on end (the dimmer end). Due north is Polaris, as always, but now Kochab, the only other moderately bright star of the Little Dipper, stands directly to the left of Polaris (by a fist and a half). They are practically twins in brightness.

And to the lower left of Kochab, the Big Dipper swings low, as if to scoop up nearly a full load of water.

Famous Moons

September's full Moon is the Harvest Moon, which is the full Moon closest to the autumnal equinox. The following full Moon, in October, is the Hunter's Moon.

Meteor Watch

The Shower
Orionids
Named for the constellation Orion, which is notable for its three-star belt and for the Orion Nebula, which is visible below the belt as a hazy smudge of light. At its best, this shower produces perhaps 15-20 meteors per hour.

Peak
Nights of October 20, 21

Notes
The Moon is full on the 20th, so its light will overpower all but the brightest meteors.

OCTOBER 16-31

Venus finally is climbing seriously higher in the twilight, and it doesn't set now until almost an hour after dark. Jupiter and Saturn continue to reign supreme in the south. Mars is still out of sight behind the Sun.

And now Mercury has its best dawn apparition of 2021. Look for the little planet quite low, almost due east, about 45 minutes to an hour before sunrise. It will be brightest and easiest during the last week of October.

As we enter the middle third of autumn, that iconic autumn sky-sign, the Great Square of Pegasus, looks down from on high. Soon after dark, you will find it still balanced on one corner high in the east-southeast. Just two hours later, though, it's a box lying level near the zenith when you face south. (It passes across the zenith for skywatchers in the southernmost parts of the United States.)

Starry signs of the coming cold are rising in the east. Below Cassiopeia are Perseus and, farther down, the star Capella, that bright overhead shiner of midwinter nights.

Extending from the left corner of the Great Square of Pegasus is the main line of the constellation Andromeda, pointing toward Perseus. Way down to the lower right of Perseus, the frosty little Pleiades star cluster is sparkling its dainty way up in the east-northeast.

Keep watch even lower, and there you'll find the orange-giant star Aldebaran glimmering balefully, as if the Pleiades is pulling it out of the horizon murk.

Keep an eye on this part of the sky in the coming hours and weeks. Greater things lurk below, preparing to make their grand appearance.

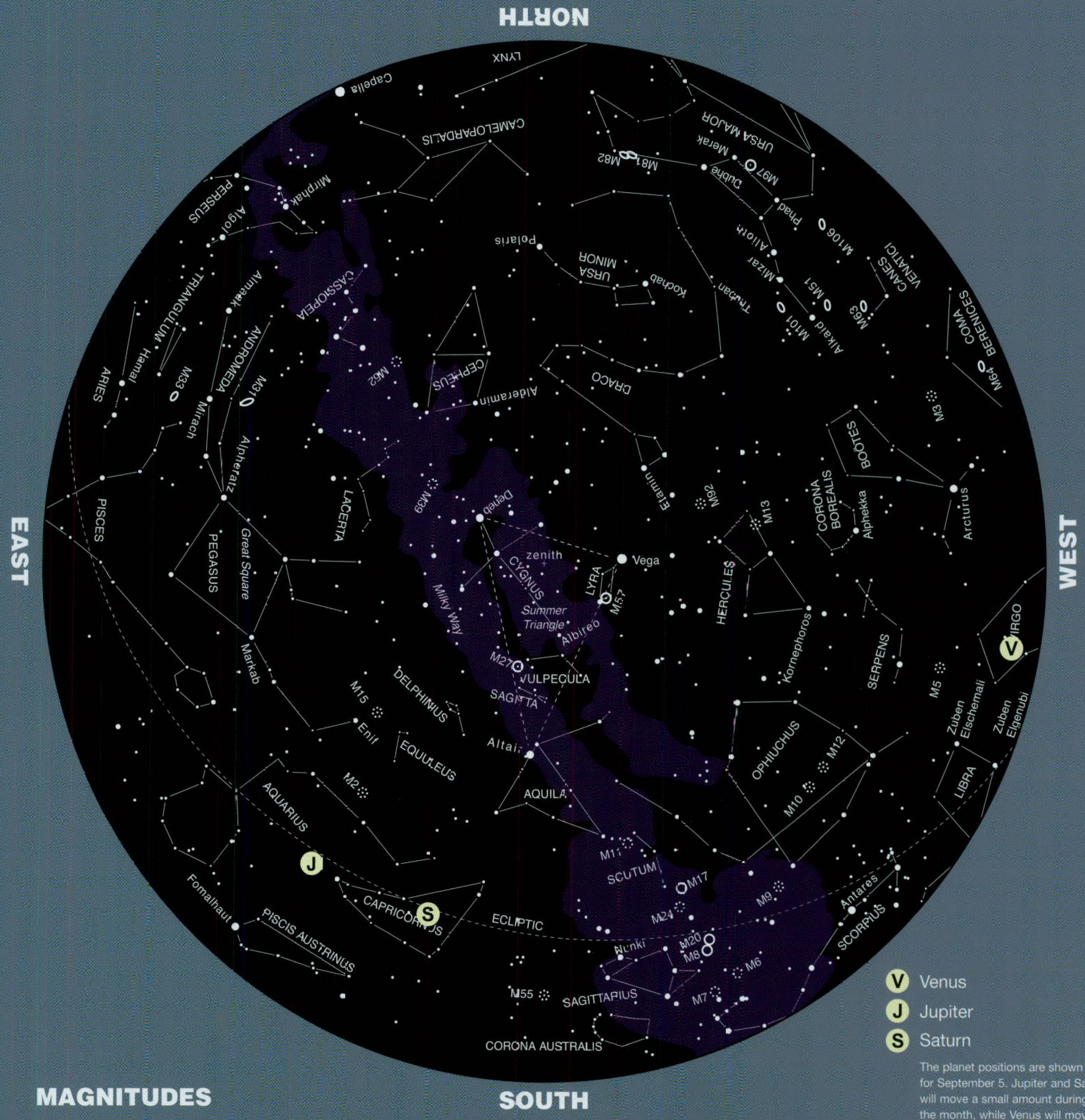
Alan MacRobert is a senior editor of Sky & Telescope.

SEPTEMBER

How to use these charts:

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

August 20	**11 p.m.**
September 5	**10 p.m.**
September 20	**9 p.m.**



MAGNITUDES

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

V Venus

J Jupiter

S Saturn

The planet positions are shown for September 5. Jupiter and Saturn will move a small amount during the month, while Venus will move a considerable distance.

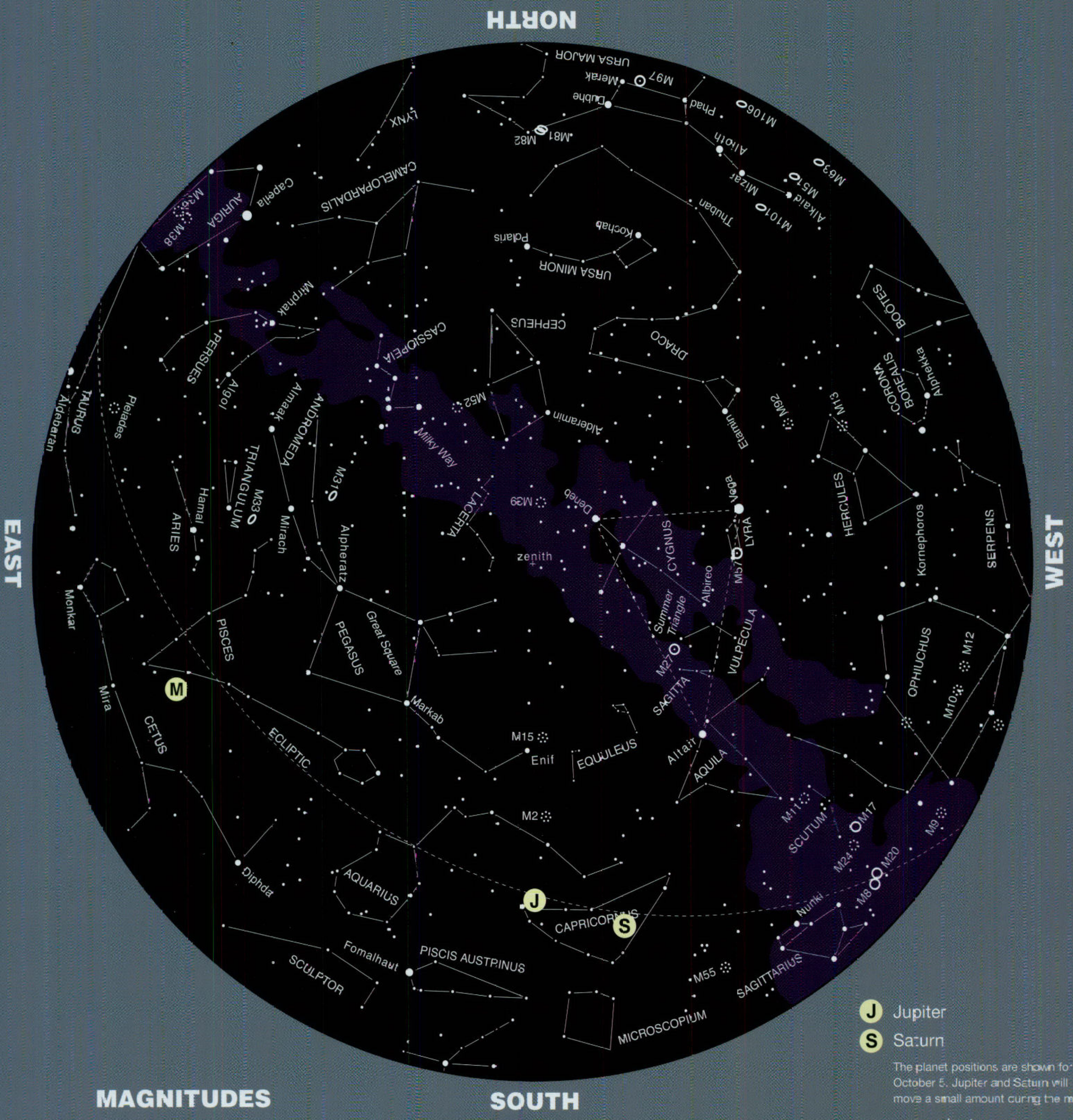
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

OCTOBER

How to use these charts:

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

September 20	**11 p.m.**
October 5	**10 p.m.**
October 20	**9 p.m.**



MAGNITUDES

- 0 and brighter
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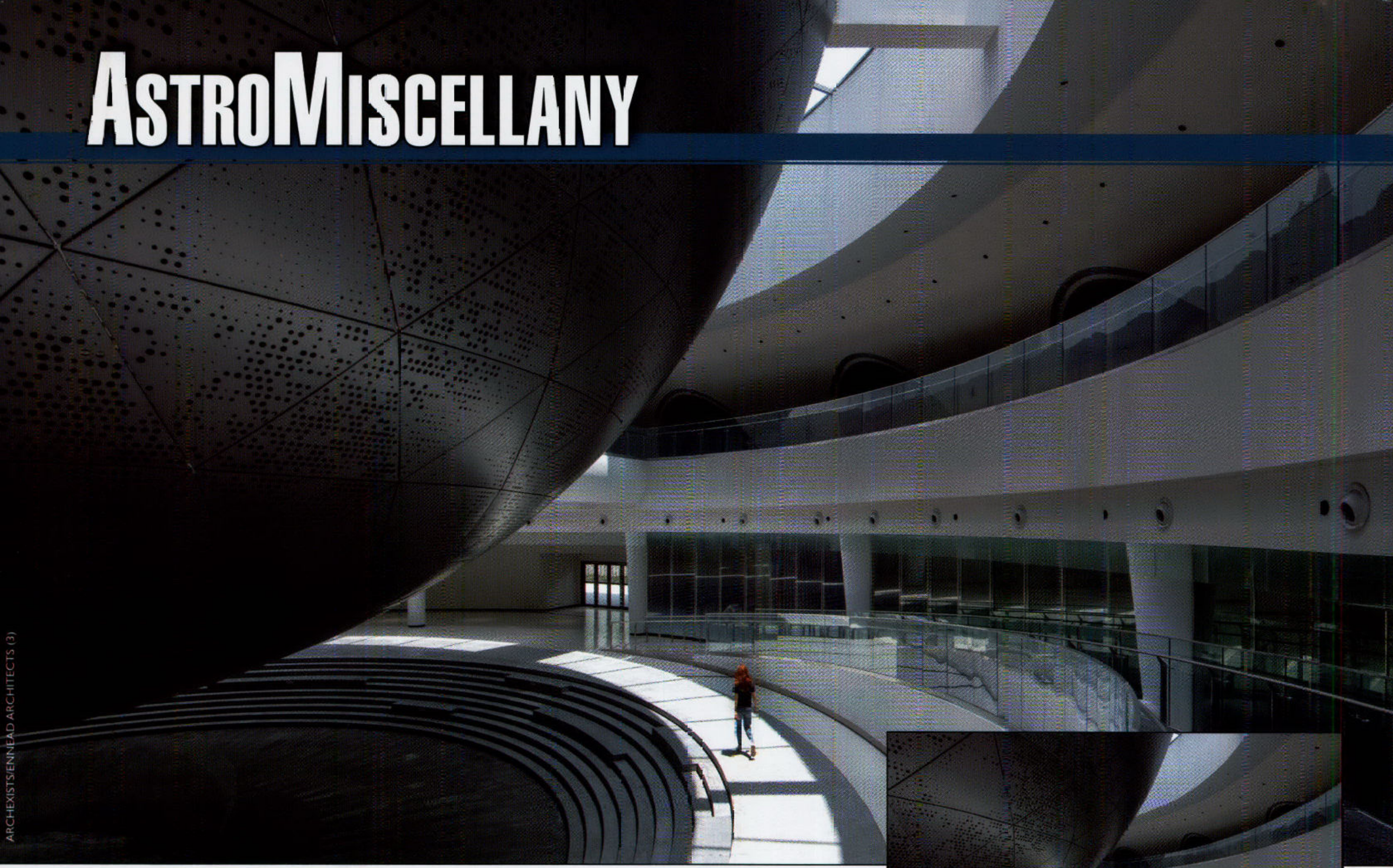
J Jupiter

S Saturn

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

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



ARCHEXISTS/ENNEAD ARCHITECTS (3)

Going Big

World's largest astronomy museum takes aim at the heavens in China

The world's largest astronomy museum, a series of spiraling nested structures, opened in July in Shanghai. It covers 420,000 square feet and includes a solar telescope, an observatory, and other outbuildings in addition to the main structure.

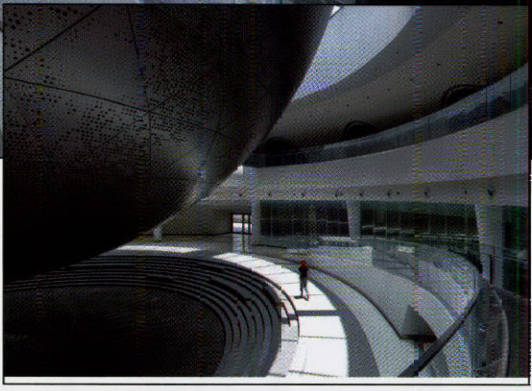
The Shanghai Astronomy Museum, a new division of the Shanghai Science and Technology Museum, consists of three linked structures. The oculus is a wide disk with a hole in the front that directs sunlight to the entry courtyard and reflecting pool. The beam of sunlight forms a circle that moves during the day. Markings on the courtyard reveal the season and the time of day. On the summer solstice, the beam forms a perfect circle that illuminates the central platform of the seasonal guide.

A sphere houses a planetarium. The sphere itself is suspended in the middle of the structure, like the Moon rising above the horizon. It's designed to provide the "illusion of weightlessness or antigravity," according to Ennead Architects, the American-based firm that designed the complex. Visitors can walk around and beneath the sphere.

Finally, an inverted dome, which crowns the complex, provides a view of the night sky. Visitors reach the platform, which is ringed by a wall that cuts off the view of the landscape, through a ramp that makes two complete turns around the building.

The museum also displays artifacts and documents from astronomical history and the Chinese and other space programs.

www.ennead.com/work/shanghai-astronomy-museum
en.sstm.org.cn

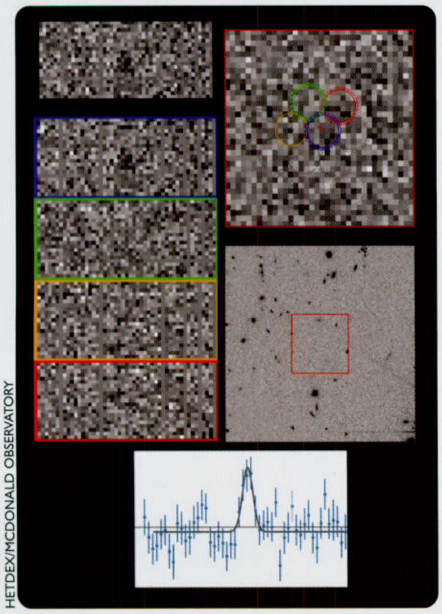


From top: A visitor walks below the planetarium, which is encased in a sphere that looks as though it's suspended in space; a nighttime view of the complex shows the planetarium below center, the oculus at left, and the inverted dome at the top; sunlight reflects off the interior of the oculus.

USPS

Galaxies to Share

Every clear, moonless night, astronomers at McDonald Observatory snap pictures of tens of thousands of distant galaxies as part of HETDEX (Hobby-Eberly Telescope Dark Energy Experiment). Their goal is to analyze the motions of these galaxies to help determine the nature of dark energy, a mysterious force that appears to cause the universe to expand faster as it ages.



HETDEX/MCDONALD OBSERVATORY

A sample data panel

Most of the galaxies are so far and faint that they're tough to see on the electronic images. Astronomers don't have the time to look through every image, and computers still don't do a great job of classifying galaxies. So thousands of volunteers are helping out through Dark Energy Explorers, in which they examine real HETDEX images for hard-to-find galaxies. Astronomers then feed those finds into their models to help train computers to detect such galaxies more efficiently.

The project began in February, and volunteers have identified more than 1.5 million galaxies to date. HETDEX has years of observations to sift through, however, with more to come, so additional volunteers are welcome to join the project. The web site offers a short training tutorial then presents newcomers with images.

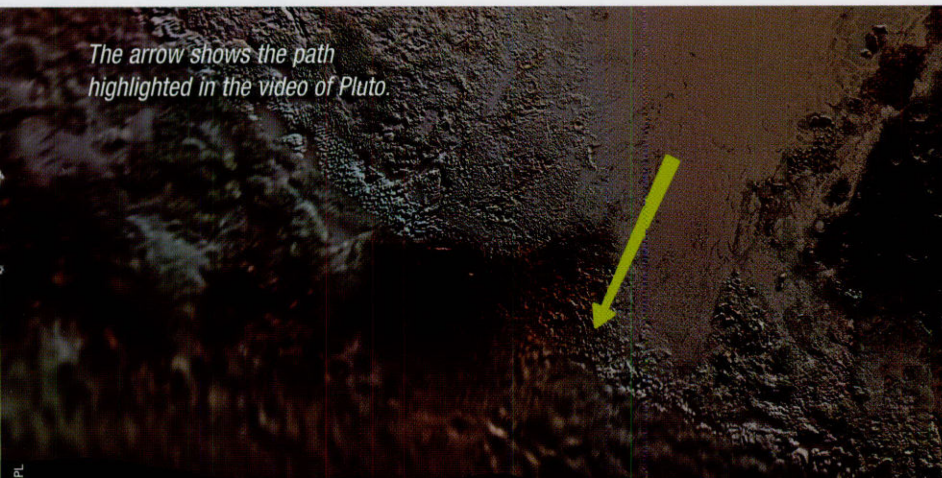
www.zooniverse.org/projects/erinmc/dark-energy-explorers

Forever Sunny

New stamps offer colorful views of our star

A recently released set of stamps shows the Sun as seen by Solar Dynamics Observatory, a Sun-watching spacecraft. The colorful stamps show the Sun in several wavelengths of light. The different views allow astronomers to study sunspots, solar flares, prominences, and other aspects of the Sun in great detail. The first-class Forever stamps are sold in blocks of 20, and are available online or at post offices.

store.usps.com/store/product/buy-stamps/sun-science-S_480804



The arrow shows the path highlighted in the video of Pluto.

NASA/JHUAPL

Skipping Across Pluto

Planetary scientist Paul Schenk has combined some of the sharpest black-and-white images of Pluto and its big moon, Charon, and other observations from the New Horizons flyby in 2015 to produce new video tours of their surfaces. The simulated tours span about 300 miles (500 km) of the surface of each world, and show details as small as 230 feet (70 meters) across on Pluto and 450 feet (140 meters) on Charon. They are the first such high-resolution videos compiled from New Horizons data.

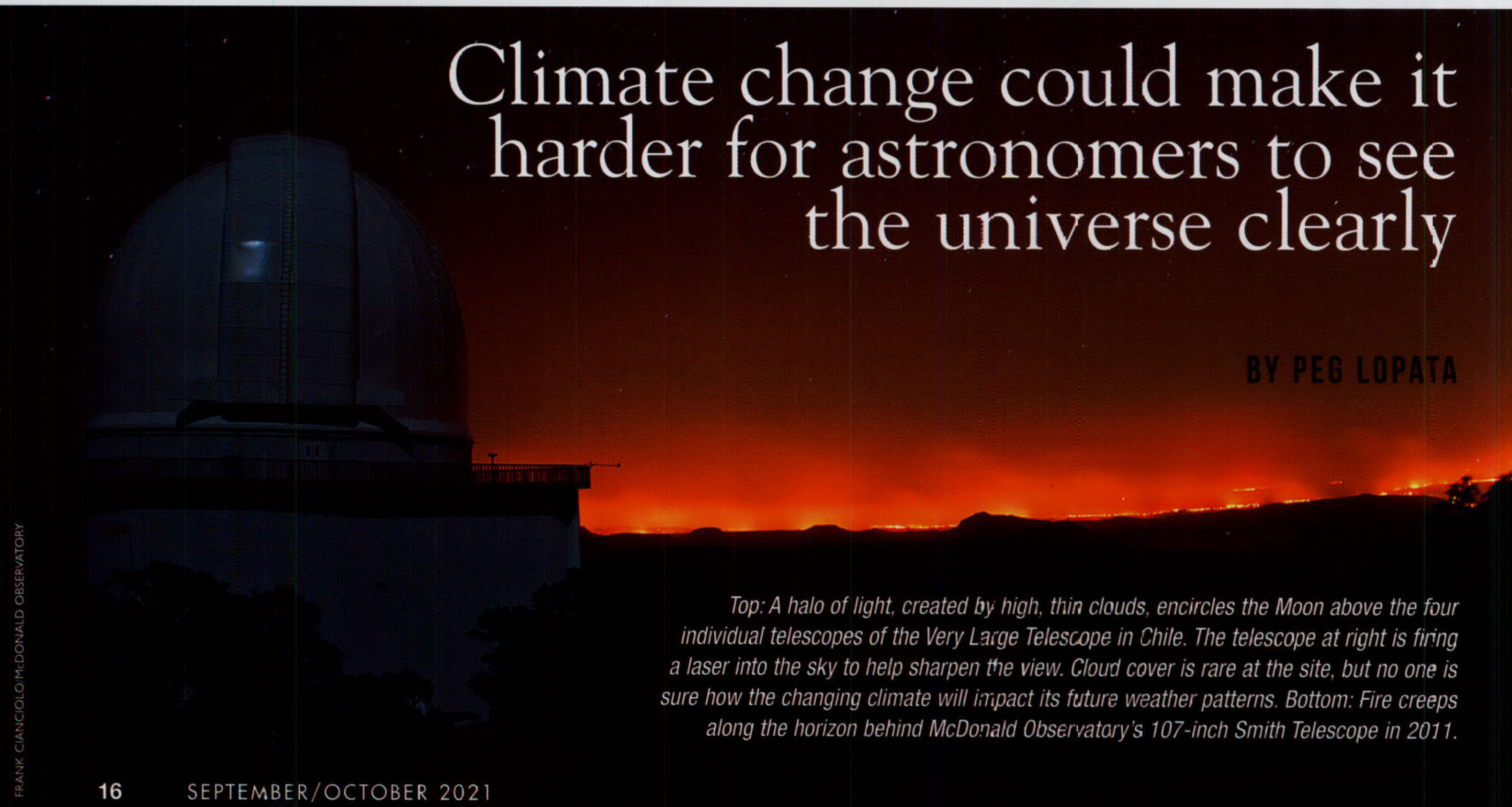
pluto.jhuapl.edu/News-Center/News-Article.php?page=20210714

ESO/JUAN CARLOS MUÑOZ-MATEOS

BLURRING THE VIEW

Climate change could make it harder for astronomers to see the universe clearly

BY PEG LOPATA



FRANK CIANCIOLO/McDONALD OBSERVATORY

Top: A halo of light, created by high, thin clouds, encircles the Moon above the four individual telescopes of the Very Large Telescope in Chile. The telescope at right is firing a laser into the sky to help sharpen the view. Cloud cover is rare at the site, but no one is sure how the changing climate will impact its future weather patterns. Bottom: Fire creeps along the horizon behind McDonald Observatory's 107-inch Smith Telescope in 2011.

If there's anything an astronomer doesn't like, it's blurry images. Astronomers build ever bigger telescopes and equip them with more sophisticated instruments to allow them to see deeper and in greater detail. So it's a nuisance when the images look less clear. And it's more than a bit alarming to think the cause could be Earth's changing climate.

Astronomers use large telescopes in high, dry places, from the mountains of Hawaii to the Atacama Desert of Chile. These locations have worked well for decades. In recent years, though, an international group of astronomers that uses the European Southern Observatory's Very Large Telescope—an array of four eight-meter (320-inch) telescopes atop Cerro Paranal in Chile—noted changes in the quality of its images. A detailed study of weather records revealed the likely culprit: the changing climate. Surface temperatures have increased and jet streams have changed. With the climate expected to warm even more by the end of the century, observatories around the world could feel the effects.

Some observatories could experience drier conditions, which could lead to even higher temperatures—a potential challenge for telescope mirrors, which need to maintain the same temperature as the outside air. Yet such a change might not be completely negative. Drier skies could improve the view in wavelengths that are invisible to the human eye.

Other sites could be blanketed by more water vapor in the atmosphere, blocking the infrared and other wavelengths and increasing turbulence, which blurs images of stars, galaxies, and other objects.

Many of the possible changes are long-term, giving observatories years or decades to develop changes for their telescopes and instruments to keep the view sharp. Many models use worst-case scenarios, which may not come to pass—it's difficult to project changes to such a dynamic system as Earth's climate decades into the future. And possible reductions in greenhouse-gas emissions in the coming decades could reduce the impact to astronomy.

While they ponder the potential effects of climate change on their observations, astronomers also are pondering ways to reduce their own impact on the environment, from cutting back the number of visits to remote observatories to obtaining alternative ways to power their profession.

Faustine Cantalloube, an astrophysicist at the Max Planck Institute for Astronomy, in Germany, studies exoplanets—worlds beyond our own solar system. To do so, she needs to observe the sky with exceptional clarity. "Exoplanets are very close to their host star," Cantalloube says. "To disentangle the two signals, it is necessary to have an exquisite angular resolution."

Turbulence in the atmosphere blurs the view of astronomical objects, though—the same effect that causes the stars to twinkle. "This turbulence in the air creates eddies and vortices that distort the light path," says Julien Milli, an astronomer at the Grenoble Institute of Planetology and Astrophysics, in France. "The light does not propagate in a straight line anymore and the images are blurred."

Astronomers use a technique known as adaptive optics to compensate for some of the blurring, but increased turbulence in the atmosphere could make the job harder. So could increased turbulence inside a telescope dome.

"We try to keep the dome that houses the telescope the same temperature as the outside air to minimize degradation in image quality," says John O'Meara, chief scientist for the W.M. Keck Observatory in Hawaii. "If your facility is warm relative to the ambient temperature, that's just terrible for telescopes," adds Chuck Claver, systems scientist and commissioning manager for the Vera Rubin Observatory, which is being built in Chile. "It causes turbulence inside the dome. It causes turbulence off the optical surfaces of the mirrors and lenses, and it just completely destroys the observing environment."

Cantalloube and her colleagues found that increasing temperatures at Paranal were making it more difficult to prevent heat waves from rippling across the mirrors of the four VLT telescopes. Weather records showed that, in 2020, sunset temperatures at the site exceeded the design limitations of the telescopes' air-conditioning systems 25 percent of the time. That decreases the acuity of the giant telescopes.

"Climate change is happening fast, and that was not anticipated at the construction of the VLT in the 1980s," says Milli. "In only 30 years, we've already reached the limit of the system."

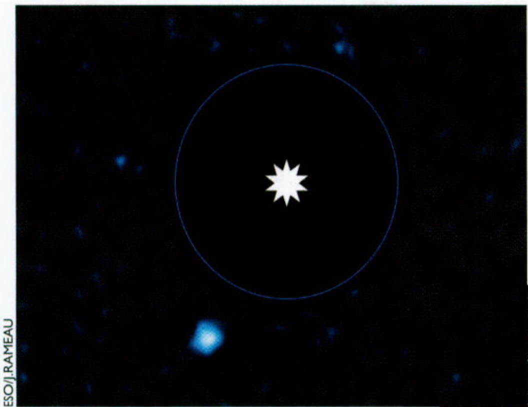
Climate records hint that the environment could be getting drier for some observatories, which could have a significant impact on their telescopes.

Many other areas, however, appear to be getting wetter.

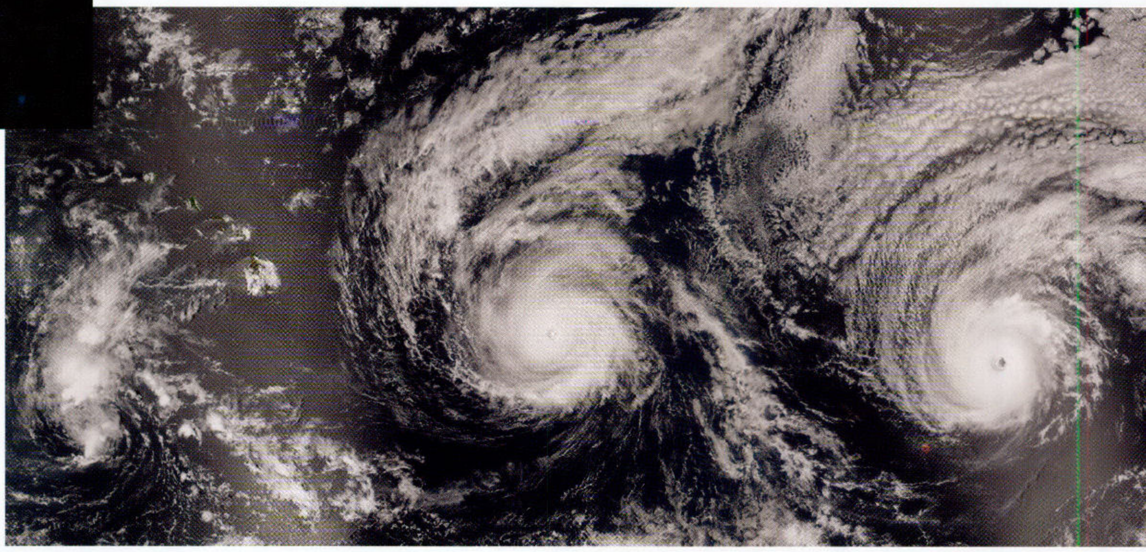
As the climate warms, evaporation from

the oceans increases, boosting the amount of water vapor in the atmosphere. "It's expected that as the climate warms up, the amount of water vapor in the atmosphere will increase everywhere, but not by a uniform amount," says Joe Galewsky, a professor of Earth and planetary sciences at the University of New Mexico. More water vapor generally increases atmospheric turbulence, creating new challenges for observatories around the world.

The increase in water vapor is especially



ESO/J. RAMEAU



Above: Hurricanes Madeline (left) and Lester roar toward the Hawaiian islands in 2016. Some climate models suggest that strong hurricanes could target Hawaii and its observatories more often in the coming decades. Top left: By masking out the light of its parent star (center), astronomers were able to snap a picture of the planet HD95086b (lower left). Increased turbulence in the atmosphere and in telescope domes could make it more difficult to obtain such images.

troublesome for the astronomers who observe the universe at infrared and submillimeter (a form of radio) wavelengths, which are invisible to the human eye. "A whole category of cold astronomical objects would not be detectable if we did not have infrared or millimeter telescopes," says Milli.

Astronomers use these wavelengths to study objects that are especially cool, such as the clouds of gas and dust that are coalescing to form new stars; brown dwarfs, which are more massive than planets but not massive enough to shine as true stars; disks of dust around young stars that may be giving birth to planets, and many others.

Water vapor in the atmosphere absorbs some of these wavelengths, preventing them from reaching the surface. That's one reason many observatories are built on mountaintops. "Altitude is your friend when it comes to water vapor," says Claver. "The big astronomical observatories are situated where they are in order to avoid water vapor. Their instruments are very sensitive to water. The higher you are, the drier the air gets and the better off you'll be."

"More water means more absorption, and so we can observe less light from the universe," says Cantalloube. If there's even a slight increase in water vapor, there will be a decrease in the quality of the images these highly sensitive telescopes can capture. "We know water vapor will generally increase with warming," says Andrew Gettelman, a senior scientist and climate expert at the National Center for Atmospheric Research in Boulder, Colorado. "If you have very little water vapor, then a slight change might double that small amount and that would be very bad for certain observations. Infrared telescopes may be significantly affected."

"[I]f there's more water vapor in the atmosphere, it's as if you have thicker cloud cover," says Galewsky. And this problem will only increase as global warming continues. "The number of water molecules in the atmosphere will go up—maybe as much as doubling by the end of the century" according to some climate models, Galewsky notes. "That's a big problem for these big submillimeter observatories. You cannot engineer your way out of that. There's nothing much you can do about that."

The increase in water vapor could create other problems for observational astronomers: more clouds and rain.

In Chile's Atacama Desert, at the moment, there's little cloud cover. In addition to Paranal, the region hosts several other large observatories, including ALMA, the largest millimeter/submillimeter-wave telescope ever built. But clouds cover the nearby coast like a thick blanket. "There's a lot of concern about these clouds off the coast of Chile," says Galewsky. "These clouds may dissipate as the climate and oceans warm up, which would be accompanied by more warming on shore and certainly more water vapor, and thus more turbulence."

Experts caution, however, that it's tough to forecast how the climate will change at specific locations. "Models are quite coarse in their resolutions," says Galewsky. "And these observatories are located at a particular point. It's really hard to make predictions of what happens at one specific point. So it's not out of the question—it could be not as much of an increase of water vapor as we're concerned about. It's possible that, locally, it could even go down."

Climate-change models suggest that some hazards will be more dramatic. More Pacific Ocean hurricanes could take aim at Hawaii, which hosts several mountaintop observatories, including multiple telescopes atop 14,000-foot Mauna Kea, for example.

"As the planet warms, Hawaii will likely see an increasing hurricane threat," says John Bravender, a meteorologist with the Central Pacific Hurricane Center in Hawaii. Tropical storms have been drifting farther northward in recent years, he says, and warmer ocean waters around Hawaii will provide more energy to sustain hurricanes. In addition, bigger and stronger hurricanes, which climate models say could become more common, tend to track northward faster than weaker ones. Computer simulations "also show a decrease in wind shear near Hawaii and increase in mid-level atmospheric moisture, both of which could indicate that hurricanes would be less likely to weaken as they approach the state," Bravender says.

Others aren't convinced the Hawaiian observatories face much of a threat, though. There's some randomness in tropical cyclones, which are influenced by decades-long ocean cycles, says Neil M. Dorst, a meteorologist in the Hurricane Research Division of the National Oceanographic and Atmospheric Administration, who notes that he's expressing his own viewpoint. "For smaller-scale items like tropical cyclones, I think [climate models] are useless. ... So I don't think the Keck observatories need to be concerned about any long-term increase in hurricanes, but there will be ups and downs on the short term."

A threat facing even more observatories is wildfires. "Observatories are at a greater risk for wildfires because they are often on mountaintops surrounded by forests," says Travis Rector, an astronomer at the University of Alaska Anchorage and chair of the American Astronomical Society Sustainability Committee. In addition, most observatories are remote and the surrounding landscape is rugged, making it difficult to tamp down encroaching flames.

Fires in 2021 almost destroyed Lick Observatory, outside San Jose, California, and Mount Wilson Observatory, which overlooks Pasadena. Fires have come close to the telescopes at Mount Graham Observatory in Arizona and, in 2003, a firestorm destroyed much of Mount Stromlo Observatory near Canberra, Australia. And in 2011, a major fire threatened McDonald Observatory in western Texas. Hotter, drier conditions could increase the threat to more observatories in the coming decades.

So far, most climate-caused problems are less dramatic. In fact, the Paranal study is the only formal review of climate conditions at any observatory to date, so there are no other indications of how changes are affecting observations elsewhere. (The same study team is examining weather records from telescope sites in Hawaii, Arizona, and elsewhere, however.)

As the climate continues to change, though, astronomers may have to consider how to adapt. "I don't think that climate change is going to drive fundamental changes in the design and engineering of ground-based telescopes," says Claver. "What I think it may do is force future telescope projects to seriously consider long-term consequences and where the next locations should be for the next telescopes." Global warming is one reason why, according to Claver, astronomers are considering placing future submillimeter observatories in the Antarctic.

One approach to reducing global warming is to use less carbon-based energy at observatories.

"Astronomers ... contribute disproportionately to the hastening of climate change through the nature of our occupation," noted a 2020 article in *Nature Astronomy*. A study in the same issue found that the professional activities of the average astronomer in Australia produced more than 40 tons of carbon dioxide per year—40 percent more than the average Australian adult. A second study found that employees at the Canada-France-Hawaii Telescope in Hawaii produced an average of 16.5 tons per year.

Some observatories are using or developing renewable energy sources to reduce their reliance on fossil fuels.

At the Rubin Observatory, engineers are planning to use regenerative power for the LSST, an eight-meter telescope that will survey the entire visible sky every 2.7 days. Much like when an electric car brakes, whenever the telescope moves or stops, the power it generates will be stored and reused. "This technology is well advanced and can and should be incorporated [into] future telescopes," says Claver. "It's the path forward to reduce our carbon footprint."

Another possibility is to build solar farms to supply the energy for telescopes. The catch, of course, is that telescopes operate at night. "A solar array produces its peak of electricity in the middle of the daytime, whereas the telescope is using up a good chunk of its electricity at nighttime. You need to be able to store that energy somewhere," says Claver. "And that technology is not quite ready for this level of industrial scale, but we're getting there."

Astronomers are exploring other ways to reduce their own carbon footprint. "We're undergoing major discussions around ways to reduce the carbon impacts of observational astronomy," says Jeff Bennett, an astronomer, teacher, and writer in Boulder, "such as increasing the use of remote observing so professional astronomers do not need to travel from their home institutions for observing runs."

In addition, astronomers are flying less for other activities, such as attending conferences (in part because of COVID-19, which has forced many conferences to switch to virtual formats). "We know that about half of our footprint comes from air travel, so we are looking for ways to reduce it," says Rector.

Although such reductions in emissions are tiny on the global scale, they are important steps in the effort to keep the skies clear—and pictures of the universe sharp—in the decades ahead.

Peg Lopata is a freelance writer based in Somerville, Massachusetts.

RESOURCES

ARTICLES

The impact of climate change on astronomical observations, by Faustine Cantalloube et al. *Nature Astronomy*, September 10, 2020
www.nature.com/articles/s41550-020-1203-3

The climate issue, *Nature Astronomy*, September 10, 2020
www.nature.com/articles/s41550-020-01216-9

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INTERNET

Global Climate Change: Vital Signs of the Planet
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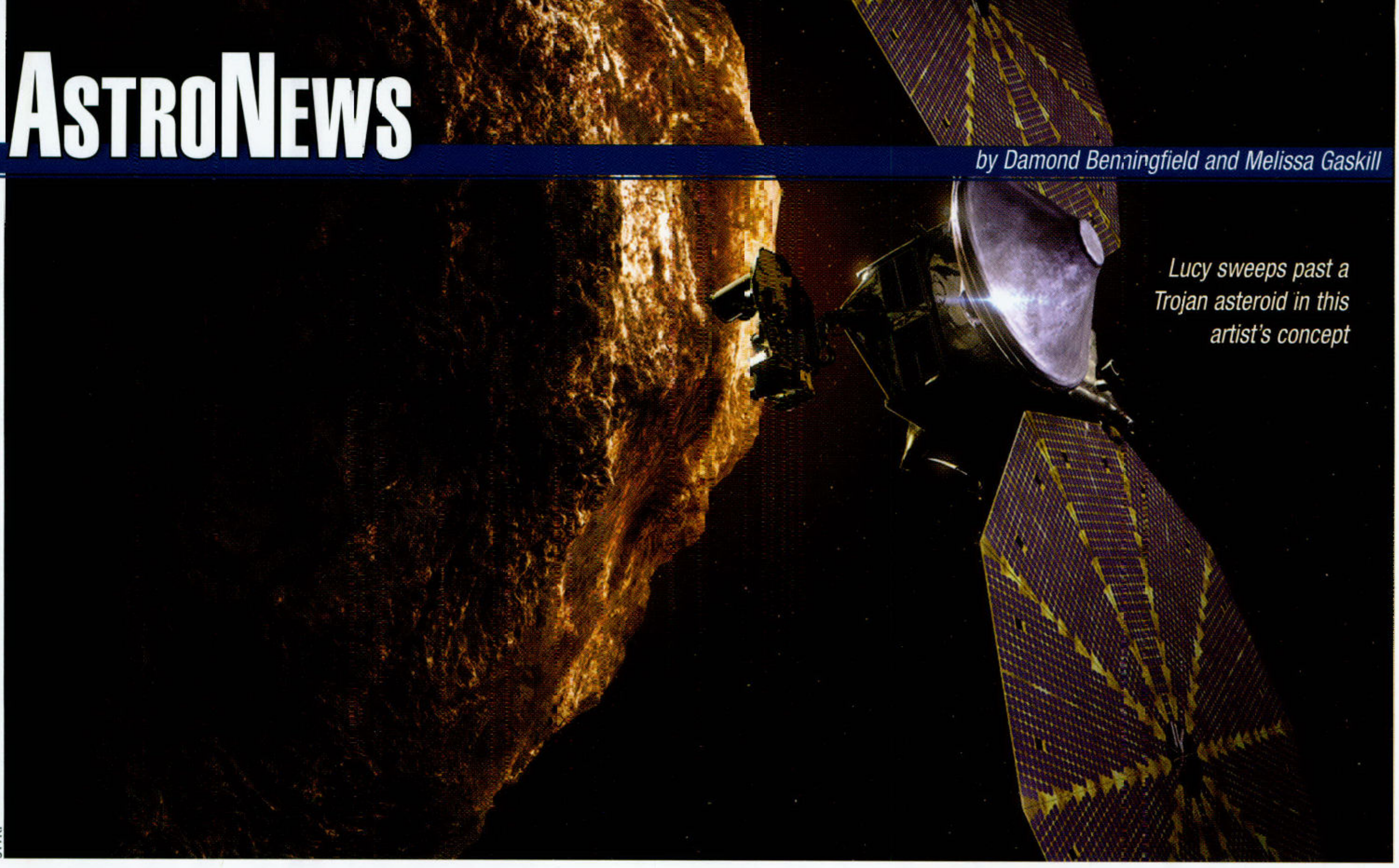
Climate Change Research
www.epa.gov/climate-research

NASA EARTH OBSERVATORY/JESSE ALLEN

by Damond Benningfield and Melissa Gaskill



Lucy sweeps past a Trojan asteroid in this artist's concept

SWRI

Lucy in the Sky With Trojans

Mission will study asteroid swarms trapped by gravity of Jupiter, Sun

Lucy, a spacecraft scheduled for launch as early as October 16, is designed to study two clumps of asteroids that have been trapped since the solar system was young. The encounters could provide new details on the materials and processes that gave birth to Earth and the other planets, and perhaps tell us more about the origin of Earth's organic compounds—the chemical building blocks of life.

The mission's main targets are Trojan asteroids, which are more than five times Earth's distance from the Sun. These chunks of ice and rock share Jupiter's orbit, although they are nowhere close to the giant planet. Instead, they are held in place by a delicate balance between the gravity of Jupiter and the Sun. One clump is centered 60 degrees ahead of Jupiter, the other 60 degrees behind. Individual asteroids move within the clumps, but they seldom escape. Astronomers have discovered almost 10,000 Trojans, but they hypothesize that the population could be in the millions.

Planetary scientists are interested in the Trojans because they probably are "building blocks" left over from the birth of the planets. As such, they would contain the same materials that were incorporated into the planets. Studying their composition should tell scientists more about how the planets formed.

In addition, many Trojans may contain large amounts of organic compounds. Similar compounds could have been incorporated into the newly forming Earth or deposited on the planet soon after its birth, so the Trojans could tell scientists more about the development of life on Earth—and the possibility of life on some of the other worlds of the solar system.

Lucy is named for the fossilized skeleton of an early human, which was discovered in Ethiopia in 1974 and was named for the Beatles song *Lucy in the Sky with Diamonds*. The craft's first asteroid target is named for one of the discoverers, Donald Johanson.

After launch from Cape Canaveral (the launch window extends from October 16 to November 5), Lucy will fly past Earth twice to pick up extra speed for its lengthy journey. In April 2025 it will encounter the asteroid Donaldjohanson, which is in the asteroid belt, a wide ring between the orbits of Mars and Jupiter.

The 3,400-pound (1,550-kg) probe will reach the first clump of Trojans, known as the Greeks because they're named for Greek heroes of the Trojan war, in April 2027. Its first target is Eurybates, which has a small moon, Queta. It will visit three other Greek Trojans (which orbit ahead of Jupiter) over the following 19 months, then begin a long swing across the solar system. It will make one final pass by Earth, then take aim at the other clump of Trojans, the Trojan Camp. It will fly past a binary pair of asteroids, Patroclus and Menoetius, in March 2033.

Lucy's mission is scheduled to end after that encounter. Mission planners say it will have plenty of propellants, however, and its solar panels, which span 47 feet (14.3 meters), should still be able to provide power, so an extension is likely, allowing Lucy to study other members of Trojan Camp. **DB**

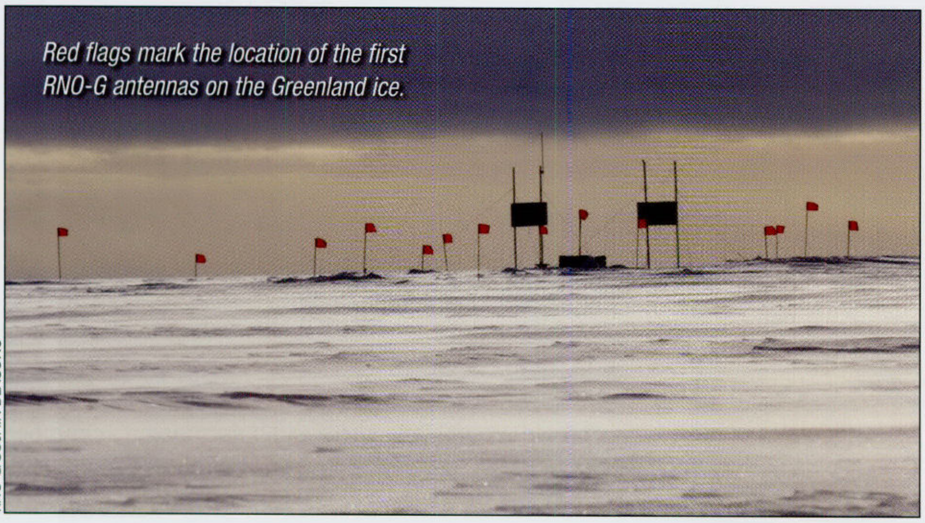
Collisions On Ice

Scientists have installed the first antenna stations for the Radio Neutrino Observatory Greenland (RNO-G), a project to detect high-energy cosmic neutrinos. These elusive particles, created in vast quantities in stars and other astronomical objects, are difficult to detect because they almost never interact with other forms of matter. About 60 billion neutrinos from the Sun alone pass through a speck on Earth the size of a fingernail every second.

Occasionally, though, a neutrino bumps into an atom. These rare collisions produce an avalanche of particles, which emit radio waves. Because ice is fairly transparent to radio waves, RNO-G should be able to pick up the signals from such encounters over distances of more than a mile.

The larger the volume of ice that can be monitored, the greater the chances of detecting a collision; plans call for 35 antenna stations, spaced about three-quarters of a mile apart. Even so, it could be months or even years before the observatory records a signal.

Astrophysicists use neutrinos to look at phenomena such as exploding stars or merging neutron stars and to track down natural cosmic particle accelerators. **MG**



Red flags mark the location of the first RNO-G antennas on the Greenland ice.

RNO-G/COSMIN DEACONU

Dark Merger

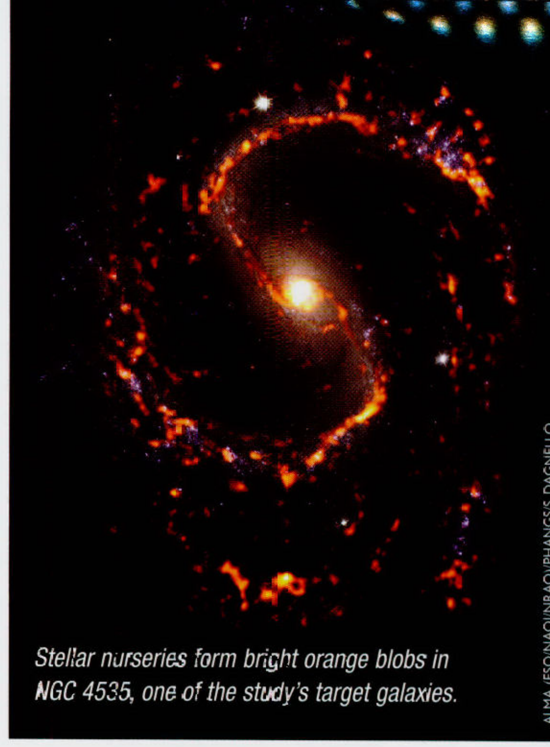
In January 2020, detectors on Earth recorded the death throes of a neutron star — the already dead core of a once-mighty star — as it was swallowed by a black hole. Scientists who analyzed the readings reported their results in July. They say it is the first observed merger of a neutron star and a black hole.

The objects, in a galaxy more than 900 million light-years away, could have been orbiting each other before they merged. Both were remnants of exploded stars, with the black hole much more massive than its companion: about 8.9 times the mass of the Sun versus 1.9 for the neutron star.

As the dense objects orbited each other they emitted the ripples in space and time known as gravitational waves. The waves carried away energy, causing the black hole and neutron star to spiral closer together. When they got close enough they merged in a massive outburst of gravitational waves, which was detected by special instruments in Louisiana and Italy. The merger wasn't seen in any other forms of energy, suggesting that the black hole consumed the neutron star in one big gulp without first tearing it apart.

A second possible black hole-neutron star merger was observed 10 days later. It was seen by just one of the instruments, however, so the level of confidence in the detection is slightly lower. Astronomers say the black hole was roughly 5.7 times the mass of the Sun, with the neutron star at 1.5 solar masses.

Studying such events reveals details about the merging objects and the environments in which they formed and died.



Stellar nurseries form bright orange blobs in NGC 4535, one of the study's target galaxies.

ALMA (ESO/NAOJ/NRAO)/PHANGS/S. DAGNELLO

Congratulations, It's a Star!

For five years an international team of researchers surveyed stellar nurseries across our corner of the universe using the ALMA telescope array in Chile. The team charted more than 100,000 nurseries across more than 90 nearby galaxies, providing new insights into the origins of stars.

ALMA uses a form of radio waves to detect the faint glow of the gas and dust that form stars.

The survey revealed that, contrary to conventional wisdom, stellar nurseries are surprisingly diverse in nature and appearance across and within galaxies. Nurseries in larger galaxies and those in the centers of galaxies, for example, tend to be denser, more massive, and more turbulent. A nursery's location and the resulting properties have an effect on its ability to make stars and its ultimate destruction.

Destruction comes fairly quickly in astronomical terms. The survey's measurements showed that stellar nurseries last only 10 million to 30 million years and, as a result, are inefficient at the job of making stars. Ironically, creating stars is what does them in. Radiation and heat from new stars vaporize and blow away the clouds of gas and dust, eventually destroying a nursery well before most of its mass can be converted to stars. **MG**

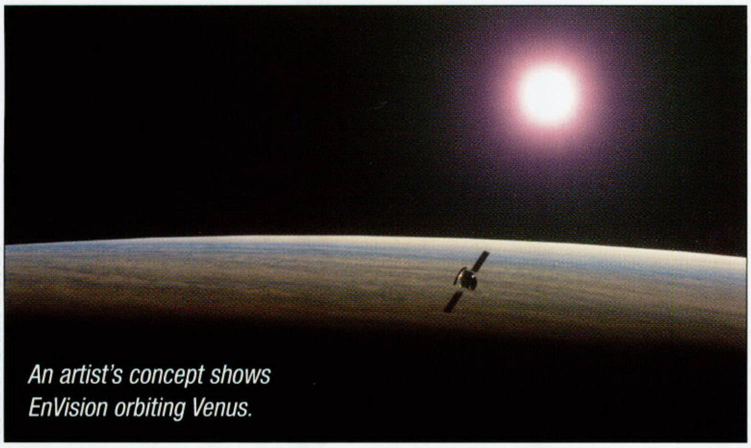
Getting to Know Our Neighbor (Better)

New missions from NASA and the European Space Agency (ESA) are set to provide the most comprehensive study ever of the planet Venus. The missions will explore how Earth and its closest neighbor turned out so differently: Despite their similar size and composition, one planet became habitable, while the other is a hellish world not fit for Earth-like life.

NASA announced two new missions, its first to Venus since 1978, which are expected to launch late in the decade. DAVINCI+ will send a sphere plunging through Venus's thick atmosphere. It will measure the composition of the atmosphere and take high-resolution pictures of landforms that resemble Earth's continents. VERITAS will orbit Venus, using radar to chart surface elevations and map infrared radiation to determine rock types and look for possible water vapor released by active volcanoes. (A recent study says volcanoes could be responsible for phosphine, a chemical found in the atmosphere that some researchers concluded could be produced by microbes.) Venus is encircled by an unbroken layer of thick clouds, so radar, which can peer through the clouds, provides the only way to see the surface.

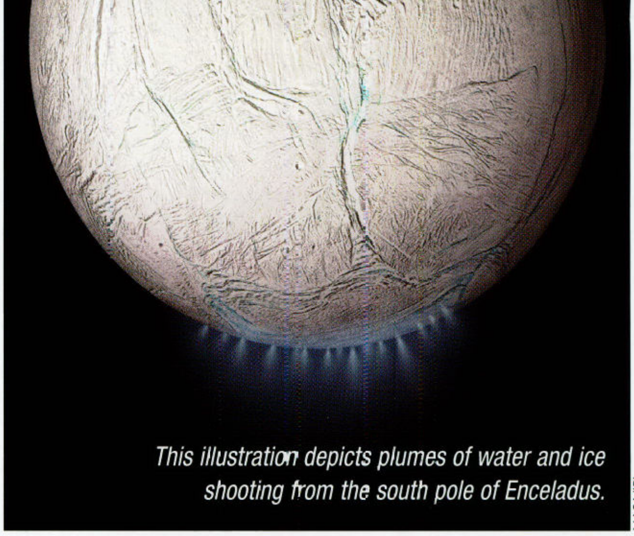
ESA's EnVision orbiter, targeted to launch in the early 2030s, will carry a sounder to reveal underground layering, a radar provided by NASA to map Venus's surface, and instruments to study its atmosphere and surface for signs of active volcanism. ESA's previous mission, Venus Express, ran from 2005 to 2014 and made discoveries that hinted at volcanic hotspots on the planet. EnVision should improve upon radar images of Venus's surface from NASA's 1990s Magellan mission.

Akatsuki, a Japanese spacecraft, is the only mission currently operating at Venus. It has been studying the planet's atmosphere since 2015. **MG**



ESA/VR2PLANETS/DAMIA BOUIC

An artist's concept shows EnVision orbiting Venus.



This illustration depicts plumes of water and ice shooting from the south pole of Enceladus.

NASA/JPL

There's Methane in Those Plumes

A global ocean of liquid water fills the space between the icy crust and rocky core of Enceladus, a moon of Saturn. Hydrothermal vents at the bottom of the ocean appear to shoot mineral-rich hot water into the ocean, providing the ingredients for life.

On Earth, such deep-sea vents are home to ecosystems that contain large numbers of microbes that produce methane. A recent study published in *Nature Astronomy* modeled the level of methane in water plumes escaping from Enceladus, which were sampled by the Cassini spacecraft as it flew past the moon. Researchers found levels of methane that appear consistent with microbial activity. According to the model, if the process does not involve life forms it must be different from any known to occur on Earth.

On Earth, cold water that seeps into the ocean floor and passes close to a heat source, such as a magma chamber, spews out through cracks in the ocean floor. This activity can product methane, but slowly. Much more comes from microbes that convert other chemicals to methane.

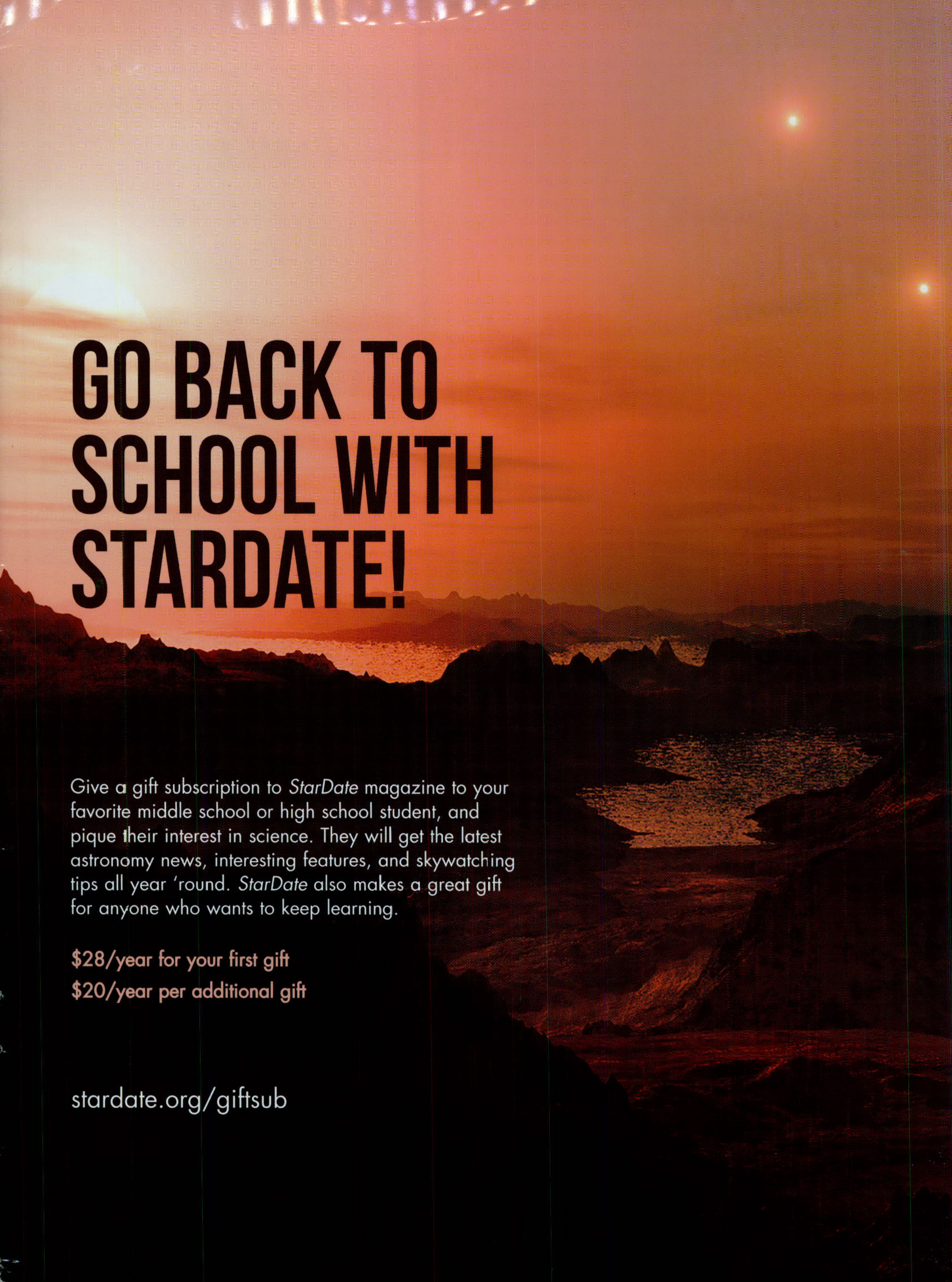
While the study results do not provide proof of life in Enceladus's ocean, they do suggest that its hydrothermal vents could be habitable by Earth-like microorganisms. After considering several chemical and physical processes as the source, the researchers determined that only a biological process could produce the amount of methane measured in the moon's plumes **MG**

A New Way for Stars to Die

An exploding star in a galaxy 31 million light-years away could be the first known example of a new type of supernova. A study classified the explosion as an electron-capture supernova, which has been theorized for four decades.

Most supernovas are triggered by either the collapse of the core of a supermassive star or a runaway nuclear explosion in a stellar corpse. An electron-capture supernova, however, would work a little differently. The model says that as a star about 8-10 times the mass of the Sun nears the end of its life, its core contains large amounts of oxygen, neon, and magnesium, plus many free-floating electrons, which generate pressure that keeps the star from collapsing. Eventually, though, so many electrons attach themselves to the heavier elements that the core collapses, triggering an explosion

A team of astronomers with Las Cumbres Observatory, an international network of telescopes (including three at McDonald Observatory), found that supernova 2018zd showed characteristics that matched predictions of how an electron-capture supernova should behave. **DB**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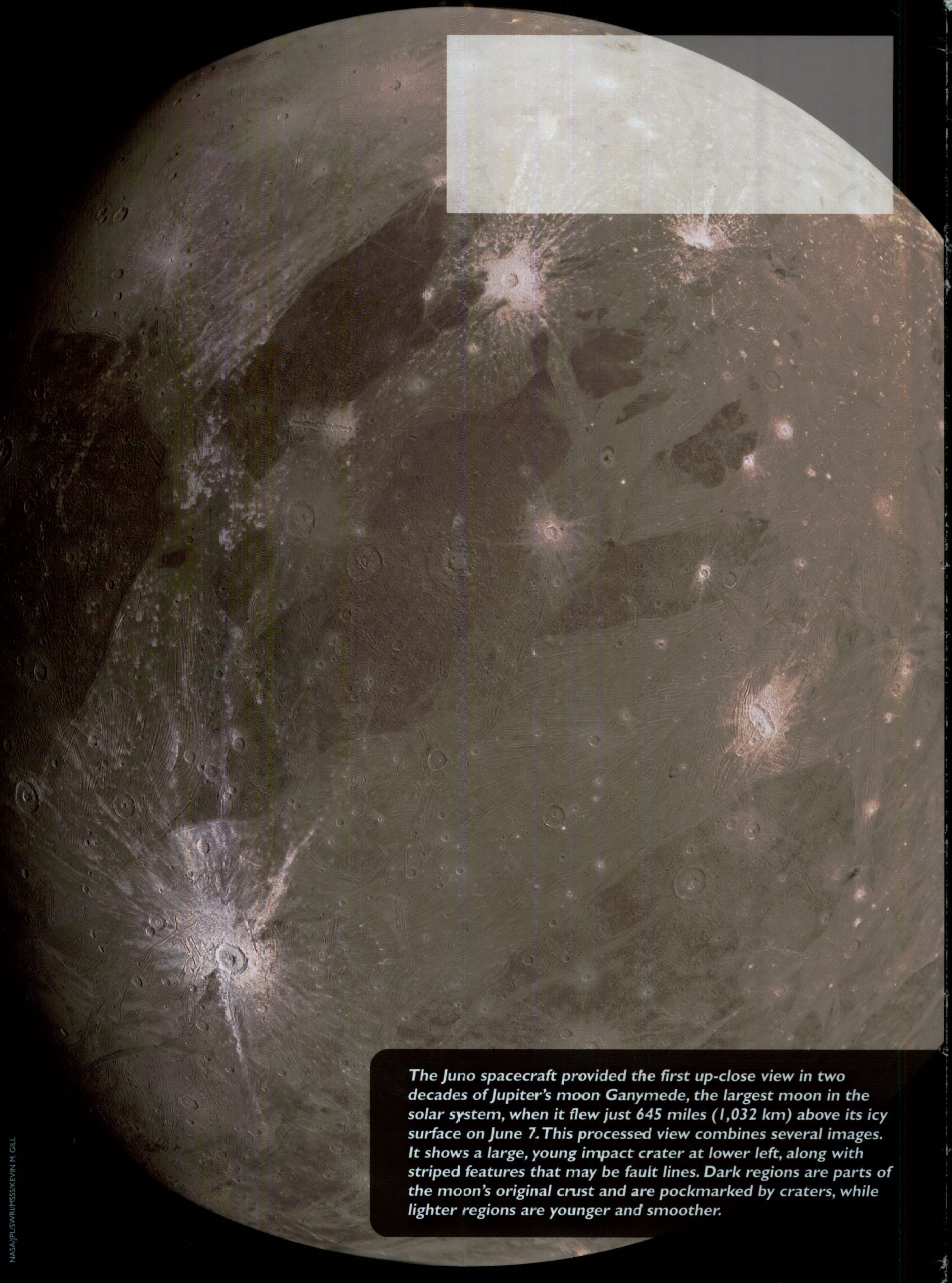

The Juno spacecraft provided the first up-close view in two decades of Jupiter's moon Ganymede, the largest moon in the solar system, when it flew just 645 miles (1,032 km) above its icy surface on June 7. This processed view combines several images. It shows a large, young impact crater at lower left, along with striped features that may be fault lines. Dark regions are parts of the moon's original crust and are pockmarked by craters, while lighter regions are younger and smoother.

NASA/JPL/SwRI/MSSS/KEVIN M. GILL