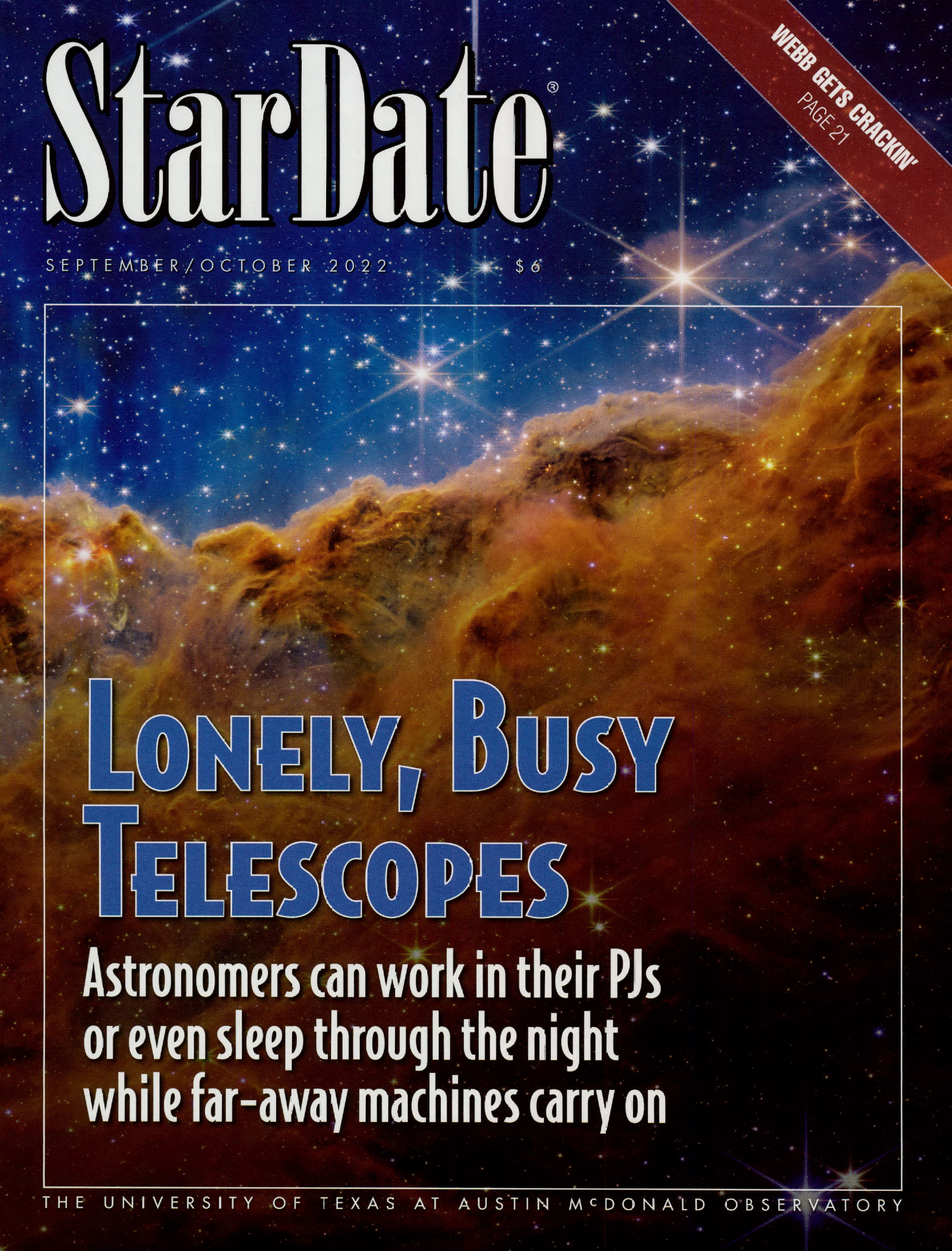

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WEBB GETS CRACKIN'
PAGE 21

LONELY, BUSY TELESCOPES

Astronomers can work in their PJs or even sleep through the night while far-away machines carry on

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

StarDate®
SEPTEMBER/OCTOBER • Vol. 50, No. 5

Features

Departments

NASA/ESA/CSA/STScI

On The Cover

A massive stellar nursery shows hundreds of young stars and many still-forming ones in this early view from James Webb Space Telescope. See more on page 21, and a longer image description on the back cover.

This Page

The last gasp of a dying star produces a giant bubble of gas and dust in this early view from James Webb Space Telescope. Known as the Southern Ring Nebula, it formed as the star reached the end of its life. The star's core got smaller and hotter, which pushed its outer layers into space, forming shells of gas and dust that continue to expand. The central star in this image is a giant companion to the dying star (which is visible as a tiny dot in the 'spike' to the lower left of the bright star).

Coming in November

Recent studies are suggesting that asteroids have been killers, perhaps even wiping out entire villages, and we'll explain. We'll also tell you about efforts to knock out asteroids that might be on a collision course with Earth.

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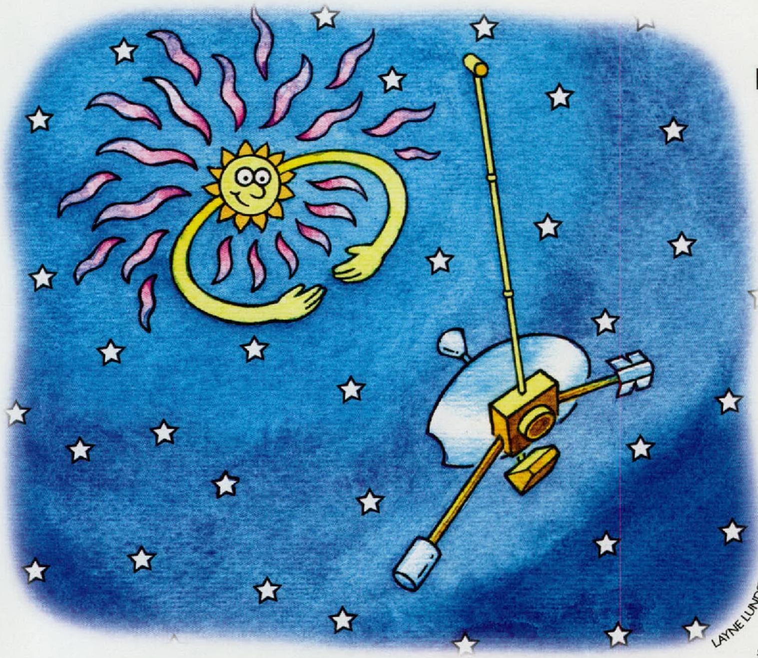
MERLIN

Dear Merlin,

How much damage is occurring to the Voyager and New Horizons spacecraft from cosmic rays, gamma rays, and X-rays while traveling through interstellar space? How much longer would you expect the spacecraft to remain operational if fuel and power were not limiting?

Mark Littlefield
Victoria, Texas



If they had plenty of power and propellant, Merlin would expect these intrepid explorers to keep going and going and going. (Okay, they'll do that anyway, but Merlin means "while still working.")

Voyagers 1 and 2 were launched in 1977 to explore Jupiter and Saturn. Voyager 2 then was targeted to fly past Uranus and Neptune. Both spacecraft were in good shape after those encounters, so they continued to study the outer solar system. Today, both have exited the magnetic "bubble" that defines the boundary of interstellar space.

New Horizons was launched in 2006 to explore Pluto, flying past the little world in 2015. It now is cruising toward the solar system's edge.

None of these spacecraft appears to have suffered any major damage from cosmic rays or electromagnetic radiation, although cosmic rays are a greater danger to the Voyagers today because they are outside the Sun's magnetic bubble, which blocks most cosmic rays from reaching the inner solar system.

A few systems have failed, such as the maneuvering thrusters on Voyager 2. In that case, a back-up system that hadn't been used in 37 years switched on just fine.

The big problem is power. The plutonium fuel in their nuclear generators decays at a steady rate, lowering the amount of available power every year. Engineers have switched off some of the Voyager instruments, heaters, and other components. The power levels are likely to drop so low later in this decade that the craft won't be able to stay in contact with Earth. New Horizons might go into the late 2030s or beyond before Earth hears its final transmissions.

Dear Merlin,

A recent report stated that the asteroid sample returned by Hayabusa is "the same stuff" that coalesced into the Sun. That sample consists of rocky material but the Sun is a gaseous entity. Please explain.

Tom Krepel
Corpus Christi

While the Sun is a big ball of mainly hydrogen and helium gas, it also contains tiny fractions of heavier element. Those elements were incorporated from the initial cloud of gas and dust that gave birth to the Sun and planets.

Hayabusa 2 brought a few grams of material from the asteroid Ryugu to Earth in 2020. Ryugu contains material from when the solar system was just a few million years old. The ratios of several of its elements are very close to those seen in the Sun, suggesting that Ryugu and the Sun formed from "the same stuff."

Dear Merlin,

The StarDate *March/April issue has a glorious spread on "Cosmic Snowflakes." Would you be so kind as to explain how galaxies are named? What do the NGC and M names tell us?*

Kate Reed
Winchester, Virginia

Those letters tell us that there are so many galaxies that astronomers can't possibly give them all proper names. Instead, they compile catalogs of galaxies up to millions of listings.

"M" is the list of Messier objects, put together by Charles Messier, an 18th-century French astronomer who hunted comets. (Discovering comets brought fame, prizes, and royal appointments.)

As Messier scanned the sky, he found many objects that resembled comets, so to save himself and others from wasting time with them, he compiled a list of more than a hundred targets, including several dozen galaxies (although no one at the time knew what they were.)

NGC is the New General Catalog of Nebulae and Clusters of Stars. It was started by John Louis Emil Dreyer in 1888. He compiled more than 13,000 galaxies and other objects. Observations by others have since been added to the list.

There are many galaxy catalogs, usually named for the astronomers who compiled them or the observatory where the work was done. Thus, we have the Arp Atlas of Peculiar Galaxies (compiled by Halton Arp), David Dunlap Observatory catalog of dwarf galaxies, the Maffei galaxies (named for Paolo Maffei), and others.

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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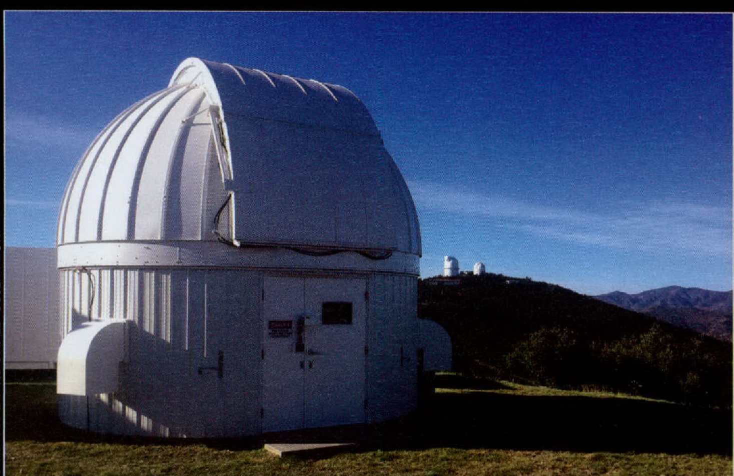
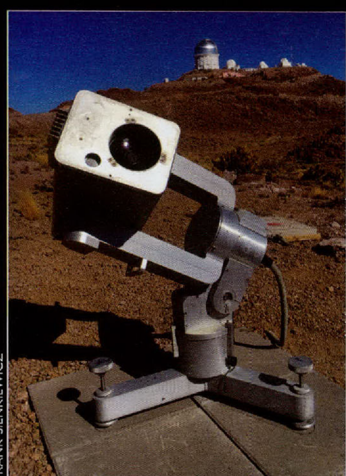
ESO/E. JEHIN

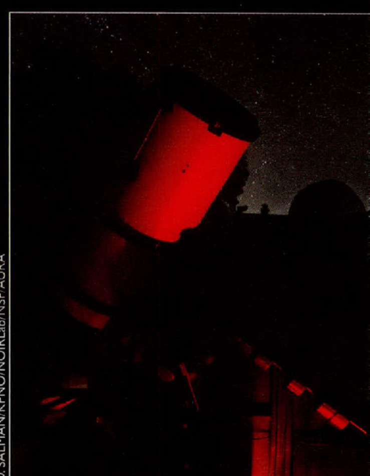
Top: A TRAPPIST telescope in Chile; Bottom, from left: A one-meter LCO telescope at McDonald Observatory; a MicroObservatory telescope in Arizona; the Kitt Peak SOLARIO telescope at work



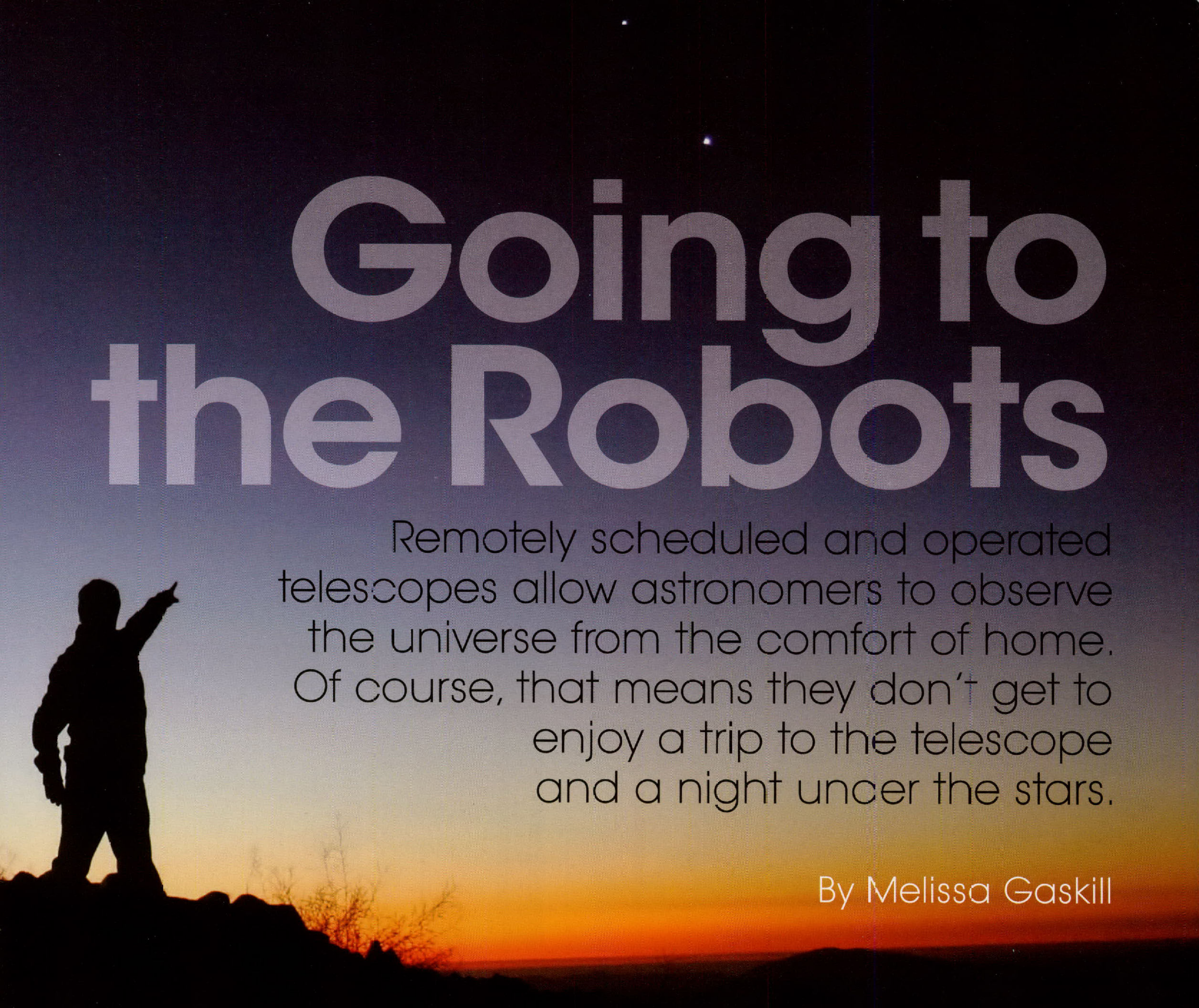
KATIE PARKER/McDONALD OBSERVATORY



FRANK SIENKIEWICZ



D. SALMAN/KPNO/NOIRLab/NSF/AURA



Going to the Robots

Remotely scheduled and operated telescopes allow astronomers to observe the universe from the comfort of home. Of course, that means they don't get to enjoy a trip to the telescope and a night under the stars.

By Melissa Gaskill

Every evening, a computer at Las Cumbres Observatory headquarters in Goleta, California, sorts through requests from astronomers around the world for observing time on its global network of telescopes. An artificial-intelligence-based scheduling system analyzes the requests and conditions at each telescope, selects which observations to make, tells the individual telescopes where and when to point, and compiles the results. It updates the schedule every five minutes so it can take requests at any time.

Welcome to robotic astronomy.

Hundreds of telescopes operating robotically around the world mean that astronomers, students, and even members of the public can select an observing target from the comfort of, well, just about anywhere with internet access. These telescopes provide world-class science, some dedicated to a single project such as hunting supernovae or planets in other star systems, and others making observations for many types of research.

Observations often are scheduled well in advance and the resulting data automatically sent to the requestor. Professional astronomers can cut travel costs, increase telescope work time, and even sleep through their observations. Teachers and students get to experience astronomy first-hand. And the public gets to enjoy views of the universe.

Las Cumbres Observatory operates around the clock. That allows it to track specific targets for days on end, or to respond quickly if it needs to follow up on an exciting new discovery.

Like most robotic telescopes, most of LCO's were custom designed to operate robotically from the get-go (retrofitting an existing one for robotic operations requires significant hardware and software changes). Its network includes 13 one-meter (40-inch) telescopes, including two at McDonald Observatory. Seven 40-centimeter (16-inch) telescopes are distributed across both northern and southern hemispheres. Most recently, the observatory has added a pair of two-meter (80-inch) telescopes, in Hawaii and Australia, with plans for several more.

The one-meter telescopes are all identical. "Uniform instrumentation is one of the hallmarks, meaning the same instrumentation is available anywhere, so an observation doesn't have to be at a particular site," says Lisa Storrie-Lombardi, LCO president and observatory director. "They're the workhorses of the network."

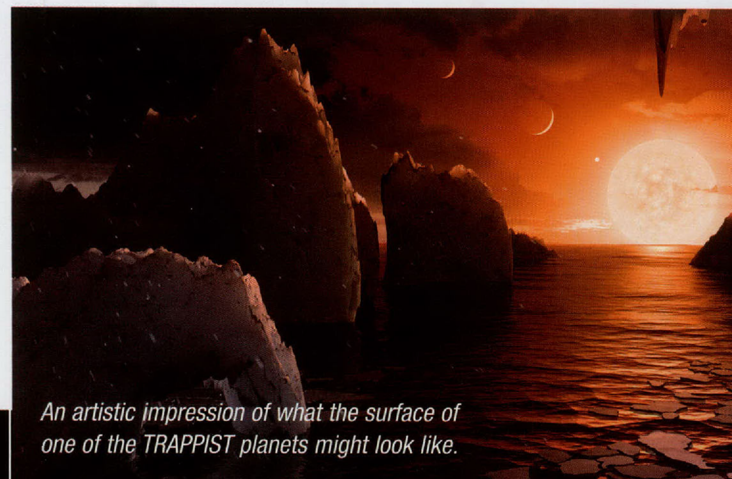
A network provides greater observing capacity than individual telescopes: "It's always dark at our observatory," says Storrie-Lombardi. "With a network of telescopes around the world, there is some telescope that can be looking at your target during a 24-hour period," says McDonald Observatory assistant director Anita Cochran. "You are not reliant on one telescope that might be weathered out. If it's cloudy in Chile, earlier it may have been clear in South Africa."

The AI scheduler is the brain of the observatory, says Storrie-Lombardi. "It makes all the decisions on what gets scheduled where, and tracks the status at each site. High-priority observations can be moved if weather causes one telescope to close. That is one of the hardest things for astronomers who haven't used this kind of facility to wrap their heads around, that they are not booking time on a particular telescope, but booking a target."

Schedules are stored at each site so the telescopes can continue observing even if they lose contact with headquarters.

Scientists use LCO for a variety of observations. They study the exploding stars known as supernovae, binary stars, exoplanets (planets orbiting stars other than the Sun), and objects in our own solar system, such as asteroids and comets.

Among many other recent results, LCO users announced last year that they had discovered the first convincing evidence for a new type of stellar explosion, known as an electron-capture supernova. Such a blast had been hypothesized for



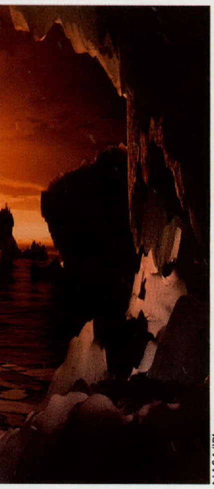
An artistic impression of what the surface of one of the TRAPPIST planets might look like.

NASA/JPL-CALTECH/R. HURT, T. PYLE (IPAC)

An artist's concept depicts the seven known planets of TRAPPIST-1 to scale. Three or more of the planets may lie in the star's habitable zone.

four decades but hadn't been confirmed. It occurs in a massive star with a lot of oxygen, magnesium, and neon in its core. When the core reaches a critical temperature, electrons begin binding with those elements. Without the free electrons bouncing around inside the star, keeping up its interior pressure, the core collapses. Its outer layers fall inward, then rebound, blasting into space with tremendous force, shining brighter than millions or billions of normal stars.

TRAPPIST-1 is one of the most intriguing families of exoplanets yet discovered. It consists of at least seven Earth-size planets orbiting a faint, cool star in the constellation Aquarius—one of the largest families of exoplanets yet discovered. Even more intriguing, as many as four of the planets appear to orbit inside the star's habitable zone, where temperatures are just right for liquid water on the surfaces of the planets. Because water is a key ingredient in Earth-like life, that makes the system a high-priority target in the search for extraterrestrial life. In fact, James Webb Space Telescope is scheduled to observe the system early in its mission.


NASA/JPL

TRAPPIST-1's first two planets were discovered by the Transiting Planets and Planetesimals Small Telescope project, which includes two robotic 60-cm (24-inch) telescopes. Both are operated from a control room at the University of Liège in Belgium. TRAPPIST detects planets when they "transit" their parent stars, blocking a tiny fraction of the stars' light. Repeated transits can reveal the size of a planet and its distance from its star, while observations with other techniques fill in more details.

Michaël Gillion, principal investigator for the TRAPPIST exoplanets program, was a postdoc at Geneva Observatory in 2007 when he and some colleagues used an amateur 24-inch (60-cm) telescope in the Swiss Alps to discover the first transit of a Neptune-mass exoplanet, GJ436b. They collaborated with astronomers at Wise Observatory in Israel to observe additional transits.

The experience inspired Gillion to develop TRAPPIST. He worked with a Liège comet expert, Emmanuel Jehin, to secure funding from the Belgian National Science Fund for a 60-centimeter telescope, dedicating 25 percent of its time to monitoring comets and asteroids (it measured the first ring system around an asteroid, Chariklo) and the rest to searching for exoplanets. The first telescope was installed at La Silla, Chile, in 2010 and the second at Oukaimeden, Morocco, in 2016.

Gillion manages another robotic project, Search for Habitable Planets Eclipsing Ultra-Cool Stars. This network of five one-meter robotic telescopes performs transit searches on 1,000 or so of the nearest ultracool dwarf stars. Larger telescopes then can perform detailed analyses of the atmospheres of any potentially habitable rocky planets it finds, Gillon says.

The project uses an automatic scheduling program to prioritize a daily target list and send instructions to each telescope's control computer. Every evening, a team member connects to the telescope and launches the observations. "We could fully automatize this task, but we prefer to a have a human check in every day," says Gillion. Observations are copied automatically to Liège, where they are analyzed.

ATLAS (Asteroid Terrestrial-Impact Last Alert System) is an example of a robotic network dedicated to a single task—looking for asteroids that might pose a threat to Earth. Developed by the University of Hawai'i and funded by NASA, it includes telescopes on two islands in Hawaii and two more telescopes in the southern hemisphere. It's the first asteroid-hunting network that can scan the entire night sky every 24 hours. ATLAS can provide a few day's warning for an asteroid 65 feet (20 meters) in diameter, and several weeks' warning for a 325-foot (100-meter) asteroid.

Because they are so close to Earth, asteroids move quickly against the fixed background of distant stars. That movement shows up when astronomers take a series of images of the same part of the sky. Every night, ATLAS takes four images of different regions of the sky 12 minutes apart, then a computer system in Honolulu searches the images for potential asteroids. The computer then tries to match those to the hundreds of thousands of known asteroids and calculate their orbits to identify Near Earth Objects (NEOs) and Potentially Hazardous Objects (PHOs). NEOs are asteroids and comets that sometimes pass within a few million miles of Earth but don't cross our planet's orbit. PHOs periodically cross the orbit, so they could someday hit Earth. To be classified as a PHO, the object must be at least 450 feet (140 meters) in diameter, so an impact could be catastrophic.

So far, ATLAS has discovered 76 potentially hazardous asteroids and about 800 near-Earth ones. "The movie 'Don't Look Up' is the gift that keeps on giving for us, that's our world," says Larry Denneau, an astronomer at the University of Hawai'i. "But we're just the discovery part." (If the project identified an asteroid on a collision course, Denneau wouldn't be hitting the news circuit the way scientists did in the movie. Any response would be up to the International Asteroid Warning Network, which includes several national space agencies, observatories, and research institutions.)

Although robotic telescopes operate on their own, they can't repair themselves if things go wrong. So most of them reside at professional observatories that have staff members who can respond to maintenance issues.

"We may not be top of the list, but we have good relationships with the people supporting us," says Storrie-Lombardi. "We also have an engineering and software staff here in California that built all these things. Before COVID, we typically sent a team to each site for maintenance every 18 months. We have had site staff do things that we would have done before, and do as much as we can remotely. It is amazing how well it all worked during the pandemic. As long as an observatory site stayed open, we were able to operate. And because everything was remote, as long as astronomers had access to a computer, they could continue observing."

Observatory staff is not necessarily available around-the-clock, though.

"That forced us to very carefully design the robotic aspect, because we can't rely on someone being there to do something," Denneau says. "When you're done, everyone needs to walk away and it has to work on its own."

In general, more telescope facilities are using remote control if not going entirely robotic, says Cochran. That can simply mean running a telescope from the base of a mountain rather than at the top. "People think a lot better at sea level than at 14,000 feet," she adds.

Most systems are set up to alert a human if something goes wrong. Many also use cameras that enable a person to keep an eye on things. Bottom line, though, "very little goes wrong," Cochran says.

the queue." That rapid turnaround is an important advantage of robotic facilities.

Robotic systems also can reduce costs and increase efficiency.

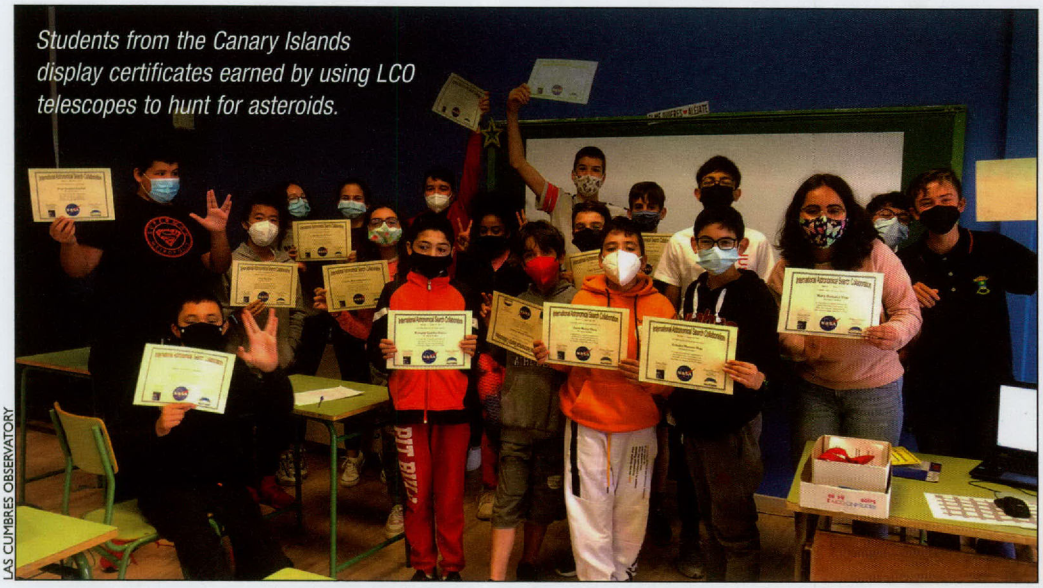
"There's no need to send an observer to Chile, Morocco, Tenerife, or Mexico, which would be very expensive [and] time-consuming," says Gillion. By allowing researchers to work from home instead of traveling hundreds or thousands of miles for each observing session, they reduce astronomy's carbon footprint. And the time that someone would have spent traveling and observing can instead be spent analyzing data.

"An astronomer doesn't have to have the funding and the time to leave for a week," Storrie-Lombardi says. "If your science program gets observing time and

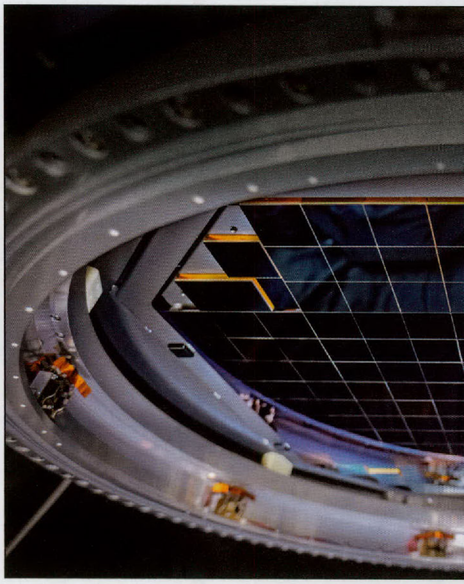
time, say 30 minutes, and then moves on to the next target.

Storrie-Lombardi notes that these systems also have limited flexibility. "We aim for robust and reliable instrumentation that does one or two things really well," she says. "But we don't switch instruments, so you can't have the variety and flexibility you may have at an observatory that is more classically scheduled."

Some researchers have used LCO many times, while others say it doesn't really do what they need it to do. "It depends on the type of science and quality of the data," Cochran says. "It's great for some things but doesn't work as well for other things. Some of our observers are pretty picky about how their observations are made."


Students from the Canary Islands display certificates earned by using LCO telescopes to hunt for asteroids.

LAS CUMBRES OBSERVATORY



Robotic systems also help make telescopes more accessible and open up more observing time.

At a classically scheduled telescope, one or a few people observe during the entire night for one or more nights. That works well for some research, but for projects such as exoplanet searches, one hour a night over multiple nights might be better, explains Cochran. That kind of schedule is almost impossible to do in person, but relatively simple for a robotic network.

"An important reason behind robotics is to intertwine different programs," Cochran says. "Another is so they can be triggered—if a supernova goes off or [a telescope] sees some object we haven't seen before, an event broker steps in, says that takes priority, and puts it next in

you have a computer connected to the internet, you can use the telescope. That is powerful on the science side and the education side."

Robotic systems can't be all things to all people, though. For complex observations, having a human observer in control probably remains best.

Robotic facilities also require users to define clearly and sufficiently what they want even for simple observations. "If you just say, I want photometry on this target every third night, that may not be specific enough," Cochran says. Fortunately, she adds, users can improve that skill with experience.

Robotic telescopes also don't allow for long observations; typically, a facility makes a requested observation for a short

For some, though, no longer visiting observatories in person may be the most significant drawback. "Observatories are just such fabulous places to visit," says Storrie-Lombardi. "I love sitting at a telescope."

Robotic telescopes also increase access for educational purposes by making observations possible from just about anywhere, any time. LCO's education program, Global Sky Partners, provides more than 1,250 hours of telescope time per year to students, teachers, and the public, for example. Many teachers run their own fully supported education projects and investigations using LCO telescopes, with mentoring and support from LCO, and learn from and support each other through a global forum.

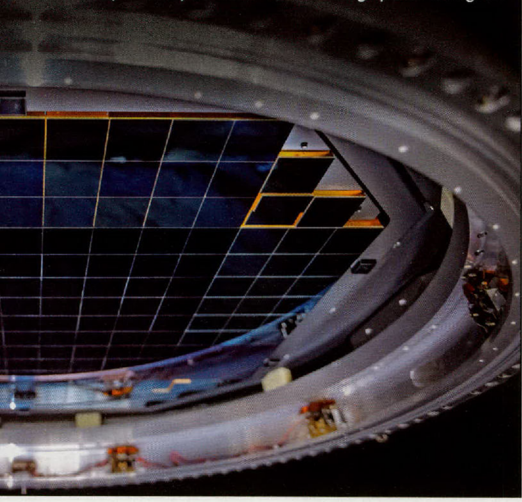
Student projects from the program,

which is supported by private foundations, have been presented at astronomy conferences and published in scientific journals.

"We have programs at high schools in the U.S. and globally, and we aim at areas that are underserved," says Storrie-Lombardi. "We have a program that targets older students, and one in sub-Saharan Africa. We do a workshop to teach students how to take and analyze data, a new set of skills that may not be available with the resources they have. These students are doing real research."

TRAPPIST includes educational programs for students at the University of Liege. Gillion's course on exoplanets includes transit observations with the TRAPPIST telescopes. That gives students first-hand experience in observational astronomy right from their campus, along with the opportunity to discover exoplanets. Jehin's comet program also includes a course on observational astronomy using the TRAPPIST telescope in the northern hemisphere. It even includes an annual trip to Morocco, where students use the telescope to perform observations. Students can collect data even if the weather does not cooperate during their visit.

The camera for the robotically operated Rubin telescope will produce 3,200-megapixel images.



JACQUELINE ORRELL/SLAC NAL/NSF/DOE/RUBIN OBSERVATORY/AURA

Students in classrooms and after-school centers across the country can schedule observing time on the MicroObservatory Robotic Telescope Network through a program called OWN (Observing With NASA). The telescopes, developed by the Harvard-Smithsonian Center for Astrophysics, are located and maintained at observatories affiliated with the center, including the Harvard College Observatory in Massachusetts and the Whipple Observatory in Arizona.

Observers choose a target from the website and select an exposure time, color filters, and other parameters, then submit a request for the telescope to take the image that night. Within 48 hours, they receive links to the images. Targets include objects within the solar system, stars and nebulae, and galaxies.

The Virtual Telescope Project, a set of robotic telescopes provided by the Bellatrix Astronomical Observatory in Italy, is accessible remotely. Users can sign up for observing time for research or just for fun. The project also offers public online observing sessions with live commentary from scientific staff.

Kitt Peak National Observatory, near Tucson, recently began offering two remote observing experiences for astrophotographers. (There's no indication yet how a forest fire that damaged the observatory will affect these and other public programs.) The first, Remote Imaging with Kitt Peak SOLARIO Telescope, uses a 38-centimeter (15-inch) telescope. Astrophotographers can operate the telescope themselves for $325 for an entire night, or with guidance from a trained expert for an additional fee. Users receive raw data within 24 hours.

Classically scheduled telescopes aren't likely to disappear, especially for specialized instruments that need a hands-on approach to get the best out of them, says Storrie-Lombardi. Many observatories already are combining classic and robotic systems to serve more users, and that trend is likely to continue or even accelerate.

LCO made its control system software open-source so that others can use the code—and some already have. "We're happy to share the tools we've been able to develop to help make some of the science possible, to respond as quickly as possible to new things," says Storrie-Lombardi.

One LCO project seeks to help astronomers more fully harness the enormous scientific potential of the Vera C. Rubin Observatory, she adds. Being developed in Chile, the observatory will include an 8.4-meter (27-foot) telescope and the world's largest CCD camera. Its 10-year Legacy Survey of Space and Time, scheduled to start in late 2023, will take images of the entire sky every 2.7 days, photographing hundreds of millions of interesting targets, including comets and asteroids, exploding stars, variable stars, transiting exoplanets, and many others. Its work will shed new light on dark matter—invisible matter that exerts a gravitational pull on the matter around it—and dark energy—a mysterious force that is causing the universe to expand faster as it ages.

"The astronomy community must be ready before the survey starts," Storrie-Lombardi says. "Through this program, the whole community will have the chance to kickstart research programs to maximize the scientific return of the Rubin Observatory."

Some people may still miss going to the telescope, says Denneau. "But doing that is hard, it wears you down. Our 'scopes produce a terabyte of data every night. In an era of big cameras and detectors that get big data, robotics is the only way to go."

Melissa Gaskill is a freelance writer in Austin and a StarDate *contributing editor.*

RESOURCES

INTERNET

Las Cumbres Observatory
lco.global

Global Sky Partners
lco.global/education/partners

ATLAS
fallingstar.com/home.php

TRAPPIST
www.trappist.uliege.be/cms/c_5006023/en/trappist

TRAPPIST-1 System
www.trappist.one

MicroObservatory Robotic Telescope Network
mo-www.cfa.harvard.edu/MicroObservatory

KPNO SOLARIO Telescope
noirlab.edu/public/announcements/ann22012

Vera Rubin Observatory
www.lsst.org

by Alan MacRobert

Bright Planets in Evening Skies

Bright planets highlight the night skies of late summer and early autumn. Saturn leads the way, followed by brilliant Jupiter and orange Mars, which grows brighter night by night. The Summer Triangle stands at its highest as summer draws to a close, while some of the best sights of autumn nights creep higher into the evening sky.

SEPTEMBER 1-15

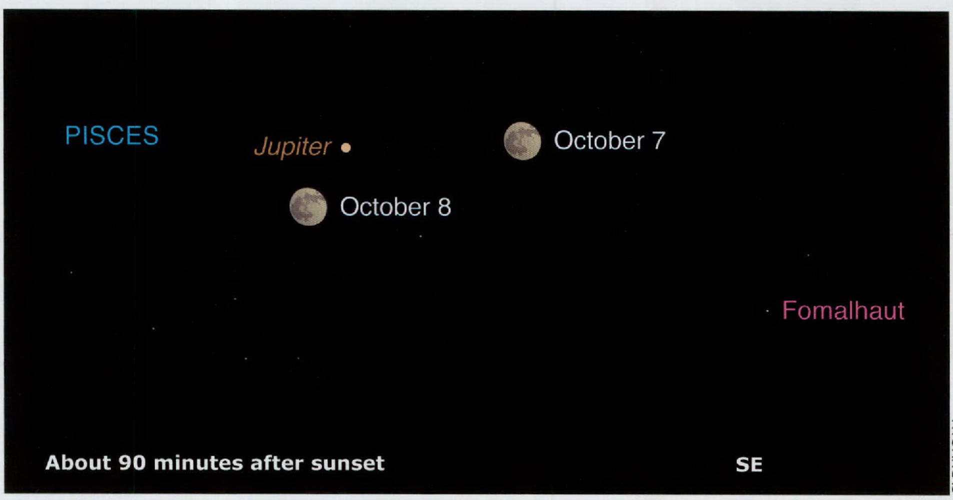
Two giant planets highlight the night. Saturn glows pale yellow in the southeast after dark, the only bright spot in the dim Capricornus-Aquarius complex. Much brighter Jupiter rises due east around nightfall. Once it's well up in the east-southeast, it dominates its dim background of southern Pisces.

The bright Moon poses with Saturn on September 7 and 8, then with Jupiter on the 10th and 11th.

Look above or to the upper left of Jupiter (depending on the time) and there's the bright Great Square of Pegasus, emblem of the coming fall. The square consists of second- and third-magnitude stars. It's tipped onto one corner, as it always is when in the east or west.

Its lower left side points diagonally down toward Jupiter. Continue that line a good deal farther past Jupiter to watch for the rise of Beta Ceti, also known as Diphda, the frog star. It's magnitude two. Between Jupiter and Diphda is fainter Iota Ceti, at magnitude 3.5.

Never heard of the frog star? The name Diphda comes from the Arabic for frog. It sits in the edge of the Great Water or Celestial Sea—a region of constellations that spans Cetus, the whale; Pisces, the fishes; Aquarius the water bearer; Capricornus, the sea goat; and Eridanus, the river. The Great Water, most of which is dim, fills much of the southern sky on autumn evenings.



CJ DUNCAN

This grouping of constellations is ancient. It seems to date from the earliest civilizations of southern Mesopotamia (now southern Iraq), including Eridu, on the Euphrates River. Eridanus is a Greco-Roman name for the Euphrates, perhaps deriving from Eridu. If so, the name of Eridanus must predate the Greeks and Romans; by their time, Eridu was an empty ruin.

Some of our oldest constellations date from these Mesopotamian cultures or their prehistoric ancestors. Capricornus, for instance, which had become an odd goat-fish creature by classical times, may have begun as a ceremonial boat with a goat's head on its high front, which appeared in annual religious rituals in Eridu. The stars of Capricornus do form a dim boat shape with a high prow. The boat ritual, judging by drawings on clay tablets, featured an Aquarius-like figure standing in the boat pouring water from a jar, and today's starry Aquarius does, in fact, stand more or less on Capricornus.

And what lay below those people's water-themed southern stars? Their own Great Water, the Persian Gulf.

SEPTEMBER 16-30

Jupiter and Saturn continue as the only planets of early evening, shining in the east-southeast and south-southeast, respectively. But soon after dark, look a little west of south. There's the Sagittarius Teapot, tipping to pour out the last of summer. It's a little bigger than the width of your fist at arm's length. Its triangular spout pours to the right.

A fist or less below the tip of the spout, see if you can still spot the star pair known as the Cat's Eyes, dropping lower as we leave summer behind. They're in the tail of Scorpius, which now lies low, almost horizontal. Antares, the scorpion's brightest star, shines redly about a fist and a half to the right of the Cat's Eyes. The farther south you are, the higher the Sagittarius-Scorpius lineup will be.

High overhead, meanwhile, the big Summer Triangle reaches its peak as summer ends.

The brightest of its stars is Vega, a little west of the point directly overhead after dark. Deneb, somewhat fainter, is the brightest star on the other side of the zenith. Altair is the brightest high in the south. Altair has a little marker flag: third-magnitude Tarazed (Gamma Aquilae), a finger's width at arm's length to the upper right of Altair.

As summer turns to fall, Arcturus, Vega's equal, settles lower in the west. Look to its right in the northwest at about the same height and there's the Big Dipper, oriented to scoop up water.

This is also the time of year when, by full darkness, W-shaped Cassiopeia has risen as high in the northeast as the Big Dipper has dropped in the northwest. Between the Dipper and Cassiopeia is Polaris, the

North Star, rather modest at second magnitude.

Late in the evening, not long before midnight, a bright planetary rival to Jupiter and Saturn rises in the east. That's Mars, in eastern Taurus. It far outshines Mars-colored Aldebaran to its right or upper right. The baleful planet is already about magnitude –0.5, on its way to a grand showing from late November through December, around opposition, when it aligns opposite the Sun.

OCTOBER 1-15

Cassiopeia climbs the northeast with its right side tilted up ever more steeply.

Below Cassiopeia, Perseus has strode into view. Both lie along the Milky Way. That means both offer open clusters (loose, young star nests) for telescopes or even binoculars. The most famous here is the Perseus Double Cluster. Here's how to find it:

First, locate the W of Cassiopeia. Find the W's third segment from the top, which currently points down. Follow its direction farther down by twice its length. There you are.

See anything? That will depend on your light pollution and/or moonlight. In a truly dark sky, the Double Cluster is an irregular little patch of Milky Way. It appears dimmer and vaguer through modest skyglow and cuts out completely under typical suburban or small-city light pollution. But binoculars reveal a pair of clusters through almost any skyglow, and a telescope shows overlapping scattered spangles.

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 crescent Moon doesn't climb into view until not long before dawn, so it won't be a problem.

As a rule of thumb, if you can see the Andromeda Galaxy with the unaided eye, you can see the Double Cluster, too. They're actually not far apart—22 degrees, to be exact (two fists).

And how do you find the Andromeda Galaxy (M31)?

Start with the Great Square of Pegasus, high in the east and tipped onto one corner. From its left corner, a big line of three stars (counting the corner itself) runs to the lower left. From the middle of those three, look to the upper left by about two finger-widths at arm's length for a fainter little fourth-magnitude star. Continue that line about the same distance farther on, and you're at the Andromeda Galaxy. Don't be distracted by the faint little star only about a finger-width below it. Nothing there? Time for the binoculars or a wide-field telescope at low power.

In a less-than-perfect sky, the little oblong glow you see floating there is only the galaxy's bright central region. The disk and spiral arms, much larger, have a much lower surface brightness than photos usually depict.

OCTOBER 16-31

Jupiter and Saturn continue to shine in the southeast and south. In early evening, Saturn is slightly the higher of the two. But as evening grows late they balance out, standing roughly level. That happens around 8 or 9 p.m., depending on the date and where you live. After that, Jupiter climbs higher and Saturn sinks.

Mars now crowds more insistently into evening view, brightening all the while. It rises about two hours after full dark in mid-October, and just one hour after by month's end. During this time it brightens from magnitude –0.9 to –1.2, blazing between the horn-tips of Taurus: Beta Tauri to its upper left, fainter Zeta Tauri closer to its lower right.

With the sky moonless now until October's last few days, we get our best viewing of faint stars and constellations. Can you spot cute little Delphinus, the dolphin, and Sagitta, the arrow? Here's how.

Start with the Summer Triangle. Bright Vega is well west of the zenith after dark, Deneb is nearly overhead, and Altair is three or four fists to the left of Vega.

Face Altair. To check that you've got it, look for its little sidekick, Tarazed, about a finger-width to its upper right.

To the upper left of Altair, by a little more than a fist at arm's length, look for the little gathering of faint stars that is Delphinus. If you can see enough of them, they make a fairly convincing dolphin shape. He's leaping upward in the edge of the Milky Way.

Sagitta is smaller and fainter, to the upper right of Altair by a lesser distance than Delphinus. The arrow points to the upper left, almost parallel to the dolphin's leap. Good luck!

Alan MacRobert is a senior editor of Sky & Telescope *magazine.*

Eastern Solar Eclipse

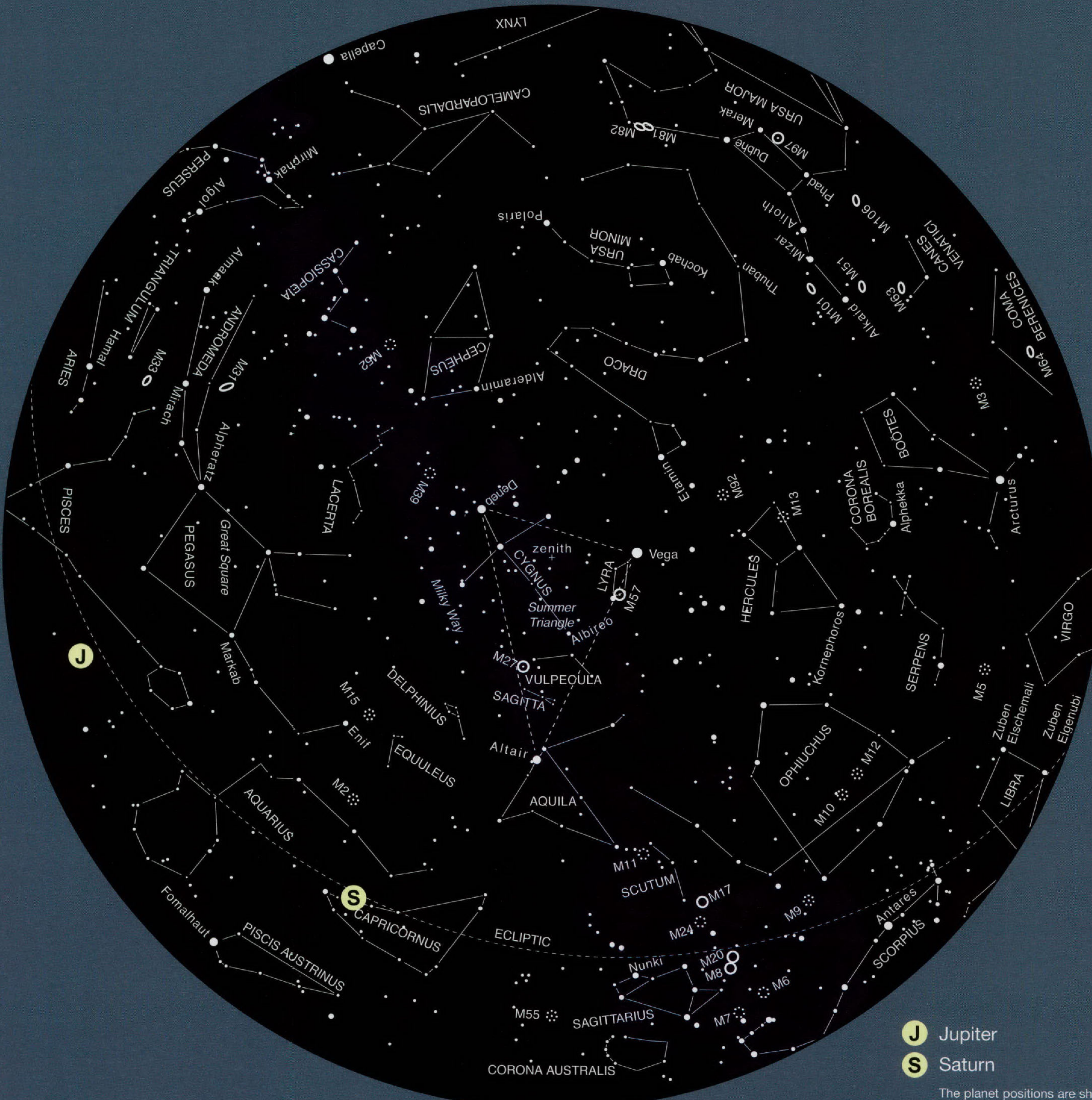
A partial solar eclipse will grace the skies of Europe and parts of Asia and Africa on October 25. The Moon will cover 82 percent of the Sun's disk at the peak of the eclipse, at 6 a.m. CDT. The sky will turn dusky and the air will grow slightly cooler. The eclipse will not be visible from the Americas.

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

J Jupiter

S Saturn

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

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

OCTOBER

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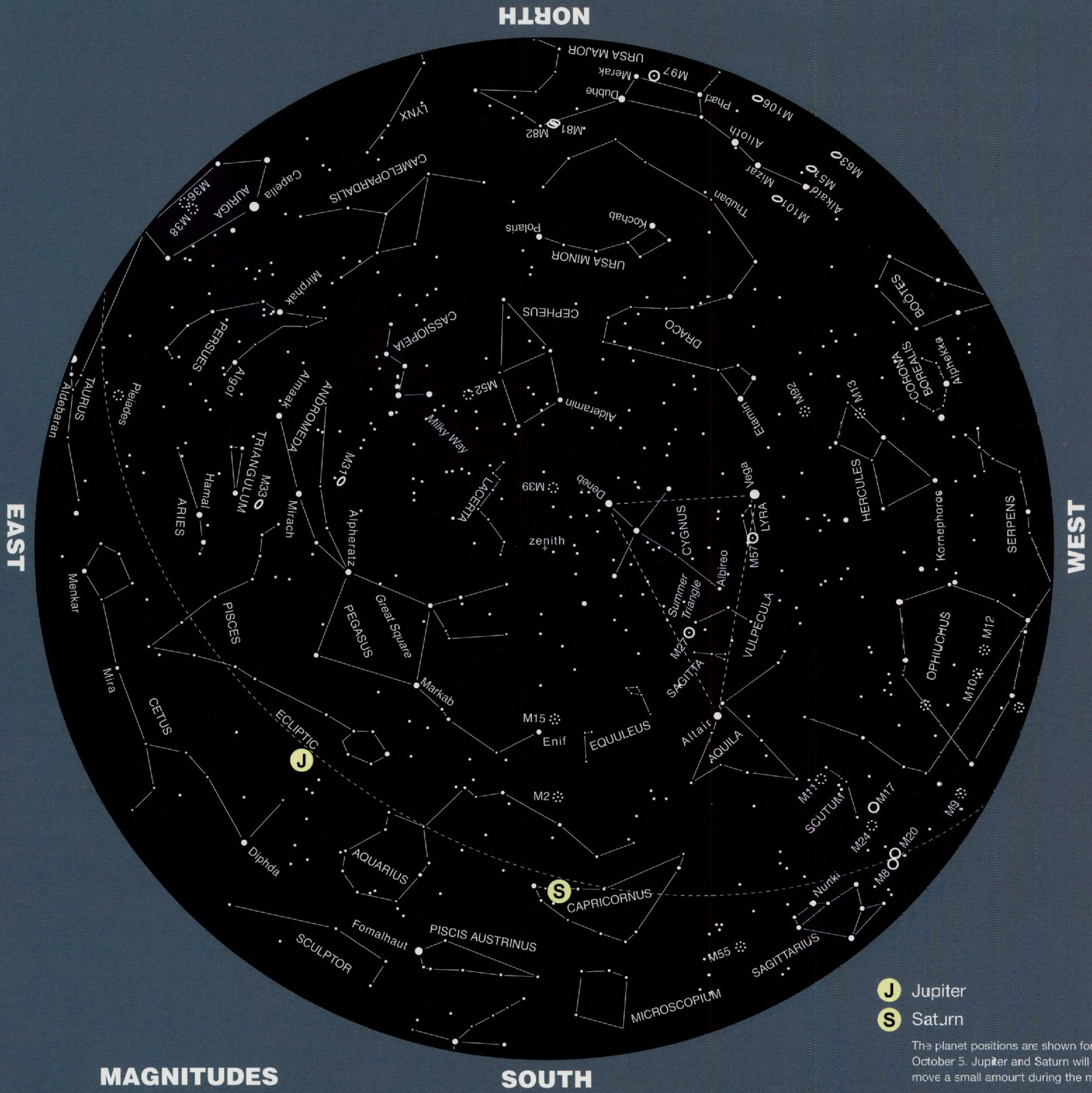

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- open cluster
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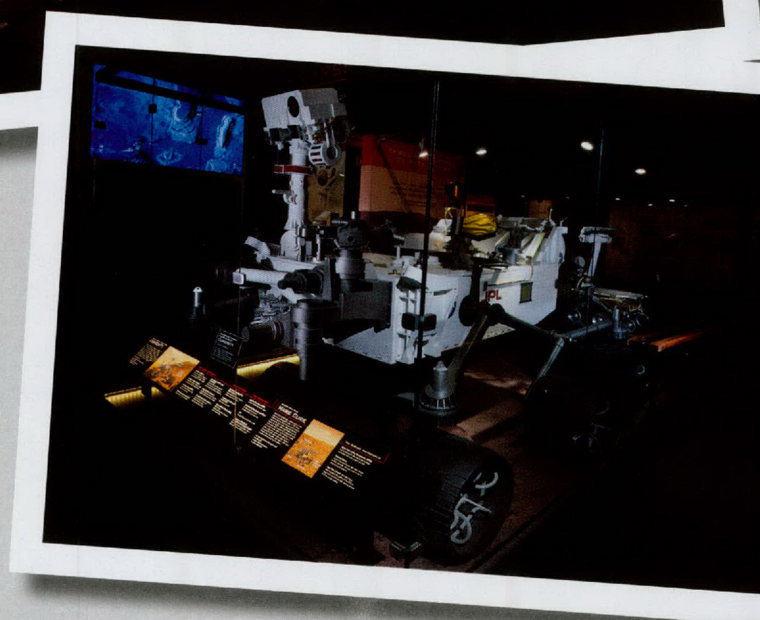
ASTROMISCELLANY



NASM/SMITHSONIAN (4)

A New Journey Through the Solar System

The Smithsonian's National Air and Space Museum in Washington, D.C., will unveil a new planetary science exhibition later this year. The Kenneth C. Griffin Exploring the Planets Gallery will cover the science and history of human exploration of the solar system and stories of individual planets.

The exhibition will feature a full-scale model of the Voyager spacecraft that explored the solar system's four giant outer planets and that now are venturing into interstellar space.

Other items on display include:

- A full-scale model of the Curiosity Mars rover, which landed on the Red Planet on August 6, 2012, and continues to trundle across the floor of Gale Crater and the flanks of its central mountain peak.
- The machine and images used by 24-year-old Lowell Observatory astronomer Clyde Tombaugh to discover Pluto in 1930. The machine, known as a blink comparator, switched between two photographic plates aligned so that distant stars remained stationary but a closer object such as Pluto appeared to move from side to side.
- Leonard Nimoy's Mr. Spock ear tips from the original Star Trek, displayed in a box built by Nimoy himself.

The new gallery is part of a multi-year renovation of the entire museum that began in 2018.

Clockwise from top left: An engineering model of Sojourner, the first Mars rover; a model of the twin Voyager spacecraft; an engineering model of Curiosity, a nuclear-powered Mars rover that landed in 2012 and continues to operate today; Mr. Spock's Vulcan ears from the original Star Trek.

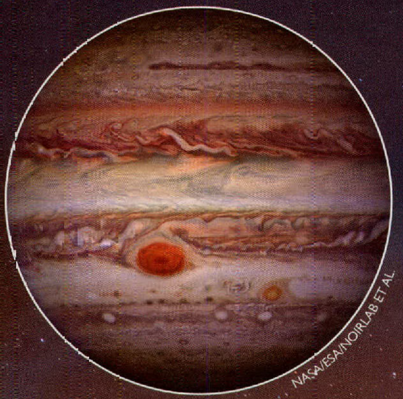
airandspace.si.edu/exhibitions/griffin-exploring-planets-reimagined

Regal Showing for a Regal Planet

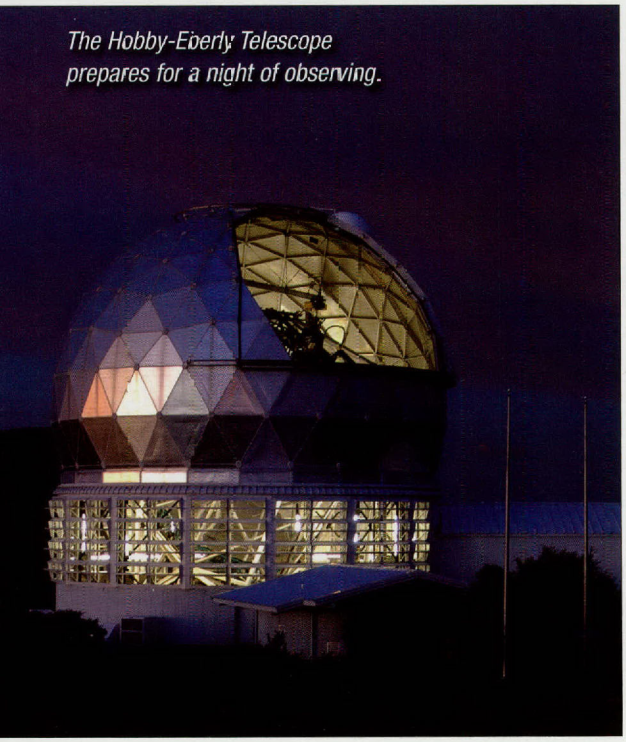
Jupiter is the king of the planets. At 11 times the diameter of Earth it's the largest of the Sun's eight major planets, and it's more massive than all the other planets and moons combined. And in September and October it really looks the part. On September 26 it reaches a point in its orbit known as opposition, which means it lines up opposite the Sun. A planet is closest to Earth at opposition, so it shines at its brightest and is in view all night.

At opposition, Jupiter will be low in the east at nightfall, arc high across the south during the night, and stand low in the west at dawn. In all the night sky, only the Moon and Venus will outshine it. As a bonus, it's easier to see Jupiter's four largest moons at opposition as well. Through binoculars, they look like small but distinct stars aligning near the planet.

Jupiter will be nice and bright in the weeks before and after opposition as well. Before opposition it rises after sunset, and after opposition it rises before sunset, keeping it in view most of the night. The Moon will team up with it on the nights of September 10 and 11 and again on October 7 and 8.



Jupiter shines through a thin layer of clouds above the Atacama Desert of Chile. Inset: A view of Jupiter features its Great Red Spot.



The Hobby-Eberly Telescope prepares for a night of observing.

Peering into the Darkness

The universe is expanding faster as it ages as the result of an unknown *something* called dark energy. Possible explanations range from an energy produced by the vacuum of space to an incomplete knowledge of the laws of gravity. Astronomers using the Hobby-Eberly Telescope at McDonald Observatory are conducting a large experiment to try to find the right explanation, with the help of on-line volunteers.

Dark Energy Explorers is open to anyone with a computer and an interest in helping in the process of scientific discovery. It provides volunteers with observations from the international Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), which is collecting data on millions of galaxies. Astronomers measure the composition and motion of the galaxies to learn how the universe's expansion rate has changed. That will help scientists narrow the range of explanations for dark energy.

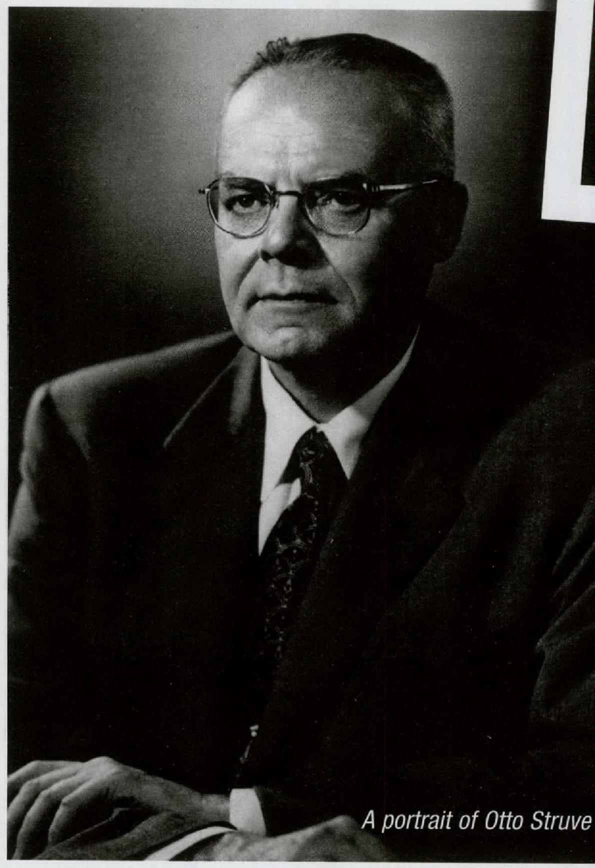
Dark Energy Explorers sift through HETDEX images to identify the right kind of galaxies. As of mid-July, volunteers had classified more than 3.4 million objects. New observations are periodically added to the site for analysis.

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

TO THE OBSERVATORY BORN

McDonald Observatory's founding director survived war and poverty, mastered one of astronomy's most important tools, and built a scientific powerhouse.

By Damond Benningfield


A portrait of Otto Struve

There was little doubt that Otto Struve would become an astronomer. His father, uncle, grandfather, and great-grandfather all were famous European astronomers and observatory directors. By the time Otto was 15, he had accompanied his father to the telescope and an astronomy conference and he was studying math and science in school.

For a while, though, Struve didn't know how or even *if* he would be able to follow his forebears. World War I, the Russian Civil War, and a long aftermath of hardship kept him away from his home, his family, and academia. He was scrambling just to survive when he happened to meet a former army colleague who was carrying a letter to Struve from Edwin Frost, director of the University of Chicago's Yerkes Observatory in Wisconsin. It was an invitation for Struve to join Yerkes as an assistant observer, studying the stars through the young field of spectroscopy.

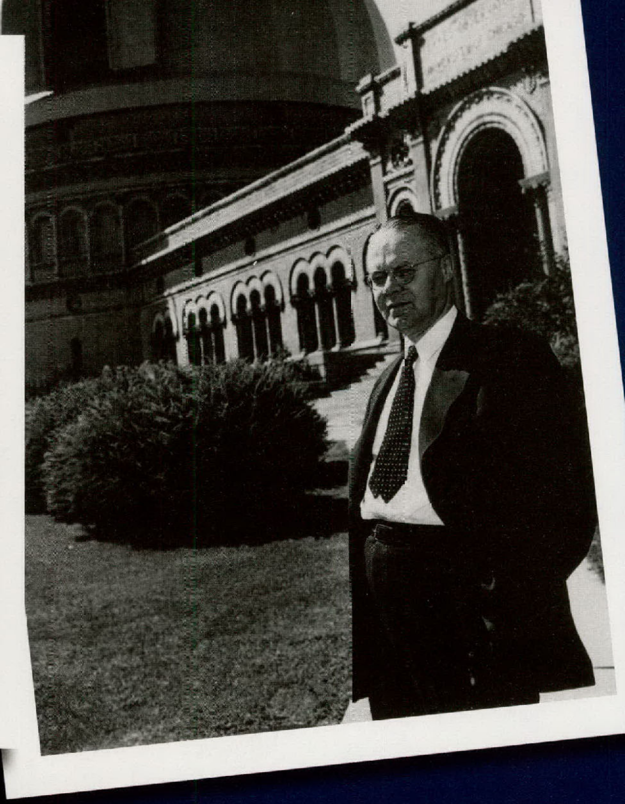
It took months to arrange Struve's journey to Wisconsin, but he arrived in October 1921, beginning a career that far eclipsed those of his ancestors. Struve directed four observatories (including McDonald Observatory, which he helped establish and build), assembled one of the world's great research teams, edited a leading astronomy journal, and led many national and international science organizations. As a researcher, he became an expert on binary stars, odd stars, gas and dust between the stars, and other areas.

"His life was uncompromisingly committed to the advancement of astronomy," wrote Leo Goldberg, a one-time graduate student under Struve, in a 1964 obituary, "an effort to which he devoted himself with brilliance and imagination, fed by what at times appeared to be an unlimited supply of energy and ideas."

"Struve's contributions to the growth of American astrophysics cannot easily be overestimated," wrote Kevin Krisciunas in a biographical memoir for the National Academy of Sciences. "Struve was exceptionally dedicated to astronomy and worked very hard, many would say too hard, to advance it."

Struve's birthplace, Kharkiv, Ukraine, today is known for the devastation wrought by the Russian invasion. When Struve was born, on






Snapshots from Otto Struve's life. From left: As a Russian army lieutenant, 1917; working at his desk; at the dedication of McDonald Observatory and its 82-inch telescope, which now bears his name; at Yerkes Observatory.

AIP EMILIO SEGRE VISUAL ARCHIVES

UNIVERSITY OF CHICAGO YERKES OBSERVATORY (3); SECOND FROM LEFT: McDONALD OBSERVATORY

August 12, 1897, however, Ukraine was a Russian province and Kharkiv was an important center of industry and culture. His family was among the city's elite; his father, Ludwig, was director of Kharkiv Observatory.

Otto joined his father for viewing sessions from the age of eight and made some of his own observations by age 10. After high school he entered the university, where he studied astronomy and mathematics. Just one semester in, though, Russia was embroiled in World War I, so Struve enlisted in the Russian Imperial Army, where he became an artillery officer and served on the Turkish front. After the war he returned to the university, where he earned his degree in 1919.

By then, Russia was deep into civil war. Struve enlisted in the White Army, which fought against the Bolsheviks. During that campaign his horse was shot from under him and a bullet punched through the sleeve of his coat jacket. When the Red Army prevailed, Struve barely managed to escape to Turkey, beginning a "period of great privation and misery," wrote T.G. Cowling in a memoir for the Royal Astronomical Society.

After a "miserable winter of austerity" in Gallipoli, Struve moved to Constantinople, which was bursting with Russian refugees. "True, there were soup kitchens (necessarily very thin soup) and soap from the Red Cross; also some marvellous striped cotton-fleece pyjamas which the refugees, their own clothes worn out, were glad to wear on the streets," wrote Cowling. "But life was hard. Struve and three others ... took on the most backbreaking jobs—Struve had a narrow escape from being killed by lightning while working as a lumberjack—but barely earned enough for subsistence."

During Struve's ordeal an aunt had been lobbying on his behalf, leading to Frost's invitation. The letter was in English, which Struve didn't speak (he was fluent in Russian and German), so he bought a dictionary and translated it. In a Hollywoodesque stroke of luck, when he sought to confirm his work, he met a Wisconsinite who knew Frost. The man found Struve a job, helped him get a visa, and convinced a rich friend in Chicago to pay for Struve's passage to America.

"With his three friends' help, Struve was fitted out with a green hat, blue coat, brown trousers and tan shoes," Cowling wrote. "In this motley outfit he arrived in the autumn of 1921 at the Yerkes Observatory, and immediately began work in the spectrographic department."

After the travails of the preceding years, Struve found the challenges facing him in the United States invigorating. He learned enough English to earn both his PhD from the University of Chicago and his American citizenship, then began ascending through the ranks of the Yerkes staff.

Perhaps most important to Struve, he acquainted himself with the intricacies of spectroscopy (he'd warned Frost that he was unfamiliar with the technique), in which the light of a star or other target is split into its individual wavelengths, creating a rainbow of colors.

Spectroscopy is the most powerful tool available to modern astronomy. It can reveal an object's motion toward or away from the observer, its rotation rate, its surface temperature, its chemical composition, and whether it has any companions.

Struve studied binary systems, which consist of two stars bound to each other by gravity. In particular, he studied systems in which spectroscopy was the only way to see evidence of two stars instead of one. As the stars orbited each other, each produced its own pattern of bright and dark lines in the spectrum—the signatures of different chemical elements in the stars. Back-and-forth shifts in the lines revealed the orbital motions.

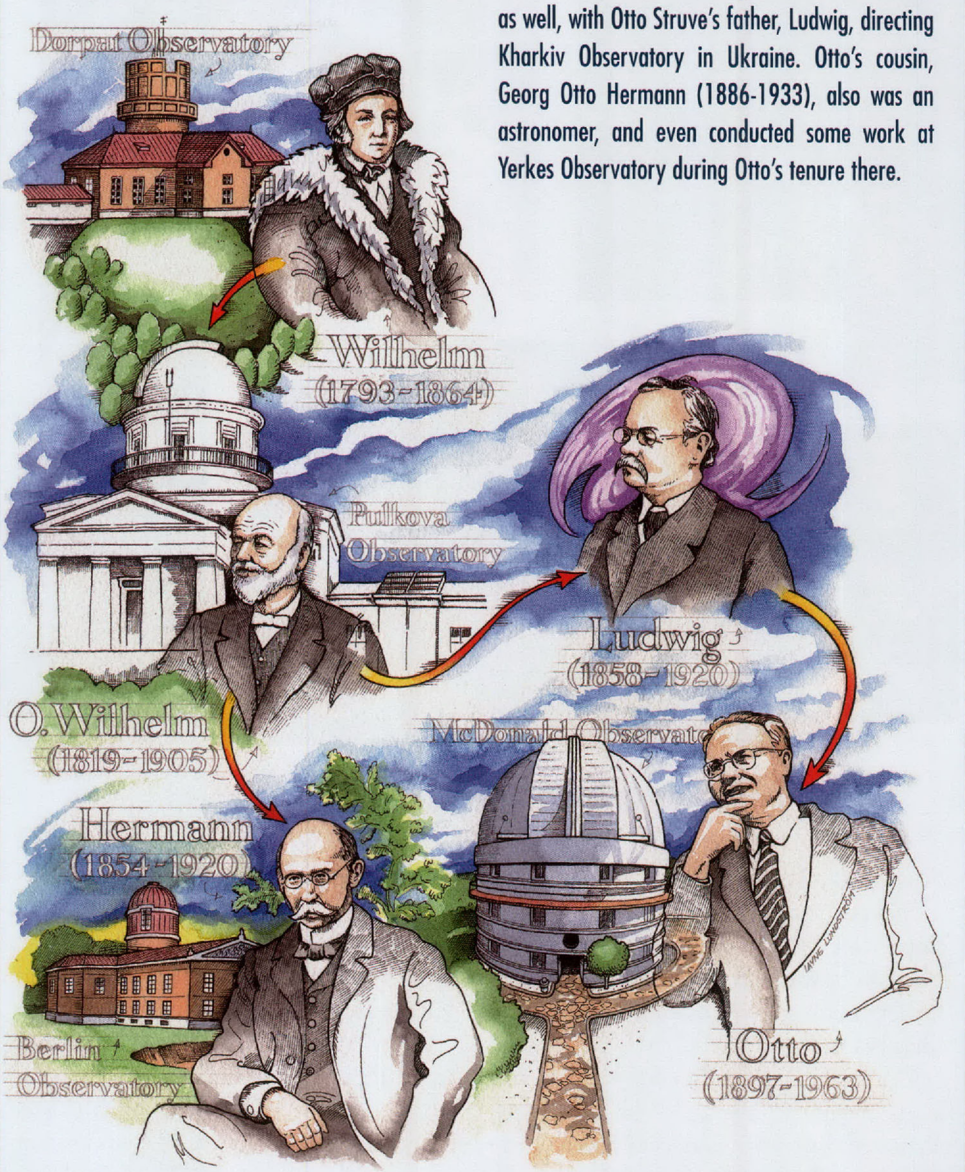
The shifts also revealed in-and-out pulsations on the surface of a star. One of the first star systems Struve studied was at first thought to be a binary. But Struve discovered that the shift in its spectral lines was too fast to be caused by orbital motions. Instead, it was caused by a single star that was pulsing once every two hours, 36 minutes. Struve presented his results at a professional astronomy meeting—the first of many such presentations.

Struve used a microscope to measure the spectral lines recorded on a photographic plate. Hours of such intense work caused him to strain his eyes, "probably weak to begin with," wrote astrophysicist and astronomy historian Donald E. Osterbrock in his 1997 book *Yerkes Observatory 1892-1950*. "As a result his two eyes often looked in slightly different directions, giving him a particularly forbidding expression."

Struve also studied the then poorly understood interstellar medium—the wisps of gas and dust between the stars. And he became fascinated with "peculiar" stars, which show unusual abundances of elements other than hydrogen and helium, which constitute the vast bulk of a star. "With him the stars were individuals, known to him by name, and each with its own individual peculiarities," according to Cowling.

END OF THE LINE

Otto Struve was the final member of the Struve astronomical dynasty. His great-grandfather, Friedrich Georg Wilhelm, directed Tartu Observatory in Estonia, then founded Pulkovo Observatory in Russia. Friedrich's son Otto Wilhelm directed Pulkovo before moving to Germany in 1889. Two of Otto Wilhelm's sons, Karl Hermann and Gustav Ludwig, became astronomers as well, with Otto Struve's father, Ludwig, directing Kharkiv Observatory in Ukraine. Otto's cousin, Georg Otto Hermann (1886-1933), also was an astronomer, and even conducted some work at Yerkes Observatory during Otto's tenure there.



LAYNE LUNDSTRÖM

As Struve mastered spectroscopy, he also began teaching on the Chicago campus and helping Frost, who was losing his own eyesight, with some of his administrative duties. He used telescopes at several observatories, visited major astronomy programs abroad, and published scores of papers. His talent, hard work, and determination made him the "power behind the throne" at Yerkes, according to David Evans and Derral Mulholland in their 1986 book *Big and Bright: A History of the McDonald Observatory*. When Frost retired, in 1932, the 34-year-old Struve succeeded him.

Both Yerkes Observatory and the overall University of Chicago astronomy program were in decline when Struve took over. "From the start he got right down to business, was deeply immersed in research at the detailed level, and never minced words with underlings in making his decisions known," according to Osterbrock.

Struve brought in world-class observers and theorists, including Gerard Kuiper, a future McDonald director, and Subrahmanyan Chandrasekhar, a theorist who would win a Nobel Prize for work he did in the 1930s. Those and other hires made the Chicago faculty a powerhouse.

Yerkes's main telescope, the world's largest refractor (which uses glass lenses to gather and focus starlight), was 40 years old, it was small compared to modern reflectors (which use mirrors instead of lenses), and its instruments were not state of the art. Worse, its location, in Williams Bay, Wisconsin, was poor. It was at low altitude, so there was a thick layer of obscuring atmosphere above it, and bad weather frequently prevented observing at all.

Struve convinced Chicago to upgrade the instruments, but there was little they could do about the viewing conditions. Struve wanted a big new telescope, built at high altitude in the southwestern United States, to supplement the Yerkes capabilities. With the Great Depression gripping the country, though, there was little prospect of that happening. So Struve came up with a clever Plan B.

In 1926, William J. McDonald, a banker in Paris, Texas, had bequeathed his fortune to the University of Texas to build an obseratory. Texas had no astronomy program, however, so it invested the money and bided its time. Struve suggested to Chicago President Robert Hutchins that the two universities team up: Texas would build the observatory and Chicago would run it. Texas agreed, and the universities signed a 30-year deal, with Struve to direct both Yerkes and McDonald observatories.

Struve and his deputies criss-crossed West Texas to find an appropriate site, and Struve picked 6,800-foot Mount Locke, in the Davis Mountains 450 miles from Austin. The telescope dome was completed in 1936 but it took three more years to finish its primary mirror, which, at 82 inches in diameter, was the second largest in the world. "The conception, planning and launching of the McDonald Observatory were all Struve's: its establishment represents one of the major triumphs of his career," Cowling wrote.

Struve reveled in his multiple duties. He shuttled between Chicago, Yerkes, and McDonald, building his empire and conducting research with the new telescope. He and his wife, Mary, would spend weeks at Mount Locke, with Struve observing at night and analyzing his plates during the day with Mary's help.

During World War II, he kept both observatories operating (although he drafted contingency plans to remove the 82-inch mirror from the telescope if Germany invaded through Mexico), and his own research continued apace. He also served as managing editor of the *Astrophysical Journal*, a leading research publication, and even began writing articles for the general public (Struve published more than 900 papers, books, and articles).

As the war ended, however, things began to deteriorate. Dedicated and demanding, a strict disciplinarian who was always addressed as "Mr. Struve," he maintained a strong grip on the astronomy program, alienating his staff. "He was upset if anyone wasted even a few minutes of observing time, by slowness in finding the object or preparing the exposure, by faulty guiding of the telescope, or simply by closing the dome when there were still a few openings between the clouds," Cowling wrote.

Struve's talented scientists weren't amused. "The bright young subordinates of 1940 had come out of the war as the young Turks of 1946," according to *Big and Bright*. "They knew that they were very good, and they knew about the technological and social revolutions that the war had set in train. The autocratic methods that Struve had learned in his upper-crust Russian family fit poorly into the new vision of the world."

After a power-sharing arrangement collapsed, Struve resigned, in 1950.

Struve had spent his entire career ensconced at the University of Chicago. He'd been offered positions at other universities, including MIT and Harvard, and had used those as leverage to improve his Chicago position. And in the late 1940s he won many professional accolades. So he had little concern about continuing his work. In fact, he quickly agreed to head the astronomy program at the University of California in Berkeley and direct its Leuschner Observatory.

The change from icy Williams Bay to sunny California seemed to rejuvenate Struve. The insomnia that had plagued him in recent years faded away, and he even became a bit jovial, smiling more than associates had ever seen. He continued his research, mainly at the nearby Lick and Mount Wilson observatories. (He fell during a night of observing at Mount Wilson, breaking some ribs and cracking two vertebrae.)

After a decade, though, Struve was ready for a fresh challenge. He was hired to direct the new National Radio Astronomy Observatory. This time, Struve was out of his depth. He knew little about radio astronomy and had a hard time catching up. He grew frustrated at his own lack of progress. Although he helped midwife the observatory's birth, he didn't stick around for its infancy; he resigned in 1962 and returned to California.

By then, Struve was beset by health problems, including hepatitis (probably contracted during the war). He was hospitalized for months, and died in 1963.

He and his wife had no children, so the Struve dynasty came to an end. Otto Struve's legacy continues, however, in the institutions he helped build or revive. And even without a fifth generation, the Struve name lives on. Astronomers named an asteroid in his honor, and another asteroid and a lunar crater after the Struve family. In 1966, McDonald Observatory named its original telescope for him as well. The Otto Struve Telescope continues to observe the sky every clear night of the year—perhaps the greatest honor of all for an astronomer who never wasted even a minute of his precious time under the stars.

Damond Benningfield is executive editor of StarDate *and writer/producer of StarDate radio.*

RESOURCES

BOOKS

Big and Bright: A History of the McDonald Observatory, by David S. Evans and J. Derral Mulholland, 1986

Yerkes Observatory 1892-1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution, by Donald E. Osterbrock, 1997

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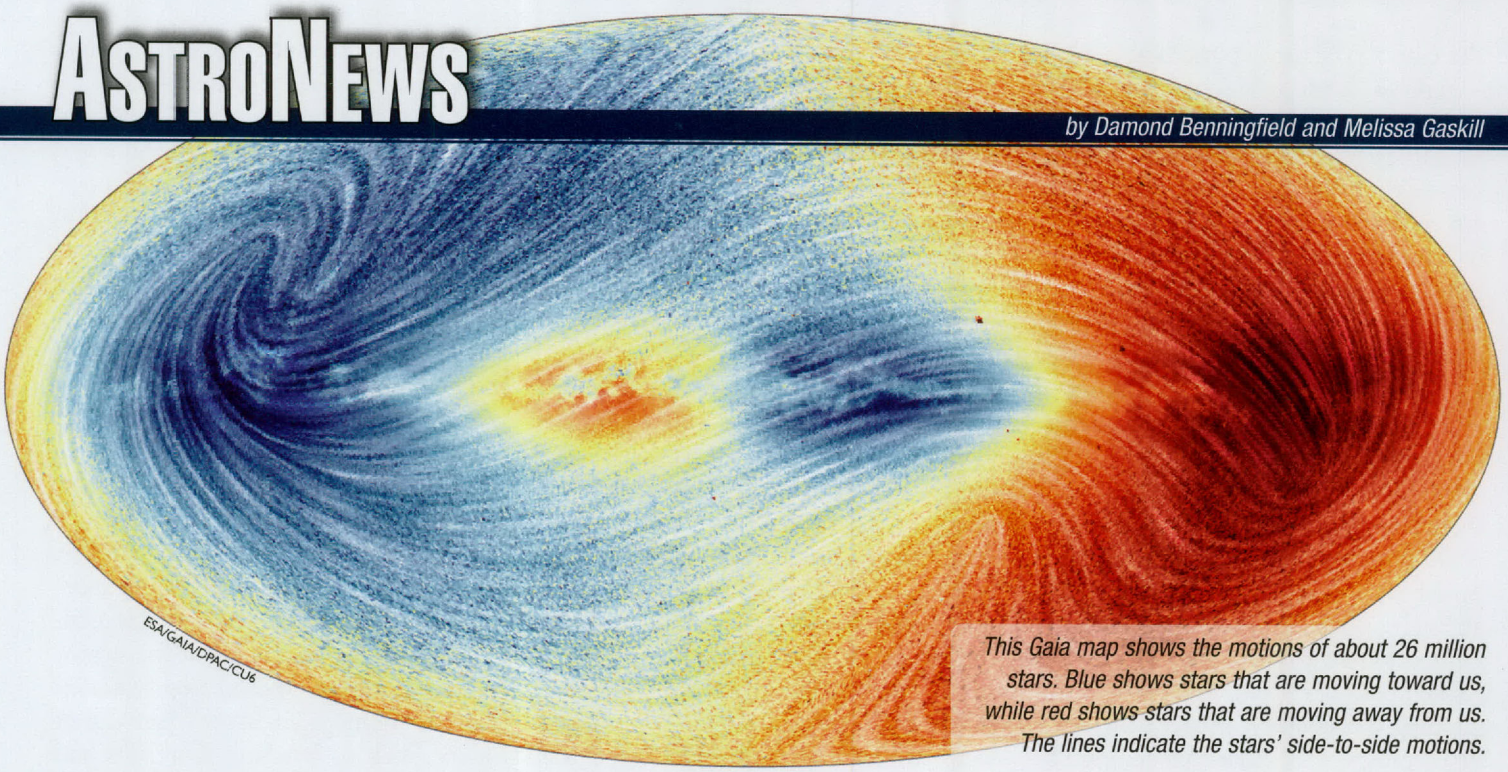
'Otto Struve, 1897-1963,' *Biographical Memoirs of Fellows of the Royal Astronomical Society*, by T.G. Cowling *royalsocietypublishing.org/doi/10.1098/rsbm.1964.0017*

'Otto Struve,' *Quarterly Journal of the Royal Astronomical Society*, by Leo Goldberg *articles.adsabs.harvard.edu/full/1964QJRAS...5..284*

'Otto Struve, 1897-1963,' *Biographical Memoirs, National Academy of Sciences*, by Kevin Krisciunas *www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/struve-otto.pdf*

by Damond Benningfield and Melissa Gaskill



This Gaia map shows the motions of about 26 million stars. Blue shows stars that are moving toward us, while red shows stars that are moving away from us. The lines indicate the stars' side-to-side motions.

Strawberry, Orange, or Lime?

Space telescope records the surface jiggles of a hundred thousand stars, logs a record haul of binaries, plots asteroids, and much more

Many stars jiggle like bowls of Jell-O. The jiggles can tell us much more than just the flavor. They can reveal a star's structure, its internal temperature and density, its composition, and more. Measuring the jiggles is tough, though. They're small, so it's hard to measure them precisely from Earth's surface. But a space telescope has measured jiggles on about a hundred thousand stars—dozens of times more than all previous efforts combined.

The jiggles were included in a huge batch of observations released in June from Gaia, a European space telescope that's studied more than 1.8 billion stars and other objects. Its work is helping astronomers map the Milky Way Galaxy, piece together the galaxy's history, and better understand how stars evolve.

Gaia makes highly precise measurements of the positions and motions of all the stars in its survey. It makes more detailed observations of tens of millions of stars in that group, including their chemical composition, surface temperature, and rotation rate. That allows astronomers to determine which stars share a common origin, which were born inside the Milky Way and which came from outside the galaxy, and more.

Gaia's new data release included details on 800,000 binary star systems—more than any previous study—plus millions of galaxies and quasars, hundreds of thousands of asteroids, and millions of stars that vary in brightness.

That includes the jigglers. Studying waves on their surfaces is known as asteroseismology, and it works much like seismology on Earth. Motions of planet-sized bubbles of hot gas at and below a star's surface generate sound waves. The waves can travel deep into the star, then reflect back to the surface, where they create "starquakes"—both up-and-down jiggles and side-to-side waves like tsunamis racing across an ocean.

A star can generate millions of waves, which travel at different speeds and reach different depths. A wave can last anywhere from minutes to months, sometimes traveling all the way around the star several times.

By measuring the characteristics of the starquakes, astronomers learn about a star's interior. Among other things, they can find the bottom of the star's convection zone—the thick layer of boiling, turbulent gas that creates the sound waves. Because the waves travel at different speeds through different materials and at different temperatures, they can reveal the composition of the star's gas and the temperature throughout the convection zone. A specific type of wave can even reach the star's core, where energy is generated through nuclear reactions.

Piecing together observations from many stars can produce a more complete picture of how different types of stars are put together and how they evolve.

Gaia determined the pulsations of many stars by measuring changes in their brightness and the in-and-out motions at their surface. Scientists analyzed 34 months of observations of hundreds of thousands of stars that are bigger, hotter, and more massive than the Sun, eventually identifying more than 100,000 that provide useful jiggles. The scientists will continue to study those stars—and others in the Gaia database, which is open to all—to learn more about the structure and evolution of all stars. **DB**

On the Job

Webb Telescope offers spectacular glimpses of the universe

In its first weeks of full science operations, James Webb Space Telescope (JWST) compiled the deepest images of the universe yet seen. Its observations revealed thousands of galaxies in much greater detail than anything produced by Hubble Space Telescope or ground-based observatories. The observations, compiled over just 12.5 hours, show that JWST is capable of carrying out its planned science mission, according to NASA officials.

JWST was launched December 25, then took weeks to reach its final position, almost one million miles farther from the Sun than Earth is. Engineers then carefully positioned its 18 hexagonal mirrors to create an overall mirror 6.5 meters (21 feet) in diameter.

The $10 billion telescope is gathering infrared light, which is invisible to the human eye. Those wavelengths will allow it to study everything from asteroids and comets in our solar system to planets orbiting other stars to the most distant galaxies in the universe. (See our wraparound cover and page 2 for some of the early JWST images.)

Fire Skirts Kitt Peak Observatory in Arizona

Assessment of damage from recent wildfires continues at Kitt Peak National Observatory, near Tucson. The observatory reports that only a dorm and three other support buildings were destroyed, but as of late July access to the observatory remained limited to staff and contractors due to safety concerns. "We are still in the important phase of working with our partners to assess our power situation and the needs of our sensitive instruments," according to a statement from the observatory's parent agency.

The site was affected by the Contreras Fire, which began on June 11 on a remote ridge of Arizona's Baboquivari Mountains, triggered by a lightning strike. Crews cleared trees and brush below Kitt Peak and around individual domes and other facilities to keep the fire at bay. By June 17, however, the fire had crested a ridge near several telescopes, and by the following day it had consumed almost 25,000 acres. Crews controlled the fire before it could destroy any of the telescopes, though. **MG**

'So Long' to SOFIA

After eight years of watching the stars, the Stratospheric Observatory for Infrared Astronomy (SOFIA) will be grounded by September 30. NASA and its partner in the project, the German Space Agency, concluded that the airborne observatory no longer meets their research goals.

SOFIA is a modified Boeing 747SP airplane. A nearly nine-foot infrared telescope is mounted in the rear of the plane. A large door opens to reveal the telescope when the aircraft reaches its cruising altitude. Operating out of Palmdale, California, SOFIA has logged an average of 980 observing hours per year since beginning science operations in 2014.

SOFIA completed its initial five-year mission in 2019 and is near the end of a three-year extension. But an evaluation by The National Academies Decadal Survey on Astronomy and Astrophysics 2020 concluded that its productivity doesn't justify its operating costs, nor do its capabilities significantly overlap with science priorities for the next decade and beyond.

SOFIA's discoveries have included identifying an unexpectedly high concentration of water molecules in the Moon's Clavius Crater. The discovery raised new questions about how water is created and how it persists on the harsh lunar surface. **MG**

Prepping for a Punch in the Nose

A NASA spacecraft is preparing to punch an asteroid in the nose. It will ram into the space rock on the afternoon of September 26 to see how the impact changes the asteroid's orbit around a larger companion. It's an early step in the effort to develop ways to protect Earth from an asteroid or comet on a collision course.

DART (Double Asteroid Redirection Test) launched last November. It's cruising toward a binary asteroid: Didymos, which is about a half mile (three-quarters of a kilometer) in diameter, and Dimorphos, which is about 530 feet (160 meters) in diameter. They're separated by an average distance of about two-thirds of a mile (one km).

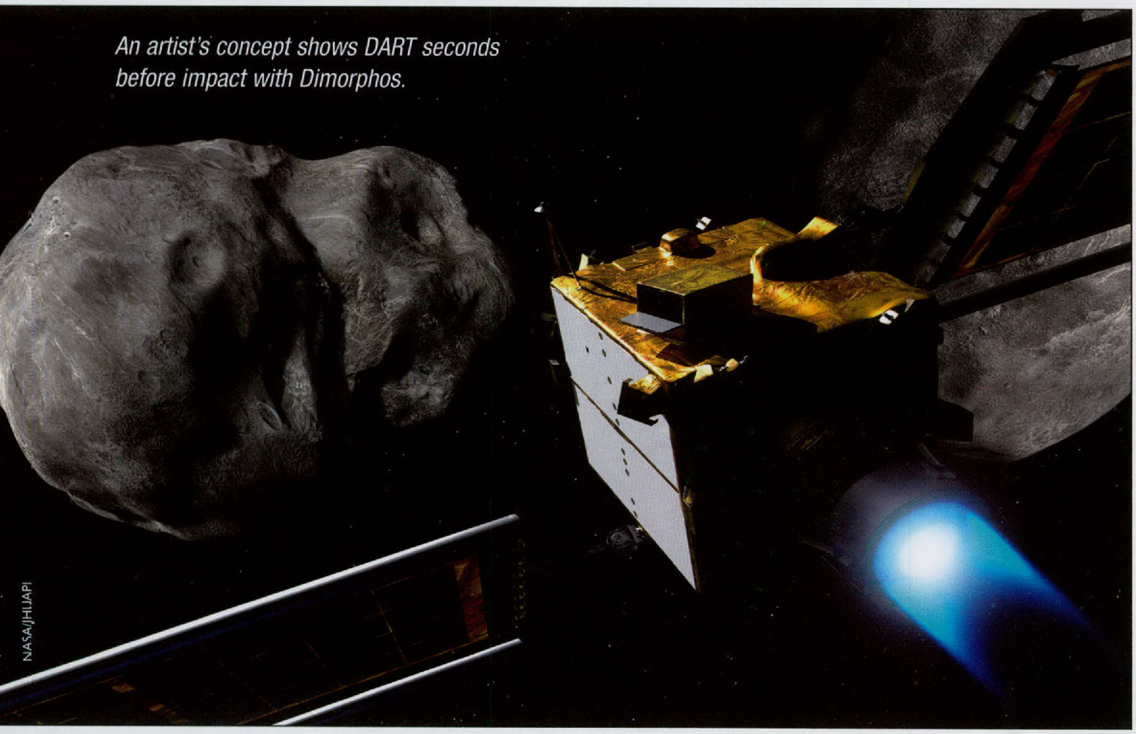
The spacecraft, which should weigh about 1,200 pounds (545 kg) at impact, will slam head on into Dimorphos at about four miles (6 km) per second. The collision should cause the asteroid to slow down a bit, bringing it closer to Didymos. Astronomers will watch the system for months to precisely measure the change.

The Didymos system stays outside Earth's orbit, so it's not a danger to our planet. Other asteroids, however, cross Earth's orbit, so they could someday slam into us. Astronomers have spent decades tracking down potential impactors, and although the effort is far from over, they have recorded almost 2,300 that are worth keeping an eye on.

Scientists and engineers also are working on planetary defense systems to deflect dangerous objects. Schemes suggested so far include painting an asteroid's surface to change the way it absorbs and radiates sunlight, having a heavy spacecraft fly along with it to function as a sort of tractor, or blasting it with nuclear weapons. With enough lead time, an impact *sans* nuke might push an asteroid off its collision course.

Dimorphos is a small target, so DART requires precise navigation. It won't get a good look at the asteroid until an hour or two before impact. As it gets closer, on-board software will refine its flight path, providing a head-on impact at the center of the asteroid. That will provide the largest possible change in Dimorphos's speed.

DART will deploy a small cubesat before impact to photograph the collision. The European Space Agency plans to launch another spacecraft, HERA, to fly through the system in late 2026. Its images will reveal how Dimorphos was changed by the impact and look deep into the scar, providing a look at the layers that record the asteroid's history. **DB**



An artist's concept shows DART seconds before impact with Dimorphos.

NASA/JHUAPL

Grounded

While DART readies for its asteroid encounter, another asteroid mission has been grounded until at least next year.

Psyche was scheduled to launch as early as August 1 to explore an asteroid of the same name. Psyche (the asteroid) is the largest member of the class known as metal-rich asteroids, which have a large percentage of iron and nickel. It's shaped like a potato, with an average diameter of about 140 miles (230 km). Scientists are especially interested in it because it could have formed as Earth did, so it could provide a peek into a planetary core that we can't get here at home.

Psyche (the spacecraft) was delayed because its flight software was not ready. With a launch in 2023, Earth and the asteroid would be farther apart, so Psyche would reach Psyche in 2029—three years later than planned.

Getting Off the Ground

Meanwhile, the European Space Agency has given the go-ahead to build Comet Interceptor, which could launch as early as 2029. It would enter a parking orbit, then wait for the right target to come along.

Previous missions have intercepted comets that had passed through the inner solar system many times before. Such comets are altered by their close passages to the Sun, with much of their ice and dust streaming away into space.

Comet Interceptor would wait for a comet that had never passed close to the Sun before—perhaps from the edge of the solar system. The probe might even target an object from outside the solar system that was just passing through. Astronomers have discovered two such objects in recent years.

McDonald Observatory Education and Outreach

What Stars Here – Changes the World

The Frank N. Bash Visitors Center at McDonald Observatory welcomes more than 75,000 visitors per year. It offers exhibits, a theater, a classroom, and an outdoor telescope park where we bring the wonders of the universe to visitors of all kinds, including school groups!

Though state-of-the-art when it opened in 2002, a lot of science happened since then. It's time for an update. And we've made a start: a brand-new Preserving Dark Skies exhibit opened in April, funded by Apache Corporation.

We're now planning new exhibits across the site to bring the story of the astronomical explorations that happen here up to date. Your gift can help make these plans a reality!

WHAT STARS HERE – STARTS WITH YOU

mcdonaldobservatory.org/support

The new Preserving Dark Skies exhibit features an immersive, multiple screen display showing a custom-made film that highlights the effects of light pollution on night skies and our efforts to reduce that impact.

Hot young stars are destroying their birthplace, the Carina Nebula, in this early image from James Webb Space Telescope. The nebula, 7,600 light-years away, has given birth to thousands of stars, and many more are being born today. Energy and winds from some of the most massive stars are eroding what remains of the nebula. Dense knots of material resist this erosion, forming tall pillars. This image was shot at infrared wavelengths, with different colors assigned to each wavelength.

NASA/ESA/CSA/STScI