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ASTRONOMERS FROM ANTIQUITY
PAGE 4

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NASA/AMES/JPL-CALTECH/T. PYLE

On The Cover

Artist's concept of Kepler-62f, the smallest planet the Kepler spacecraft has found orbiting in a star's habitable zone. Kepler's mission recently ended, but its successors will continue to probe exoplanets for their secrets. For more, see Page 16.

This Page

Hydrogen gas glows red in the Ghost Nebula, seen by Hubble Space Telescope 550 light-years away in the constellation Cassiopeia. The gas is heated by blasts of ultraviolet radiation from the nearby blue giant star Gamma Cassiopeiae (not shown), which is 34,000 times more powerful than the Sun.

Coming Up

Our May/June issue brings you excerpts from new books in astronomy and space science to spice up your summer reading. We'll also bring you summer skywatching notes and charts, Merlin's answers, and more.

Dear Merlin,

Celestial bodies (planets, asteroids, comets, etc.) obey the laws of gravitational physics. Is it possible to have a celestial object that travels askew to the gravitational forces of the solar system — something that plays by rules that transcend our local forces?

Bill Dockery
Knoxville, Tennessee

Following the laws of physics isn't just recommended, it's required. There is no way for any object to break those laws. That's a comforting thought, because otherwise scientists would have no way of knowing where any object was going, so they might never know if an object endangered Earth.

Having said that, Merlin will add that the motions of objects in the solar system can be affected by objects outside the solar system. A passing star, for example, can stir up the Oort Cloud, which is a vast shell of comet-like bodies that extends a light-year or more from the Sun. These objects can get enough of a push to fall toward the Sun, where they could possibly run into Earth or another body.

Such encounters strictly follow the laws of physics, however — no cheating allowed!

Dear Merlin,

As I understand black holes, they tend to exist in the centers of galaxies, and that nothing (even light) can escape their gravita-

tional force. Presumably they continue to draw in matter (and grow larger and gravitationally stronger) until all the nearby matter is absorbed. Is it possible, then, that the galaxies we observe — billions of light-years distant, and therefore billions of years in the past — have been consumed by a giant black hole and no longer even exist in our time frame?

Owen Daniel
Fort Worth

Possible, but highly unlikely. Black holes in the centers of galaxies can grow to monstrous proportions. The largest yet measured top 10 billion times the mass of the Sun, which certainly produces a powerful gravitational pull.

Yet several things conspire to prevent a black hole from devouring its entire host galaxy. For one thing, as a black hole "feeds," it surrounds itself with a spinning disk of gas. As the gas gets closer to the black hole it moves faster, so it produces friction. That heats the gas to millions of degrees, so it produces a lot of radiation. The radiation produces pressure that pushes away the material that's trying to fall toward the black hole. That acts as a tidy regulator, preventing the black hole from overindulging. (The outward-moving pressure also can cause clouds of gas around the black hole to collapse and



give birth to new stars.)

Also, keep in mind that while 10 billion solar masses is a lot, it's insignificant compared to the mass of a major galaxy. The Milky Way, for example, has a mass of more than a trillion Suns, and its disk spans 100,000 light-years or more. All of that material exerts its own gravitational pull, keeping stars and gas clouds from falling toward the central black hole.

So while astronomers can't be sure that black holes haven't sucked up their entire galactic homes, they know that it's not likely.

Dear Merlin,

Why is Planet 9 so difficult to track down, especially if it is as large as presumed? Is it too far away from the Sun? Would it be found on the ecliptic with the other planets?

Corrin Gani
Austin

Astronomers have inferred the presence of Planet 9 from the alignment and motions of a group of iceballs outside the

Kuiper Belt, which is a doughnut-shaped region beyond the realm of the major planets. The calculations aren't precise enough to pinpoint the possible planet's location, though, so astronomers must scan large regions of the sky — far from the ecliptic — to try to find it.

Even though the planet is estimated to be several times Earth's diameter, it is hundreds of times farther from the Sun than Earth is, so sunlight would be only a tiny fraction as strong as at Earth. It the planet is at its farthest projected distance, in fact, sunlight would be less than one-millionth as strong as at Earth, which means there would be little to illuminate it. Objects in that part of the solar system typically are darkened by long exposure to cosmic radiation, too, so a possible Planet 9 would be quite dark.

The planet might shine brighter in the infrared, but still would be a faint target. So, as with the discovery of Pluto almost a century ago, if Planet 9 exists it will take a lot of patient searching to find it.



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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POETS, PHILOSOPHERS, QUEENS, ASTRONOMERS

Early women astronomers drafted calendars, plotted eclipses, built observatories, and helped shape humanity's early understanding of the universe

By Jasmin Fox-Skelly



Visitors check out Cheomseongdae, the observatory created by Sonduk. Opposite page, from left: Sonduk; a modern depiction of Hypatia

TOP: BIN/WIKIPEDIA; LEFT: PAGE, FROM LEFT: WIKIMEDIA, NASA/CXRO/CFR

Henrietta Swan Leavitt helped make the expanding universe possible. She discovered that a class of bright pulsating stars made perfect “standard candles” for determining the scale of the universe: Measure such a star’s maximum brightness and the length of its pulses and you could determine its distance. Edwin Hubble used those stars to discover that swirling, spiral-shaped motes of matter are far outside the Milky Way galaxy, greatly increasing the size of the known universe. He also used them as a first step in determining that the universe is expanding.

Leavitt’s discovery helped revolutionize humanity’s concept of the universe. She wasn’t the first woman to do so, however. History is full of examples of female astronomers whose work changed the way we think about the cosmos. In fact, some of the very first astronomers were female, and women have been studying the stars since antiquity. From the ancient Greeks, Romans, Egyptians, and Sumerians, here are the stories of some of the earliest women astronomers.

EN HEDU’ANNA

En Hedu’anna was a princess who was born about 4,300 years ago in Sumer, part of the historical region of southern Mesopotamia, which is part of modern-day Iraq. Her father, King Sargon of Akkad, united the cities of northern and southern Mesopotamia and established a mighty empire. To help consolidate his power he appointed his daughter as head priestess of the temple of the Moon goddess in the city of Ur.

En Hedu’anna’s job involved deciding when crops should be planted and harvested and when important religious festivals should take place. To do this, she observed the Moon and tracked its position across the sky

throughout the year, allowing her to create a lunar calendar. She also likely recorded the seasons and the position of the Sun.

“The term ‘scientist’ did not come into general use until the mid-19th century,” says Sethanne Howard, an astronomer and author of the book *The Hidden Giants*, which tells the story of more than 4,000 years of women in science, technology, engineering, and mathematics. “Instead, scientists were known as astronomers/mathematicians, philosophers, or priestesses.

“En Hedu’anna controlled the extensive agricultural enterprise surrounding the temple as well as religious activities scheduled around the year. Her calendar was based on track-

ing the Moon, which means building a table that plotted the phase and position of the Moon at various times of day throughout the month. It could then be used to forecast crop planting and harvesting dates.”

According to Howard, it is from the work of these early astronomers that modern religious calendars developed. For example, we date Easter, Passover, and Ramadan using work derived by the ancient Sumerians.

En Hedu’anna is perhaps most famous as the first known poet in history, earning her the title of the “Shakespeare of Sumeria.” Like other Sumerian writings, her poems were imprinted on damp clay tablets, which were left to harden in the sunlight. Many of

An ancient Sumerian disk depicts En Hedu’anna (third figure from right).



these still survive, including three long poems to the goddess Inanna, three poems to the god Nanna, and 42 temple hymns that can be found in translation today. The most famous tablet, honoring Inanna, is at the University Museum in Philadelphia.

Many of her writings allude to her work studying the Moon and stars. For example, in one hymn she writes:

*In the gipar the priestesses' rooms
that princely shrine of cosmic order
they track the passage of the moon.*

Another reads:

*The true woman who possesses
exceeding wisdom,
She consults a tablet of lapis lazuli
She gives advice to all lands...
She measures off the heavens,
She places the measuring-cords on
the earth.*

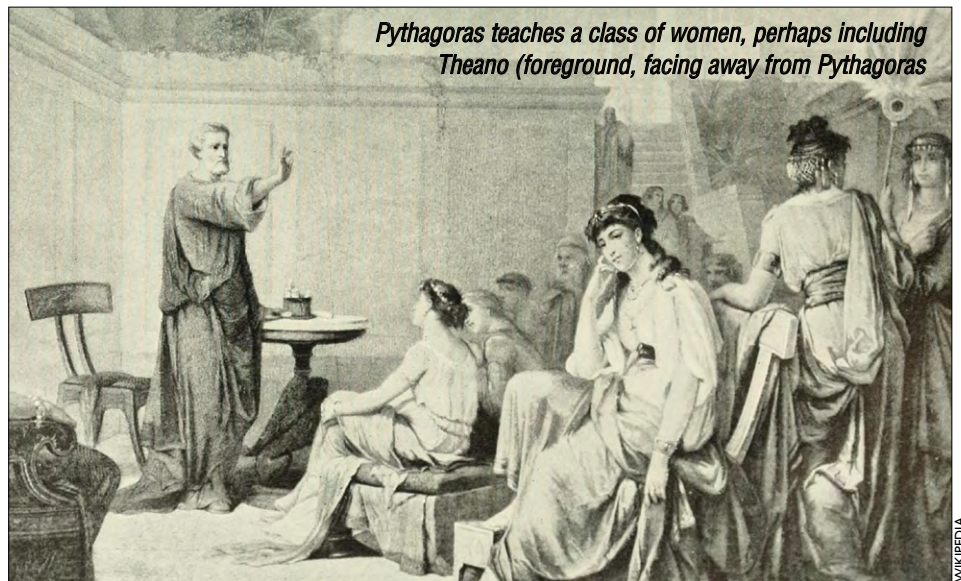
“This poem describes the work of a scientist and leader,” says Howard. “To measure off the heavens is to engage in astronomy, whilst to measure the Earth requires surveying skills as well as astronomy. These are all technical subjects requiring great skill to accomplish.”

En Hedu’anna was the first in a long line of Sumerian astronomer-priestesses, of whom little is known. Her achievements are especially remarkable considering that she lived and worked 2,000 years before the Golden Age of Greece and just 900 years after writing had been invented.

THEANO

To find the next female astronomer of whom anything is known, fast forward to circa 546 BC and the ancient Greeks. One of the scientific leaders of the era was Pythagoras, a philosopher who founded a movement of political and religious teachings and calculated the numerical constant pi, which, among other things, can be used to calculate the area of a circle. However, few know that his wife, Theano, also was an accomplished astronomer and mathematician. After her husband’s death she supposedly led his followers, the Pythagoreans.

Theano reportedly wrote many texts on medicine, physics, mathematics, and psychology, and was especially interested in issues related to children.



Pythagoras teaches a class of women, perhaps including Theano (foreground, facing away from Pythagoras)

WIKIPEDIA

She wrote books entitled *Cosmology*, *The Theorem of the Golden Mean*, *The Theory of Numbers*, and *The Construction of the Universe*. She also wrote a biography about her husband, *Life of Pythagoras*.

Theano theorized that the universe consists of 10 concentric spheres, which held the Sun, Moon, Saturn, Jupiter, Mars, Venus, Mercury, Earth, an unseen counter-Earth, and the stars.

AGLAONICE

Around the time that Greek astronomers first used geometry to predict that Earth was round, Aglaonice, the daughter of Hegetor (or Hegemon) of Thessaly, was using her observations of the phases of the Moon to master the art of predicting lunar eclipses. In fact, not only did she predict the times of lunar eclipses, she also calculated their degree of brightness. She was said to be able to predict when an eclipsed Moon would completely disappear — a trick she used to her advantage when convincing people that she could command the Moon.

Total “blackouts” of the Moon, in which the eclipsed lunar disk turns completely black instead of orange or red, are almost unheard of, and have sometimes been attributed to volcanic dust spewing from an eruption. However, historical records show that there were no such eruptions during Aglaonice’s time, making it a mystery as to how the sky became so dark that people believed the Moon had disappeared. In a paper in the 1980s, Peter

Bicknell, a classical scholar at Monash University in Victoria, Australia, theorized that Aglaonice’s disappearing Moons could have occurred during a solar cycle that is different from its well-known 11-year cycle of increasing and decreasing magnetic activity.

Whatever the case, Aglaonice is written about in a number of ancient Greek texts. In the book *Instructions for Married Couples*, written around the end of the first century AD, Plutarch, a renowned biographer and essayist, writes:

“Aglaonice the daughter of Hegetor



A modern-day artist's impression of Aglaonice

ALZINOUS/WIKIMEDIA

being thoroughly conversant with the periods of the Full Moon when it is subject to eclipse, and knowing beforehand when the moon was due to be overtaken by the Earth's shadow, imposed upon audiences of women and made them all believe that she drew down the Moon."

In fact, Aglaonice was so famous in her time that she was the subject of an ancient Greek proverb, "as the Moon obeys Aglaonice." It's likely that she was seen as a sorceress, and later authors referred to her and other female astronomers of the period as the "witches" and "enchantresses" of Thessaly.

HYPATIA

Perhaps the most famous female astronomer of ancient times was Hypatia, who was born in Alexandria, Egypt, which at the time was controlled by Rome. Although still a center of culture and learning, by the time Hypatia was born, sometime between the years 350 and 370, the city was in decline. Its famous library, home to half a million scrolls, had been burned down (although it was rebuilt). By 364, the great Roman Empire had split in half, and fighting had broken out between Alexandria's Christians, Jews, and pagans.

Hypatia was the daughter of Theon, the last known member of Alexandria's university (which was associated with the library) and a mathematician and astronomer. Hypatia continued her father's work and taught philosophy, math, and astronomy. Her lectures were well attended, and people traveled from great distances to hear her talk.

The philosopher Damascius wrote after her death: "Donning [the robe of a scholar], the lady made appearances around the center of the city, expounding in public to those willing to listen on Plato or Aristotle."

Hypatia was one of the last great thinkers of ancient Alexandria, and wrote commentaries on such famous classical works as Diophantus' *Arithmetica*, an ancient Greek text on mathematics and algebra. Other texts that she wrote commentaries about include Euclid's *Elements*, a mathemati-

cal treatise considered by some to be the most influential textbook ever written, and Book III of Ptolemy's *Almagest*, which described the movements of the stars and planets and suggested that the Sun revolves around Earth — a model of the universe that wouldn't be overturned until the time of Copernicus and Galileo.

Hypatia also taught students, including a man named Synesius. Much of what we know about her comes from letters between the two. These letters include instructions on how to construct an astrolabe — a sort of portable astronomical calculator that can keep track of the Sun, Moon, and stars.

Hypatia never married, although the *Suda Lexicon*, a Byzantine 10th-century encyclopedia of the Mediterranean world, describes her as being "exceedingly beautiful and fair of form ... in speech articulate and logical, in her

actions prudent and public-spirited, and the rest of the city gave her suitable welcome and accorded her special respect."

One man with whom she developed a particularly close friendship was the governor of Alexandria, Orestes. Unfortunately for Hypatia, though, her association with him would lead to her gruesome death.

Hypatia lived in an era of extreme religious and sectarian conflict. The archbishop of Alexandria, Cyril, was particularly intolerant of other faiths.

A power struggle broke out between Cyril and Orestes, with Hypatia caught in the middle. The conflict between them peaked after Cyril led a mob that expelled the Jews from the city and ransacked their homes and temples, which followed the massacre of a group of Christians by Jewish extremists. Orestes complained to the Roman



An illustration of the 1893 play 'Hypatia,' based on an 1853 novel. Hypatia's life has been depicted in many books, plays, and movies, including the 2009 film *Agora*.

government in Constantinople, which led to a rift between the two men. When Orestes refused Cyril's attempts at reconciliation, Cyril's monks tried unsuccessfully to kill him.

Unfortunately for Hypatia, a rumor spread that she was preventing Orestes and Cyril from reconciling. As a pagan who publicly spoke about non-Christian ideas, she was an easy target, and in the year 415 or 416, a mob of Christian fanatics led by Peter the Lector dragged her from her carriage into a church, where they stripped her, beat her to death, tore her body apart, and burned it.

Alexandria's university and library were burned not long afterward, ending the city's long reign as one of the world's leading centers of learning and science.

QUEEN SONDUK

The final female astronomer on our list is Queen Sonduk, the first female ruler of the Korean Buddhist kingdom known as Shilla, who ascended to the throne in 632. She had developed a keen interest in the stars as a child, but was prevented from studying astronomy because women were seen as subordinate to men, and education for girls was considered improper. When she was 15, it is rumored that Sonduk asked the Chinese ambassador, Lin Fang, who was also an astronomer, to teach her more about the universe. He reportedly replied, "Surely you cannot imagine that I would converse on such a serious subject with a young lady? It would be unnatural and wholly against the laws of propriety."

The relationship between Sonduk and Lin Fang deteriorated further when Lin Fang convinced the king to introduce a new official calendar based on the Chinese Sui calendar. After Sonduk correctly predicted when a solar eclipse was to occur, an event missed by the official calendar, the ambassador became angry and reportedly said, "Astronomy is not for women. Go do something female like look after silkworms."

The king consequently forbade Sonduk to study astronomy. At the age of 15, in a message she placed in her grandmother's ancestral jar, Sonduk



Queen Sonduk

wrote: "Will we ever know the truth about the stars? I am too young to venture a theory about our universe. I only know that I want to understand more deeply. I want to know all I can know. Why should it be forbidden?"

After she became queen, Sonduk created Cheomseongdae ("tower of the stars"), an observatory that was built according to her design. The milk bottle-shaped tower, which is about 30 feet tall, was constructed from 365 stones, one for each day of the year. Observations of the Sun and Moon probably helped determine the planting and harvesting seasons, while observations of the stars, which were important to astrology, would have had important political significance. The observatory is still standing — the oldest surviving astronomical observatory in East Asia.

These five examples show that despite facing incredible obstacles, women have shared the exciting world of science with men from the beginnings of written history, making important contributions to humanity's ever-increasing knowledge of the universe.

Jasmin Fox-Skelly is a science writer in Cardiff, Wales, and a previous contributor to StarDate.

RESOURCES

BOOKS

The Unforgotten Sisters: Female Astronomers and Scientists before Caroline Herschel, by Gabriella Bernardi, 2016

The Hidden Giants: 2nd Edition, by Sethanne Howard, 2013

Hypatia of Alexandria: Mathematician and Martyr, by Michael A.B. Deakin, 2007

Hypatia: Her Life and Times, by Faith L. Justice, 2013

Hypatia: The Life and Legend of an Ancient Philosopher, by Edward J. Watts, 2017

INTERNET

Women Astronomers Through History
adsabs.harvard.edu/full/2008POBeo..85..207D

Theano
www.agnesscott.edu/lriddle/women/theano.htm

Hypatia of Alexandria
<http://www-history.mcs.st-andrews.ac.uk/Biographies/Hypatia.html>

Hypatia, Ancient Alexandria's Great Female Scholar
www.smithsonianmag.com/history/hypatia-ancient-alexandrias-great-female-scholar-10942888

Hypatia of Alexandria: The Passing of Philosophy to Religion
www.ancient.eu/article/76/hypatia-of-alexandria-the-passing-of-philosophy-to

The Unforgotten Sisters: Sonduk, the astronomer queen
cosmosmagazine.com/space/the-unforgotten-sisters-sonduk-the-astronomer-queen

Queen Seondeok
www.ancient.eu/Queen_Seondeok

UNESCO: Cheomseongdae Observatory
www3.astronomicalheritage.net/index.php/show-entity?identity=19&idsubentity=1

Spring has sprung, and its stars are making their move into prominence. Regulus, Leo's bright heart, is moving high across the south. Spica, shining in Virgo, rises high by March's end. In April, look for the Moon and Mars to stage appearances alongside Taurus, the bull, and its bright eye Aldebaran.

MARCH 1 - 15

Is a planet ever unwelcome? When Mars is in the evening sky, it's always that guest who just stays and stays. And, like the inebriated life of the party who never gets the message, Mars just keeps turning dimmer and less interesting.

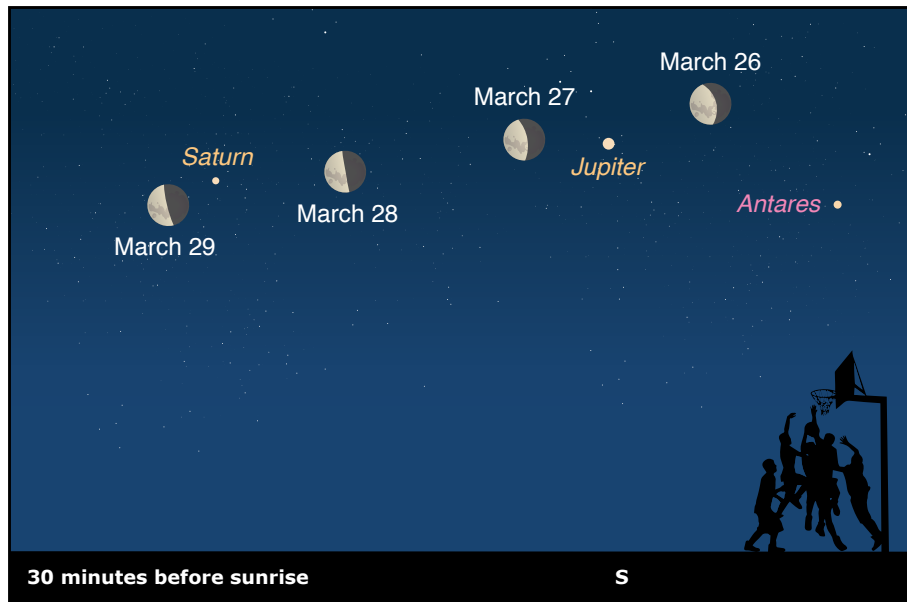
Last summer, the Red Planet was the night-life dazzler, attracting everyone's attention with its closest, brightest opposition in 15 years. Those days are gone, but Mars isn't. It remains high in the west in early evening, a mediocre remnant of its former self.

Why does Mars always do this? The situation is not caused by Mars itself, but by our viewing platform from the moving Earth. We're the next planet closer to the Sun, and not by very much as solar-system distances go. So, after opposition, Mars moves along its orbit only a little slower than Earth does on its. This means that compared to the other outer planets, Mars takes a long time to fall behind us in its orbit.

Here's another way to view the situation. Mars' fast motion eastward against the evening constellations, from our viewpoint, partly counteracts

the seasonal westward turning of the constellations as Earth goes around the Sun.

But by now we've far outrun Mars and left it in the distance, small and faint. So in early March, as we see it crossing Aries, it's a paltry magnitude +1.2 (paltry for a naked-eye planet). And in a telescope it looks like a tiny, disappointing little blob.



Spot it in the west after dark. It's the brightest point below the Pleiades. As always, its fire-orange color helps to give it away. The waxing crescent Moon hangs under it on the evening of March 10 and to the left of it on the 11th.

Sirius shines much brighter in early evening in the south. The star sparkles white with 12 times as much light (at magnitude -1.5) as Mars. At

the height of the planet's ostentatious display last summer, it was three times brighter than Sirius!

Look to the upper right of Sirius for Orion. Procyon shines to Sirius' upper left. Betelgeuse, Orion's Mars-colored shoulder, teams up with Sirius and Procyon to form the Winter Triangle, showy and equilateral.

Leo stands high in the east to southeast, with Regulus as his modestly bright forefoot. Leo's Sickle asterism extends to the upper left from Regulus.

And since it's now almost spring, the Big Dipper stands on its handle high in the northeast as soon as the stars

MARCH 16 - 31

Sirius, brightest spark of the evening sky, now shines due south as the stars begin to come out. How early can you spot Sirius in the fading light of day? Face south. To tell how high to look, subtract your latitude from 73 degrees. For example, Austin is at latitude 30 degrees. So at Austin you'll find Sirius 43 degrees above horizontal when it's due south.

And how high is that? For most people, your fist at arm's length is about 10 degrees tall. That's a good enough measuring tool to get you close.

Sirius is the brightest star of Canis Major, the big dog. More of the constellation comes into view as night arrives. Look for Murzim 5 degrees to Sirius' right. Its name means "The Announcer;" Murzim always precedes Sirius across the sky, like a herald clearing the way for the king.

Look about 10 degrees below Sirius, and a bit to the left, for the triangle of the dog's hind-quarters and tail-tip. These four stars plus Sirius form a big-bladed meat cleaver with a short handle at the bottom; Sirius is a sparkle on the cleaver's top back corner.

With the arrival of deep night in an un-light-polluted sky, the full stick figure of Canis Major comes into view. He's seen in profile, prancing on his hind feet. Sirius is a shiny dog tag on his chest, Murzim is his forefoot, and

come out.

For early risers, three planets await in early dawn. Jupiter dominates the south as morning twilight begins, with Antares and the head of Scorpius to its right. Look two or three fists to Jupiter's lower left for Saturn, dimmer and yellowish. Follow this line farther to the lower left and you hit bright Venus, lower every morning.

Meteor Watch



The Shower

Lyrids

Peak

Night of April 22

Notes

The Lyrids are modest, with around one or two dozen meteors per hour at best. The Moon climbs into view before midnight and is about 90 percent full, so it will wash out most of the meteors.

his faint, pointy-nosed head is a long triangle to Sirius' left and upper left. The stick figure becomes obvious once you know it.

Now that winter is turning to spring, Orion tips southward, to the right of Sirius as soon as night is fully dark — and Orion's Belt is in its horizontal springtime orientation. The belt points to the left, back to Sirius, and a little farther to the right, toward Aldebaran in Taurus.

Look to the lower right of Aldebaran for Aldebaran-colored Mars. How closely, to your eyes, do their colors match? To me, the tint of Mars looks just a trace deeper orange.

APRIL 1 - 15

Mars remains in the west during and just after twilight, as it will continue to do through May. But now it has an interesting partner. You may have noticed the Pleiades cluster descending toward it for

the last several weeks. By April 1, the Pleiades is passing a couple of finger widths to Mars' right. The cluster moves down to the lower right thereafter.

Look to the left of Mars for Aldebaran, slightly brighter. On the evening of April 8, the waxing crescent Moon hangs under the arc of Mars, Aldebaran, and the Pleiades. On the 9th, the Moon poses above Aldebaran.

With the coming of April, Arcturus, "the spring star," twinkles in the east. Spica, not quite as bright, is well off to its right or lower right. If you live as far south as Miami, you'll find Arcturus and Spica equally high. Farther north of there your eastern horizon is tilted differently with respect to the stars, so Arcturus appears higher.

High to the upper left of Arcturus, in the northeast, the Big Dipper is starting to turn over to dump April showers. The dipper's curving handle arcs back toward Arcturus.

The dipper handle can also guide you to a lesser-known sight. If you picture the handle and the side of the dipper bowl that it's attached to as a segment of a (very rough) circle, then near the circle's center is modestly bright Cor Caroli, a grand yellow-and-violet double star in a telescope. It's in the dim constellation Canes Venatici, the hunting dogs.

And the star at the bend of the dipper's handle, Mizar,

is perhaps the most famous double star for amateur telescopes, though its components are a less interesting icy white.

APRIL 16 - 30

The Arch of Spring is forming up nicely high in the west. Pollux and Castor, nearly horizontal, form its top. The south end of the Arch is Procyon, to their lower left. The other end, farther flung to their right, consists of Menkalinan (Beta Aurigae) and Capella.

The Arch of Spring is the last, trailing half of the even bigger Winter Hexagon. But not all the other Hexagon stars are yet gone. Sirius sparkles brightly, low in the southwest, for a while during and after twilight. From there, look to the right for Orion with his horizontal belt. Can you still spot Rigel down under the belt? Continuing to

down when you face north.

Look below the Big Dipper for the much dimmer Little Dipper. It's highlighted only by Polaris, its handle-end on the left, and the two stars forming the end of its bowl on the right: Kochab and Pherkad, the "Guardians of the Pole," forever circling Polaris.

If you have an open horizon to the north, look low on the other side of Polaris from the Big Dipper for the dipper's eternal opposite: W-shaped Cassiopeia, lying low for the warm season.

Turn around. Look high overhead in the south for Leo. We see the lion in profile, stalking westward, with its tail-star Denebola on the left and the Sickle pattern forming the lion's head, mane, and forequarters on the right.

Leo always announces spring. Now that spring is

Springing a New Season

Spring begins in the northern hemisphere at 4:58 p.m. CDT March 20 as the Sun crosses the equator heading north. For many of us in modern times, that moment, the spring equinox, is little more than a notation on the calendar. But to many cultures in bygone centuries, it was a time for celebration, as the Sun warmed the earth and banished the long, cold nights of winter.

the right from the belt, you come to Aldebaran, now with Mars above or to its upper right.

Meanwhile, the Big Dipper is assuming its highest position after dark, floating upside

here, he's already walking westward on his way to departing into the sunset come summer.

Alan MacRobert is a senior editor of Sky & Telescope.

MARCH	6		10:04 am	14		5:27 am	20		8:43 pm	27		11:10 pm
	APRIL	5		3:50 am	12		2:06 pm	19		6:12 am	26	

Moon phase times are for the Central Time Zone.

MARCH

How to use these charts:

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

February 20

11 p.m.

March 5

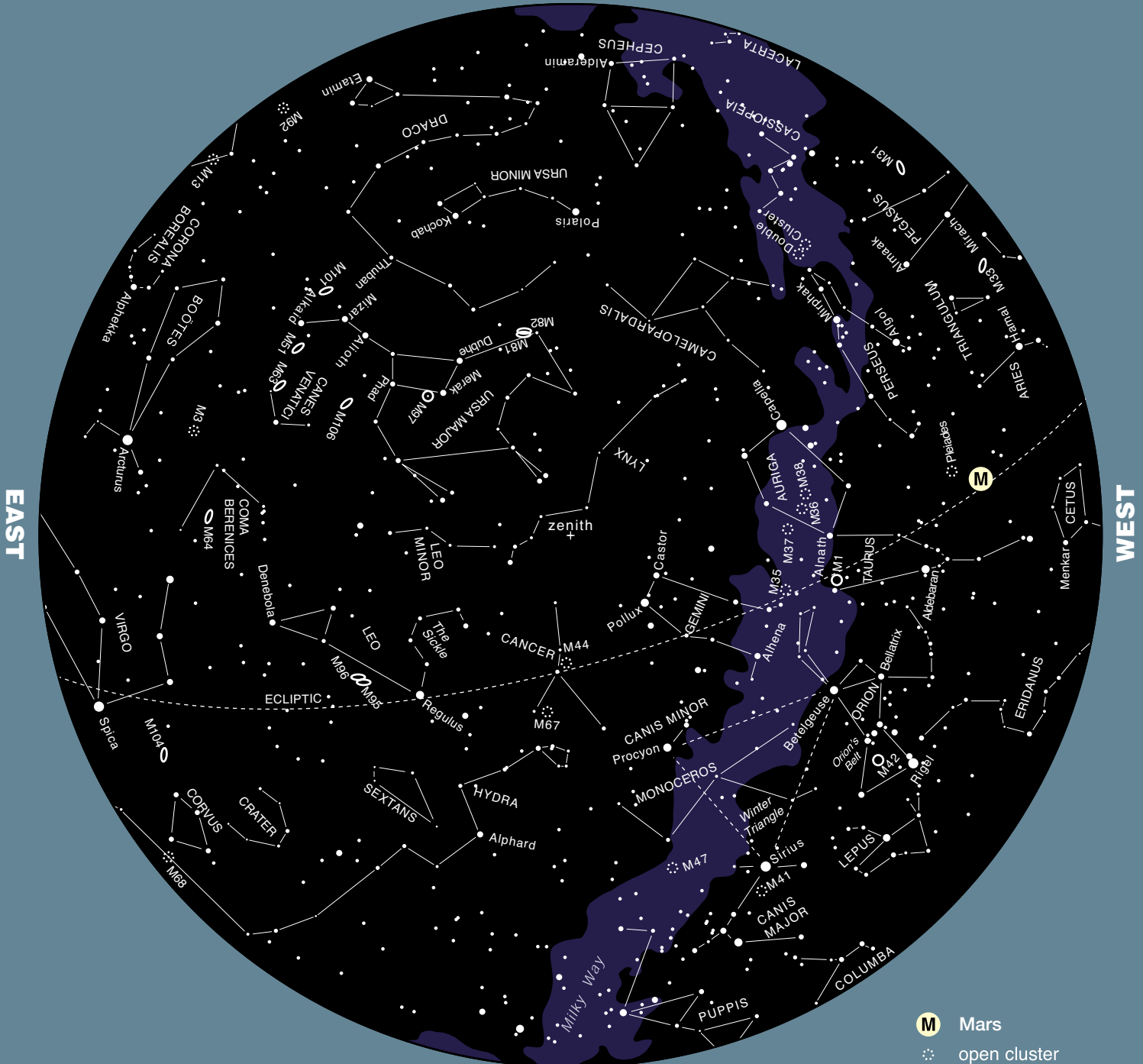
10 p.m.

March 20

8 p.m.*

* Daylight Saving Time begins March 10.

NORTH



MAGNITUDES

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

- M** Mars
- ☉ open cluster
- ☼ globular cluster
- ☽ nebula
- ☾ planetary nebula
- ☿ galaxy

APRIL

How to use these charts:

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

March 20

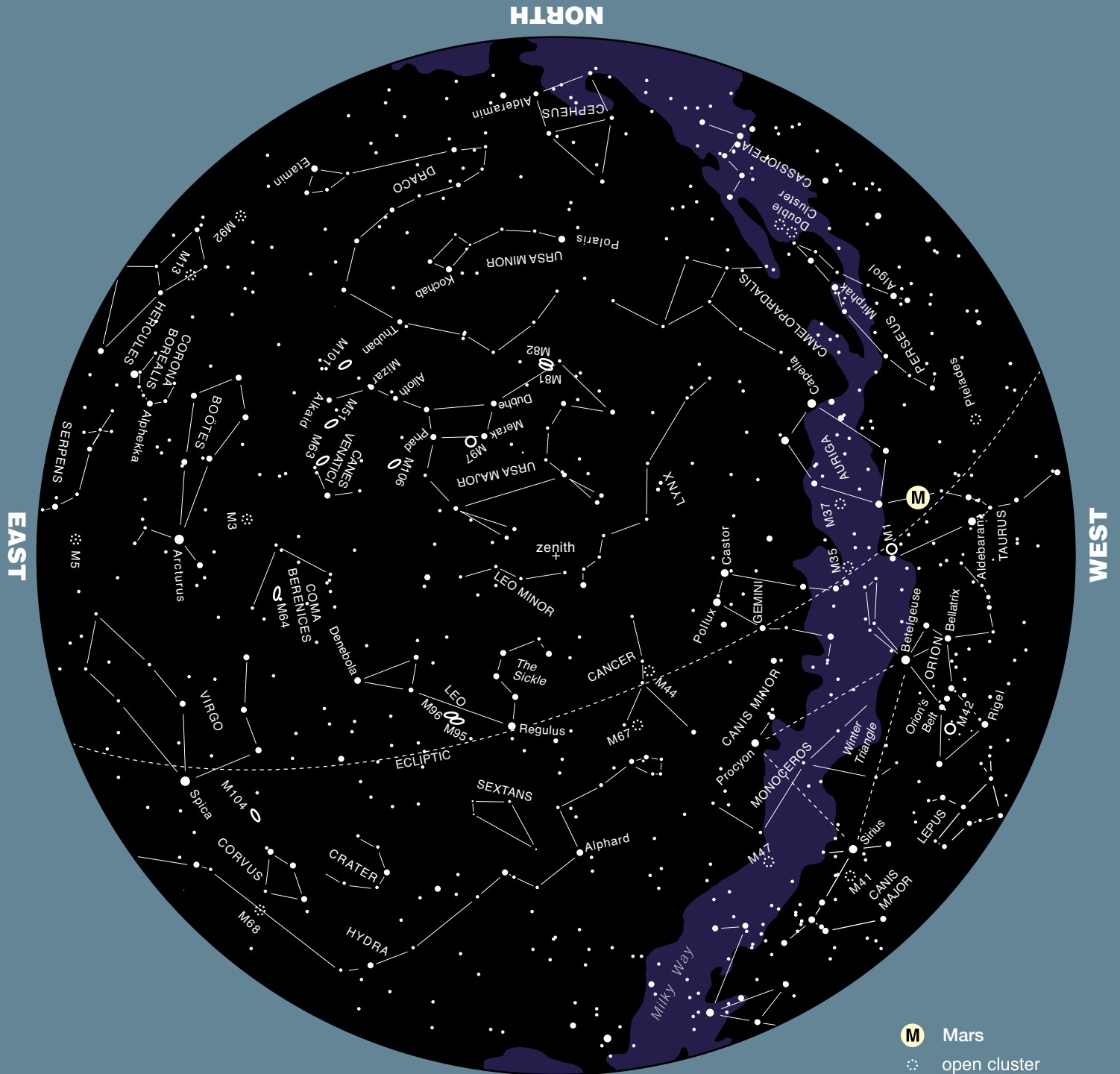
April 5

April 20

11 p.m.

10 p.m.

9 p.m.



MAGNITUDES

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

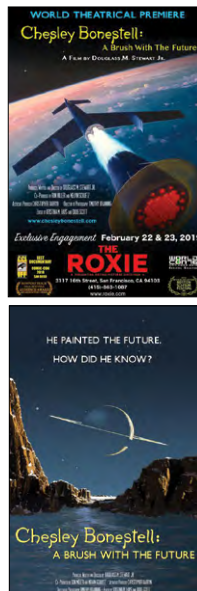
- M Mars
- ⊙ open cluster
- ⊙ globular cluster
- nebula
- planetary nebula
- galaxy

Picturing a Destiny in Space

Until Surveyors and Mariners and Voyagers began beaming back close-range pictures of the worlds of the solar system, most Americans saw the Moon, Mars, and other worlds through the eyes of Chesley Bonestell, an architect, designer, and artist.

Bonestell and his work are profiled in a documentary that will appear at several venues this year. "Chesley Bonestell: A Brush With the Future," chronicles his career and his influence on space exploration.

Bonestell began painting depictions of the Moon and planets, rockets, and other space-related subjects in the 1930s. His work appeared in magazines and books and in "War of the Worlds," "Destination Moon," and other classic sci-fi movies. He



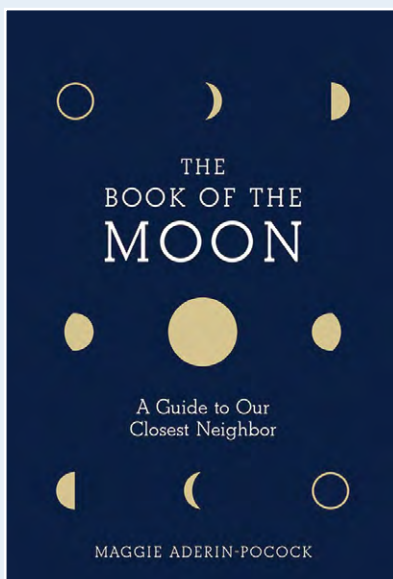
teamed with rocket pioneers Willy Ley and Wernher von Braun to publish a book and a series of magazine articles that showed how humans could expand into the solar system.

The documentary, which premiered last year, includes clips of Bonestell himself, as well as interviews with rocket scientists, filmmakers, artists, and other notables, who discuss his influence on our concept of worlds beyond our own.

UPCOMING SHOWINGS:

- March 24 The Filoli Estate, Woodside, California
- March 27-31 Sonoma International Film Festival
- April 23 Mount Diablo Astronomical Society, Walnut Creek, Calif.
- July 18 Wings Over the Rockies Museum, Denver

www.chesleybonestell.com/home.html



The Book of the Moon
A Guide to Our Closest Neighbor
By Maggie Aderin-Pocock
Penguin Books, \$24.99 (April 1)
www.abramsbooks.com/product/book-of-the-moon_9781419738494

Getting to Know the Moon Bit by Bit

More than 30,000 years ago, the Aurignacians, the earliest modern humans in present-day Europe, notched a series of holes and crescents in a short segment of eagle's bone. The bone was discovered in the early 20th century at Abri Blanchard, a rock shelter in France. Decades later, an archaeologist concluded that the notches represented the phases of the Moon, and that the bone was the earliest known lunar calendar.

People have been recording the Moon ever since, on walls, mountainsides, canvases, video screens, and especially paper. One of the latest is *The Book of the Moon: A Guide to Our Closest Neighbor*. Written by Maggie Aderin-Pocock, a scientist and host of BBC television's weekly

Sky at Night, it is a compendium of just about every Moon-related topic.

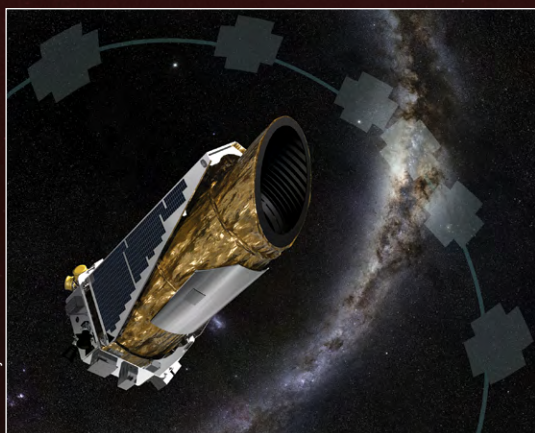
Aderin-Pocock talks about observing the Moon, the history of moonwatching (including the Abri Blanchard calendar), the Moon in folklore and science fiction, the history of lunar exploration, lunar science, and the possible future commercialization of lunar resources, from water and solar power to helium-3, a possible fuel for nuclear fusion reactors.

Although each section is brief, it provides a thorough overview of each topic without getting bogged down in too much detail. So readers can learn about everything from moonquakes to H.G. Wells to lunar volcanism to werewolves in a quick, easy package.

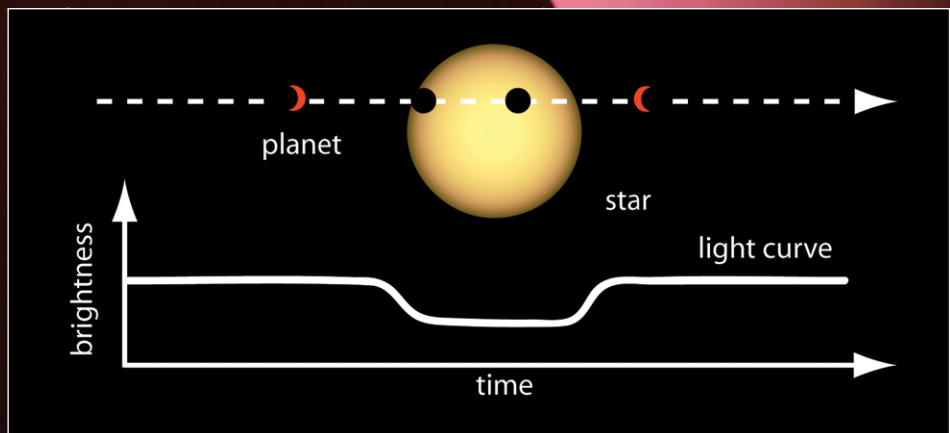
KEPLER PASSES THE TORCH

As a successful planet-hunting spacecraft came to the end of its mission, a successor took flight. Several others are expected to follow in the next decade


By Rebecca Johnson



NASA/AMES/JPL-CALTECH/T. PYLE



NASA/AMES



On October 30, NASA announced that its premier planet hunter, Kepler, had run out of fuel and could no longer conduct science. A few weeks later, the agency sent its final commands to the spacecraft, severing its communication link with Earth. Kepler's mission ended on November 15, 388 years to the day after the death of its namesake, the astronomer Johannes Kepler. The spacecraft is now drifting in a safe orbit around the Sun, 94 million miles from Earth. After nine years and thousands of planets, Kepler is passing the torch to newer planet hunters.

Kepler began its journey with a night launch from Cape Canaveral on March 6, 2009. It soon began searching for planets around other stars by looking for transits. In these events, a planet passes in front of a star, briefly eclipsing a small portion of the star's surface, causing it to grow a tiny bit fainter.

Over its 3.5-year primary mission, Kepler kept a constant eye on the light of 150,000 stars in the constellations Cygnus and Lyra. The mission's larger goals were to use this sample to extrapolate the total number of Earth-like planets in the Milky Way galaxy, and to better understand the characteristics of other solar systems to help scientists put our own in context.

Soon after its primary mission ended, Kepler's science halted when one of its reaction wheels, which helped keep it pointed at its target, failed. The Kepler

team found a workaround, which involved allowing the spacecraft to change its field of view every few months. A new mission, called K2, then began as Kepler continued hunting planets, now all across the sky. All told, the spacecraft probed more than half a million stars for orbiting planets.

What the spacecraft found has changed the picture of planets in our galaxy.

"When we started conceiving this mission 35 years ago we didn't know of a single planet outside our solar system," says Bill Borucki, who created the Kepler concept and served as the mission's original principal investigator, based at NASA's Ames Research Center in California.

McDonald Observatory research professor Bill Cochran worked with Borucki on planning the mission, discussing the scientific and technical hurdles they would have to overcome and helping to

work through all of them.

Borucki "converted me from a skeptic to a true believer" in the concept, Cochran says. Cochran served as co-investigator on "all four proposals that got turned down, until the fifth one was successful," he recalls.

By the time Kepler launched, astronomers had found a few handfuls of planets orbiting other stars using ground-based telescopes (using a different technique from Kepler). So the question of whether other planets were out there — long believed, but never proven — had been answered. But there weren't nearly enough known planets to do any kind of statistical studies — to know the variety of planets or their parent stars.

Kepler produced a torrent of new planet discoveries. By early February, 2,662 planets discovered with Kepler have been confirmed, and a roughly equal number of candidates await confirmation. About 3,000 scientific papers based on Kepler research have been published so far.

"Kepler has shown that virtually all of the stars that we see in the sky probably host planetary systems," Cochran says. "Now we are discovering that a significant number of those systems are very much like our own and may have the capability of being habitable."

After launch, Cochran and his team at McDonald Observatory, along with astronomers at other observatories around the world, conducted follow-up observations to confirm or disprove Kepler's discoveries. Their observations could distinguish between a genuine planet transit and other behaviors in stars that can mimic it, such as starspots.

This ground-based work studies these stars in a completely different way than Kepler, using a technique called the "radial velocity" method. It entails monitoring

The planet K2-288Bb, seen at bottom in this artist's concept, orbits two red dwarf stars. It's the latest find in the Kepler data archive. Left: Kepler and TESS hunt for planets using the transit method, looking for a dip in a star's light output that indicates a planet is passing in front of it. Far left: This artist's concept shows how Kepler's field of view changed positions across the sky during the K2 mission.

the star's motion toward and away from Earth to detect any wobbles caused by the gravitational pull of orbiting planets.

The McDonald observations helped confirm the first Earth-sized planet orbiting in the habitable zone of a star (Kepler-22); the most Earth-like planet yet seen orbiting another star (Kepler-452); the first multi-planet system orbiting a binary star (Kepler-47); a system of six planets, some near-Earth-sized, orbiting in the habitable zone of a star (Kepler-11); and an ancient system of five Earth-sized planets that dates to the dawn of the Milky Way galaxy (Kepler-444).

Kepler's landslide of discoveries has helped astronomers learn a lot about planets in the Milky Way.

There are more planets than stars in the Milky Way, for example, and small planets are common. In fact, as many as half of the stars in the Milky Way may have small, rocky planets orbiting in the habitable zone, the distance from a star where temperatures are just right for liquid water to exist on a planet's surface — a likely prerequisite for life, at least life as currently understood.

Planets come in diverse forms. And the most common form, which appears to be between Earth and Neptune in size, does

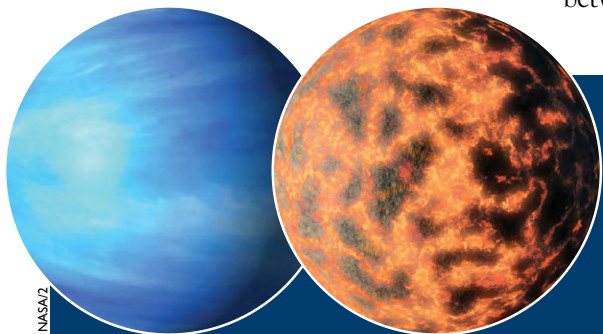
not exist in our own solar system.

Other solar systems often have many planets orbiting very close to their parent stars, making our solar system look sparse in comparison. While our system has four small, rocky planets close to the Sun, some have as many as eight planets within the same distance. Astronomers want to know if these packed-in planets formed close to their parent stars, or formed farther out and later migrated inward.

Kepler's findings provide a tantalizing beginning for future exoplanet searches.

"Now that we know planets are everywhere," Borucki says, "Kepler has set us on a new course that's full of promise for future generations to explore our galaxy."

Indeed, one of Kepler's successors is already hard at work.



Artist concepts of HD 21749b (left) and a lava world like LHS 3844b

Kepler's immediate follow-up mission was launched from Cape Canaveral April 18. As its name indicates, the Transiting Exoplanet Survey Satellite (TESS) is searching for planets using the same transit method as Kepler. What's different is the types of target stars. While Kepler looked at faint stars between 300 and 3,000 light-years away, TESS is studying closer stars that are 30 to 100 times brighter.

Over its initial two-year mission, TESS will survey about 200,000 nearby red-dwarf stars, covering an area of sky 400 times larger than Kepler did. Red dwarfs are smaller and cooler than the Sun, but they are the most common type of star in the galaxy.

Astronomers at McDonald Observatory are planning to follow up TESS planet discoveries, too. A new instrument for the Hobby-Eberly Telescope, one of the world's largest optical telescopes, has been designed to study red-dwarf stars and their potential planets. Called the Habitable Zone Planet Finder (HPF), it is being commissioned now.

Michael Endl is a senior research scientist at McDonald Observatory who has worked on Kepler follow-up with Cochran, as well as projects using ground-based telescopes to look for planets around red dwarfs. He was involved in the discovery of Proxima b, the planet orbiting the nearest star to the Sun, a red dwarf called Proxima Centauri.

"TESS and HPF are working together," Endl says. "TESS announces a candidate,

TESS Logs Busy Start

TESS began logging exoplanet discoveries just a few months after its launch. By late January, it had discovered eight confirmed planets and almost 350 additional candidates. It also recorded more than two dozen exploding stars, flares on the surfaces of red-dwarf stars, and scores of other flickering objects.

"The torrent of data is starting to flow already," said George Ricker, TESS principal investigator, during a press conference at the American Astronomical Society meeting January 7 in Seattle. "TESS is going to be a robust planet finder and a supernova machine," added Thomas Barclay, a mission scientist at NASA's Goddard Space Flight Center.

One of the most recent discoveries is HD 21749b, orbiting a small, cool star about 53 light-years away. The planet is about

23 times the mass of Earth but only three times Earth's diameter, which places it in the same category as Neptune, the outermost of the Sun's major planets. It's separated from its star by just 20 percent of the Earth-Sun distance, though, so its surface is too hot to be inhabited by Earth-like life.

A second, unconfirmed, planet in the system appears to be about the same size as Earth but about 2.5 times as massive, making it a "super-Earth."

LHS 3844b is an Earth-sized world orbiting a stellar pipsqueak known as a red dwarf. Although the star is a faint ember, the planet, whose mass has not yet been determined, is so close to it that "it's probably a lava world," said Chelsea Huang, a mission scientist at the Kavli Institute at MIT.

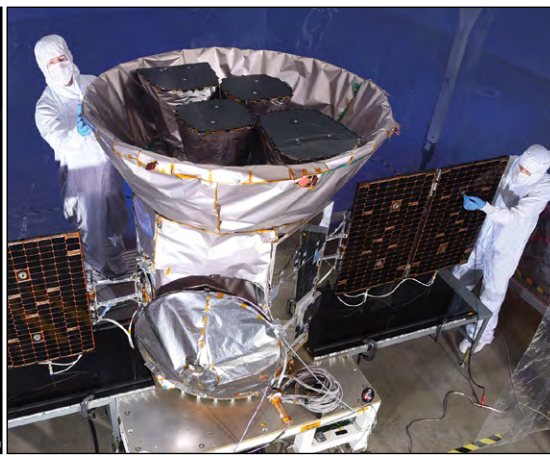
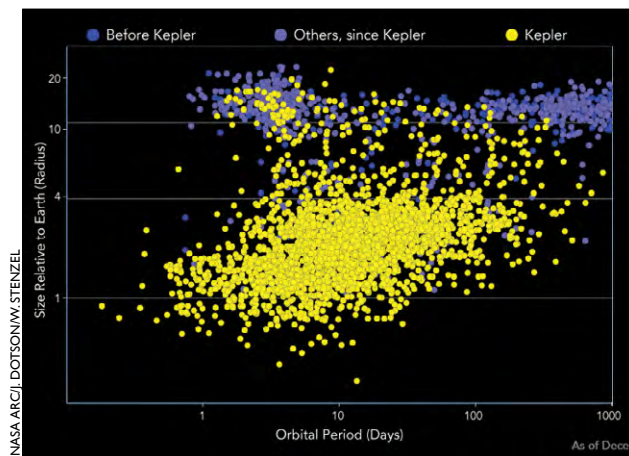
TESS also has discovered many other types of astronomical objects, including dozens of

exploding stars.

Some of its planet hunting and astrophysics work overlap.

For example, it discovered a planet orbiting the star HIP 116158. It also used a technique called asteroseismology to discover dozens of sets of vibrations on the star's surface, which are caused by the motions of gas and other processes deep within the star. The vibrations revealed that the star is 1.2 times the mass of the Sun and 2.9 times its diameter, about 4.9 billion years old, and that it's beginning the transition to its red-giant phase, when it will get much bigger and brighter.

The combination of observations, along with follow-up work from the ground, then produced a dossier on the planet, which is classified as a "hot Saturn": It's about 9.2 times Earth's diameter but 60 times Earth's mass, so it's big and fluffy. **DB**



and then everybody jumps to follow up.”

TESS has begun to return some results (see sidebar). Its planets should be close enough to Earth for astronomers to begin looking for signs of life using spectroscopy — spreading the light from the planet into its component wavelengths to look for chemical elements and compounds in its atmosphere that could have been produced by living organisms.

A few more planet-hunting and -studying spacecraft are scheduled to launch soon.

CHEOPS (CHAracterizing ExOPlanets Satellite) is a joint project of the European Space Agency (ESA) and the Swiss Space Office, with the participation of several other nations. Set to launch in October or November from the Guiana Space Center on the South American coast, its mission will last at least 3.5 years.

Unlike Kepler or TESS, which use surveys of many stars to discover exoplanets, CHEOPS will study systems with already known planets. Specifically, it will target exoplanets smaller than Saturn that orbit bright stars with orbital periods of less than 50 days. By zeroing in on such a specific set of exoplanets, mission planners hope to narrow down the structure of these planets and figure out how they formed and evolved.

James Webb Space Telescope (JWST) is another near-term space mission that will follow up on known exoplanets. Unlike CHEOPS, though, it's not made exclusively for planet work. JWST, which currently is scheduled for launch in 2021, will study a wide range of phenomena in infrared light, including in-depth follow-up observations of exoplanets. The telescope will take spectra of these planets to study their atmospheres. It may even be able to take images of planets that are

A graphic from December 2017 (left) shows how Kepler provided a landslide of planet finds (yellow) compared to missions before and since (blue, purple). Technicians prepare TESS for its April 18 launch (right).

large, bright, and relatively far from their parent stars.

Because missions can take decades of planning and technology development, space agencies are already planning missions with exoplanet-studies goals that won't launch until well into the next decade or beyond.

WFIRST (Wide Field InfraRed Survey Telescope) will take on multiple science missions. In addition to studying dark energy, it will study exoplanets in a couple of ways. First, it will conduct a survey by staring at a dense region of stars toward the center of the galaxy to look for brightenings caused when two stars exactly align. Such alignments, called microlensing events, also reveal the presence of planets around the stars, and mission planners expect WFIRST to detect more than 2,000 worlds. The telescope also will take direct images of perhaps 50 planets around other stars.

Europe's PLATO (PLANetary Transits and Oscillations of stars) mission is scheduled to launch in 2026. It's a follow-up to CHEOPS, and will build on that mission's findings. "With PLATO, we are focusing on Earthlike planets orbiting in the habitable zone around other stars which are similar to our Sun," said Johann-Dietrich Wörner, director general of ESA. "This will be a major step towards finding another Earth."

A few years later, ESA will launch ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey). This satellite is designed to study the atmospheres of a diverse group of about 1,000 exoplanets.

With Kepler, the study of exoplanets got its first motherlode of data, providing key new insights. And now it's time for the new kids on the block to make their contributions.

"As NASA's first planet-hunting mission, Kepler has wildly exceeded all our expectations and paved the way for our exploration and search for life in the solar system and beyond," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate. "Not only did it show us how many planets could be out there, it sparked an entirely new and robust field of research that has taken the science community by storm. Its discoveries have shed a new light on our place in the universe, and illuminated the tantalizing mysteries and possibilities among the stars."

Rebecca Johnson is editor of StarDate.

RESOURCES

INTERNET

Exoplanet Exploration
<http://exoplanets.nasa.gov>

Kepler & K2
<http://nasa.gov/kepler>

TESS
<http://nasa.gov/tess>

JWST
<http://jwst.nasa.gov>

CHEOPS
<http://sci.esa.int/cheops>

WFIRST
<http://wfirst.gsfc.nasa.gov>

PLATO
<http://sci.esa.int/plato>

ARIEL
<http://sci.esa.int/ariel>

Resetting the Clock on Saturn's Rings

Beauty is ephemeral. Consider, for example, the rings of Saturn. These bands of ice and dust are among the most beautiful features in the solar system, yet they could be short lived. Recent research suggests they are no more than 100 million years old, and could disappear in as little as 100 million years more — a mere blink in the planet's 4.5 billion-year lifetime.

The [Cassini spacecraft](#) provided new details on the rings during the last phases of its 13-year reconnaissance of the Saturn system, which ended when the craft plunged into Saturn's atmosphere in September 2017. Cassini passed between Saturn and the inner edge of the rings during each of its 22 final orbits of the giant planet. The rings' minuscule gravitational pull allowed scientists to "weigh" them more precisely than ever before. The passages also provided a close view of interactions between

the rings and Saturn itself.

Previous estimates of the age of the rings have varied widely, with some suggesting the rings are as old as Saturn itself.

The trajectory measurements showed that the rings are about 40 percent the mass of Mimas, a small moon of Saturn, or roughly half the mass of the ice sheet covering Antarctica. According to models of ring formation, the low mass suggests a recent origin — probably in the last 10 million to 100 million years. The rings probably formed when a small comet or one or more small moons passed too close to Saturn. The planet's powerful gravity pulverized the unlucky progenitor. Over time, collisions ground the debris to smaller and smaller particles, which spread out to form the magnificent rings.

Today, the rings consist primarily of tiny bits of ice, with a smattering of dust and pebbles. Some of the material at the inner edge of the closest major

ring, the D ring, "rains" into Saturn's upper atmosphere. Much of this falls toward the equator. (The D ring may be resupplied by material from the next ring out, the C ring.)

Cassini found, however, that a substantial amount of material rains toward higher latitudes, roughly 45 degrees north and south of the equator.

When researchers combined the Cassini observations with some older views of Saturn from a ground-based telescope, they found changes in the planet's ionosphere, an electrically charged layer of the atmosphere. The changes may be caused by bits of ice in the rings falling toward Saturn. The particles have their own electric charge, so they're guided by Saturn's magnetic field. As they hit the atmosphere, they wash away particles of haze, leaving dark bands detected by the ground-based observations. The researchers calculated that this icy rain

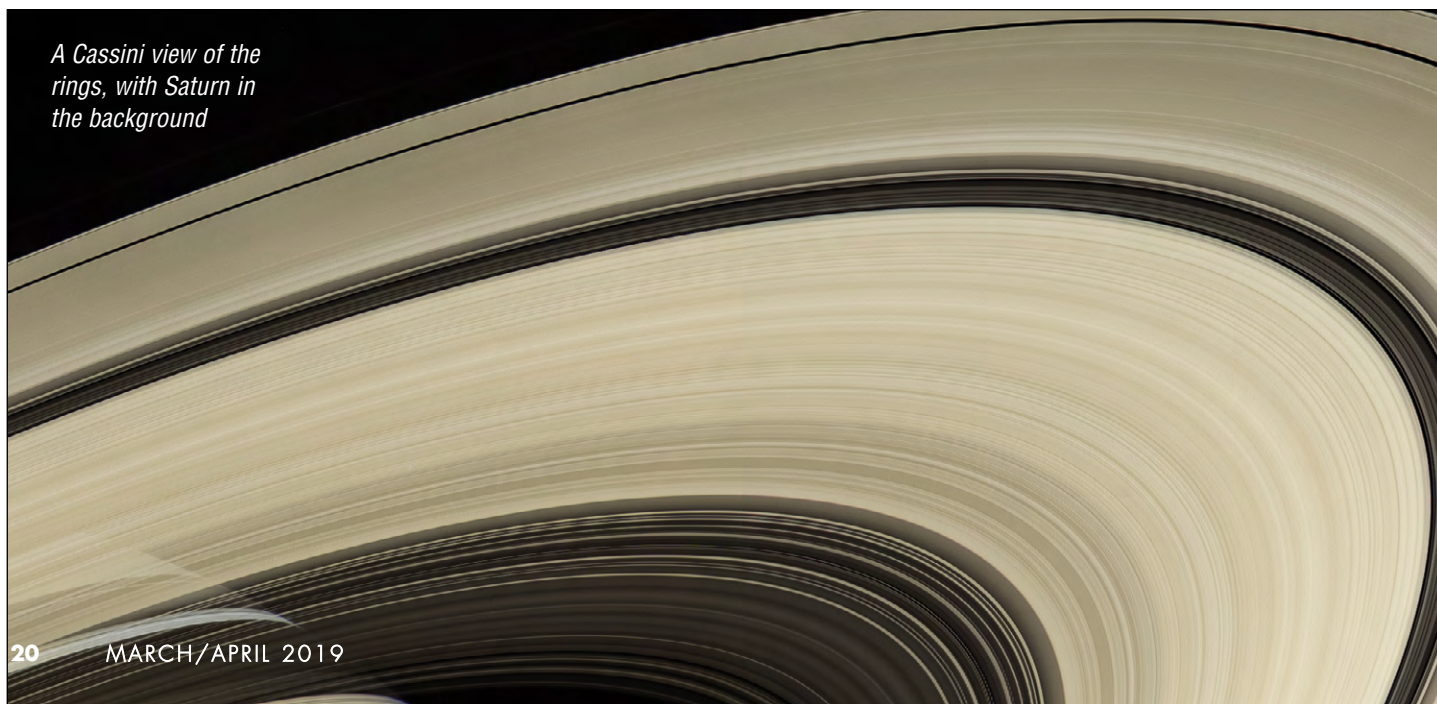
could make the rings vanish in as little as 100 million years.

Researchers also used observations of Saturn's rings to determine the length of the planet's day: 10 hours, 33 minutes, 38 seconds.

Scientists have been unable to determine the rate of Saturn's rotation because there are no solid landmarks on the gas-giant planet to follow. Attempts to determine the rotation rate using variations in Saturn's magnetic field yielded estimates that varied by as much as 10 minutes.

Cassini scientists, though, determined that the rings resonate to motions deep within Saturn itself, creating waves that ripple through the rings. The waves were difficult to separate from waves caused by the gravitational influence of Saturn's moons, but careful analysis revealed the waves caused by the planet's own gravitational field, yielding what the researchers say is the best measurement of Saturn's day. **DB**

A Cassini view of the rings, with Saturn in the background



Chasing Away Planet Nine

As the search for a possible Planet Nine continues, one team of researchers reported that the planet may not be needed to explain the motions of several objects in the Kuiper Belt, a region beyond the orbit of Neptune that contains millions of chunks of ice and rock. Instead, a bulked-up population of small objects in a wide disk beyond Neptune might do the job just as well.

Astronomers suggested in 2016 that a planet about 10 times as massive as Earth, orbiting billions of miles from the Sun, might have nudged a group of large iceballs in the Kuiper Belt into odd orbits. The possible planet has yet to be discovered.

Simulations by researchers from [Cambridge University](#) and [the University of Beirut](#), however, showed that the gravity of a disk of iceballs and other small debris with a combined mass equal to about 10 Earths, combined with the gravity of the Sun's major planets, could push objects into orbits matching those that spurred the claim of a possible Planet Nine.

Current estimates put the mass of the Kuiper Belt at no more than about one-tenth of the mass of Earth, leaving too little material to do the job. But the researchers say that other studies show that the Kuiper Belt and the region beyond it could contain much more material. They also note that many other stars are encircled by massive disks.

The researchers add that it's possible there could be both a Planet Nine and a heavier disk in the outer solar system.



Clouds surround the almost totally eclipsed Sun.

Chillin' Under the Sun

The total solar eclipse of August 2017 wasn't just a cool sight, it brought some cool air as well. As the Sun disappeared from view, temperatures dropped an average of almost six degrees.

Anthony Papol, a student at Brown University, analyzed National Weather Service records for more than 700 sites along the eclipse path. He presented his findings at an astronomy conference in January. Some results:

- The temperature reached its minimum, 5.8 degrees Fahrenheit cooler than before the eclipse, an average of 10.2 minutes after the total eclipse ended.
- There was no overall trend in wind direction, but many locations saw a peak shift in the direction 7.4 minutes before totality.

Birth of a Black Hole or Death by Black Hole?

Astronomers are at odds over the nature of a brilliant flash of light seen in the constellation Hercules in June. Some say it was the death throes of a star that was being ripped apart by a black hole. Others, however, say it was the birth cry of a black hole or a neutron star.

The flash was discovered on June 18. It was designated AT2018cow and nicknamed "the Cow" for the last three letters. The object, which appears to reside in a galaxy about 200 million light-years away, reached its peak brightness in just three days, compared to 10-20 days for a typical supernova, and peaked at a level 10 times brighter than a typical supernova produced by the death of a massive star. The Cow then faded over a period of several months. Astronomers studied the object with many telescopes on the ground and in space, covering wavelengths from radio waves to gamma rays.

Astronomers presented their views of the Cow at the January meeting of the American Astronomical Society.

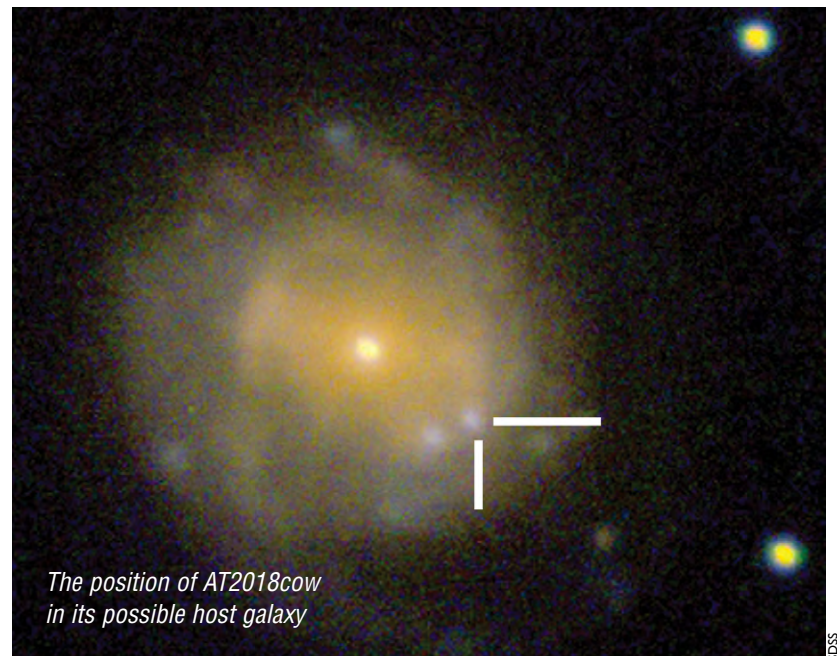
One possibility, presented by Amy Lien of NASA and the University of Maryland-Baltimore County, is the

[destruction of a white dwarf](#) — the dense "corpse" of a star like the Sun. As the star passed close to a black hole roughly 100,000 to one million times the mass of the Sun, the black hole's gravity pulled it apart, triggering the outburst. Some of the gas was flung back into space, but a large portion of it circled around the black hole at high speed, creating a bright display.

A second possibility, outlined by Raffaella Margutti of Northwestern University, says the Cow was created by an unusual supernova.

In this scenario, the core of a massive star collapsed to form the ultra-dense remnant, while the star's outer layers were blasted into space at a few percent of the speed of light. Debris from the blast was less dense than that surrounding a typical supernova, allowing space telescopes to detect X-rays from hot gas falling onto the neutron star or black hole.

Astronomers routinely observe supernovae in other galaxies but hadn't seen events so close to the collapsed core, suggesting that they might have been witnessing the birth of a black hole or neutron star for the first time. **DB**



The position of AT2018cow in its possible host galaxy

Speeding Up the Expanding Universe

Dark energy, a mysterious force that appears to make the universe expand faster as it ages, [may be growing stronger](#), according to a recent study. If the finding is confirmed by other experiments, it may eliminate one of the leading possible explanations for dark energy.

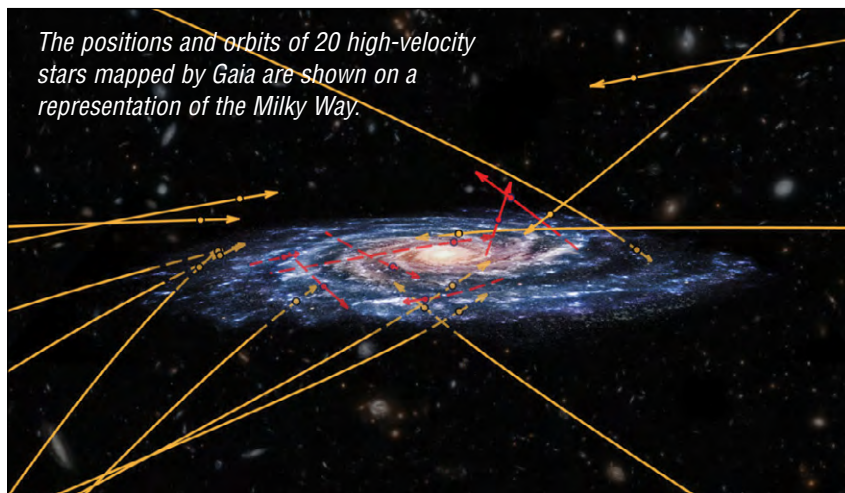
Astronomers discovered dark energy by measuring how fast the home galaxies of a class of exploding stars are moving away from Earth. They found that more-distant galaxies are moving much faster than expected. That suggests that something is causing the universe to expand faster. This “something” was named dark energy, and scientists have invested enormous effort in discovering its nature.

One possibility is a cosmological constant, which posits that the energy comes from the vacuum of space itself. If so, then the expansion rate should be constant throughout the history of the universe.

Astronomers at the University of Florence in Italy and Durham University in the U.K., however, reported that new observations indicated that the expansion rate has changed since the early universe.

The researchers used two X-ray space telescopes and a ground-based telescope sensitive to ultraviolet light to study quasars — brilliant disks of hot gas around supermassive black holes. Their technique allowed them to estimate the distances of the quasars, revealing that we’re seeing them when the universe was between 1.1 billion and 2.3 billion years old. The quasars are farther than the most-distant supernovae used to measure the expansion rate.

Measurements of the quasars’ motions away from Earth show that the rate of expansion has changed since the quasars emitted their light. If that is confirmed, it could eliminate the cosmological constant as an explanation for dark energy.



The positions and orbits of 20 high-velocity stars mapped by Gaia are shown on a representation of the Milky Way.

ESA/MARCHETTI ET AL./NASA/HUBBLE

Gaia Spies Galaxy-Hopping Stars

Astronomers studying the latest catalog of the properties of more than a billion stars from Europe’s Gaia satellite were expecting to find some stars heading out of the Milky Way. Instead, they found many that were hurtling inward, perhaps migrating from other galaxies.

“Of the seven million Gaia stars with full 3D velocity measurements, we found 20 that could be travelling fast enough to eventually escape from the Milky Way,” said Elena Maria Rossi of the Netherlands’ Leiden University.

“Rather than flying away from the galactic center, most of the high velocity stars we spotted seem to be racing towards it,” said the study’s lead author, Tommaso Marchetti, also of Leiden. “These could be stars from another galaxy, zooming right

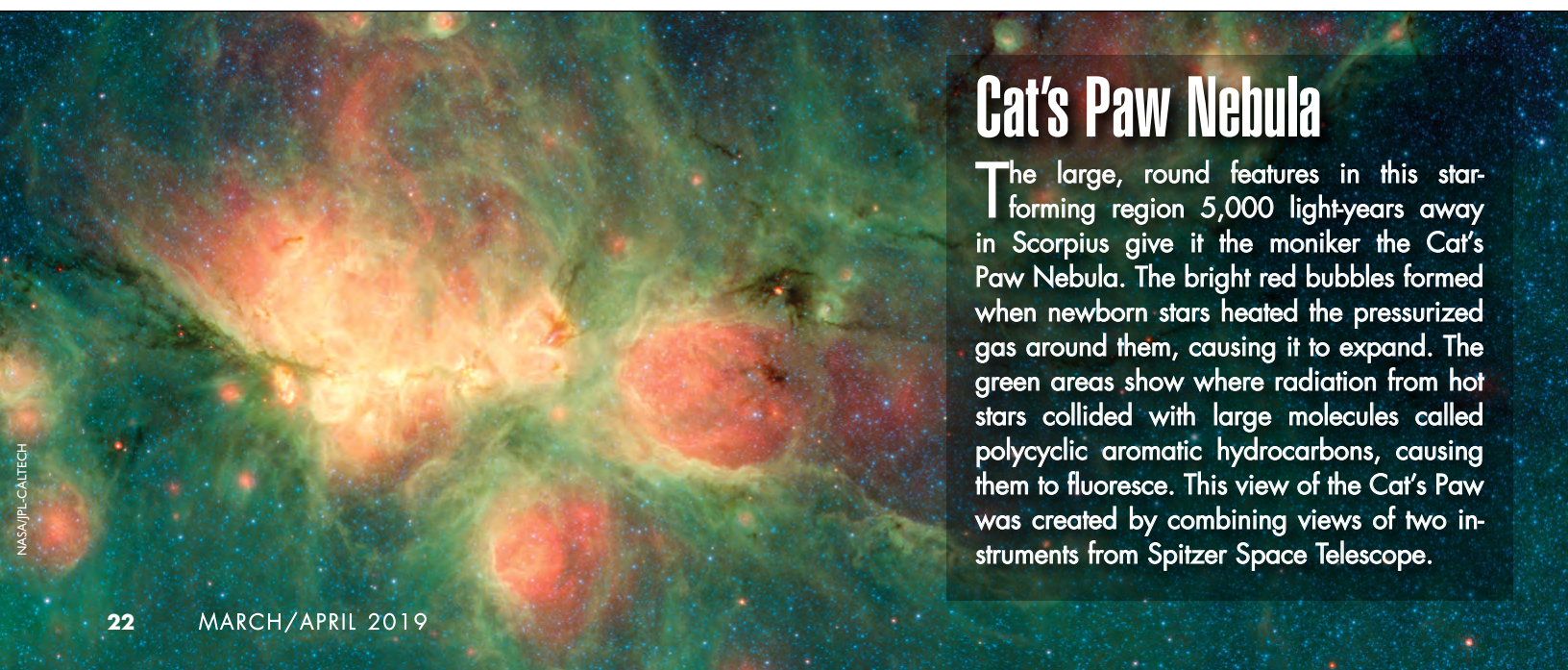
through the Milky Way.”

The stars could be coming from the Large Magellanic Cloud (LMC), one of the Milky Way’s small satellite galaxies. The stars’ presence in our galaxy might be proof that they were slung out by the gravity of a black hole at the heart of the LMC.

“So the presence of these stars might be a sign of such black holes in nearby galaxies,” Rossi said. “But the stars may also have once been part of a binary system, flung towards the Milky Way when their companion star exploded as a supernova. Either way, studying them could tell us more about these kinds of processes in nearby galaxies.”

The team plans follow-up observations of these stars with ground-based telescopes to understand their chemical compositions in order to pinpoint their birthplaces.

RJ



Cat's Paw Nebula

The large, round features in this star-forming region 5,000 light-years away in Scorpius give it the moniker the Cat's Paw Nebula. The bright red bubbles formed when newborn stars heated the pressurized gas around them, causing it to expand. The green areas show where radiation from hot stars collided with large molecules called polycyclic aromatic hydrocarbons, causing them to fluoresce. This view of the Cat's Paw was created by combining views of two instruments from Spitzer Space Telescope.

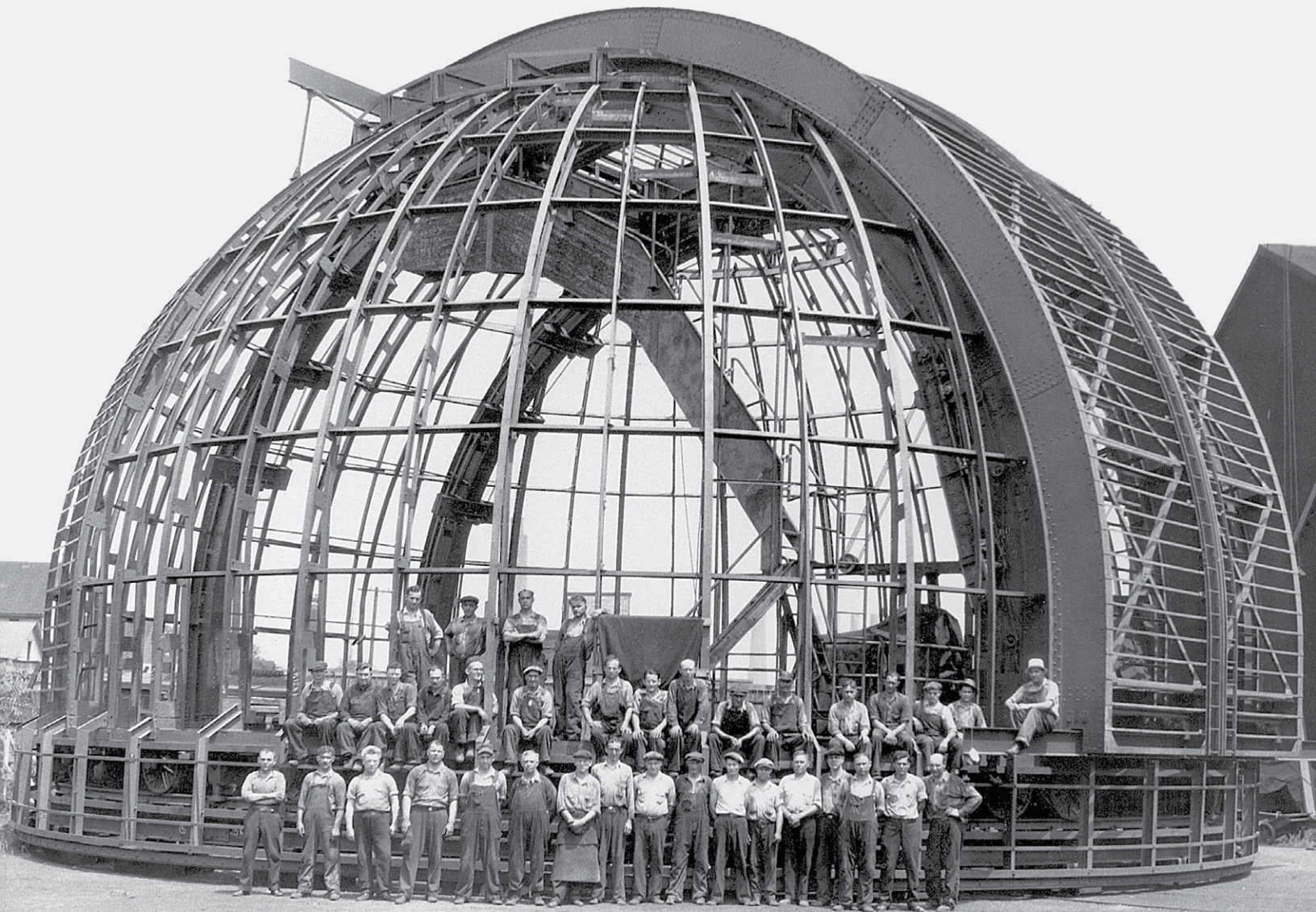
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80 Years!

The first large telescope was built at McDonald Observatory during the Great Depression, and dedicated on May 5, 1939. The dome housing the 2.1-meter Otto Struve reflector contained not only the telescope, but offices, a library, and

sleeping quarters for visiting astronomers. From this one building blossomed the modern observatory we operate today. Help us celebrate our 80th anniversary this year with special events on site and online!

- Watch for program announcements at mcdonaldobservatory.org.
- Subscribe to SkyTips, our free monthly e-newsletter, on our website.
- Follow McDonald Observatory on Facebook, Twitter, and YouTube.



Hubble Space Telescope recently compiled this detailed image of M33, the Triangulum Galaxy. It is the third-largest member of the Local Group, after the Andromeda Galaxy and our home galaxy, the Milky Way. M33 is three million light-years away, and it is about 60,000 light-years in diameter, which is roughly half the size of the Milky Way. This image shows the galaxy's bright center and its delicate spiral arms, which are outlined by bright, young stars and dark lanes of dust. Although M33 is far less massive than the Milky Way, it is giving birth to more stars. One busy stellar nursery is the blue blob at the bottom of the picture.

