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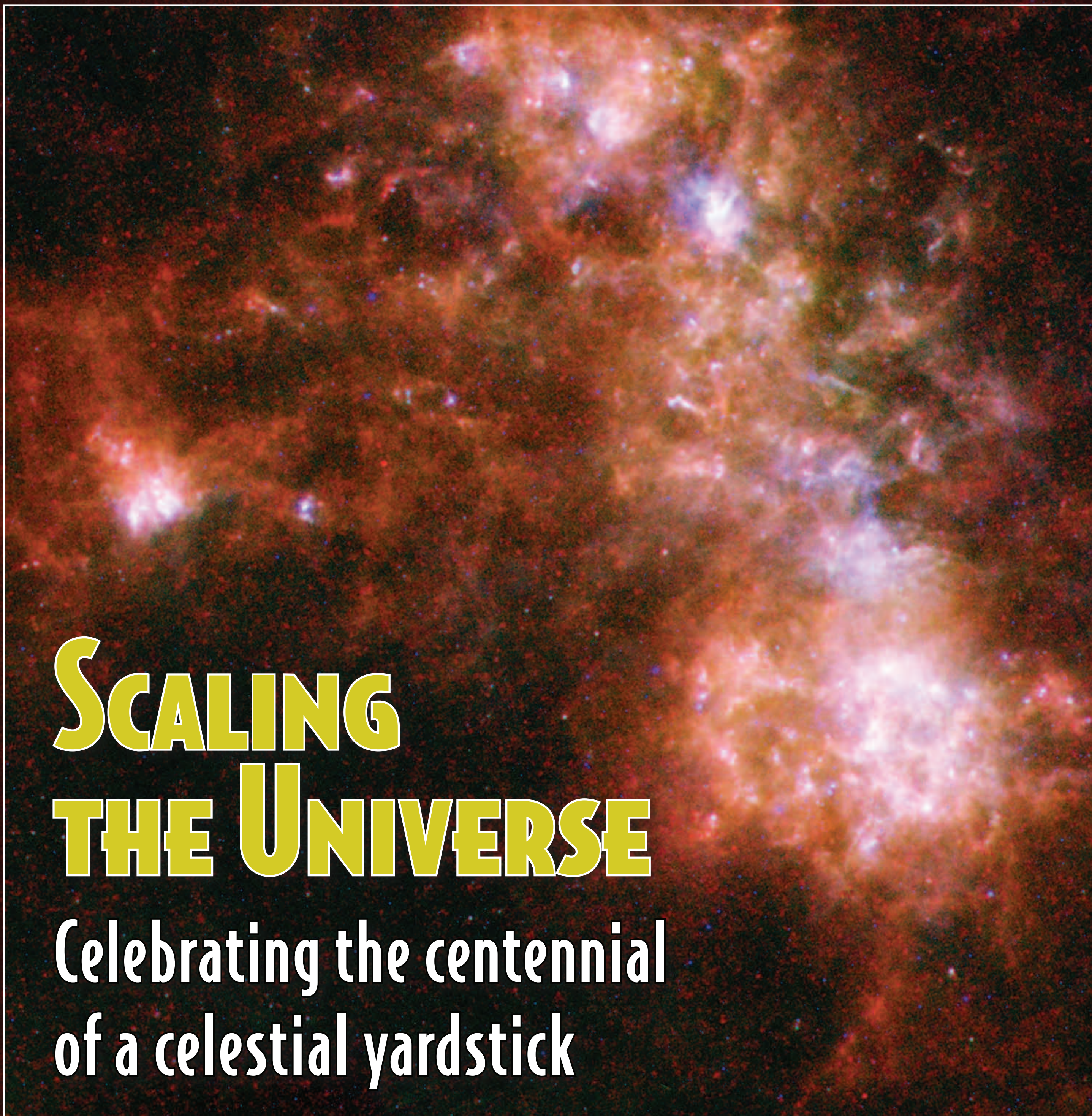

Scaling the Universe

Celebrating the centennial of a celestial yardstick

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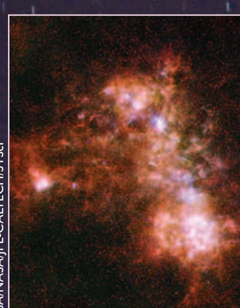
Features

Departments



ESA/NASA/JPL-CALTECH/STScI

On The Cover

Henrietta Swan Leavitt's studies of variable stars in the Small Magellanic Cloud, seen here in a recent composite image from the Herschel and Spitzer infrared space telescopes, changed how we measure the cosmos. To learn how, see Page 4.

This Page

Comet Lovejoy, which survived a plunge near the surface of the Sun, rises above Earth's atmosphere in this December 22 view from the International Space Station. Lovejoy passed less than one million miles from the Sun on December 15. The encounter stripped away its original tail but left the comet itself intact. A new tail quickly sprouted as more ice at Lovejoy's surface vaporized.

Coming Up

The May/June issue will bring you detailed information on the May 20 solar eclipse for the western United States, as well as the scoop on the transit of Venus in early June . We'll also bring you Merlin's answers to your tough astronomy questions and the latest astronomy news.

NASA

Merlin

Dear Merlin,

My husband and I disagree about the motion of the International Space Station across the night sky. I think it is not moving but fixed at a place in orbit and it is the spinning Earth that makes it look like it is moving. My husband thinks it is propelled.

Tina Lipman
Port Angeles, Washington

The space station is in a low orbit (about 230 miles/370 km), so it is, in fact, its own motion that you are seeing (more than 17,000 miles per hour). For it to remain at a “fixed” point in the sky, it would have to be in geosynchronous orbit, at an altitude of 22,300 miles (35,700 km). If that were the case, though, it would appear to remain at a fixed point in the sky, although it would be moving in orbit around Earth at the same rate as Earth’s rotation on its axis.

It’s not correct to say that the station is propelled, however; it is “falling” around Earth, with its orbital speed keeping it in space. Astronauts do occasionally fire its thrusters to tweak its orbit, which decays as the station passes through thin wisps of the atmosphere.

For those who haven’t seen it, the station can appear shortly before sunrise or after sunset, moving across the sky fairly quickly, like a fast airplane. It shines almost as brightly as Venus, the brilliant morning or evening star.

Dear Merlin,

I understand that the surface of Mercury has some of the most valuable real estate in the solar system, its surface covered with heavy metals like gold, silver, and platinum. Why are these metals so abundant on Mercury yet rare on Earth? And how do I stake a claim in “them thar hills?”

Roy
Reading, Pennsylvania

Merlin suggests holding off on filing a claim just yet. First, such things are subject to international treaties, which means lots of paperwork. And second, no one has yet measured the composition of Mercury in enough detail to determine how much of these precious metals it contains.

Like Earth, Mercury is a dense, metal-rich world, with a large core made of iron and nickel. It’s reasonable to assume that it has smatterings of other heavy metals, including gold, silver, and platinum. The planet has also had abundant volcanic activity (and may have some ongoing activity today), which is involved in concentrating such elements.

Yet the amounts of these elements, their distribution, and many other factors are completely unknown. The MESSENGER spacecraft is studying Mercury’s composition from orbit, but it doesn’t have the ability to detect individual deposits of interesting metals or other materials. A more detailed understanding will have to wait for orbiters with more sensitive instruments, or, better yet, landers that can actually dig into the surface to see what’s there.

Dear Merlin,

I have noticed over the years that the first day of autumn was generally either September 21 or 22. In 2011, however, it was September 23. What causes this variation?

Jerry Hequembourg
Eastham, Massachusetts

Actually, over the last few decades, the September equinox, which marks the beginning of autumn in the northern hemisphere, has most often fallen on the 22nd.

The difference is caused by the difference between the calendar year (either 365 or 366 days) and the true year, which is 365 days, 5 hours, 48 minutes, and 45 seconds long.

On average, the time of the equinox advances by those extra few hours and minutes each year (the exact timing varies somewhat because of the gravitational pull of the Moon and the other planets in the solar system). Leap Year essentially pushes the equinox back to its starting position every four years. So today, for three consecutive years the equinox occurs on the 22nd for the Lower 48 states, then it jumps to the 23rd the year before Leap Year, as it did in 2011.

This arrangement doesn’t completely balance the books, however. If uncorrected, it would cause the date of the equinox to move about one day earlier every 128 years. (In the first half of the 20th century, for example, the equinox occurred most frequently on the 23rd, not the 22nd.) The current calendar system drops Leap Year in “century” years (such as 1800 or 1900), unless those years are divisible by 400 (such as the year 2000).

For the most part, these adjustments keep the September equinox on the 22nd or 23rd.

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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HARVARD COLLEGE OBSERVATORY (2)

Above: Henrietta Swan Leavitt, about 1910. Background image: This 1905 view of the Large Magellanic Cloud (LMC) taken at Harvard's Boyden Station in Arequipa, Peru, is one of many Leavitt studied in her search for Cepheid variable stars. Today we know the LMC is a satellite galaxy of the Milky Way.

Henrietta and the Cepheids

A hundred years ago, one woman's patience and tenacity in pouring over photographic plates packed with stars changed our view of the cosmos

A century ago this month, a human computer announced a finding that eventually expanded the size of our universe as much as Galileo's first telescopic look at the stars. It was on March 3, 1912, that astronomer Henrietta Swan Leavitt's finding about the behavior of a specific kind of pulsing star was published in the *Harvard College Observatory Circular*. Her finding allowed astronomers to discover that the Milky Way is not the whole of the universe, and today remains an important rung on the "extragalactic distance ladder" that allows astronomers to measure distances across the cosmos.

Measuring the distances to stars had been a longstanding, and highly frustrating, problem in astronomy (and still poses problems today). In the 16th century, Nicolaus Copernicus, who devised a new model of the universe in which Earth orbited the Sun, knew that the distances to stars must be much greater than the distance from Earth to the Sun. If the stars were close, Copernicus reasoned, then observers would be able to easily detect stellar parallax, the shift in a star's apparent position when viewed from different points on Earth's orbit.

By Barbara Ryden

In 1838 Friedrich Bessel, after painstaking efforts, measured the first stellar parallax, to 61 Cygni. From the tiny parallax he measured, he deduced that the distance from the Sun to 61 Cygni was 657,700 times the average Earth-Sun distance, equivalent to 10.3 light-years.

Although parallax is the gold standard for determining stellar distances, the minuscule angles are difficult to measure, even for the nearest stars. As late as 1910, more than seven decades after Bessel's breakthrough, the *Encyclopedia Britannica* lamented the inability to measure stellar parallax for stars more than 70 light-years away. Compared to the size of our galaxy, a sphere 70 light-years in radius is ludicrously small; it contains about 4,500 of the hundreds of billions of stars in the Milky Way.

Henrietta Swan Leavitt was to make a great stride beyond this limited neighborhood. She entered this world without fanfare, unless you count the Independence Day celebrations on July 4, 1868, the day of her birth. She was named after her mother, the former Henrietta Swan Kendrick, who in turn was named after her mother, born Henrietta Swan. The infant Henrietta's family tree bloomed with doctors and ministers. Her father, George Roswell Leavitt, had a master's degree from Andover Theological Seminary. Her father's father, Erasmus Darwin Leavitt, was named as a tribute to a then-famous English natural philosopher, the grandfather of Charles Darwin.

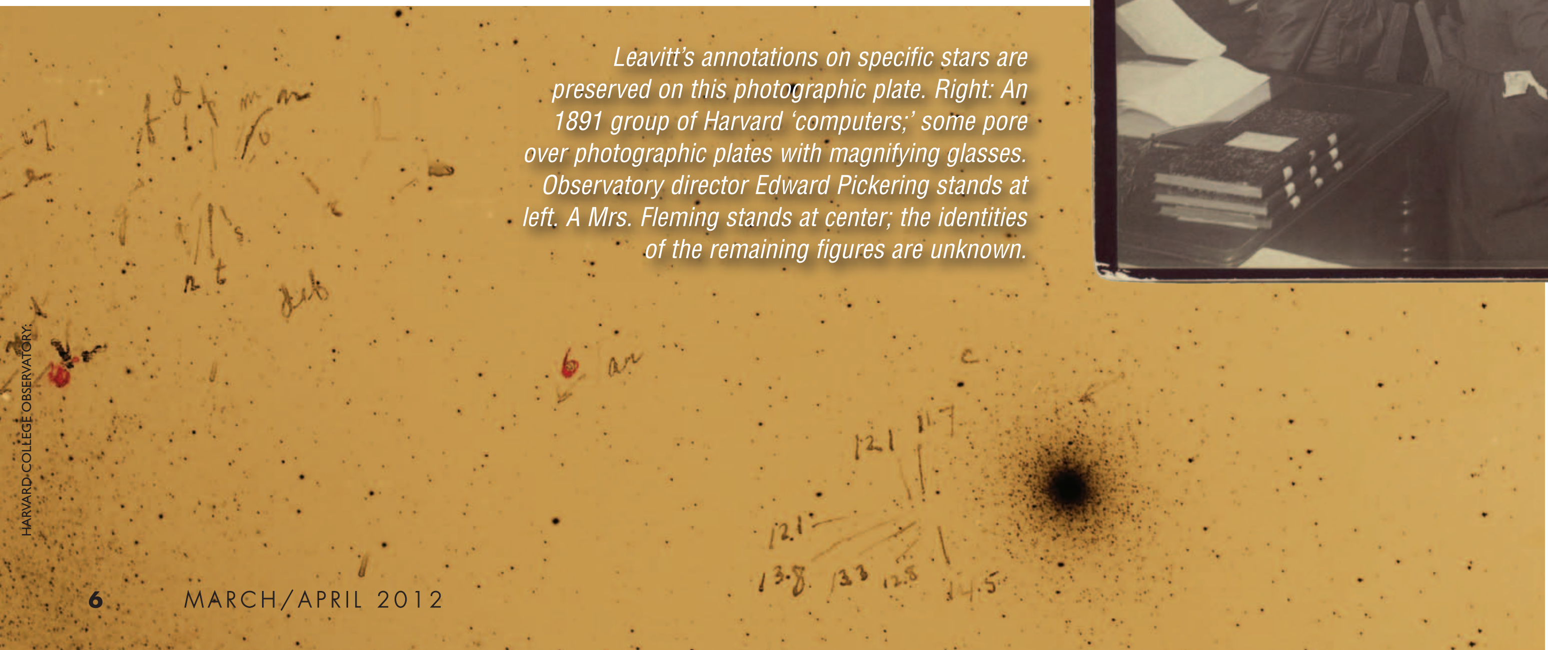
The Leavitt family dedication to learning extended — unusually for the time — to supporting higher education for women. Henrietta Swan Leavitt was the oldest of five surviving siblings, all of whom attended college. Leavitt's advanced education began after her father became pastor of a church in Cleveland in 1885, enabling her to enter nearby Oberlin College. (She enrolled simultaneously in Oberlin's conservatory of music, indicating that the deafness that afflicted her later in life was not yet troublesome.)

After her sophomore year, Leavitt transferred to the Society for the Collegiate Instruction of Women in Cambridge, Massachusetts. At the time, the Society was better known by its nickname, the Harvard Annex. To posterity, it is known by the name under which it was later chartered: Radcliffe College. The Harvard Annex was founded to give young women the benefit of the same instruction that was received by young men at Harvard College, taught by the same professors.

The sole astronomy course that she took there, "Descriptive Astronomy," was during her senior year. In that course, Leavitt and the seven other students were, according to the course catalog, "given opportunities for practical studies of the stars … occasionally with the large telescope of the Harvard Observatory." Leavitt earned an A-minus for the course, and was left with a permanent love of astronomy. After her graduation in 1892 (one of 10 women receiving "certificates" from the Harvard Annex), Leavitt did additional graduate work in astronomy and worked as a volunteer research assistant at Harvard College Observatory.

The observatory director at the time was Edward Pickering, a pioneer in the use of large photographic surveys in astronomy. Pickering realized that the vast amounts of data contained on photographic plates of the stars would require equally vast amounts of data processing. Thus, Pickering was in need of a small army of human "computers." He decided to hire women for the job, in part, because they were thought to have longer attention spans when doing repetitive tasks, like sewing or number crunching. Mainly, though, Pickering hired women because he had a limited budget, and women were customarily paid less than a man doing the same job.

HARVARD UNIVERSITY ARCHIVES, HUV 1210 (9-4)



Leavitt's annotations on specific stars are preserved on this photographic plate. Right: An 1891 group of Harvard 'computers;' some pore over photographic plates with magnifying glasses. Observatory director Edward Pickering stands at left. A Mrs. Fleming stands at center; the identities of the remaining figures are unknown.

HARVARD COLLEGE OBSERVATORY

Any skepticism about the ability of women to handle the task of scientific computing was soon dispelled by results. According to an admiring article in the May 12, 1893, issue of *The Boston Globe*, "These young women deal with difficult problems quite as successfully as do men in other observatories. They not only accomplish in a very satisfactory manner the regular routine work of computers at the same fixed rate per hour as men, but are encouraged also to undertake scientific investigation."

Henrietta Leavitt made her first appearance in the Harvard College Observatory's annual report in 1896. "An interesting investigation has been made," Pickering reported, "by Miss H. S. Leavitt on the photographic brightness of circumpolar stars." However, that year

marked a temporary break in Leavitt's astronomical career. She spent two years traveling in Europe, and on her return to the United States she went to Beloit, Wisconsin, where her father had taken up a new ministry.

Leavitt, however, could not be kept away from astronomy permanently. In May 1902, she wrote to Pickering asking to resume an unfinished project: "I am more sorry than I can tell you that the work I undertook with such delight … should be left uncompleted." She wanted a paid position in astronomy, but her doctor had forbidden her to observe on winter nights, fearing that the cold would worsen her deteriorating hearing. "Do you think it is likely," Leavitt wrote to Pickering, "that I could find employment either in an observatory or in a school where there is a mild winter climate?"

Pickering wrote back immediately, offering Leavitt a position at Harvard College Observatory. Although Massachusetts is not known for its mild winter climate, the job Pickering offered was an indoor position as a computer. "I should be willing to pay thirty cents an hour in view of the quality of your work," Pickering wrote, "although our usual price, in such cases, is twenty five cents an hour." Leavitt, in accepting the position, referred to Pickering's offer as "very liberal," but that may have been sheer politeness. Although the average American wage in 1902 was just 22 cents an hour, this was at a time when just 6 percent of Americans were high school graduates. For a college graduate — even if she suffered the economic disadvantage of being female — a wage of 30 cents an hour was not large.

After Leavitt returned to Harvard in August 1902, her new project involved looking at photographic plates to find variable stars (stars that change brightness) in the Small and Large Magellanic Clouds, which are small companion galaxies to the Milky Way. Since the galaxies are too far south to be seen from Massachusetts, Leavitt looked at plates that had been snapped through a telescope near Arequipa, Peru. The fragile glass plates were sent by railway to the Peruvian coast, where they started their long sea voyage to Boston. The fruit of Leavitt's long hours examining these plates is summarized in the title of her 1908 scientific paper "1777 Variables in the Magellanic Clouds."

The sheer number of variable stars that Leavitt found was impressive; she roughly doubled the number of variables known to astronomers. "What a variable-star 'fiend' Miss Leavitt is," wrote Charles Young of Princeton. "One can't keep up with the roll of new discoveries."

Her most important result, though, is barely mentioned in the 1908 paper. The last of six tables in the paper contains a list of 16 variables in the Small Magellanic Cloud for which the period of variation was well determined; the periods range from 1.3 days to 4 months. In the text, Leavitt mentions, "It is worthy of notice that in Table VI the brighter variables have the longer periods."

This preliminary result intrigued Leavitt. Unfortunately, she was delayed in following up her results, first by illness, and then by her father's death. The much-postponed culmination of Leavitt's work didn't come until March 3, 1912, with the publication of *Harvard College Observatory Circular 173*. Although the three-page circular went out over the signature of Pickering, its first sentence reads, "The following statement regarding the period of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt."

The new, larger sample enabled Leavitt to find what she called "a remarkable relation between the brightness of these variables and the length of their periods." Leavitt pointed out that since all the stars in the Small Magellanic Cloud are at nearly the same distance from Earth, the differences in the apparent brightness of the stars in the galaxy are a result of differences in their true brightness (or luminosity). Thus, Leavitt could conclude, for example, that a star with a pulsation period of 15 days is twice as luminous as a star with a period of 6.6 days.

What Leavitt had discovered was a universal period-luminosity relation for a particular class of variable star. Although she didn't explicitly use the name, the stars Leavitt was looking at were Cepheid variable stars, named after their prototype, Delta Cephei.

The possible usefulness of the relation she discovered was obvious. If you could measure the luminosity of just one Cepheid, you could use Leavitt's law to compute the luminosity of any Cepheid whose pulsation period was measured. Once you know the luminosity of that Cepheid, you could compare that to its apparent brightness to compute its distance. Thus, the discovery of a period-luminosity relation for Cepheids provided a way of computing the distance to any galaxy in which these special stars could be observed.

Leavitt pointed the way to making the Cepheid period-luminosity relation a useful distance indicator. "It is to be hoped," she wrote, "that the parallaxes of some variables of this type may be measured." Knowing the parallax and apparent brightness of a nearby Cepheid would allow astronomers to compute its distance and luminosity.

Unfortunately, though, Cepheid stars are scarce. The nearest Cepheid (which happens to be Polaris, the North Star) is 430 light-years away, outside the little sphere in which stellar parallax can be accurately measured by ground-based telescopes.

After reading Leavitt's 1912 paper, Danish astronomer Ejnar Hertzsprung found a way to bypass the need to measure parallax. He knew the proper motions (the distance a star moves across the sky, measured in arcseconds per year) for 13 relatively nearby Cepheids. His sample included Polaris and Delta Cephei. He also knew that the Sun's motion through space relative to its nearest neighboring stars is about 12 miles (20 km) per second. He then asked, "If the Sun is moving at 20 kilometers per second, how far away must the Cepheids be, on average, to produce their observed proper motions?" Hertzsprung's answer was that the 13 Cepheids were at an average distance of 93 light-years, and that a Cepheid with a period of 6.6 days had a visual absolute magnitude of –2.3. In the Small Magellanic Cloud, a Cepheid with the same period had a visual apparent magnitude of 13, according to Leavitt's law. (In the stellar magnitude scale, smaller numbers represent greater brightness.) Given these numbers, Hertzsprung calculated that the distance to the Small Magellanic Cloud is approximately 30,000 light-years. (Unfortunately, a typographical error in his paper reduced this number to 3,000 light-years. A careless typesetter can really shrink your universe.)

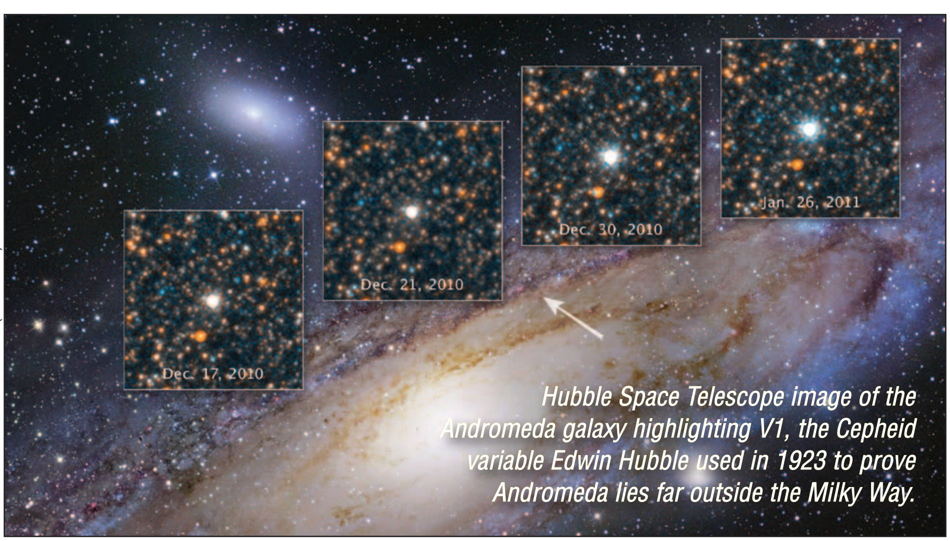
In 1918, an improved calibration by American astronomer Harlow Shapley led to an increase in the estimated distance to the Small Magellanic Cloud, to 63,000 light-years. Even with Shapley's correction, this still falls short of the currently measured distance of 200,000 light-years. Still, as the first attempt to stretch a yardstick to a galaxy beyond our own, the efforts of Hertzsprung and Shapley were impressive.

'Miss Leavitt's work on the variable stars in the Magellanic Clouds has afforded us a very powerful tool in measuring great stellar distances.'

– Harlow Shapley

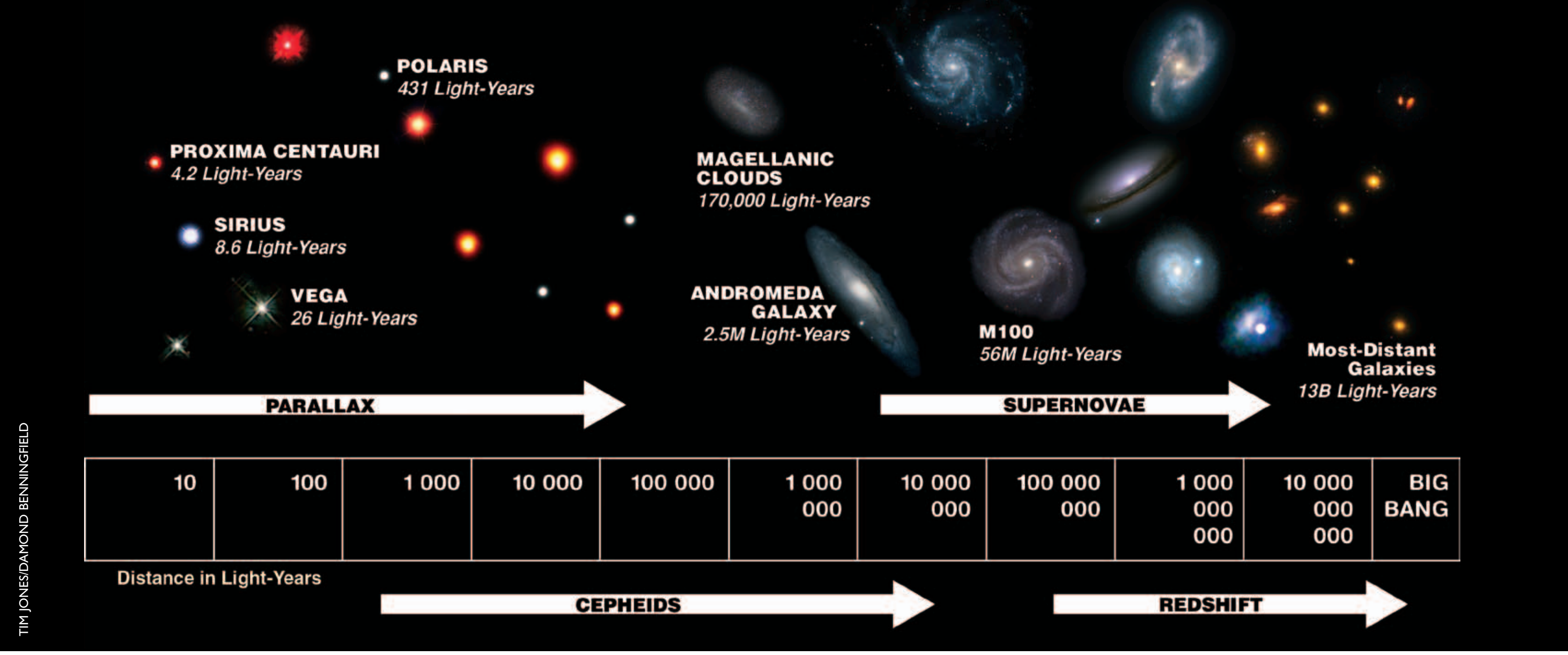
In fact, Shapley's accomplishments, of which measuring the distance to the Small Magellanic Cloud was just one, led to his becoming the new director of Harvard College Observatory in 1921. Shapley had little opportunity to interact with Leavitt, however. "I met her first when I went to Harvard as director," Shapley recalled much later. "She was dying of cancer, but we didn't mention it." Leavitt's death from stomach cancer came on the cold, rainy evening of December 12, 1921. The appraised value of her estate, which she left to her mother, was merely $314.91. Although she left behind little of monetary value, Leavitt left behind an enviable reputation among her fellow astronomers. (Outside astronomy, though, she was less well known. *Science* magazine, for instance, in its December 23 issue, noted the passing of "Henrietta Swan Jewett," along with the wrong date of death.)

A haunting coda to Leavitt's untimely death came in March 1925, when a letter addressed to Henrietta Leavitt arrived at Harvard College Observatory. It proved to be from Swedish mathematician Magnus Gustaf Mittag-Leffler, telling "Honoured Miss Leavitt" that "I feel seriously inclined to nominate you to the Nobel prize in physics for 1926, although I must confess that my knowledge of the matter is as yet rather incomplete." It fell to Shapley to write the regretful reply that Leavitt had died more than three years earlier (making her ineligible for a Nobel Prize). "Miss Leavitt's work on the variable stars in the Magellanic Clouds," Shapley wrote, "which led to



NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA)

Hubble Space Telescope image of the Andromeda galaxy highlighting V1, the Cepheid variable Edwin Hubble used in 1923 to prove Andromeda lies far outside the Milky Way.



the discovery of the relation between period and apparent magnitude, has afforded us a very powerful tool in measuring great stellar distances."

The great power of Leavitt's discovery has been amply illustrated in the decades since her death. As early as February 1925, for instance, Shapley received a letter from Edwin Hubble, starting "Dear Shapley: You will be interested to hear that I have found a Cepheid variable in the Andromeda Nebula." This was interesting news indeed; using Leavitt's law, Hubble was able to estimate the distance to the Andromeda Nebula as one million light-years (the current measurement is roughly 2.4 million). At this great distance, it was clear that the Andromeda Nebula was actually the Andromeda Galaxy, comparable in size to our own galaxy. Before Leavitt's discovery, it was uncertain whether the universe ended at the edge of the Milky Way, or was populated with other galaxies of stars far outside our own. After Hubble's findings, it was clear that we live in an immense universe full of galaxies.

Leavitt's period-luminosity relation is not a dusty, outmoded tool, but is used to the present day. The underestimated distances of Hertzsprung, Shapley, and Hubble were later corrected upward when the dimming effects of interstellar dust were better understood. Studies of how Cepheids actually pulsate in and out have led astronomers to realize that the pulsation period for a star of a given luminosity depends on the star's density. Thus, the period-luminosity relation for Cepheids is actually a relation among period, luminosity, and density.

For early observers such as Hubble, one difficulty of observing Cepheids in distant galaxies was that the light from the Cepheid star was blurred together with the light from numerous ordinary stars around it. This blurring makes it difficult to detect the variability of the Cepheid and to measure its brightness with the desired accuracy. To reduce the blur, the best solution is to hoist a telescope above the atmosphere. Thus, one of the main motivations for building and launching Hubble Space Telescope was an ambitious project to observe Cepheids in galaxies as far as 70 million light-years away. By developing a more accurate distance scale in this region, the project has given us a reliable measuring stick to use for intergalactic distances. Before Henrietta Leavitt's discovery of the period-luminosity relation, astronomers were unable to measure accurately distances greater than 70 light-years; by making use of Leavitt's law, we are now able to find the distances to galaxies a million times farther.

Barbara Ryden is a professor of astronomy at Ohio State University and a frequent contributor to StarDate.

Scaling the universe: The most accurate tool for measuring cosmic distances, parallax, reaches nearby stars. Understanding Cepheid variables extended astronomers' reach to nearby galaxies. By observing how a certain type of supernovae brighten and dim, astronomers can gauge distances of several billion light-years. To reach even further, they study redshift, the effect of the universe's expansion on light traveling toward us from the most distant galaxies.

Resources

Books

Miss Leavitt's Stars, by George Johnson, 2005

The Day We Found the Universe, by Marcia Bartusiak, 2009

Internet

Cosmic Distance Ladder
aavso.org/cosmic-distance-ladder

Carnegie Cosmology Timeline
cosmology.carnegiescience.edu/timeline/1912

StarDate: Beyond the Solar System
stardate.org/astro-guide/btss

Cosmic Rulers
telescopes.stardate.org/research/cosmic_rulers

SKY CALENDAR

by Alan MacRobert

March and April bring astronomy-rich evenings even if you live in the heart of a light-polluted city. Most of the brightest stars and planets are up and waiting to show off.

MARCH 1 - 15

Start your tour of the March sky with brilliant Venus and Jupiter, shining high in the west during twilight. Venus is the brighter of the two. They begin the month 11 degrees apart, which is about a fist-width at arm's length. Watch them march toward each other day by day. They pass just three degrees apart (about two finger-widths at arm's length) on March 12, 13, and 14. Venus and Jupiter are the brightest objects in the heavens after the Sun and Moon. Mark your calendar to be sure to catch this beautiful twilight conjunction.

And in the first week of March, while twilight is still bright, look far below Venus and Jupiter and a bit to their right to spot little Mercury, the innermost planet, low in the fading glow of sunset. There's nothing else there to confuse it with.

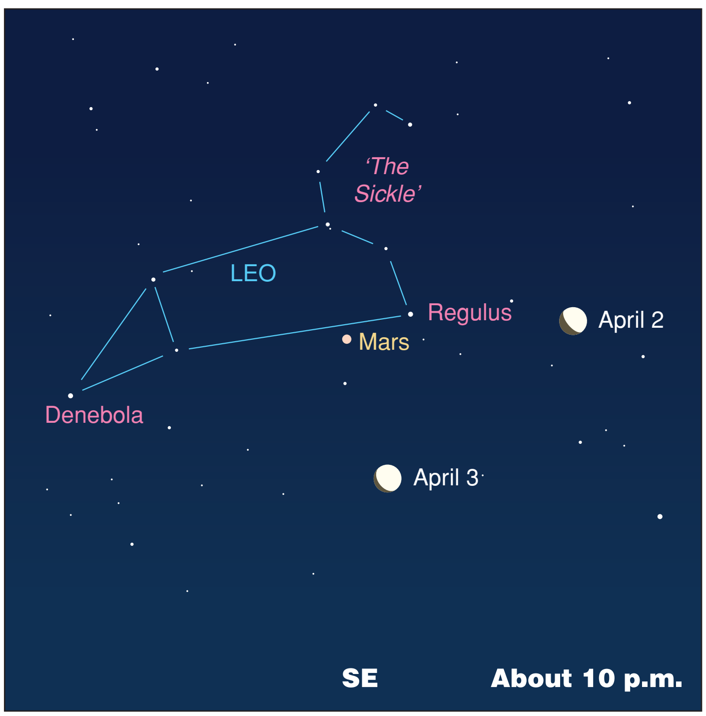
Bright Capella, the goat star, shines near the zenith at that hour.

As darkness falls, Orion stands high in the south to southwest. It is, of course, the brightest and most recognizable constellation of the season.

Sirius, the brightest star in the night sky, shines to the lower left of Orion. It is the closest object beyond the solar system that is visible to the unaided eye from our mid-northern latitudes.

To the upper left of Sirius shines Procyon. These are the big and little dog stars, respectively. With Betelgeuse in Orion's shoulder, they form the bright, equilateral Winter Triangle.

Turn farther left now to face east, where you will see the planet Mars shining fiery yellow-orange, almost as bright as white Sirius. Mars is at opposition (opposite the Sun in our sky) on March 3 and closest to Earth on March 5. Don't expect too much of it in a telescope, though; this is a distant opposition, and Mars appears only 13.9 arc seconds wide — a tiny ball. With a good telescope on a night of steady atmospheric seeing, however, you should be able to make out Mars' north polar ice, subtle dark markings, and perhaps some signs of white clouds around the planet's rim.



C.J. DUNCAN

To the upper right of Mars by a fist-width or a bit more shines dimmer Regulus, in Leo. The evening Moon glares to the right of Regulus on March 6, then to the right or lower right of Mars on the 7th.

By late evening, two more points are up in the east-southeast: Saturn, and to its right, Spica. Far off to their left in the east shines brighter Arcturus, the "spring star," a match for Capella — which, as the evening grows late, is moving down the sky's northwestern wall.

MARCH 16 - 31

Venus and Jupiter spend the second half of March pulling apart from each other in the western evening sky. Jupiter is heading downward, toward the Sun (and will pass behind the Sun in May). Brighter Venus stands almost still from week to week, as high in the evening twilight as we ever see it.

The waxing crescent Moon passes Jupiter and Venus late in the month. It hangs with Jupiter on the evening of the 25th and with Venus on the 26th.

The rest of March's panorama of brightness remains much the same as it was in the first half of the month, except that Mercury is gone and everything has shifted westward with the advancing season. On the eastern side of the sky, celestial "westward" means up, so Mars and Regulus shine higher in the east after dusk.

And the Saturn-Spica pair rises in the east earlier now, at roughly 10 p.m. Saturn is the one on the left, shining with a steadier glow than twinkly Spica. The two are lined up nearly horizontally, three or four fingers apart.

Brilliant Sirius is now due south at nightfall. It's the bright dog tag on the chest of Canis Major, the big dog. If you live under typical city light pollution, only five stars of Canis Major show through, forming more of a meat cleaver than a dog. Sirius is a bright glint on the top corner of the cleaver. A fainter star to Sirius' lower right, Mirzim, marks the front corner of the cutting edge. Three stars farther to the lower left form the narrower back of the cleaver and its stubby handle. These last three stars are, from right to left, Adhara, Wezen, and Aludra. They are about as high right now as they ever get.

In a dark sky more stars come out, and with only a little imagination (and a good constellation guide) you can spot the dog's dim triangular head to the upper left of Sirius. Adhara is the dog's hind leg, Wezen is his rump, and Aludra is his tail.

APRIL 1 - 15

Changes are afoot in the western twilight. Jupiter is dropping farther away from Venus, while Venus has an encounter with the Pleiades. On April 1, Venus shines just below the little star cluster. On the 2nd and 3rd it's practically inside the group, then on subsequent days it moves above them.

Or rather, Venus is standing still with respect to your twilight landscape and the Pleiades are sliding down to the lower right behind it. And so is the entire western starry backdrop. Aldebaran, for instance, is the orange point roughly a fist to Venus' upper left early in April, then to its left, and then to its lower left as the month proceeds.

Meanwhile, Capella is moving downward, high to Venus' upper right.

With spring under way, Orion is tipping down into the southwest and his three-star belt is becoming horizontal. Orion's Belt points to the right, roughly to Aldebaran, the Pleiades, and Venus. It points leftward toward ever-brilliant Sirius.

Meteor Watch

The Shower

Lyrids

Named for the constellation Lyra, the harp, which is notable for its brightest star, Vega, the third-brightest star visible from most of North America.

Peak

Night of April 21

Notes

The Lyrids are a modest shower, with perhaps a dozen or two meteors per hour at best. The Moon is new on April 21, providing perfect conditions for viewing the shower.

It can't be spring without the Big Dipper. Look for it standing on its handle high in the northeast as the stars come out. It moves even higher and tips leftward as the evening advances. By midnight it's almost upside down, high in the north.

Follow the curve of the dipper's handle down and to the right, by a bit more than a dipper-length, and you will find yourself at bright Arcturus, the "spring star." Its ascent in the eastern evening sky parallels the rising of temperatures, leaves, and flowers in March, April, and May.

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

APRIL 16 - 30

And *still* Venus holds its twilight position, flaming whitely high in the west as the "evening star." Aldebaran and the Pleiades are moving farther below it. And Jupiter is much lower still, riding away into the sunset. Capella remains higher to Venus' upper right, though it is less high every week. The waxing Moon poses near Venus on April 24.

And look much closer above Venus for the star El Nath (Beta Tauri), which just missed fame and recognition by not quite qualifying as a first-magnitude star (it is magnitude 1.6). It is moving closer to Venus every day.

Mars and Regulus are at their highest in the south now at dusk. For a while they were making the moves on each other, but seem to have decided against it. They were five degrees apart at the start of April, closed to within four degrees around mid-month, and have now separated to five degrees again and will be going their own ways henceforth.

Arcturus now rules high in the eastern sky. But a challenger to its warm-season preeminence is beginning to make itself known. Low in the northeast now, Vega rises by late evening. Like Arcturus, it is magnitude zero, which is one step brighter than first-magnitude on the stellar brightness scale. (This actually makes sense once you know the history.) Vega is beginning a long ascent to claim the zenith as the "summer star."

Alan MacRobert is a senior editor of Sky & Telescope *in Cambridge, Massachusetts.*

MARVELOUS MONTH OF MARS

NASA

A view of Mars from Hubble Space Telescope

Mars marches boldly into March (which, like the planet, is named for the ancient god of war), shining as the fifth-brightest object in the night sky. The planet is at opposition on March 3, when it lines up opposite the Sun. For several nights around opposition, Mars rises at sunset, climbs high across the sky during the night, and sets at sunrise. It passes closest to Earth around opposition as well, so it's brightest for the year. It looks like a brilliant orange star, not far from Regulus, the brightest star of Leo, the lion.

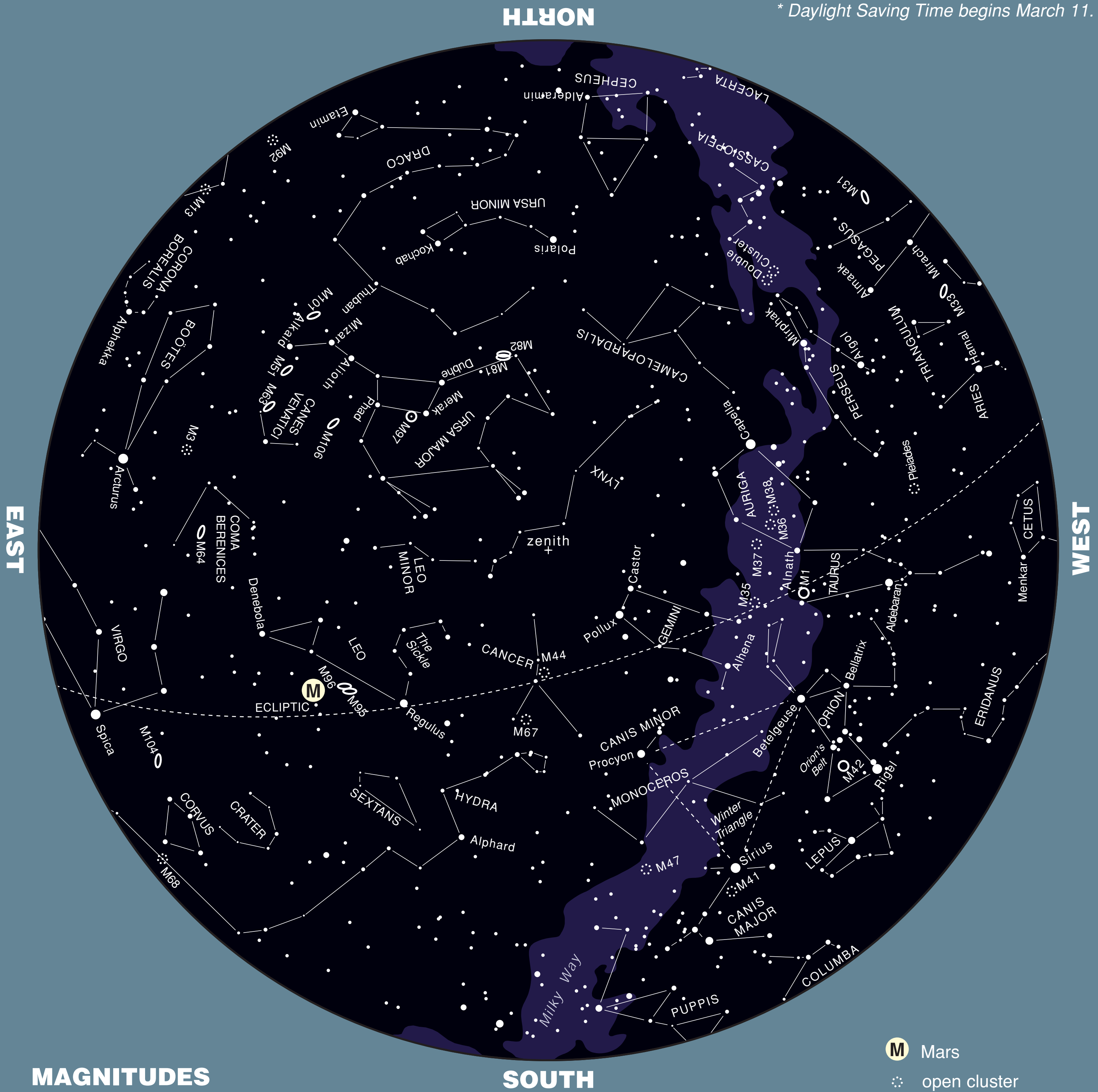
This is not a great opposition for Mars, however. Earth passes more than 60 million miles from the planet, versus just 35 million miles a few years ago. Mars follows a much more elongated orbit than Earth does, so its distance from the Sun varies by tens of millions of miles. When we pass Mars at this time of year it's close to its farthest point from the Sun. In the years when we pass it during summer, though, and especially in August, Mars is much closer, so it shines much brighter.

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	**10 p.m.***

** Daylight Saving Time begins March 11.*



MAGNITUDES

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

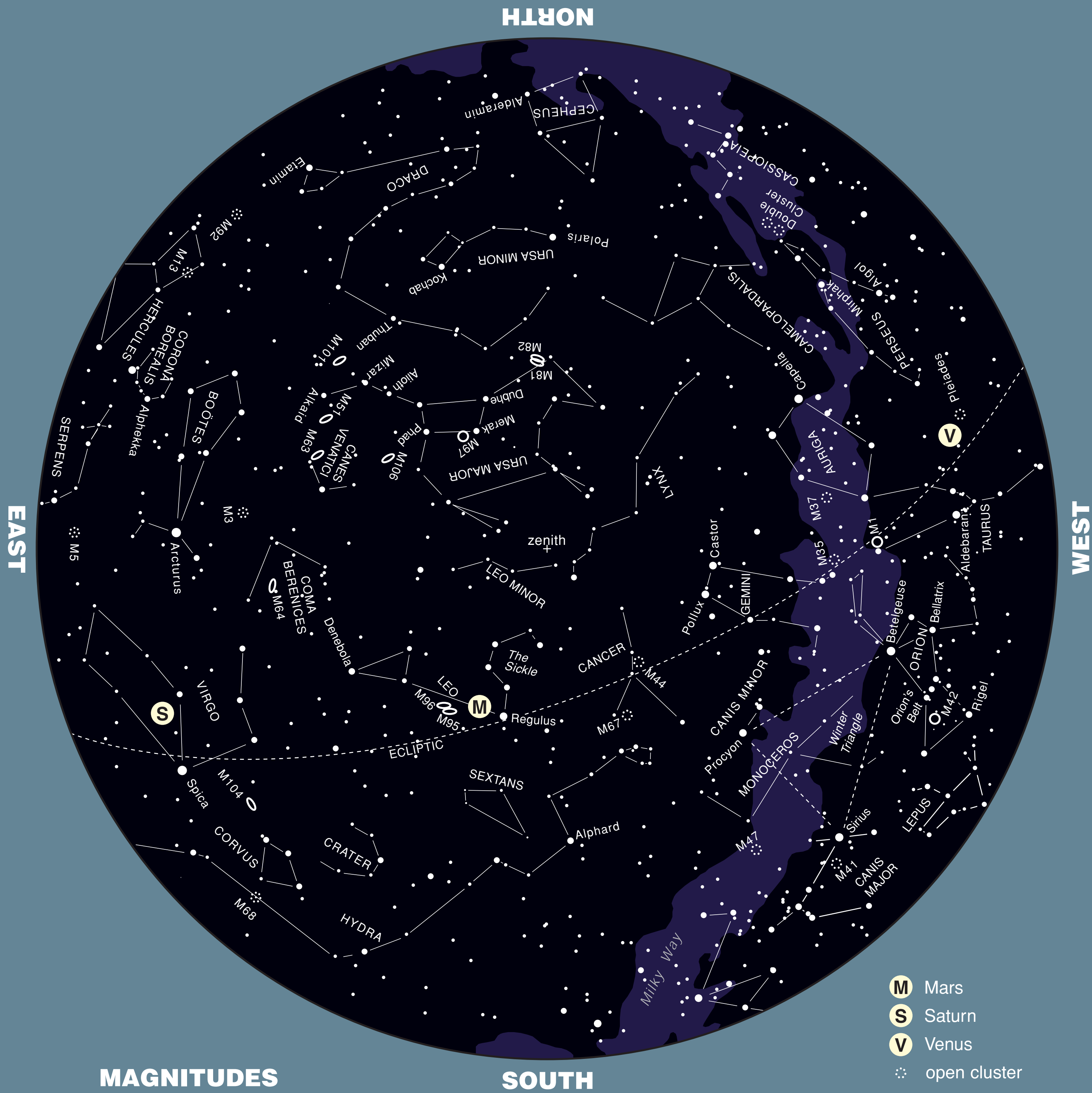
M Mars
open cluster
globular cluster
nebula
planetary nebula
galaxy

Charts produced with Voyager II software.

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	**11 p.m.**
April 5	**10 p.m.**
April 20	**9 p.m.**



M Mars
S Saturn
V Venus
open cluster
globular cluster
nebula
planetary nebula
galaxy

MAGNITUDES

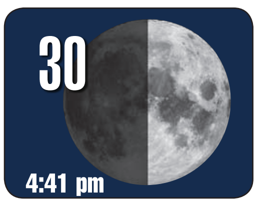
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

Charts produced with Voyager II software.

Sky Highlights

by Damond Benningfield

MARCH



Moon phase times are for the Central Time Zone.

3 Mars is at opposition, which means it lines up opposite the Sun in our sky. It puts in its best showing of the year. It rises at sunset and remains in view all night. The planet looks like a bright orange star, and is passing through the constellation Leo, where it stands about halfway between the lion's brightest stars, Regulus (above Mars) and Denebola (to its lower left).

5 Mercury is farthest from the Sun for its current evening appearance. It looks like a bright star low in the west as night begins to fall, and sets in early evening. It is well below brighter Jupiter and Venus.

6/7 The Moon, Mars, and Regulus team up. They are in the east in early evening and climb high across the sky later on. On the 6th, Regulus is close to the left of the Moon, with brighter Mars to their lower left. Mars is to the upper left of the full Moon on the 7th, with Regulus well above them.

9/10 The Moon slides past the planet Saturn and the star Spica. As they rise on the night of the 9th, Spica is to the lower left of the Moon, with Saturn farther along the same line. The next night Saturn is to the upper left of the Moon, with Spica about the same distance above the Moon.

Su	M	T	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

20 Spring begins in the northern hemisphere with the vernal equinox at 12:14 a.m. CDT. The Sun crosses the celestial equator, which is the projection of Earth's equator on the sky, at that moment, heading from south to north.

24-26 The crescent Moon climbs past Venus and Jupiter, which are the brightest objects in the night sky after the Moon itself. The Moon is well below them on the 24th, just to the upper right of Jupiter on the 25th, and just to the upper left of Venus on the 26th.

APRIL

2/3 Brilliant Venus, the "evening star," slides past the Pleiades.

3 Bright orange Mars lines up to the upper left of the Moon at nightfall, with the star Regulus close to the upper right of Mars.

6 The Moon lines up with the star Spica and the planet Saturn. Spica is close to the left of the Moon at nightfall, with brighter Saturn farther to the left of Spica.

9 Venus and Aldebaran are in the west at sunset, with fainter Aldebaran about the width of a fist at arm's length from brighter Venus.

Su	M	T	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

15 Saturn, the second-largest planet in the solar system, is at its best for the year. It rises around sunset and shines all night in Virgo, with the constellation's brightest star, Spica, to the right of Saturn. Saturn looks like a bright golden star.

22 Brilliant Jupiter, which is about to disappear in the Sun's glare, stands directly below the Moon as evening twilight descends.

23 The crescent Moon passes through Taurus. The bull's brightest star, Aldebaran, is to the upper left of the Moon, and its shoulder, the Pleiades star cluster, about the same distance to the lower right.

24 Evening-star Venus is to the upper right of the Moon this evening.

30 Venus shines brightest for its current evening appearance.

30 Orange Mars stands to the upper left of the Moon at nightfall, with the star Regulus closer to the upper right of the Moon.

NASA/ARC/JPL

Get StarDate on Your Smart Phone!

The free University of Texas iPhone app now provides a plethora of frequently updated information from StarDate and McDonald Observatory. With the app, you can listen to dozens of StarDate radio podcasts (excluding the current day's show), see what's in the latest issue of *StarDate* magazine, and get weekly skywatching information from StarDate Online. You can check out a guide to the constellations, read up on the latest research from McDonald Observatory, see a photo gallery, and get information on visiting McDonald — with an interactive map and driving directions. The app also will connect you with StarDate and McDonald Observatory's social media sites on Facebook, Twitter, and YouTube.

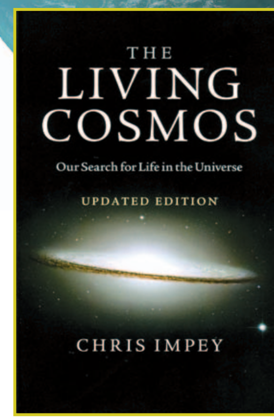
To get the app, visit: **www.utexas.edu/iphoneapp**

The journal *Astronomy Education Review* recently compiled a list of astronomy apps for smart phones:

aer.aas.org/resource/1/aerscz/v10/i1/p010302_s1

Looking for Neighbors

Just about every issue of this magazine brings you tales of newly discovered planets, including a few that follow roughly Earth-like orbits around Sun-like stars. Indeed, the count of known planets in other star systems is nearing 700, and almost certainly will top 1,000 by year's end. Yet there is no hint of life from these or any other of the billions of planets that may populate the galaxy.



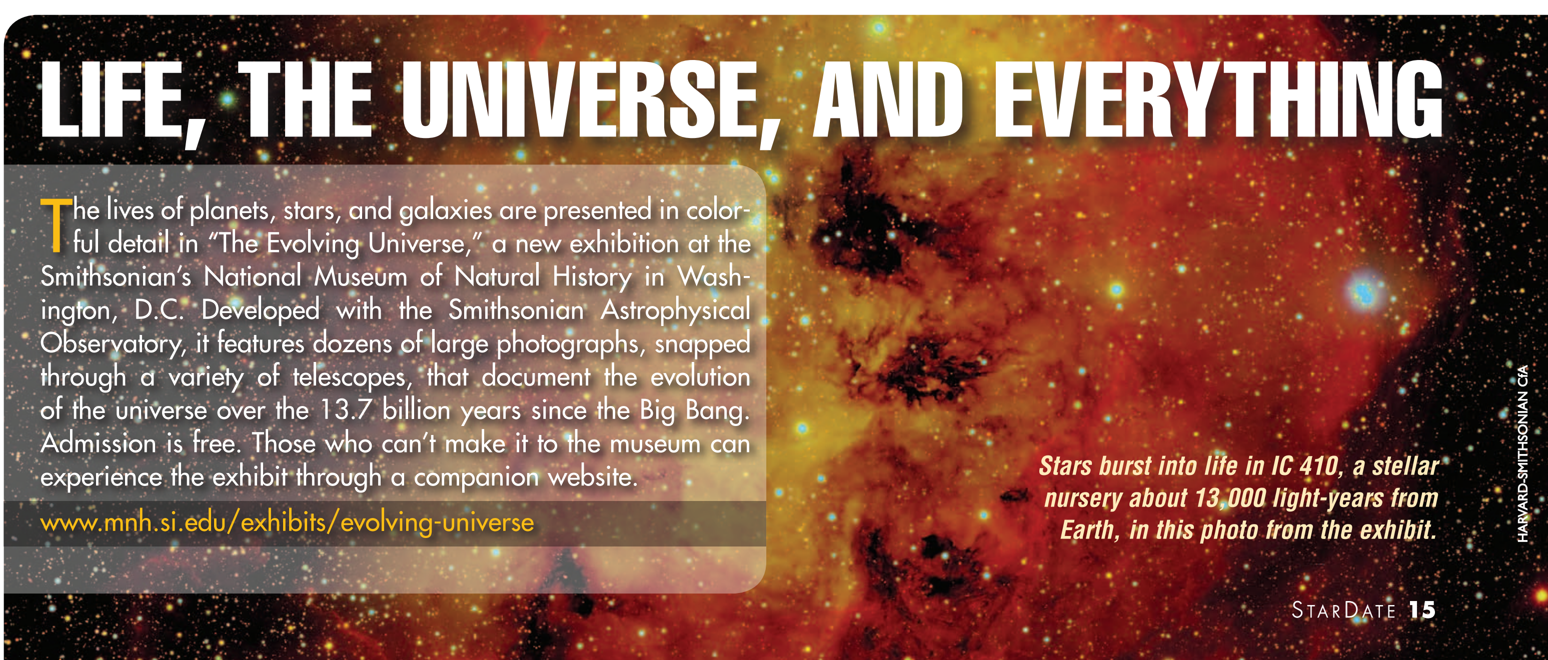
In the newly updated *The Living Cosmos*, Chris Impey, astronomy chairman at the University of Arizona and a skilled writer for non-academic audiences, explores not only the challenges of finding life in the universe, but the challenges of life itself: the conditions necessary for life, the twisting branches of evolution, the threats from the universe. He also explains our current knowledge of life's hardiness and of the birth and evolution of planets, and he discusses humanity's future in space and the chances that we're not the only intelligent life in the universe.

The Living Cosmos:
Our Search for Life in the Universe
By Chris Impey
Cambridge University Press, $20

LIFE, THE UNIVERSE, AND EVERYTHING

The lives of planets, stars, and galaxies are presented in colorful detail in "The Evolving Universe," a new exhibition at the Smithsonian's National Museum of Natural History in Washington, D.C. Developed with the Smithsonian Astrophysical Observatory, it features dozens of large photographs, snapped through a variety of telescopes, that document the evolution of the universe over the 13.7 billion years since the Big Bang. Admission is free. Those who can't make it to the museum can experience the exhibit through a companion website.

www.mnh.si.edu/exhibits/evolving-universe



Stars burst into life in IC 410, a stellar nursery about 13,000 light-years from Earth, in this photo from the exhibit.

HARVARD-SMITHSONIAN CfA

A NEW FOCUS ON THE X-RAY SKY

NuSTAR will scan the heavens to better understand high-energy X-ray phenomena like exploding stars, black holes, and jets from distant massive galaxies

ORBITAL SCIENCES CORPORATION

by Rebecca Johnson

Astronomers will gain new insights into the chaotic center of our Milky Way galaxy and uncover previously hidden supermassive black holes in remote dusty galaxies as early as this spring thanks to a satellite that's scheduled for launch in March. NuSTAR (Nuclear Spectroscopic Telescope Array) is an X-ray telescope that will study the high-energy X-ray sky with much greater sensitivity than any previous instrument.

NuSTAR is a Small Explorer mission, which means it was designed and built much more quickly and inexpensively than billion-dollar projects like Hubble Space Telescope and its fellow Great Observatories.

"Not only will it be a factor of 500 times more sensitive than anything [like it] that's been launched before, it's a factor of more than 10 times cheaper," said Caltech's Fiona Harrison, the mission's principal investigator, in a recent public talk at NASA's Jet Propulsion Laboratory, which manages the mission.

NuSTAR will probe the universe at wavelengths that have received scant attention before. Large X-ray telescopes like Chandra X-Ray Observatory and Europe's XMM-Newton have studied the low-energy X-ray universe in depth. Both are still flying — but powerful as they are, they can't see into all the dusty, hidden regions that NuSTAR will probe.

"The particularly interesting thing about observing high-energy X-rays is that they're very penetrating," Harrison said. "Baggage scanners at the airport, dental X-rays — these are all high-energy X-rays."

High-energy X-ray telescopes of the past have been fairly crude. They operated much like sophisticated pinhole cameras rather than telescopes. That's because focusing X-rays is notoriously difficult.

"X-rays only bend very slightly," Harrison said. "You can reflect X-rays, but the key, the challenge is that it only works at very glancing angles — much less than a degree." The only part of a parabolic mirror that has such a shallow angle is the edge, which makes for a tiny collecting area for an X-ray mirror.

To increase the collecting area, which increases the instrument's ability to see fine detail, engineers take multiple mirrors and stack them in concentric shells inside an X-ray telescope. NuSTAR has two telescopes, each using 130 concentric mirror shells. (Chandra has four such shells.) Special atom-thick coatings on the mirrors allow them to reflect higher-energy X-rays.

The two telescopes will focus the incoming X-rays to two identical detectors. The images from the two telescopes will be added together once the data are transmitted to Earth.

These complicated optics will be used to tackle a diverse list of science goals. One is to take a census of black holes, both inside and outside our galaxy.

Inside the Milky Way, NuSTAR will look for stellar-mass black holes that can form when a heavy star burns all of its nuclear fuel and either explodes as a supernova or implodes before it can explode. Of course, no telescope can see a black hole directly — they don't emit light. But a black hole's powerful gravity pulls matter into a swirling disk around it. This matter gets so hot that it emits X-rays.

NuSTAR also will study the chemistry of material spewed into space by supernova explosions by probing the expanding clouds of gas and dust known as supernova remnants. The composition of this detritus will provide clues about the explosions themselves, and in turn the physics of what goes on inside massive stars. These studies also will help astronomers better understand how chemical elements forged in supernova explosions are incorporated into the next generation of stars.

NuSTAR will look outside our galaxy for supermassive black holes at the hearts of distant galaxies. These monster black holes, weighing in at millions or billions of times the Sun's mass, also are surrounded by hot, swirling disks that give off X-rays. Though some have been studied, NuSTAR will add many more to the census because it can see the ones currently hidden inside dusty galaxies.

In digging into the secrets of supermassive black holes, NuSTAR will attack one of the toughest problems astrophysicists currently face, Harrison said: They don't really understand the relationship between a supermassive black hole and the galaxy that surrounds it. Astronomers know there is a tight correlation between the black hole's mass and the mass of the galaxy's central bulge. They also know there's a relationship between the black hole's mass and the galaxy's rate of star formation. What they don't know is *how* the black hole is influencing the surrounding galaxy, and vice versa.

Until now, it's been a difficult mystery to probe because the best pictures of high-energy X-rays coming from near supermassive black holes look like shapeless blobs.

"This is what we want to do with NuSTAR," Harrison said. "We want to turn [the blobs] into point sources, whose brightness, energy output, positions, distances we can all measure, so that we can say, 'What kind of galaxies are these black holes growing in? How much of this dust that they're hidden behind are they actually swallowing?'"

A Pegasus XL rocket will propel NuSTAR into space. In mid-March, the rocket will be dropped at 40,000 feet from an L-1011 aircraft flying from the Ronald Reagan Ballistic Missile Defense Test Site on the Kwajalein Atoll in the Marshall Islands. After free falling for five seconds, it will ignite and carry NuSTAR into low-Earth orbit for its two-year primary mission.

Once it enters orbit, the spacecraft will deploy a boom that will push its optics out to 10 meters (33 feet) from the detectors. Focusing X-rays requires such a long focal length, and the extendable boom made it possible for NuSTAR to fold and fit into the Pegasus rocket. Once the boom is extended and the systems check out, astronomical observations will begin.

By bringing both the nearby and distant high-energy universe into focus for the first time, NuSTAR will foster a new understanding of many diverse realms of the cosmos.

Rebecca Johnson is editor of StarDate *magazine.*

A Chandra X-ray view of a jet shooting out of Centaurus A, a galaxy with a supermassive black hole at its core. NuSTAR will offer a sharper view of this and other X-ray sources.

NASA/CXC/CfA/R.KRAFT

Resources

Internet

NuSTAR Mission Homepage
www.nustar.caltech.edu

Launch Information
www.nasa.gov/mission_pages/nustar/launch

Slide Show
www.scientificamerican.com/article.cfm?id=nustar-telescope-photos

Articles

"X-ray Vision: NASA's NuSTAR Telescope," by Fiona Harrison and Charles J. Hailey, *Scientific American*, February 2011

"How to Make Telescopes Lenses to Spot Black Holes (for Cheap)," by Cassie Rodenberg, *Popular Mechanics*, May 4, 2010

"Urban Jungle," by Damond Benningfield, *StarDate*, September/October 2011

JOIN THE CLUB!

ASTRONOMY CLUBS PROVIDE OPPORTUNITIES FOR LEARNING, FRIENDSHIP, AND VOLUNTEERING

As a *StarDate* reader, you know that you don't have to be an expert astronomer to enjoy the wonders of the cosmos. But in addition to books, magazines, and websites, there is another great resource that can help you gain a deeper delight and appreciation for the night sky. I'm talking about an astronomy club.

There are at least 250 clubs in the United States, comprising almost 20,000 members. The largest is the Texas Astronomical Society of Dallas, with about 700 members. No matter where you live, though, there's a good chance there's one close to you.

The Astronomical League, which has been around since 1947, is the national umbrella organization for most clubs. Not every club belongs to the Astronomical League, but most do, and its website is a good place to start looking for a club near you.

Additionally, you could contact the physics or astronomy department of your local university or community college, or check with local camera shops or astronomy supply vendors.

Astronomy clubs offer lots of benefits for their members. First, there's the sense of camaraderie you get from being with people who share a passion for the night sky. This fellowship can be a blessing if your friends and family members don't share your enthusiasm for staying up late at night outdoors in the cold to look skyward!

BY LINTON G. ROBERTSON

TWAN/BABAK TAFRESHI

This support can take many forms. For example, regular meetings are the backbone of any club. They tend to be light, informative, and extremely friendly. Programs usually consist of a short introduction, a welcome for newcomers, some information on what the club is doing that month, and the main event: a talk on a topic in astronomy.

Big names in astronomy often give these talks. You might hear a lecture from a famous comet discoverer, a NASA bigwig, an astronomer who has just discovered an extrasolar planet, or an astronaut. You never know who is going to turn up, but it might be someone you otherwise would see only on TV.

Once you've attended a meeting or two and decided to join the club, the possibilities can be truly remarkable.

Many clubs schedule field trips to NASA centers and science museums. They can also be your gateway into your local state or community college's observatory, where you can get a look through some pretty big telescopes.

Some clubs also have their own "dark-sky sites." A dark sky site can range from a farmer's field in the middle of nowhere (with the farmer's permission, of course!), to more sophisticated club-owned sites. The latter could offer bathrooms, showers, concrete pads with electrical outlets where members and guests can set up their telescopes, barbecue pits, visitor parking, and a club-owned telescope.

Some clubs have monster telescopes that they open to the public twice a month or more, and they are happy to train you, as a club member, to use it yourself. This is a truly marvelous plus to those who have no telescope of their own, but, for a small membership fee, will have full use of a 17-inch, 22-inch, or perhaps even a 36-inch giant.

"Warming rooms" for winter and "cooling rooms" for the heat of summer can be a real blessing, and many clubs even feature meal preparation facilities at their observing sites. These amenities can extend your yearly calendar of visits to the club site quite a bit, especially if you live in an area where the dark-sky site is in the desert or mountains.

Some clubs even offer telescopes that you can control from your home computer. This removes the need to trek miles into the outback to get a good look at the sky targets of your desire.

Many clubs offer small specialty groups, and finding your niche can be rewarding. Some people enjoy astrophotography, some like observing and learning about comets and planets in our own solar system, some prefer the deep-sky wonders of galaxies and nebulae. Some people like to observe variable stars, and others concentrate strictly on meteor showers. And there are some who are as fascinated with the observing equipment as in what they're using it to observe.

The better-developed clubs lease private telescope pads where you can come and go as you please, miss the crowds, bring a few friends, and host your own star party at the club's site. This may cost extra, usually paid yearly, and you may have to pledge to use it or lose it; policies vary from club to club.

HALFBLUE

Many clubs sponsor on-line chats, texting, and group message boards for members to ask questions, keep up to date on happenings, and notify members of unusual skywatching events. For the really adventurous, clubs frequently sponsor telescope-making classes taught by a master. If you have the time, you can build an instrument of superior optical quality for the same or less money than purchasing one.

If you're more interested in buying a telescope, club members can steer you toward good manufacturers, makes, and models, and save you a lot of grief. Ask questions, and don't be shy about asking to look through another person's telescope. (Always ask first, though! It's good astro-etiquette.) This is a wonderful way to learn about binoculars, telescopes, filters, vendors, and the like before taking the plunge. Many a greenhorn has thrown away a lot of money on bad equipment because he or she doesn't wish to appear ignorant by asking questions.

Club membership also gives you plenty of chances to give back. For example, you can help out at public star parties. Clubs stage skywatching events to educate and amaze school groups and the public. You also could volunteer your time to the club itself: sites have to be maintained, and events are always in need of docents and organizers.

There's work to be done, too, in the field of preserving our night sky from the continuing and accelerating problem of light pollution; many clubs work directly with the International Dark Sky Association and provide clout when cities decide to put up bad street lighting or adopt lighting ordinances that threaten the night sky.

In short, membership in a club can enhance your love of the night sky in ways you never envisioned.

Linton Robertson has been a lover of the night sky since 1956, when his late mother took him as a five-year old to Griffith Observatory in Los Angeles.

Resources

Internet

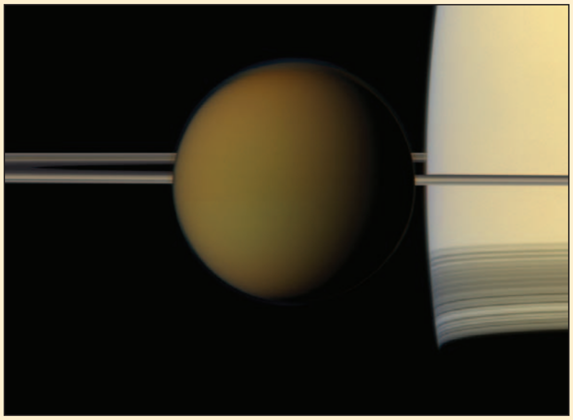
The Astronomical League
astroleague.org

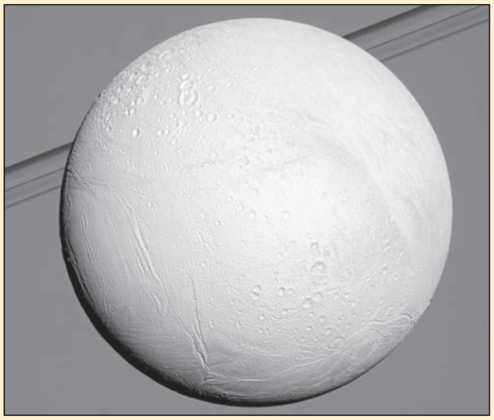
World Astronomy Clubs
astronomyclubs.com

Beginner's Guide to Stargazing
stardate.org/nightsky/bguide

International Dark-Sky Association
www.darksky.org

by Rebecca Johnson and Damond Benningfield





NASA/JPL/SSI (3)

From left: Smog-enshrouded Titan against Saturn's rings and the planet itself; icy Enceladus; the best look at Janus to date

Five Moons in Four Days

Saturn orbiter to probe cold skies and warm geysers, and look for hidden moons

The Cassini spacecraft faces a busy few days in late March. The Saturn orbiter will scan five of the giant planet's moons, taking a look at everything from clouds to geysers.

During the March 26-29 encounters, Cassini will take regular looks at Saturn's largest moon, Titan, which is enveloped by a thick, cold atmosphere, with clouds of frozen methane floating through its skies. Cassini will watch the motions of the clouds to plot the big moon's weather.

The craft will also look for tiny moons orbiting at gravitational balance points near Titan and another moon, Rhea. And it will make its closest approach yet to the small moon Janus, which shares an orbit with yet another moon. The two of them work together to clear out a gap in Saturn's rings.

The star of the week, though, is Enceladus. Geysers of water and ice shoot into space from "hot spots" near the moon's south pole. Cassini has taken several close looks at that region, and at the geysers.

On March 27, Cassini will swoop to an altitude of 46 miles (74 km) above Enceladus. The craft will approach from the nightside, so it will see the spray of ice backlit by the Sun. It then will pass around to the dayside, providing a 3D view of the geysers, plus one of the best looks yet at the hot spots that give them birth.

Cassini will stage equally close encounters with Enceladus on April 14 and May 2, providing the most detailed look to date at the ice-covered moon and its explosive geysers. **DB**

Astronomers Find Two Ways to Make a Star Go Boom

Last year's Nobel Prize for Physics honored the discovery of dark energy — a mysterious force that is causing the universe to accelerate faster as it expands. Astronomers discovered the expansion by measuring the speeds of exploding stars known as Type Ia supernovae in galaxies at different distances from Earth. These stars all appear to brighten and fade in the same way, making them good "standard candles" for measuring intergalactic distances.

Yet the stars themselves don't seem to meet a single standard. Instead, recent research suggests there are two ways to create a Type Ia supernova.

All of these explosions occur when extra matter piles atop a dense stellar corpse known as a white dwarf, triggering an explosion that blasts the star to bits. It is unclear, however, whether the extra matter comes from a flow of gas from a companion star or from a collision with a second white dwarf.

Hubble view of a supernova remnant that might have been triggered by the merger of two white dwarf stars.

NASA/ESA/HUBBLE HERITAGE TEAM

LSU astronomers Ashley Pagnotta and Bradley Schaefer examined Hubble Space Telescope images of four supernova remnants in the Large Magellanic Cloud, a companion galaxy to the Milky Way. In three of these expanding clouds of gas and dust, they found stars near the explosion site that could have supplied the gas needed to trigger an explosion. In the fourth, however, they found no possible companion at all, suggesting that the blast was triggered by the collision of two white dwarfs, which left no surviving stars.

The possibility that the explosions can form in different ways doesn't lessen their value for measuring the expansion of the universe, Pagnotta said during a recent presentation. "They're still good standard candles even if they come from different [types of] systems," she said.

Ready, Aim, Fire!

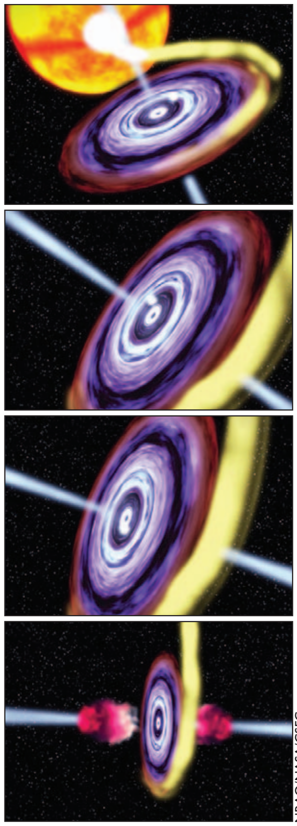
A black hole near the center of the galaxy is firing bullets. Once every eight months or so, it shoots a blob of superheated gas into space at a quarter of the speed of light.

The black hole, known as H1743-322, is about 28,000 light-years away, in the constellation Scorpius. It's probably about 5 to 10 times the mass of the Sun, with a companion star that probably resembles the Sun. The two are so close together that the black hole pulls gas off the surface of the companion, forming a spinning disk around the black hole. The gas gets so hot that it produces X-rays, although their intensity varies.

Three years ago, a team of astronomers monitored the system with a network of radio telescopes on the ground and an X-ray telescope in space. They found that shortly after the intensity of the X-rays peaked, the black hole fired two bullets into space. The bullets followed jets of charged particles that shoot into space from the poles of the black hole.

The bullets probably formed as gas piled up in the disk around the black hole, forming a dense knot. Just before it reached the black hole itself, the knot was blasted into space along the lines of its magnetic field, which funnel the jets into space.

There are several ideas for how that happens, but all of them have problems. Watching the whole process of such an eruption is helping astronomers narrow the list.



NRAO/NASA/GSFC

An artist's concept shows, from top: the black hole steals gas from its companion star; some of the gas forms a 'knot' in the disk around the black hole; the knot moves close to the black hole itself; magnetic fields eject the knot as twin 'bullets'

Artist's concept of a neutron star's surface cracking during a powerful 'starquake'

DARLENE MCELROY/LANA

NASA Turns Off the Lights for X-Ray Telescope

An orbiting X-ray telescope that studied some of the most bizarre objects in the universe was shut down on January 4, ending a 16-year mission. The telescope, Rossi X-ray Timing Explorer (RXTE), was showing signs of age, and a review panel recommended ending its operations to save money for higher-priority projects.

Among its many accomplishments:

- Confirmed the existence of magnetars, which are highly magnetic versions of the crushed stellar corpses known as neutron stars.
- Provided the first observational evidence that black holes drag spacetime around them like a cosmic whirlpool, confirming a prediction from Albert Einstein's theory of gravity.
- Provided the strongest confirmation to date of the existence of an event horizon, which is the point of no return for matter falling into a black hole.
- Studied the process by which black holes and neutron stars steal gas from companion stars, and how the gas behaves as it nears the dense objects.
- Measured a powerful starquake on the surface of a neutron star, providing new insights into its inner structure.

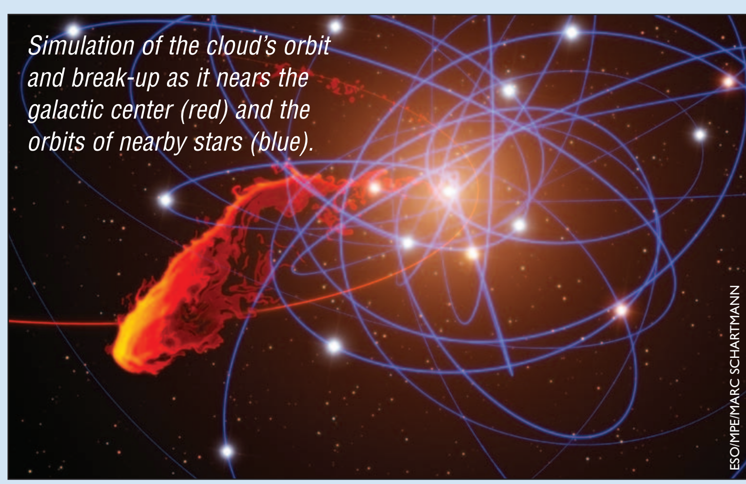
Don't Miss the Big Show Coming to the Galactic Center!

The black hole at the center of the Milky Way galaxy is usually pretty quiet. But it lurks, waiting for tasty morsels to get pulled in by its immense gravity. Astronomers expect to see such a show pretty soon.

In 2008, Reinhard Genzel of Germany's Max Planck Institute for Extraterrestrial Physics and his partners discovered a gas cloud three times the mass of Earth picking up speed as it approaches the Milky Way's black hole. The cloud of hydrogen and helium could fall into the spinning disk of material around the black hole within a year. By 2013, it should give off X-rays and radio waves as it's pulled apart.

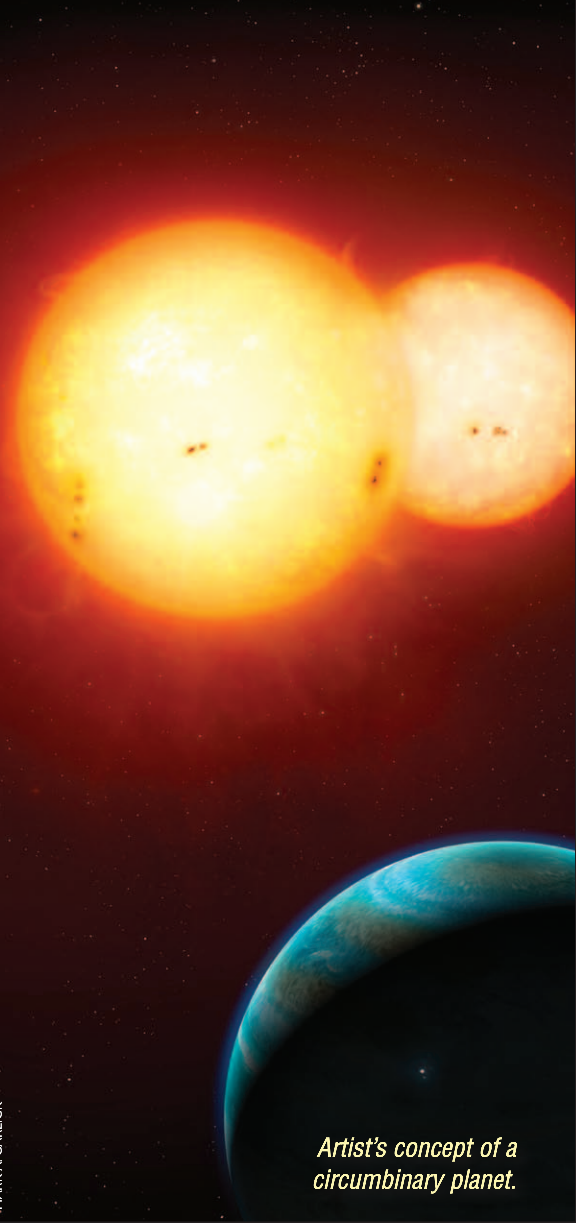
"This is an unprecedented opportunity to obtain unique observations and insight into the processes that go on as gas falls into a black hole, heats up and emits light," Genzel said. "It's a neat window onto a black hole that's actually capturing gas as it spirals in."

Genzel's group calculated that the region around the black hole could grow 100 to 1,000 times brighter. Chandra X-Ray Observatory and other space- and ground-based telescopes will watch the fireworks throughout the year. **RJ**



Simulation of the cloud's orbit and break-up as it nears the galactic center (red) and the orbits of nearby stars (blue).

ESO/MPE/MARC SCHARTMANN



Artist's concept of a circumbinary planet.

Milky Way Teeming with Billions of Planets, Some Orbiting Binary Stars

Scientists presented a hoard of recent findings on planets around other stars at a meeting of the American Astronomical Society in Austin in January.

A study by Kailash Sahu of the Space Telescope Science Institute indicates that our galaxy contains at least 100 billion planets. Sahu heads a large team that looks for planets using a technique called gravitational microlensing. When a star passes in front of a more distant one, the nearby star's gravity acts like a lens that bends and magnifies the distant star's light. If a planet is orbiting the nearby star, its presence will magnify that light just a little bit more, in a characteristic way. Knowing precisely how much more tells astronomers the planet's mass.

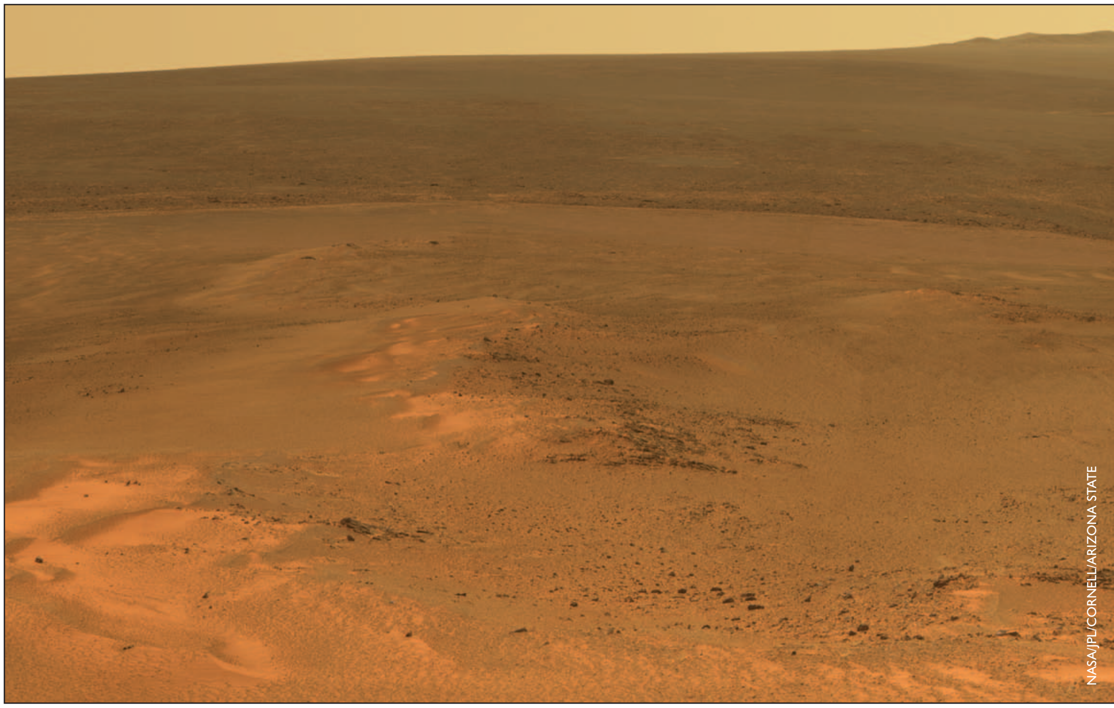
Over several years, Sahu's team predicted and observed about 40 of these microlensing events. Their findings indicate that one in six Milky Way stars hosts a Jupiter-like planet, half host Neptune-mass planets, and two-thirds have Earth-mass planets. Overall, their findings indicate the Milky Way holds at least 100 billion planets, and small rocky planets are more abundant than large gas giants.

A vastly different study from NASA's Kepler mission agrees with Sahu's conclusions on the abundance of small planets. Caltech astronomer Philip Muirhead announced that his team used Kepler to discover a miniature solar system in which three planets smaller than Earth orbit a red dwarf star. The smallest planet is about the size of Mars; all are presumably rocky. As red dwarfs are the most common stars in our galaxy, the finding suggests there could be lots of small, rocky planets in the Milky Way.

Kepler also has helped astronomers discover more examples of a new class of planets. William Welsh of San Diego State University mined Kepler data to discover two examples of planets that orbit both stars in a binary star system. Such planets are called circumbinary. Together with the first case, announced in September, which astronomers thought might be an anomaly, Welsh's announcement indicates there may be millions of circumbinary planetary systems in the galaxy. **RJ**

Bedding Down for a Long Winter's Nap

The Opportunity rover is hunkering down for the Mars winter on the inner rim of Endeavour crater (right). Opportunity's solar panels are covered with so much dust that it must stand still during the winter and use most of its energy to stay warm. It is studying nearby rocks, however, and scientists are using its radio transmissions to help probe the Martian interior. Opportunity arrived at Mars in early 2004, and has covered more than 21 miles (34 km). The next rover, Curiosity, which will arrive at Mars in August, is monitoring solar radiation and cosmic rays during its interplanetary cruise. The readings will help scientists determine the risk to Mars-bound astronauts.



NASA/JPL/CORNELL/ARIZONA STATE

SPRING BREAK AT McDONALD OBSERVATORY

Spend your bring break with us under starry West Texas skies. We've expanded our schedule of tours and star parties March 10-17. Daytime tours include large research telescopes and 100-mile vistas in a beautiful mountain setting. After hours, enjoy one of our famous star parties under the darkest night skies of any professional observatory in the continental United States. To guarantee your spot, make your reservations online at mcdonaldobservatory.org/visitor.

EXPANDED SCHEDULE OF GUIDED TOURS*

March 10-17:
10:30 a.m., 11:15 a.m., 12 noon, 12:45 p.m., 1:30 p.m., 2:15 p.m., 3 p.m., 3:45 p.m.

March 12-14, 16-17:
All of the above, plus 4:30 p.m.

TWILIGHT PROGRAM AND STAR PARTIES*

March 10:
Twilight program at 4:45 p.m. and 6:05 p.m.
Star party starts at 7:30 p.m.

March 12-14, 16-17:
Twilight programs will be offered at 6:15 p.m. and 7:35 p.m. Star parties start at 9 p.m.

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For more information
mcdonaldobservatory.org/visitor | toll-free 877-984-7827

*Daylight Saving Time begins March 11. Event times listed for March 10 are Central Standard Time. All other dates are Central Daylight Time.

Thousands of young stars are being born in Cygnus X, one of the largest stellar nurseries in the galaxy, in this infrared image from Spitzer Space Telescope. The image shows bubbles blown by hot young stars, which compress clouds of gas and dust around them, giving birth to more stars. The long finger-like structures are columns of gas and dust that are being eroded by radiation from the hot stars. Many contain starbirth activity at their tips. The white regions, which are the hottest in this false-color depiction, are the most vigorous areas of starbirth. Green represents relatively warm dust, while red is cooler dust and gas. The complex is centered about 4,500 light-years away in the constellation Cygnus.

NASA/JPL/CALTECH/HARVARD-SMITHSONIAN CfA