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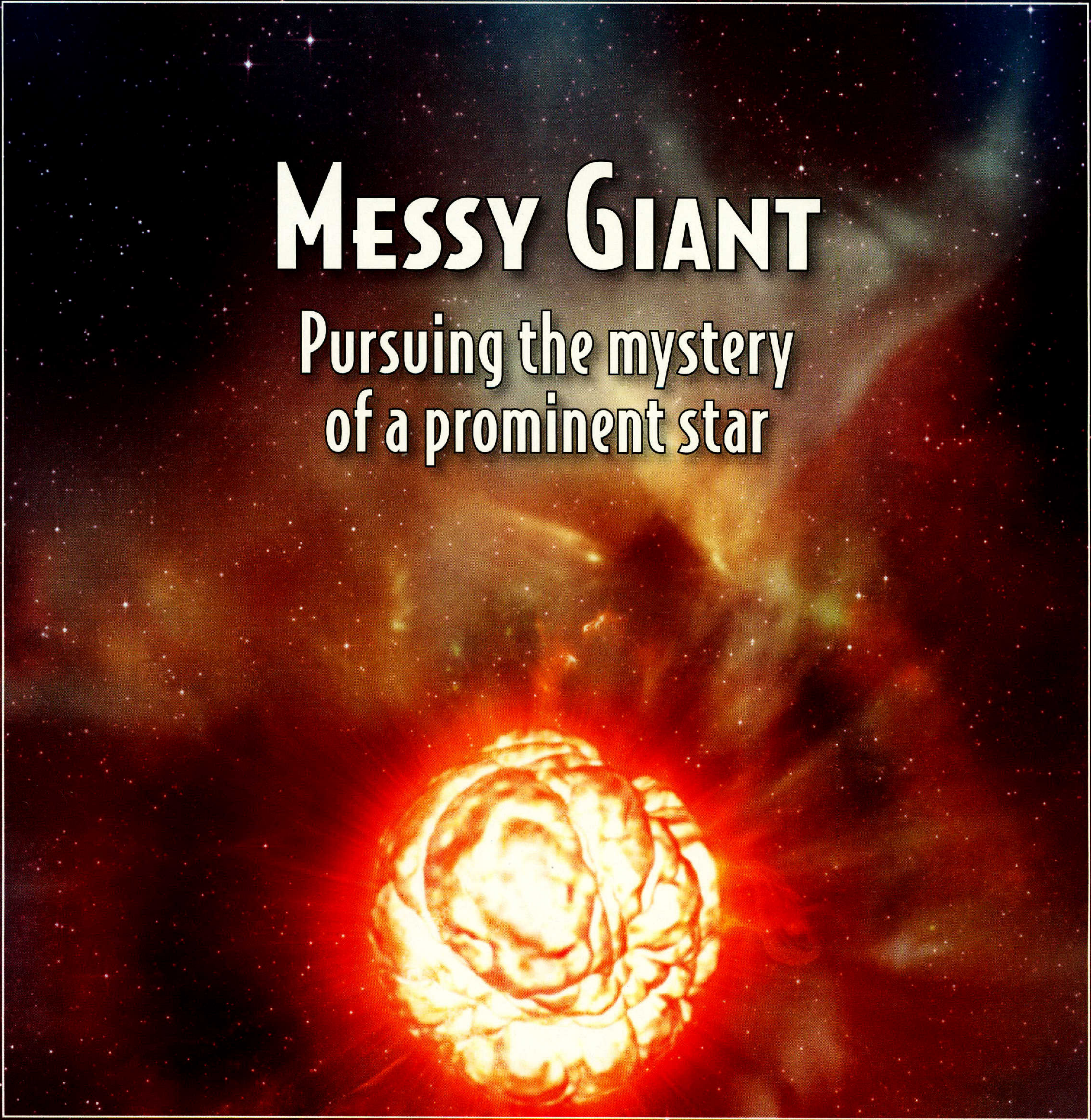
WARTIME ASTRONOMY
Page 4



MESSY GIANT

Pursuing the mystery of a prominent star

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

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Features

Departments

ESO/L. CALCADA

On The Cover

An artist's concept shows the roiling surface of the supergiant star Betelgeuse, with a massive plume of gas streaking off into space. For more about the star's 'messy' behavior, read the feature on page 16.

This Page

Here's a piece of Hubble Space Telescope's largest-ever image, and the most detailed view to date of the Andromeda galaxy. Though 2.5 million light-years away, scores of individual stars are revealed. The bottom of this image points toward Andromeda's central bulge, where a higher density of stars gives off a golden glow.

Coming Up

Our Summer Reading Issue is coming your way in May. We'll recommend new books in astronomy and space science, and bring you feature-length excerpts from some of our favorites. And of course, we'll bring you tips to start your summer stargazing.

NASA/ESA/J. DALCANTON/B.F. WILLIAMS/L.C. JOHNSON (UNIV OF WASHINGTON)/PHAT TEAM/R. GENDLER

MERLIN

Dear Merlin,

Is there a connection between gravitational waves and the spiral arm structure of normal and barred spiral galaxies?

Leonard Boucek
Monmouth Junction, New Jersey

Nope.

Gravitational waves are generated by the motions of all objects, which create tiny "ripples" in space itself. These waves are far too weak, though, to have any effect on the motions of stars in a galaxy. (Gravitational waves have not yet been directly detected, although several experiments are looking for them.)

A spiral arm probably is created by a "wave" in the galaxy's disk, though not a gravitational wave. As stars and gas clouds pass through the wave, they pile up like cars passing through a traffic jam. This dense environment causes clouds of gas and dust to collapse, giving birth to new stars. Many of these stars are hot and massive, so they make a spiral arm shine brightly.

Dear Merlin,

I'm at the beach and thinking of you. Please explain the alignments of the Moon and Sun that make the tides. Why are there two high tides and two low tides each 24-hour period? Why are they not all exactly six hours apart?

Shanti Thompson
Bedford, Virginia

Merlin is flattered that you were thinking of him, although a bit worried that you might have spent too much time under the Sun.

Speaking of which, as you noted, the Sun plays a role in raising the ocean tides. The tides are created by the gravitational pull of the Moon and Sun, which create "bulges" of water on the ocean surface. Although the Sun is much more massive than the Moon, it's also much farther away, so its influence is only about half that of the Moon's.

As a result, the ocean bulges are closely synchronized with the Moon's orbital motion around Earth. There's a bulge on the side of Earth that faces the Moon, where the Moon's gravitational pull is strongest, plus one on the opposite side, where the pull is weakest. As each bulge sweeps into the shoreline it creates a high tide; as the bulge moves away, it creates low tide.

Since there are bulges on opposite sides of the planet, there are two tidal cycles each day. On average, though, the Moon rises and sets about 50 minutes later each day, so a tidal "day" — the time it takes to experience two high tides and two low tides — is roughly 24 hours, 50 minutes long.

The tides are highest at new Moon and full Moon, when the gravity of the Moon and Sun are pulling along the same line, and weakest at quarter Moons, when the Sun and Moon tug against each other. And the tides are especially high when new or full Moon coincides with the Moon's closest approach to Earth.

All of this makes the tidal cycles a bit complicated, which is perhaps more than you want to ponder as you watch the tide roll in on a nice warm beach.

Dear Merlin,

Since the Rosetta spacecraft used the gravity assist method to gain the necessary speed (more than 80,000 mph) to catch comet 67P/Churyumov-Gerasimenko, what's the highest speed a spacecraft could reach using the gravity assist or slingshot method?

Tom Rees
Tehuacana, Texas

That depends. If you're willing to endure some major discomfort, then you could reach speeds of millions of miles per hour by skimming just above the surface of the Sun. Without substantial shielding, though, your craft would be roasted by the Sun's heat and zapped by deadly X-rays and charged particles.

In fact, a NASA spacecraft, Solar Probe Plus, will reach speeds of roughly 450,000 miles per hour (700,000 kph) when it passes 3.7 million miles (6 million km) above the surface of the Sun a decade from now. And engineers are working on designs for spacecraft propelled by solar sails that would come closer and get a bigger gravitational boost.

Many spacecraft have used the gravity of one solar system body as a "slingshot" to propel them to another body. Such a boost cuts months or years from a probe's travel time, reduces its size and the size of its launch vehicle, and saves many millions of dollars. Each encounter is carefully designed to keep the spacecraft safely away from the planet's atmosphere or rings, which limits most gravitational kicks to a few tens of thousands of miles per hour.

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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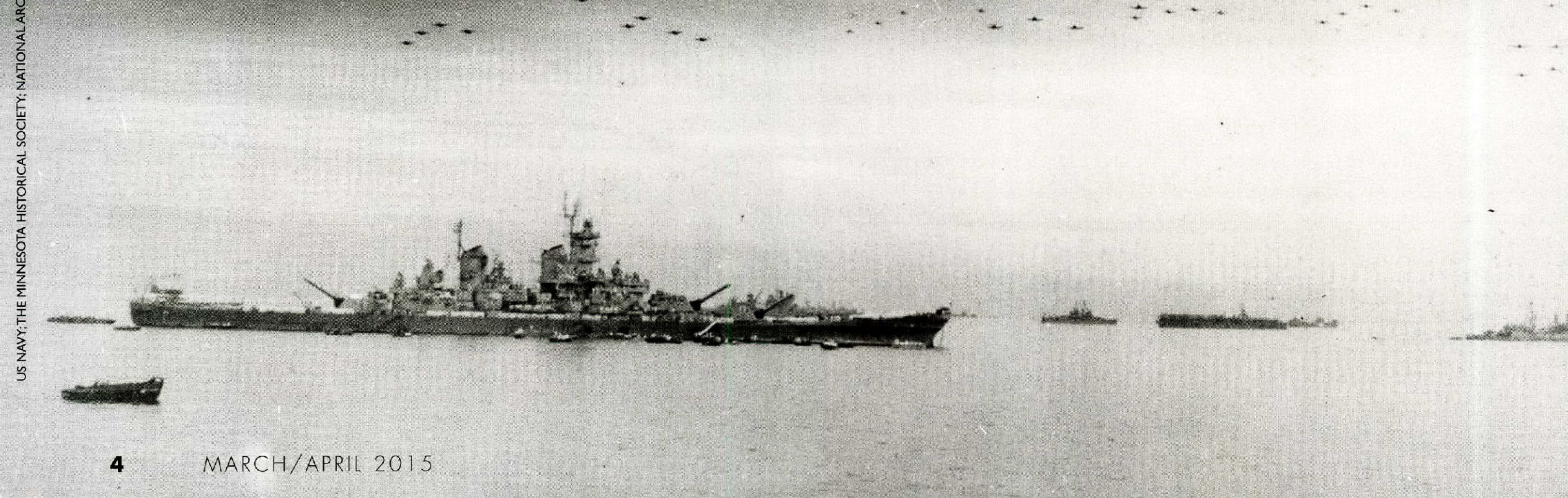
ASTRONOMY AND THE SECOND WORLD WAR

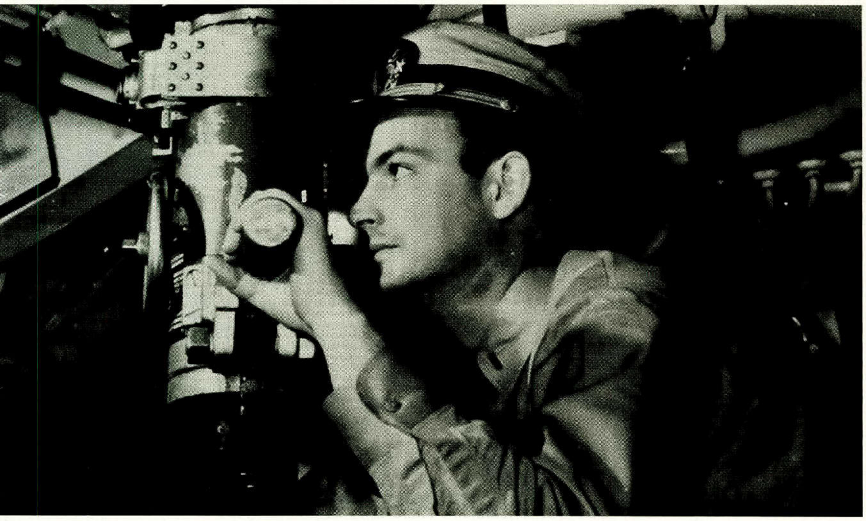
Astronomers and observatories made important contributions to the war effort, many of which played key roles in post-war science

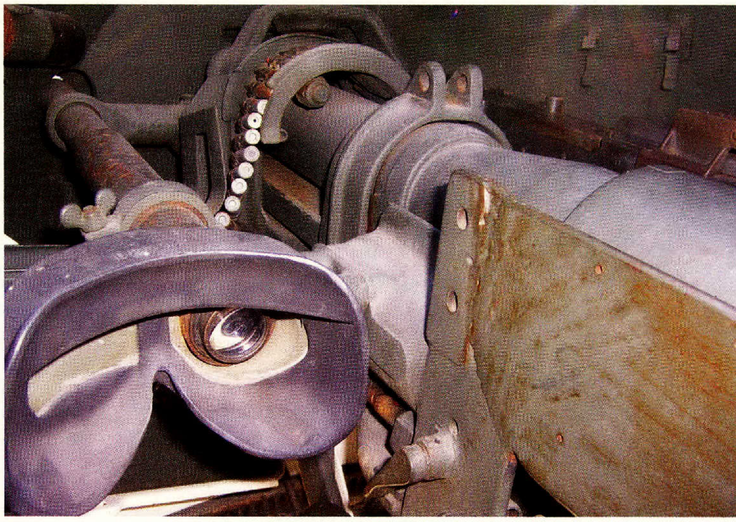
By Bruce Dorminey



US NAVY; THE MINNESOTA HISTORICAL SOCIETY; NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

Last year saw events around the world commemorating the 75th anniversary of the start of World War II. As we honor all who worked toward the Allied victory, we should include the work of astronomers who made significant contributions. Observatories cut back on their scientific observations of the sky to use their astronomical knowledge to generate sea and air almanacs for navigation, telescopes for tanks, periscopes for submarines, and wide-field aerial reconnaissance cameras. And their war-required technology contributed to civilian astronomy in the years after the war.





Astronomers contributed sky maps, telescopes, and more for ships, aircraft, and ground vehicles in the war. Above left: Submarine periscope. Right: Telescope from an armored car.

One major war requirement was directing and tracking thousands of ships, submarines, and aircraft around the world. The U.S. Naval Observatory had been producing nautical almanacs for navigational purposes since 1855, but more advanced warfare brought new challenges.

New long-range aircraft required quicker and more efficient means of stellar navigation than previously available. Troublesome or lengthy calculations were out of the question at the speeds and distances these airplanes traveled; their navigation had to rely more heavily on ready-made tables for easy review and quick decisions. As Vibert Douglas noted in the March 1944 issue of the *Journal of the Royal Astronomical Society of Canada*: "[When a] navigator takes a sight on a star or planet, he reads his chronometer and then if his calculations take five minutes to perform, he and his plane are already perhaps twenty-five miles away from the ascertained position. Every minute that astronomers have been able to cut off the time for computation of position is of the greatest value to airman ... [particularly when the] objective [is] a mere dot on the map — a railway yard, a factory, an airfield."

Thus, before the United States even entered the war, the Naval Observatory recruited Columbia University celestial mechanic Wallace J. Eckert to use new, automated punch-card equipment to provide astronomical computations for a new Air Almanac. Eckert noted that "erroneous figures could quickly result in the loss of a plane and its crew, with no time for cross-checks or recovery as in ocean navigation."

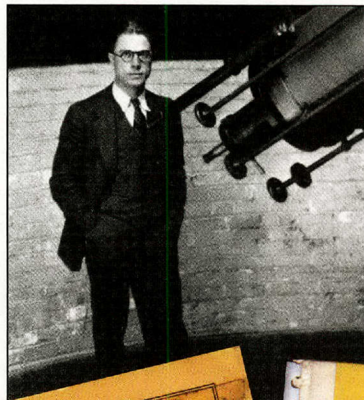
On the civilian side, many American observatories slowed or ceased their normal observing activities to focus their time and talents on the war effort.

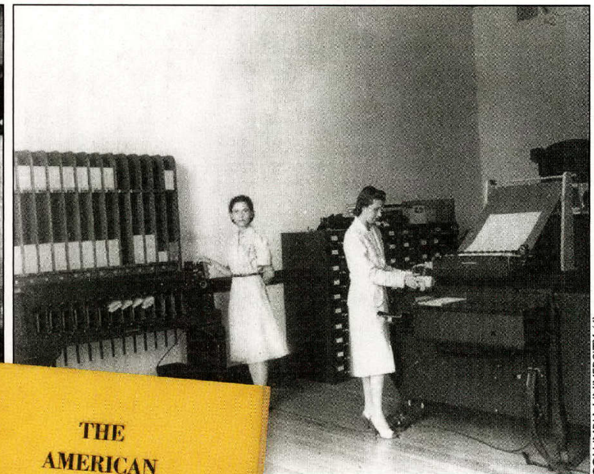
The University of Chicago's Yerkes Observatory in Williams Bay, Wisconsin, for example, soon found itself in the thick of it, due in part to the attitude of Otto Struve, its Russian émigré director.

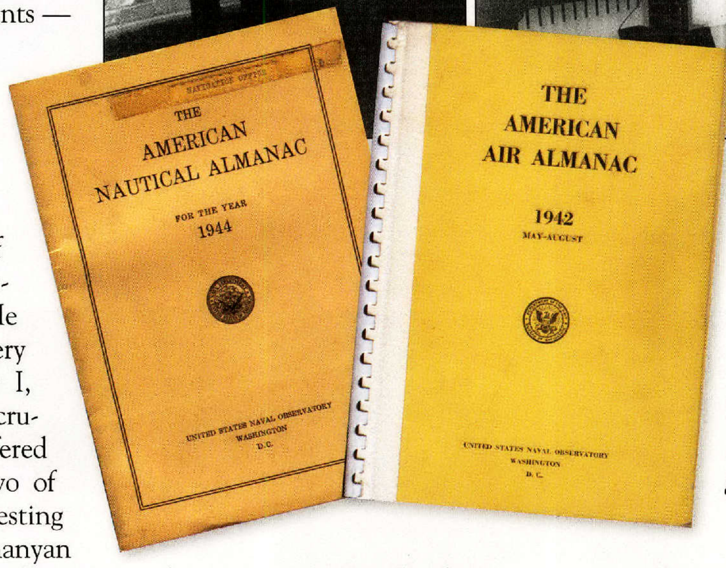
Struve had been a fixture at Yerkes since 1921. In 1932, he became director. (That year he also worked out an arrangement with the University of Texas to operate its new McDonald Observatory, and became the observatory's first director.) Struve sensed that to ensure his observatory's survival, it should aggressively join the war effort. By early 1942, he had arranged navigation classes for local residents — particularly potential air corps and navy recruits.

A few days after Japan attacked Pearl Harbor, plunging the United States into the war, Struve wrote to Vannevar Bush, director of the federal Office of Scientific Research and Development, to offer Yerkes' services. He echoed statements by George Ellery Hale made during World War I, noting that pure science was crucial "even in total war." He offered the government the help of two of Yerkes' best astronomers, suggesting that Gerard Kuiper and Subrahmanyan Chandrasekhar could help the military by using their knowledge of Earth's atmosphere to make scientific models to predict the weather.

Struve established an independent optical workshop in concert with the Office of Scientific Research and Development to design everything from aerial cameras to anti-tank telescopes to improved submarine periscope systems that could detect and identify enemy ships. The shop even made projection systems for in-flight training.







COLUMBIA UNIVERSITY (4)

Astronomer and computing pioneer Wallace J. Eckert left teaching at Columbia University for the duration of the war to serve as director of the U.S. Naval Observatory. He invented computing and printing machines to improve the military's nautical almanacs and begin production of an air almanac.

Yerkes astronomers noted that the military was demanding. "Get magnification as high as you can have it [with] aperture as small as you can get it, so that you don't get shot when you're looking through the telescope through an opening in the tank armor," one said.

Yerkes provided the military with systems that lived up to expectations, and their workmanship stood the test of time: Some of their wide-field eyepieces were still used by amateur and professional astronomers years after the war, having been sold as military surplus.

Although astronomers and the military would seem to make odd bedfellows, they developed a grudging respect for each other.

Astronomer Jesse Greenstein noted the professional soldiers' situation was "like [that of] science in many ways. [The] best scientists are like the very best colonels … . We never were allowed to talk to the people doing rival work in the same field. It was rather an odd business." It appears that the biggest complaint from astronomers involved in research on hush-hush military projects was the complete inability to commiserate with other scientists engaged in the same projects.

Optical work also was a top priority at Mount Wilson Observatory near Pasadena, California, which was manufacturing telescopic cameras for use in aerial night photography.

Unlike Yerkes, though, Mount Wilson also was conducting pure astronomical observations. Partial wartime blackouts in Los Angeles and the San Gabriel Valley created extremely dark skies — perfect astronomical seeing conditions. Thus it was during World War II that staff astronomer Walter Baade made some of his best observations.

Baade was born, educated, and lived in Germany until his late thirties. He moved to the United States in 1931, and was working at Mount Wilson. When the war broke out, Baade maintained his support for Germany, so he was classified

RESOURCES

BOOKS

Yerkes Observatory, 1892-1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution, by Donald E. Osterbrock, 1999

Centennial History of the Carnegie Institution of Washington: Volume I, The Mount Wilson Observatory, by Allan Sandage, 2013

Boffin: A Personal Story of the Early Days of Radar, Radio Astronomy and Quantum Optics, by R. Hanbury Brown, 1991

Operation Paperclip: The Secret Intelligence Program that Brought Nazi Scientists to America, by Annie Jacobsen, 2014

Science with a Vengeance: How the Military Created the US Space Sciences After World War II, by David H. DeVorkin, 1993

as an "enemy alien."

In April 1942, the army issued a curfew requiring all enemy aliens to be home between 8 p.m. and 6 a.m. This meant Baade could not use the telescopes at Mount Wilson.

Eventually, however, he received permission from Vannevar Bush, who agreed the astronomer should have nighttime access to the observatory. As a result, Baade was able to continue observations of the Crab Nebula, which he (correctly) suspected were the remnants of a supernova. He published his results in 1942.

But arguably his most noteworthy discovery during the war (or any other time during his career) was the discovery that the Milky Way galaxy and others like it contain two distinct populations of stars. He called these Population I and Population II.

Population I stars (like the Sun) make up the disk of our galaxy. Population II consists of ancient stars in globular clusters that live in the galaxy's outlying territories, the spherical shell known as the halo. The high-quality photographs Baade made from Mount Wilson in August, September, and October of 1943 enabled him to figure out many facets of the Milky Way's galactic structure and motions. That fall was a watershed moment in defining the shape of our galaxy.

Baade published his results in *The Astrophysical Journal* in August 1944, just as most of the world was transfixed by the allied armies muscling their way across France just months after the allied invasion of Normandy.

A noted incident mars Baade's wartime achievements at Mount Wilson. As the conflict raged in Europe, a couple of years before Pearl Harbor, he had been angling for the directorship of Germany's Hamburg Observatory. To help convince the Third Reich of Baade's qualifications, Hamburg Observatory advised Berlin that Baade was "nationally disposed" and of Aryan origin (criteria needed to apply for any German academic post at the time).

When it was suggested that his chances of getting the directorship would be helped if he joined the Nazi party, Baade declined. He replied that if he came back to Germany as director, though, he would prove he could work with the Nazi regime.

Baade eventually was offered the directorship of Hamburg Observatory. By then, he had changed his mind. He declined the position, saying that he was staying in California "in the German interest," to make sure his homeland was represented at the 200-inch telescope then in the planning stages for nearby Palomar Observatory. He signed his letter "Heil Hitler!"

Today, Baade's defenders prefer to think his interactions with the Nazi regime were motivated more by ambition than politics.

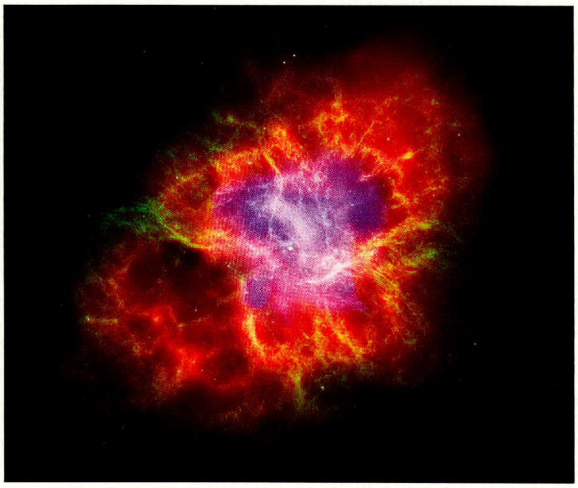
MCDONALD OBSERVATORY; KYLE CUDWORTH/UNIVERSITY OF CHICAGO

Otto Struve put Yerkes Observatory to work for the war effort.

Outside the United States, the observatories and astronomers of allied countries were doing similar war work to Yerkes and Mount Wilson. The staff of Australia's Mount Stromlo Observatory ballooned from 10 to 70 to facilitate its new role as a wartime optical workshop, with work spread among 25 establishments, from university physics departments to private firms.

At the same time that Australia feared a Japanese invasion, Mount Stromlo became an optical munitions factory making precision optics for gun sights and other applications. It also produced some optics for anti-aircraft predictors and air compasses, as well as various devices for army munitions. But the observatory workshop's main task was to produce sighting telescopes, artillery directors, and range finders.

The observatory also employed a number of Jewish refugees from Nazi Germany and other parts of Europe. Although the Australian government officially classified them as enemy aliens, their highly valued technical skills al-



MT. WILSON OBSERVATORY; NASA/ESA/CXC/JPL-CALTECH/STScI

Walter Baade took advantage of wartime blackouts in Los Angeles to make observations under dark skies from Mount Wilson. He correctly deduced that the Crab Nebula (shown in a modern view from Hubble, Spitzer, and Chandra space telecopes) was the remnant of an exploded star.

lowed the observatory to employ them during the war.

By October 1940, most of Mount Stromlo's astronomical work had come to a halt. However, the observatory did send a team to South Africa to observe a solar eclipse. But even this wasn't just academic astronomy: The team was directed to study how an eclipse would effect long-distance radio transmissions crucial for fighting the war.

Much wartime technology was later adapted for non-military purposes. The advent of radar (the U.S. Navy coined the acronym in 1940 for radio detection and ranging) helped bring about the discovery that the Crab Nebula is one of the brightest radio sources on the sky.

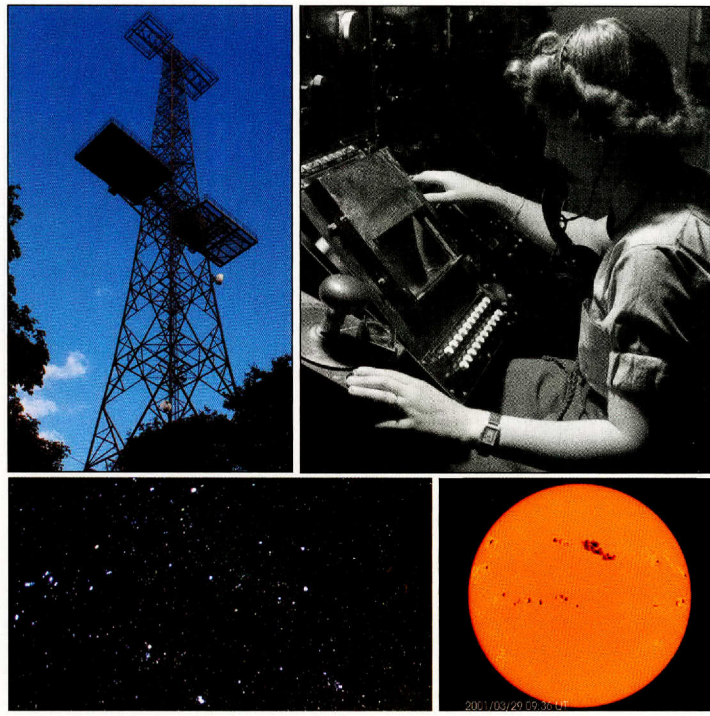
In 1942, crude British radars designed to give early warning of German aircraft slipping across the English Channel were sometimes ineffective due to electronic jamming from an unknown source. When the expected enemy planes failed to materialize, British physicist J.S. Hey realized that the radar jamming was actually coming from the Sun — to be precise, from large sunspots on its surface.

Two years into the Nazis' V-2 bombing of civilian populations in the United Kingdom, Hey modified anti-aircraft radar in hopes of giving the British people advanced warning of incoming missiles. Instead, he noticed radar echoes at a height of more than 60 miles and rates of 10 per hour. It wasn't until after the war that Hey realized these transient events — which created false bombing alarms during the height of the Blitz — were caused by meteor trails in Earth's upper atmosphere. Some of radio astronomy's earliest observations were driven by studies of such events.

In fact, radio astronomy largely got its start from decommissioned World War II radar equipment. Near the war's end, a few prominent astronomers, such as Jan Oort of Leiden University in The Netherlands, were realizing that the radio waves might also be a great way to explore obscured parts of the center of the Milky Way galaxy. Early radio astronomer Grote Reber had already proposed that the hydrogen atom's radio emission would allow astronomers to probe the whole disk of the Milky Way, unimpeded by the intervening dust that absorbs optical light.

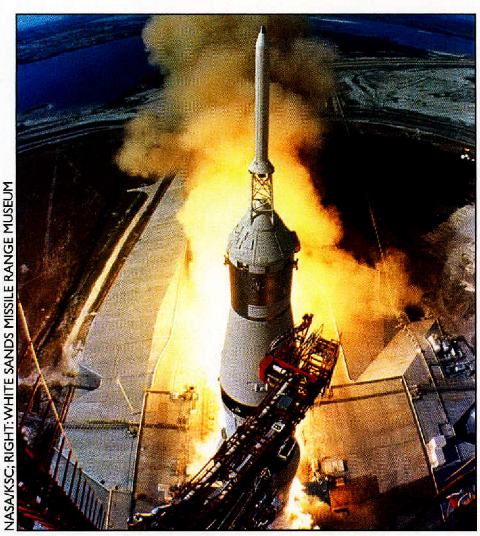
Radar also found its way into quantum physics. Nobel Prize-winning physicist Charles Townes, who in 1941 worked on radar bombing systems at New Jersey's Bell Labs, was four years later arguing that microwave radar could be used to investigate quantum mechanics, as well as to study the chemical composition of molecular clouds in space.

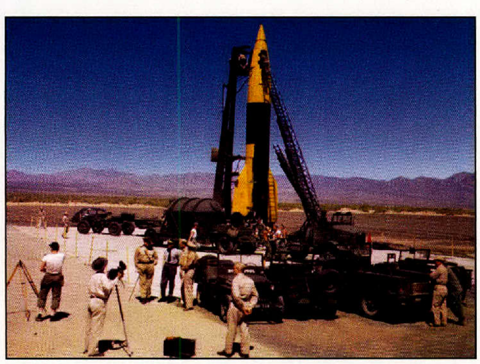
The war effort also produced some important American astronomical institutions that live on today. Johns Hopkins University's Applied Physics Lab (APL) in Baltimore is one example. The lab was set up to design and manufacture a miniature radio proximity fuse (a device that would remotely detonate an artillery shell). By the war's end, this new device had been successfully deployed in the Pacific theatre. Today, APL is known for managing NASA space missions, including the asteroid probe NEAR Shoemaker; the



STUART116AXE; A. GOODCHILDE/RAF; BROCKEN INAGLORY; SOHO/ESA/NASA

Clockwise from top left: Radar towers in the Chain Home system, like the one shown here at Great Baddow, ran the length of the British coast to provide early warning of German bombers. Astronomers discovered that radar operators also picked up radio waves coming from sunspots (seen in a modern view from NASA's SOHO orbiter) and radar echoes from meteor trails.





NASA/KSC; RIGHT: WHITE SANDS MISSILE RANGE MUSEUM

Left: American and British military personnel prepare to test a modified V-2 rocket at White Sands Missle Range on May 10, 1946. Far left: The V-2's descendent, the Saturn V rocket, carries Apollo 11 astronauts aloft on July 16, 1969.

MESSENGER Mercury orbiter, which is nearing the end of its mission; and New Horizons, which will reach Pluto later this year.

Technology from the Axis powers contributed to astronomy after the war in a different way. With the Allies' 1945 capture of Wernher von Braun, architect of Germany's rocket programs, the long process of repurposing Nazi technology for Cold War missile technology and space science had begun. (Von Braun, an advocate of human spaceflight and travel to the Moon and planets, had developed the V-2. His efforts often used the slave labor of concentration camp inmates and prisoners of war, although this part of his story was concealed for decades.)

Caltech astrophysicist Fritz Zwicky, a Swiss national and adamant anti-Nazi, interrogated von Braun. Von Braun reportedly lectured Zwicky on the potential scientific and military applications of long-range rockets, including manned spaceflight and as intercontinental ballistic missiles.

By the fall, New Mexico's White Sands Proving Grounds began seeing convoys of captured V-2 rocket parts delivered from Germany. Scientists there realized that there was science to be had in Earth's high atmosphere. And in 1946, the United States' first sounding rocket lifted off from White Sands, carrying instruments to study the stratosphere.

However, it would be another quarter century before von Braun's pre-war visions of manned missions to the Moon would see their fruition. On a hot July morning in 1969, Apollo 11 astronauts headed skyward aboard another of von Braun's designs: the Saturn V Moon rocket — a booster descended from one of the terror weapons of World War II.

Bruce Dorminey is a science journalist and the author of Distant Wanderers: The Search for Planets Beyond the Solar System.

PREPPING FOR WAR

McDONALD OBSERVATORY

The 82-inch mirror from McDonald Observatory's giant reflector that Otto Struve wanted to protect. In this picture from about 1935, officials inspect the mirror before shipping it to Texas.

Observatories within the United States were concerned about possible attacks on their facilities, and many made plans in case the fateful day came.

At the newly opened McDonald Observatory in West Texas, fear of attack had real roots in the history of the last war: Germany had attempted to persuade Mexico to attack the United States in World War I. McDonald Observatory lies less than 100 miles from the international border, and locals have a long memory for such threats. With his observatory newly dedicated in 1939, Director Otto Struve was determined to be prepared for any eventuality.

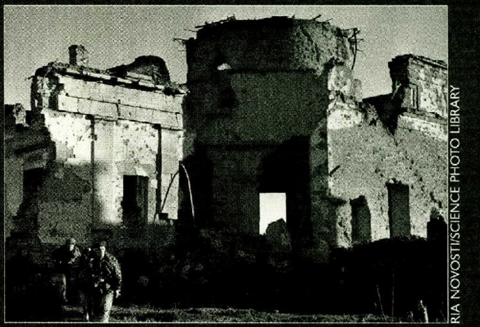
Struve saw to it that astronomical observing continued throughout the war as much as possible with a reduced staff. He told his employees, however, that one of their top priorities was to protect the giant telescope, its dome, and sensitive equipment. Should an air attack happen, he said, staffers should remove the giant 82-inch mirror from the telescope and store it inside its aluminizing chamber. Walter Adams had made similar provisions at Mount Wilson to protect the 100-inch Hooker Telescope, then the world's largest.

Struve tried to go even farther. In 1940, he contacted the McDonald telescope's manufacturer, Cleveland-based Warner and Swasey Company. He wanted to borrow heavy equipment from them to bury the giant mirror underground, should he deem it necessary.

Luckily, the feared attack on the continental United States during World War II never came. Observatories escaped damage, beyond the interruption of routine science and the departure of scientists and engineers for critical war work.

The war did interrupt the construction of the world's forthcoming largest telescope, however. The 200-inch Hale Telescope was planned for California's Mount Palomar. In 1936, the mirror traveled by train from New York's Corning Glass Works to Pasadena, California, for its final shaping and polishing at Caltech. Planned to take only a year or two, instead the mirror waited out the length of the war at the university. The telescope finally saw first light at Palomar in 1948, when its first observer was Edwin Hubble.

Observatories in other parts of the world weren't so lucky, and both Allied and Axis scientific facilities suffered heavy damage in the war. The Royal Observatory at Greenwich was hit, but was repaired and continued working. During the siege of Leningrad, however, Russia's historic Pulkovo Observatory was completely destroyed (it was rebuilt after the war). In Germany, RAF bombs destroyed Königsberg Observatory, where in 1838 Friedrich Wilhelm Bessel had made the first measurement of the distance of a star.



RIA NOVOSTI/SCIENCE PHOTO LIBRARY

German soldiers outside the ruins of Pulkovo Observatory near St. Petersburg, Russia, in 1944.

SKY CALENDAR

by Alan MacRobert

As spring begins, Saturn graces the dawn sky. Three planets shine at dusk: Jupiter, Venus, and Mars. Stellar beacons Regulus and Spica shine in Leo and Virgo, respectively. Early April brings a total lunar eclipse, and the Moon snuggles up to several planets.

MARCH 1 - 15

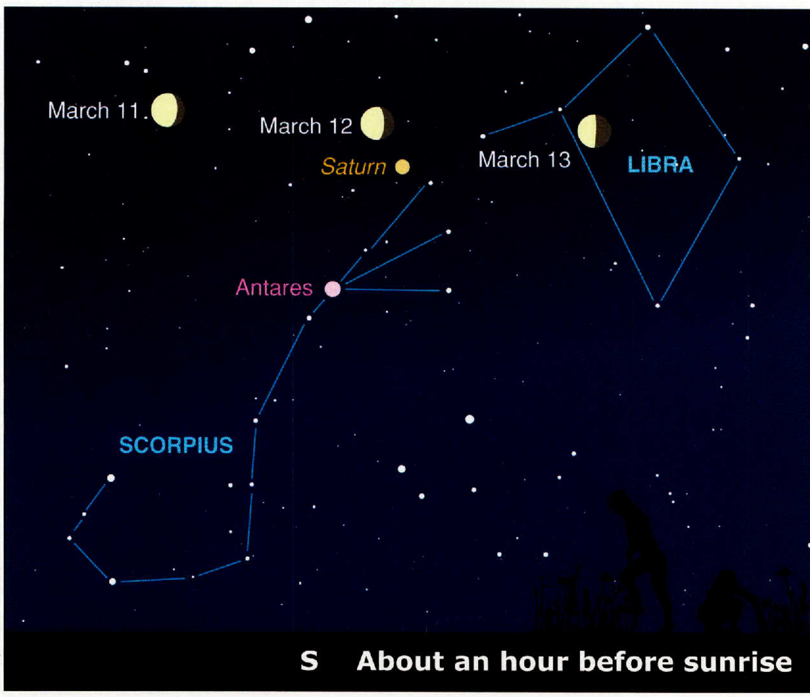
March begins with Venus and Mars still together in the western evening twilight, pulling apart from their February 20-21 conjunction. Venus stands above Mars, outshining it by 130 times. On March 1, they're still a bit less than four degrees apart (about two finger-widths at arm's length). But by mid-March, Mars sinks to 10 degrees to the lower right of Venus and becomes harder to see.

If you could see far behind Venus and Mars, you'd spy dim Uranus and much dimmer Eris. Remember Eris? It was briefly known as "the tenth planet" after its discovery in 2005. The next year, astronomers demoted it, as well as Pluto and a bunch of similar objects beyond Neptune, to dwarf planet status (rather than let these small bodies run up the planet count indefinitely). Eris is almost identical in size to Pluto, but it's 27 percent more massive judging from the gravitational effect that each has on its moons. Apparently, Eris contains more rock and less ice than Pluto.

On the opposite side of the sky, bright Jupiter shines high in the east as the stars begin coming out. It reaches its highest position in the south by 10 p.m. Standard Time, or 11 p.m. Daylight Saving Time after most of North America springs its clocks forward on the morning of March 8.

Jupiter shines in dim Cancer, forming a big, almost equilateral triangle with Procyon to its right (in the evening) and Pollux above them. Castor, slightly fainter, is above Pollux.

As it happens, Procyon is also part of a more permanent equilateral triangle: the Winter Triangle, which Procyon forms with Betelgeuse to its right and brilliant Sirius below them. The Winter Triangle is somewhat larger than the Procyon-Jupiter-Pollux triangle.



CJ DUNCAN

MARCH 16 - 31

Venus is creeping higher in the west at dusk, and little Mars is sinking away. Catch the thin waxing crescent Moon pairing up with Mars on the evening of March 21 (the day after spring begins), and then more spectacularly with Venus the next evening.

Look far above or to the upper left of Venus for the fingertip-sized Pleiades cluster, also called the seven sisters. Orange Aldebaran shines to the upper left of this pretty blue batch.

As winter turns to spring, Aldebaran, the eye of Taurus, is the right-hand end of a well-known lineup of stars in early evening. Look to Aldebaran's left, by two fist-widths at arm's length or a bit more, for Orion's Belt. The belt is now nearly horizontal, with Betelgeuse above it and Rigel below it. Sirius shines about two fist-widths farther to the left of the belt.

How horizontal this line appears depends on the date, the time since sunset, and your latitude. Even so, it's a marker of the transition from winter to spring throughout the mid-northern latitudes of the world.

Jupiter, meanwhile, shines high in the south after dark. Look to its lower right shortly after nightfall, or directly below it later at night, for the dim head of the constellation Hydra, the sea serpent. The head is a group of 3rd- to 5th-magnitude stars, somewhat elongated and roughly the size of your thumb at arm's length.

The rest of Hydra snakes away far across the sky to the lower left. Its brightest star is Alphard, the sea serpent's dull-orange heart, shining about two fist-widths to the lower left of the head. Alphard is 2nd magnitude, not an eye-catcher but easy enough to see from almost anywhere. Most of the rest of Hydra needs a fairly dark sky.

Hydra is one of three big carnivores coming up out of hibernation into the spring sky. To the left of Hydra is Leo, the lion, with bright Regulus marking his forefoot. Leo's famous Sickle star pattern extends from Regulus to the upper left. It's shaped like a backward question mark, and it's about a fist and a half at arm's length long.

The Big Dipper stands far off to the left of Leo, in the northeast. At the beginning of spring, the dipper is standing upright on its handle, with its bowl open to the left.

Both the Big Dipper and the Sickle are *asterisms* nicknamed star patterns within official constellations. The Sickle doubles as the head and forequarters of Leo. The Big Dipper forms the back and tail of Ursa Major, the great bear.

APRIL 1 - 15

Watch Venus in the west as it climbs toward the Pleiades night by night. It passes closest

Meteor Watch

The Shower

Lyrids

Peak

Night of April 22

Notes

The Lyrids are modest, with around a dozen or two meteors per hour at best. The crescent Moon sets by around midnight, so it won't interfere with the meteors, which are at their best after Lyra climbs into view in the wee hours of the morning.

by them, just a little to their lower left, on April 10 and 11. Venus keeps climbing higher in the dusk each week as the stars slide down to the lower right behind it. By April 15, Venus stands to the right of Aldebaran.

Venus, low in the west, and Jupiter, high in the south after dusk, are the two brightest points of light in the sky. At the beginning of April they're still a huge 80 degrees apart. But watch them in the months to come. They'll close in on each other toward a super-close conjunction at the end of June, when they're destined to pass just one-third degree apart.

The brightest star shining in the east now is Arcturus, the "spring star," still rather low.

The Big Dipper, far to Arcturus' upper left, is climbing ever higher week by week. The dipper's handle curves in an arc that points back more or less toward Arcturus, slightly more than a dipper-length away.

The Big Dipper has begun tipping over toward the left — as if dumping water toward the faint Little Dipper. The Little Dipper is notoriously hard to recognize. However, the star marking its handle-end is easy enough: it's Polaris, the North Star, due north. The two pointer stars forming the front of the Big Dipper's bowl (the top two just now) point to the lower left toward Polaris, about three fist-widths away.

The other end of the Little Dipper, the lip of its squarish bowl, is marked by another modestly bright star like Polaris. This is Kochab, currently to Polaris' right at nightfall (by about a fist and a half).

Turn back to Arcturus. Look three fist-widths at arm's length to its lower right to identify lesser Spica, blue-white, rising higher as evening advances.

Look to Spica's right and you'll find a lesser-known constellation that's nevertheless an eye-catcher. Corvus, the crow, has no truly bright stars, but four shine at 2nd or 3rd magnitude in the form of a dented square. Their shape is often likened to a four-sided sail. Find it a little less than two fist-widths to Spica's right or, later, lower right.

The sail of Corvus can be seen even through suburban light pollution, quite well for such a relatively obscure constellation. If you have a dark enough sky, fainter stars can be included to form a stick-figure crow standing in profile and eyeing shiny Spica as if to steal it. Once you recognize the crow, it will always be a part of your spring evening landscapes.

APRIL 16 - 30

While Jupiter and Venus continue to dominate the evening sky toward the southwest and west, respectively, a third naked-eye planet begins to take stage in the southeast if you stay out late. Saturn is up by about 11 p.m. now, depending on where you live. Running away to Saturn's lower right is the lineup of fainter stars marking the head of Scorpius. By about midnight, Saturn is high enough that Antares, Scorpius' orange heart, twinkles in plain view below it.

Back to twilight time. If you want to catch Orion in late April, look early, just as twilight fades. Orion is dropping in the west at dusk as spring advances, and it soon sets.

Sirius still sparkles two fist-widths to Orion's left; Aldebaran and brilliant Venus are farther to Orion's right. On April 16, Venus is about level with Aldebaran, but by the 30th it's high above the star.

And look for Gemini standing upright in the west above Orion right after dusk.

Low in the northeast, keep an eye out for Vega on the rise. Sometimes called the "summer star," Vega is already beginning its many-months climb to the zenith.

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

APRIL 4

Moon Stages Brief Eclipse

A blink-and-you'll-miss-it lunar eclipse will decorate the pre-dawn sky on April 4. Skywatchers in the western half of the United States will see all of the total phase of the eclipse, while those in the east will experience only part of the show.

The eclipse begins at 5:16 a.m. CDT, when the Moon first touches the dark core of Earth's shadow. The Moon will be fully immersed in the shadow by 6:58 a.m. The Moon barely tucks inside the shadow, however, so it will remain fully eclipsed for less than seven minutes. During that "total" phase of the eclipse, the lunar disk will be colored dark red or orange by faint sunlight filtering through Earth's atmosphere.

The eclipse ends when the Moon exits the shadow at 8:45 a.m. Since the eclipse occurs at full Moon, the Moon will have set across almost the entire U.S. by then, so only those on the far West Coast and in Alaska and Hawaii will see the entire event.

TOM RUEN/WIKIMEDIA

MARCH	5 12:05 pm	13 12:48 pm	20 4:36 am	27 2:43 am
APRIL	4 7:06 am	11 10:44 pm	18 1:57 pm	25 6:55 pm

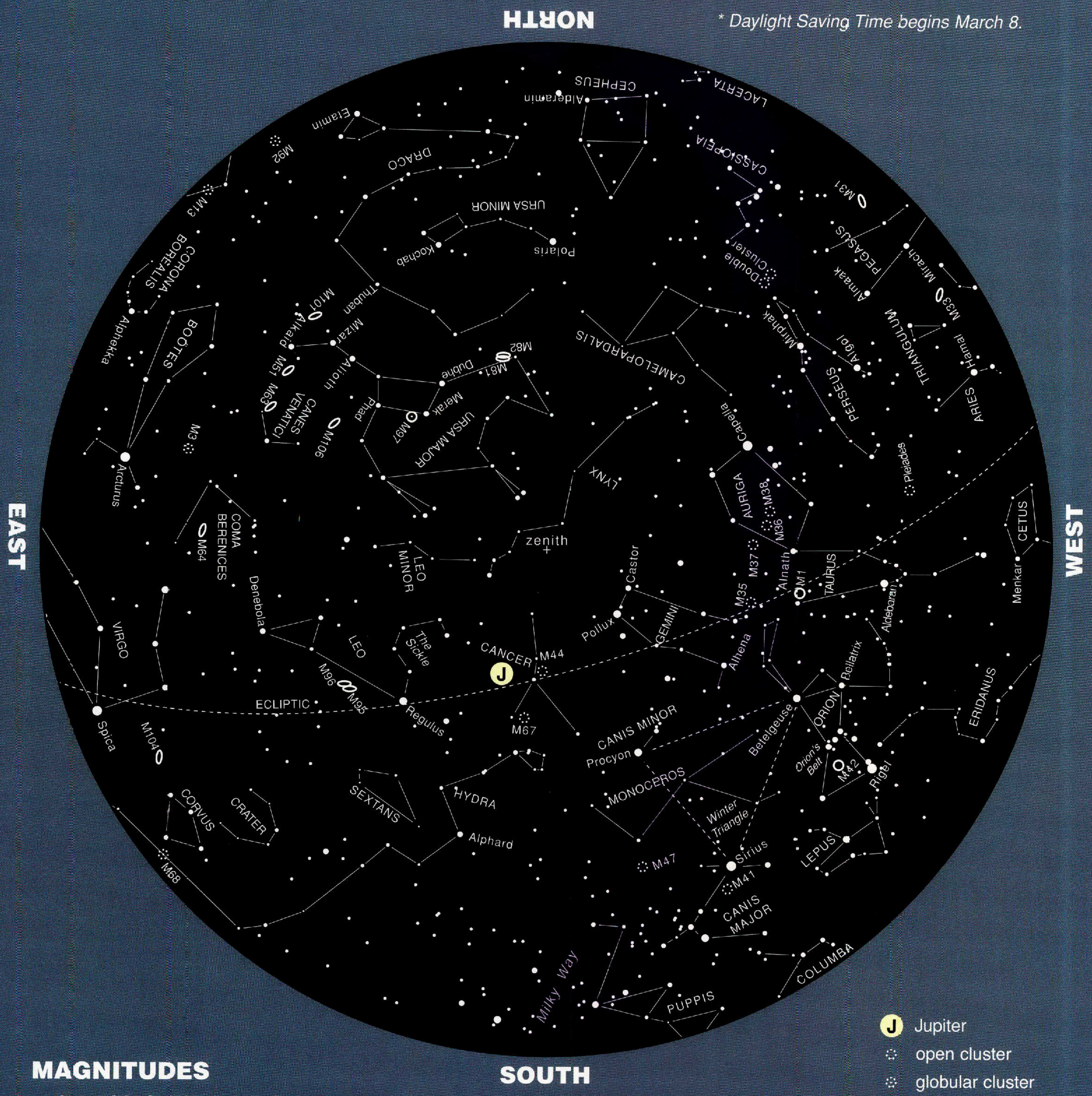
Moon phase times are for the Central Time Zone.

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 8.*



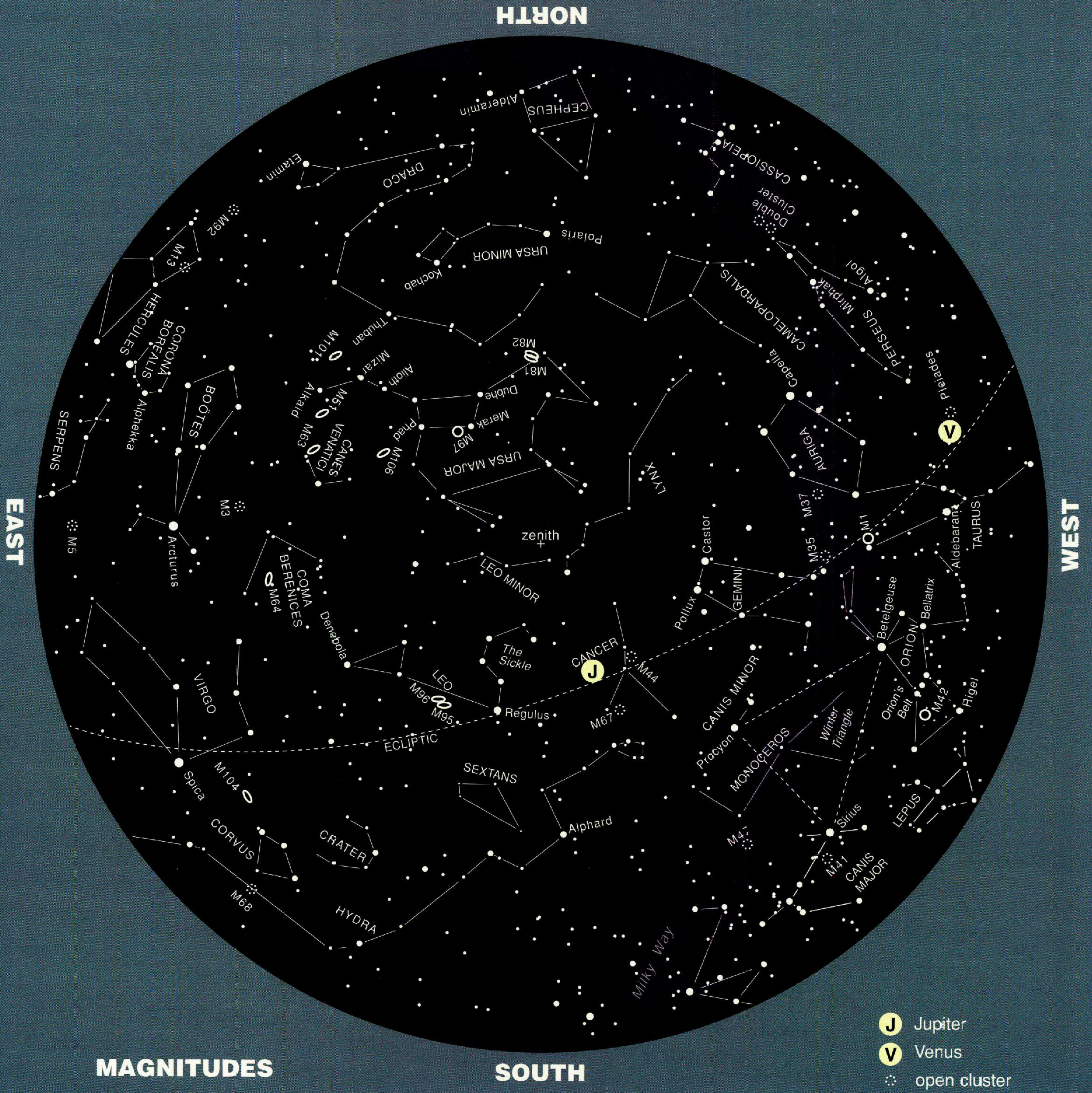
MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

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



MAGNITUDES

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

- J Jupiter
- V Venus
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

The Milky Way arcs above La Palma Island

© PROJECT NIGHTFLIGHT

Tuning in the Night

A NASA web site and app offer music created from the wonders of deep space, while another site offers the music of the night to accompany astrophotos snapped from Austria and the Canary Islands.

The NASA project, known as CRaTER Live Radio, converts real-time data from a cosmic-ray detector aboard Lunar Reconnaissance Orbiter into music. The music is generated automatically, with changes in pitch, tempo, volume, and instrumentation reflecting changes in the number and intensity of cosmic rays, which come from the Sun and from powerful events outside the solar system. The music plays 24 hours a day, with brief repeats when the spacecraft is behind the Moon.

In the other project, known as Nightflight, photographers recorded the natural sounds of the night while shooting the Moon, Milky Way, and other astronomical views. Those recordings have been posted with the astrophotos to create a more immersive night-sky experience.

CRaTER Live Radio
prediccs.sr.unh.edu/craterweb/craterliveradio.html

Nightlight
www.project-nightflight.net/sounds.html

Power to the People

As reported frequently in *StarDate* in recent years, crowdsourcing has become a popular tool in astronomical research. That is when scientists create online platforms for the public to contribute time and effort to help with large research projects.

Some efforts have been wildly successful. *Disk Detectives* is a project in which volunteers comb through data from the WISE mission to help classify cosmic objects that might be stars surrounded by dust disks in which planets could form (*StarDate*, May/June 2014). NASA recently reported that in less than a year, volunteers have classified more than 1 million objects via the site (diskdetectives.org).

Overall though, crowdsourcing has met with various degrees of success. An article in the January 20 issue of the *Proceedings of the National Academy of Sciences* by Henry Sauermann of Georgia Tech took a hard look at the practice to determine its strengths and weaknesses. Sauermann studied seven crowdsourcing projects run from the Zooniverse platform, most of which are astronomy-related.

He found that though crowdsourcing supplies a lot of labor at low cost, a small share of the participants do most of the work. He also found that most participants visit a project website only once, all volunteers visit less frequently over time, and the number of contributions per day or week varies significantly throughout a project and is hard to predict.

Sauermann says that to get the best out of crowdsourcing, project organizers need to work to attract new volunteers over the lifetime of a project, and also make plans to continually re-engage the interest of existing users. **RJ**

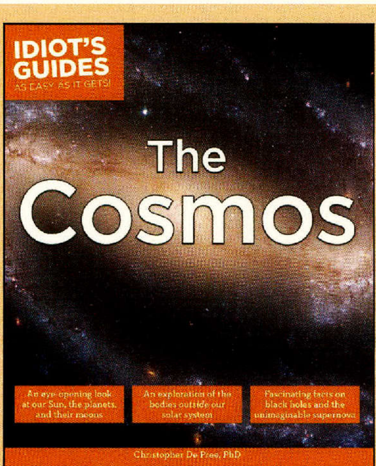
by Rebecca Johnson and Damond Benningfield

Bite-Sized Universe

Like an encyclopedia for the Twitter age, *The Cosmos*, the latest entry in "The Idiot's Guides" series, offers short blurbs about almost any astronomical topic you can think of, from the birth of the Moon to dark matter to the astronomical distance scale. Most topics are presented in two-page spreads, although a few (such as Venus and Mars) get extra pages.

The writing is clear and concise, although some of the more esoteric topics, such as cosmic inflation and the age of reionization, may be a bit dense for some readers. The book is profusely illustrated, and most of the images help explain the core concepts. A few are so small, though, that they're not helpful at all. And some of the typography is difficult to read, with small type spread all the way across the page, or black text printed over dark, complex background images.

Overall, though, *The Cosmos* is an easy read for those who want a quick overview of the workings of the universe.



Idiot's Guides: The Cosmos
by Christopher De Pree
$21.95 paperback; also available in e-book formats
www.dk.com/us/idiots-guides

Excerpt

'An early version of the best current model of the formation of the solar system was suggested independently in the 1700s by German philosopher Immanuel Kant and French mathematician and astronomer Pierre-Simon LaPlace. They both proposed that the Sun and all the planets began as a large, slowly rotating cloud of gas and dust. Gravity caused this cloud to contract in size and rotate faster and faster. That little bit of rotation is important, because the gravitational forces in a rotating cloud of gas and dust will concentrate most of the mass at the center (this is the protosun), and the remaining mass will fall into a flat disk that orbits it. This scenario, called the nebular hypothesis, describes what many today think happened in the solar system.'

Touch Eternity with a Flashlight

Shine a flashlight up at the clear night sky. What will become of that stream of photons you're sending from your hand?

In less than a millisecond, about 10 percent or 20 percent of them will be absorbed or scattered by Earth's atmosphere. But most will escape into space. Then what?

They'll leave the solar system within hours, probably after you're in bed. In several years, they'll start passing the distances of the nearest stars: 4.3 years for the distance of Alpha Centauri, 25 years for the distance of Vega, 37 for Arcturus.

If you aimed your flashlight at the band of the Milky Way, some thousands of years from now most of your photons will come to an end upon hitting an interstellar dust grain. But if you aim your flashlight straight up on a spring evening, you're pointing out of the Milky Way. What then?

Your light will leave our galaxy for the bigger, darker spaces beyond. Once in a while, for millions and then billions of years to come, your photons will pass by another galaxy. But space is mostly empty, and it's getting emptier as the universe expands. In fact, its expansion is speeding up with the passage of time. So your light beam might travel through ever-emptier emptiness forever. **Alan MacRobert**

BETELGEUSE BEHAVING BADLY

This famous star has befuddled modern astronomers and those of old with its behavior, but recent observations and computer models are helping to explain it

A few years ago, science news outlets shouted the news that Betelgeuse, the familiar orange star marking the shoulder of Orion, was shrinking. Nobel Prize-winner Charles Townes and his team from The University of California, Berkeley, had announced that the star's volume had been steadily decreasing for 15 years, and had shrunk by 15 percent. The case was bewildering: No star of its type is known to have changed size so much. That team and others have continued monitoring Betelgeuse, and they are getting closer to understanding what's going on.

Betelgeuse is one of the brightest stars in the northern hemisphere, as well as one of the largest stars visible to the unaided eye. It is a red supergiant, and it could explode as a supernova any time in the next 100,000 years. It's about 650 light-years away — distant enough that Earth would be safe from the explosion's harmful radiation, but close enough that we would see a dramatic change in the winter sky. Whenever it happens, Betelgeuse will brighten over several days to become visible in daylight, much as Venus is at its brightest. Then it will slowly fade, over a period of months or years.

By Leila Belkora

Despite this understanding of its fate, nobody knows exactly what a red supergiant star does leading up to its explosion. Betelgeuse's strange behavior in recent years could be a prelude to the coming disaster. Keeping our eyes — and telescopes! — on Betelgeuse until that day should help solve that mystery.

Charles Townes' research group started monitoring Betelgeuse's size using a telescope at southern California's Mount Wilson Observatory in 1993. Called the Infrared Spatial Interferometer (ISI), it's actually a system of three 1.65-meter (65-inch) telescopes working together.

Using multiple telescopes simultaneously to observe a target permits a technique known as interferometry. The technique allows for higher resolution, which is needed to resolve a point-like target (such as a star) into a disk with a measurable size. Even today, only a handful of nearby stars can be resolved by Hubble Space Telescope or other large instruments. And in fact, it was the study of Betelgeuse nearly 100 years ago, from atop Mount Wilson, that proved the concept of interferometry could work.

The signals from the three ISI telescopes are combined to achieve a resolution of about 20 milliarcseconds — equivalent to seeing a dime from a distance of 115 miles.

Townes' team uses ISI to study Betelgeuse in infrared light. The wavelength distinction is important, because stars can show different sizes when observed at different wavelengths.

When its work began in 1993, the team found Betelgeuse's radius to be about 5.5 astronomical units. (Astronomers measure solar-system-scale distances in astronomical units, or AU, which is the Earth-Sun distance of approximately 93 million miles.) So at its 1993 size, if Betelgeuse were placed at the center of our solar system, the star would have extended beyond the orbit of Jupiter. This was not too surprising, as red supergiants are among the largest stars in the Milky Way galaxy.

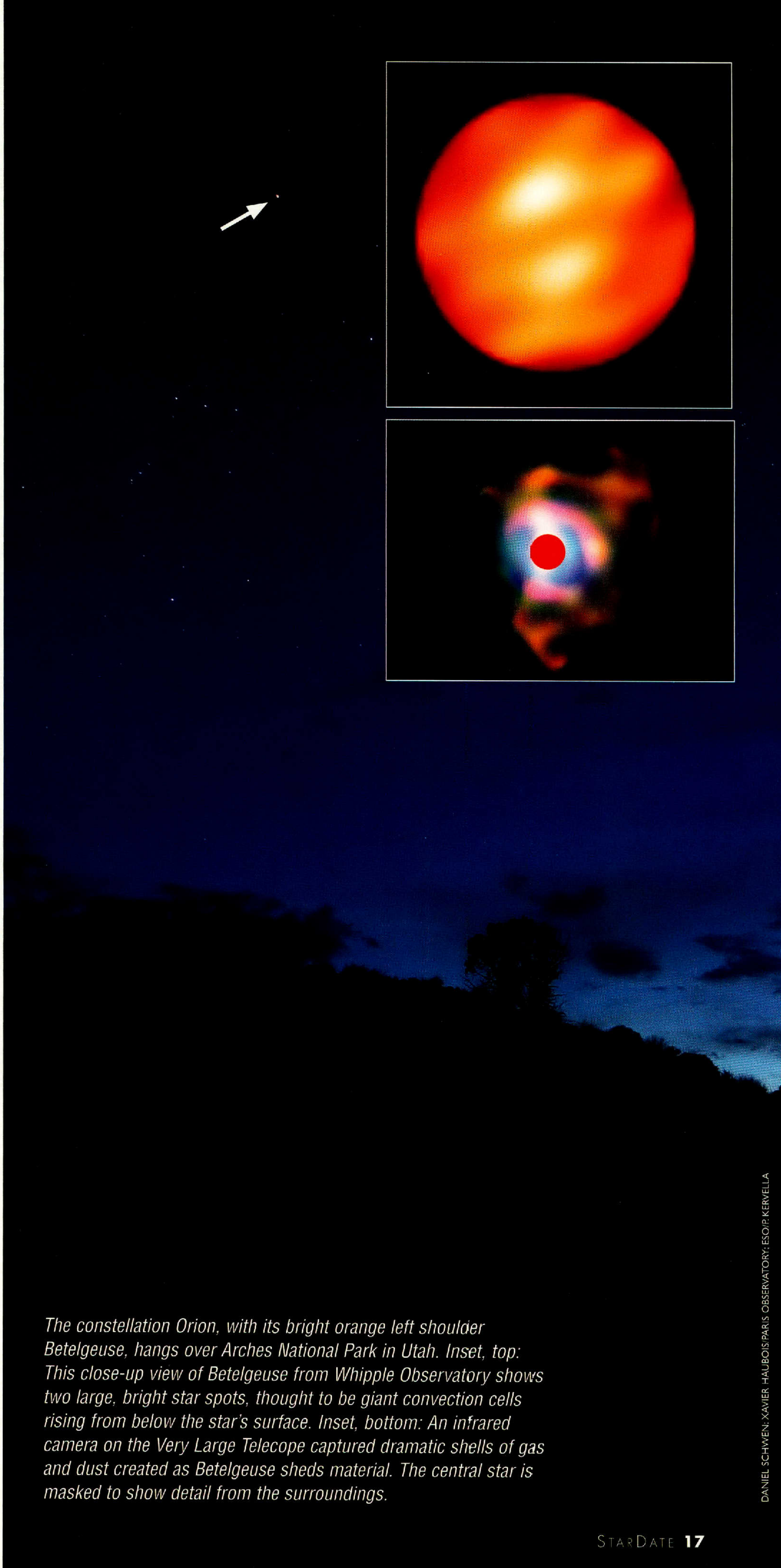
At its smallest during the 15-year monitoring period, however, Betelgeuse's radius shrank to about 4.7 AU. At this size, the star would still have reached far beyond the orbit of Mars, and almost to Jupiter. The apparent change in the star's volume was striking, and led to much excitement in news stories in 2009.

What followed was even stranger: In 2009, Betelgeuse started growing again. By 2011, it had ballooned to a bit larger than Jupiter-orbit size.

Townes' team, and others who are studying the star at different wavelengths, have been sifting the clues and coming up with models to explain what's going on. And the fact that this star has been studied intensively for not just decades, but centuries, means there are a lot of clues to consider.

Astronomers long have known that Betelgeuse varies in brightness even as seen with the unaided eye. In the 1800s, they regularly eyeballed how bright Betelgeuse seemed through a telescope compared to nearby stars, such as Aldebaran in the constellation Taurus. In the late 1830s, English astronomer John Herschel called Betelgeuse's variations "striking and unequivocal."

In the modern era, as a relatively rare red supergiant that's close enough to study in detail, the star's popularity



The constellation Orion, with its bright orange left shoulder Betelgeuse, hangs over Arches National Park in Utah. Inset, top: This close-up view of Betelgeuse from Whipple Observatory shows two large, bright star spots, thought to be giant convection cells rising from below the star's surface. Inset, bottom: An infrared camera on the Very Large Telecope captured dramatic shells of gas and dust created as Betelgeuse sheds material. The central star is masked to show detail from the surroundings.

DANIEL SCHWEN; XAVIER HAUBOIS/PARIS OBSERVATORY; ESO/P. KERVELLA as a target continues. Observations in optical and ultraviolet wavelengths show cycles of brightening and dimming on timescales of months, superposed on waves of brightening and dimming on timescales of decades. Betelgeuse also appears to have bright spots that can change brightness and position in as little as eight weeks.

Betelgeuse also shows irregularity in its shape. In 1995, Hubble Space Telescope's Faint Object Camera snapped pictures of Betelgeuse — the first ultraviolet views of the surface of a star other than the Sun. It captured an enormous "hot spot" that distorted the star's shape, from round to somewhat lumpy.

Other observations have revealed irregular arrangements of cool gas and dust. Astronomers have found clumps of relatively cool gas interspersed among regions of hotter gas, at distances from the star from about 10 to 15 AU. Farther out, they have found a shell of dust at about 40 AU, and more shells or arcs of dust at about 200 and 400 AU.

Ultimately, what makes the extended atmosphere and more-distant environment of Betelgeuse so complex is that the star itself, underneath the layers of gas and dust, is boiling furiously, like an overheated pot of spaghetti sauce.

Many stars "boil" to some extent; heat from the central regions of the star gets transported up to the surface by the motion of the gas itself, a process called convection. The surface of the Sun is densely covered with thousands of convective "cells," where the Sun's contents are turning over. But red-supergiant stars don't have as many small convective cells. Instead, they form just a few really large ones (an example on Betelgeuse measured twice the diameter of Earth's orbit). When these giant cells spurt up, they affect the layers of atmosphere above them.

Research teams have tried to take all of this into account in constructing their models of what's going on with Betelgeuse.

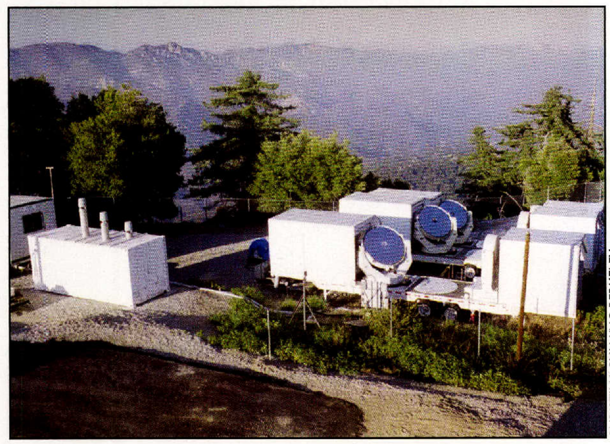
The star's extended atmosphere probably consists of several layers, not necessarily distinct, but gradually changing from cool and filled with water molecules to cold and dusty. Townes' model focuses on the close-in regions of the atmosphere.

The model starts with a basic spherical red-supergiant star, with a surface temperature around 6,000 degrees Fahrenheit (3,300 C). (The Sun's surface temperature is 10,000 degrees Fahrenheit (5,500 C). Because Betelgeuse is so much larger than the Sun, the red supergiant's surface is much farther from its central nuclear furnace, causing the surface to be relatively cool.)

A layer of cool gas surrounds this basic star out to about 1.4 times the star's radius. Varying in temperature between 1,400 and 3,200 degrees Fahrenheit (750-1,800 C), the gas in this layer is cool enough to form molecules of hydrogen, water, aluminum oxide, and silicon monoxide. There are lots of electrons zipping around, too. In the star's real atmosphere, it's likely that in addition to these, other unknown atoms and molecules also are present.

To fit their observations to their model, the Berkeley astronomers have found that the molecular layer must have one or two regions that are brighter than the others. These bright regions do not correspond straightforwardly to the large-scale convective cells on the surface of the star; instead, they are higher up in its atmosphere. Further, the bright spots seen in infrared light are too hot to be caused directly by these boiling bubbles. In any case, other studies have shown that when hot spots are seen in optical wavelengths, they may not be present


DAVID HALE/UC BERKELEY


CHRISTINA RYAN/UC BERKELEY

Top: Charles Townes, seen cleaning one of the three mirrors of the Infrared Spatial Interferometer (ISI) atop Mount Wilson, passed away January 27. Bottom: The full ISI.

RESOURCES

INTERNET

StarDate: Betelgeuse
stardate.org/astro-guide/betelgeuse

Betelgeuse
stars.astro.illinois.edu/sow/betelgeuse.html

Supergiant Stars
astronomynotes.com/evolutn/s5.htm

Mount Wilson Observatory
mtwilson.edu

Infrared Spatial Interferometer
isi.ssl.berkeley.edu

at the infrared wavelengths used by the Berkeley team.

Nevertheless, astronomers think the giant convection cells on the surface alter the extended atmosphere of the star. Perhaps the molecular layer gets infused with more electrons, or maybe more dust particles (solid particles that form when molecules link together) start to form. Something happens to change the brightness of the layer, but irregularly, in spots. And this intermittently spotted layer could explain the variations in Betelgeuse's size as seen in the infrared. Perhaps the star was relatively inactive at the beginning of the monitoring period (in the early 1990s), but then the amount of dust in the molecular layer rapidly increased, and this showed up as bright areas and an apparently larger size in the infrared observations.

These models are providing some much-needed insight into the atmospheres of red-supergiant stars. Understanding their mechanisms is important, as massive stars in their supergiant phases play a huge role in enriching the galaxy with building blocks for later generations of stars by giving off torrents of dusty particles. One of the big unanswered questions about these supergiants is where exactly this dust forms, and how it gets blown off into space.

To further probe the extended atmosphere of Betelgeuse, the Berkeley team is developing new instrumentation to enhance the ISI. A spectrometer will enable them to study the chemical makeup of the star's watery molecular layer. They hope to identify more of the molecules present, and to study how the dust or gas components are moving.

So the next time you gaze up at Betelgeuse, think of the star burbling away its mass into misty layers of dust and gas — and know that others may be pointing powerful instruments at it at the same time, hoping to figure it all out.

Leila Belkora is an astronomer at The University of California, Irvine, and a frequent contributor to StarDate.

Betelgeuse and the Birth of Interferometry

Interferometry is the combination of two or more electromagnetic waves. When the waves meet inside an instrument, their peaks and troughs "interfere" with each other. The result is recorded as a pattern of light and dark bands, called fringes. The interference pattern can be used to measure the angular size of the source of the light.

An interferometer is two or more telescopes, each collecting one of the waves to be interfered. Together, the telescopes make up one larger telescope with finer resolution than each would have separately. (Resolution is the level of detail that can be seen; in photographic terms, a higher resolution means more pixels per inch.)

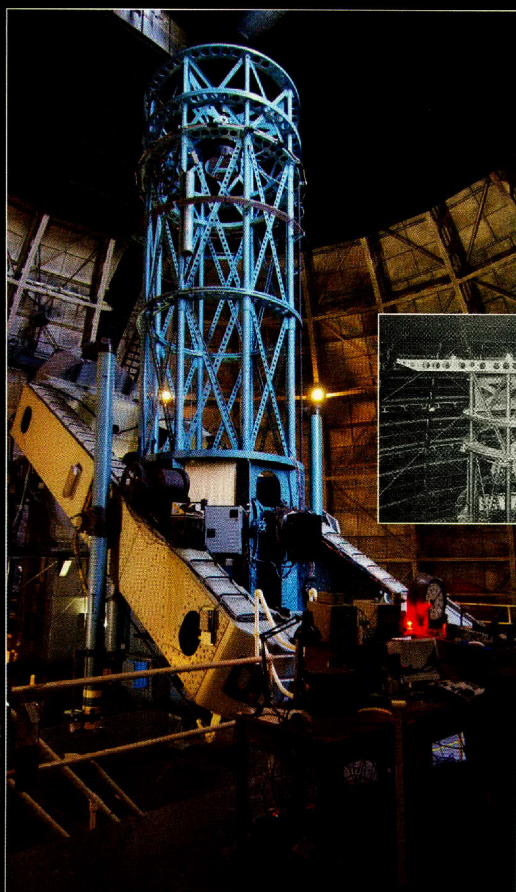
Physicist Albert Michelson was the first to develop the technique of interferometry to study the sizes of astronomical objects. From 1919 to 1922, Michelson and other Mount Wilson observers applied the technique to Betelgeuse.

Michelson mounted two sets of mirrors near the opening of the great 100-inch Hooker Telescope. The aperture of the telescope itself was covered. Michelson could move the mirrors closer together or farther apart along a straight track projecting beyond the sides of the telescope, and send the light from those mirrors down into the telescope through two holes in the covering. The two beams of light would then be combined, forming interference fringes.

When the mirrors were close together, the interference fringes were coarse and displayed high contrast. As the mirrors were moved apart, the fringes became progressively finer, but the pattern became fainter. Were Betelgeuse truly a point source — that is, not able to be resolved — the pattern would maintain the contrast as the mirrors were moved apart. Michelson recognized that the reduction of contrast is a consequence of the star's size. He measured mirror separation when the contrast went to zero to determine the angular size of the star.

"This experiment on Betelgeuse was the first time that anyone had measured the angular size of a star," notes Ed Wishnow, a research physicist at Berkeley's Space Science Laboratory, and a member of a team that is studying Betelgeuse. "This was a remarkable achievement for 1920."

Betelgeuse spans about 46 milliarcseconds of the sky. To determine how big that angular size was in miles or kilometers, astronomers in 1920 figured into their calculations the distance to Betelgeuse. They underestimated the distance, so they underestimated the size of the star. Still, commented an astronomer of the time, Betelgeuse was "a whale of a thing." **LB**



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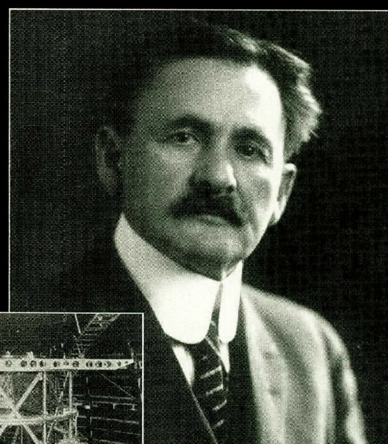
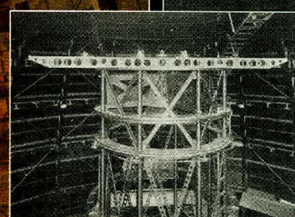




The 100-inch Hooker Telescope at Mount Wilson. Albert Michelson (top right) built a 20-foot interferometer instrument (inset) and used it to resolve the disk of Betelgeuse in 1920. The instrument is seen mounted at the top of the telescope.

by Damond Benningfield

Rendezvous Two

More than two years after leaving one asteroid, Dawn is ready to orbit another

An innovative spacecraft is set to make history in March when it enters orbit around the dwarf planet Ceres, the largest member of the asteroid belt. It will become the first craft to visit a dwarf planet and the first to orbit two worlds other than Earth and the Moon.

The Dawn spacecraft was launched September 27, 2007. It orbited Vesta, another large asteroid, for 14 months before heading toward Ceres. It is scheduled to enter orbit around Ceres on March 6, then spend a few weeks maneuvering to its final altitude before beginning full science observations.

At 592 miles (952 km) in diameter, Ceres is roughly one-quarter the size of the Moon. Yet it could be far more interesting than our satellite world because about half of its volume consists of water. Most of it is frozen, but some could form a large reservoir or even ocean of liquid water far below the surface, some of which could escape into space through cracks in Ceres' crust.

"There may be evidence of some [liquid] water from deep down making it to the surface," says principal investigator Chris Russell, a physics professor at UCLA. "Not standing water, but perhaps features created by water. There may be geysers. Herschel Space Telescope saw water vapor around Ceres, so there may be evidence of water in its atmosphere. My guess is Ceres is probably not completely frozen today, so we may see some evidence of liquid water."

In addition to photographing the surface, Dawn will produce global maps of the surface mineral and chemical composition and measure the dwarf planet's magnetic and gravitational fields, which can probe Ceres' interior. These and other observations should allow planetary scientists to piece together the history of Ceres' birth and evolution.

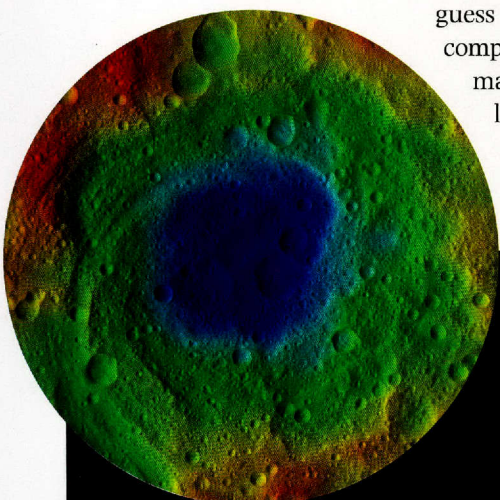
Dawn was able to orbit two asteroids because of its unusual propulsion system. Most probes use chemical rockets, which are powerful but require large amounts of propellants. Dawn, however, is driven by ion engines. These electric-powered engines produce only a tiny amount of thrust, but they can fire non-stop for days or weeks at a time, so their "kick" adds up. And they require only a fraction as much fuel as standard engines, so their use drastically reduced Dawn's size and cost.

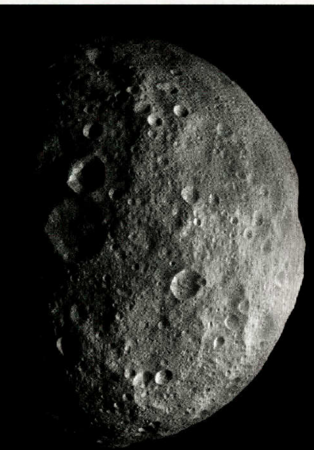
The craft has lost some of its maneuvering capability, so it has switched to a backup system that is a bit cumbersome. Even so, Dawn should still achieve all of its top objectives, Russell says: "We're aging, but we're doing well."

Although Dawn is snapping pictures during its approach to Ceres, the first major scientific observations won't begin until late April. After that, Russell says, Dawn should operate through the end of 2016, providing a detailed look at the solar system's largest asteroid.

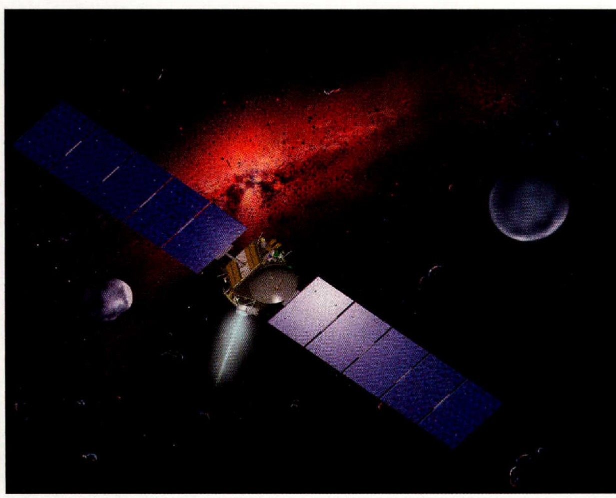
Rendezvous, Too

While Dawn takes aim at Ceres, the New Horizons mission is scheduled to begin scanning another dwarf planet: Pluto. Its instruments will take aim at Pluto in April, with closest approach scheduled for July.





Views of Vesta: A final look after departure, an elevation map (above) around the north pole, where blue areas are lower and red areas are higher. Right: Artist's concept of Dawn with Vesta (left) and Ceres.



NASA/MCREL/WILLIAM K. HARTMANN; LEFT: NASA/JPL/UCLA/MPS/DLR/IDA (2)

Kepler Bolsters List of Possible Habitable Worlds

Future interstellar travelers will have at least four more destinations to choose from — and perhaps as many as 10 — thanks to some recent additions to the list of confirmed planets beyond our own solar system. All of these new worlds are roughly the size of Earth and lie inside the habitable zones of their parent stars, where temperatures should be just right for liquid water, one of the key ingredients for life.

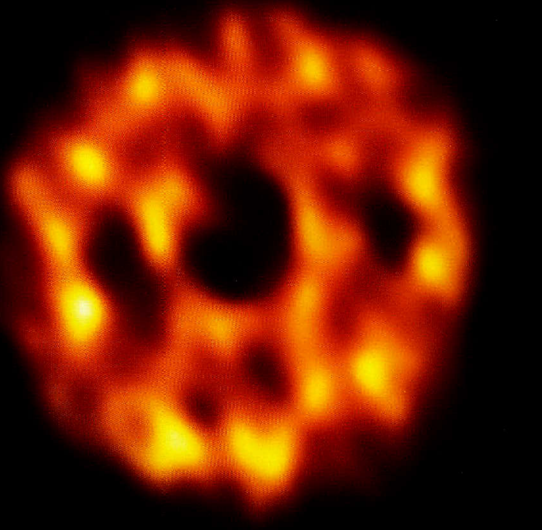
All four of the confirmed planets were discovered by the Kepler space telescope, which spent four years looking for evidence of planets around 150,000 stars in a single area of the sky. Technical problems halted the initial search, but a new one allows it to look for planets around a smaller number of stars in different patches of sky. The craft has logged more than 1,000 confirmed planets and 3,000 additional candidates in its initial survey, with even more worlds yet to be plucked from its observations.

Three of Kepler's newly confirmed habitable planets were discovered in its initial survey, with the fourth found after the telescope was revived last year. "These are the closest analogs to the Earth-Sun system that Kepler has found to date," said Kepler scientist Fergal Mullally during a January press conference. Each planet is less than twice the size of Earth, so it probably consists mainly of rock, as Earth does. Such worlds are considered to be more likely homes for life than much larger planets, which consist mainly of ice or gases.

Kepler scientists also announced that a new batch of 554 possible planets winnowed from the craft's obervations includes eight Earth-size planets in their stars' habitable zones, six of which orbit stars that are similar to the Sun.

The discoveries highlight the quick pace of exoplanet detection and study. Astronomers are conducting several extensive surveys to find more worlds, and are following up with detailed observations to learn about each planet's mass, temperature, composition, and more. That work has revealed a variety of possible planetary systems, including one with a "swarm" of Pluto-size bodies around the central star.

Using the ALMA array in Chile, radio astronomers detected a vast cloud of small dust grains orbiting the infant star HD 107146. The dust grains could be debris from collisions between many small chunks of rock and ice that are being stirred up by the gravity of objects similar to Pluto, the most famous of the Sun's dwarf planets. The ALMA observations also hint at the presence of an Earth-size planet more than seven billion miles from the central star — roughly 75 times the distance from Earth to the Sun.



L. RICCI/NRAO/NAOJ/ESO; B. SAXTON/NRAO/AUI/NSF

ALMA view of the dusty disk around HD 107146. Dust is thicker in the disk's outer regions, suggesting the presence of many Pluto-size objects.

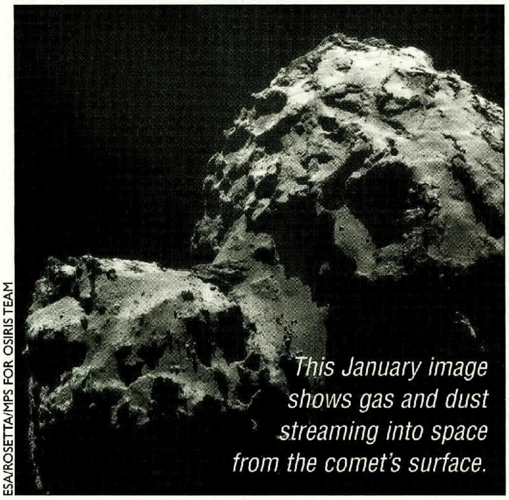
BOBBING ALONG WITH A COMET

Comet 67/P Churyumov-Gerasimenko is like a giant cork bobbing through the outer solar system, according to observations by Rosetta, a spacecraft that has orbited the comet since August. Precise measurements of the comet's volume and mass reveal its density, which is less than half that of water or about the same as cork. That means the comet essentially consists of weakly bonded clumps of ice separated by small spaces, according to project scientists.

Churyumov-Gerasimenko is shaped like a rubber duck, with two large lobes connected by a skinny neck. On-going observations of the comet's composition may reveal whether the lobes were originally separate bodies that stuck together, or a single structure that's been whittled away around its middle.

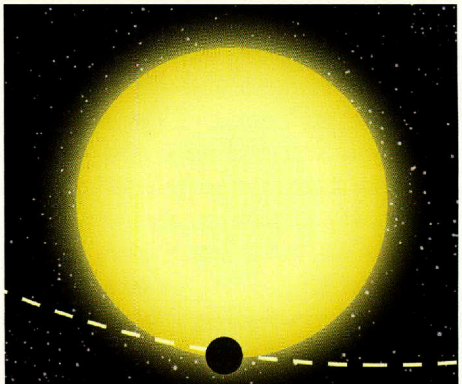
The comet is moving closer to the Sun, warming its surface. Ice at the surface vaporizes and escapes into space, carrying particles of dust up to an inch in diameter along with it. Most of this activity comes from the comet's neck, although some comes from deep pits in the two lobes. The comet will be closest to the Sun in August, so scientists expect to see even more activity over the next few months.

Rosetta has mapped about 70 percent of the comet's surface, with the remainder in shadow. That portion of the comet will move into the sunlight later this year, though, allowing the European probe to see the entire surface.



ESA/ROSETTA/MPS FOR OSIRIS TEAM

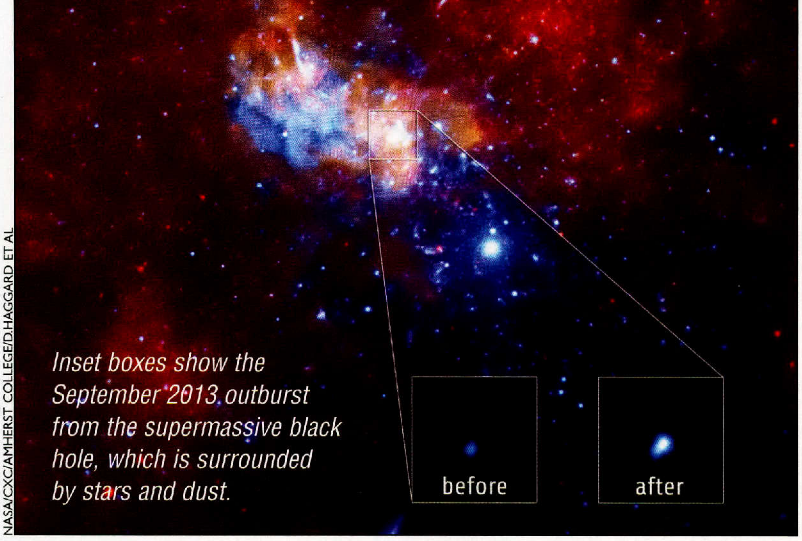
This January image shows gas and dust streaming into space from the comet's surface.



Kepler's Bounty

A partial tally of Kepler's candidate planets

4,175	Total
808	Earth-Size (up to 1.25 times Earth's diameter)
1,233	Super-Earth (1.25-2 times Earth's diameter)
1,542	Neptune-Size (2-6 times Earth's diameter)



Inset boxes show the September 2013 outburst from the supermassive black hole, which is surrounded by stars and dust.

NASA/CXC/AMHERST COLLEGE/D.HAGGARD ET AL

Misplaced Fireworks

Astronomers view outbursts from Milky Way's black hole, but not the ones they expected to see

The supermassive black hole at the center of the Milky Way remained frustratingly quiet last year, as a suspected giant gas cloud looped around it without a peep. Yet the close encounter was bracketed by two brief but brilliant flares from the black hole that were unrelated to the gas cloud.

The black hole, known as Sagittarius A* (Sgr A*), is about 4.5 million times as massive as the Sun. It is quieter than many other monster black holes, though, with little gas funneling into its gravitational maw.

Astronomers expected that to change last year with the close passage of the massive cloud of gas, known as G2. They used telescopes on the ground and in space to monitor the passage because they expected the black hole to gobble up some of the gas, which would shine brightly before it plunged into the black hole. Yet none of the observations revealed any fireworks.

A team led by UCLA astronomer Andrea Ghez, who has studied Sgr A* extensively, suggested that G2 wasn't a gas cloud at all. Instead, the team's observations suggested that G2 was a big star surrounded by a shell of gas and dust. The black hole stripped away streamers of the material around the star, but not enough to trigger any major outbursts.

While it studied G2, however, the space-based Chandra X-Ray Observatory did see the two most powerful outbursts yet recorded from Sgr A*. In the first, in September 2013, the X-ray glow from material around the black hole flared about 400 times brighter than normal. The second flare, 13 months later, was about half that bright.

Each outburst lasted only a couple of hours, though, suggesting they were not triggered by streamers of gas from G2. Instead, scientists say Chandra probably caught the black hole snacking on fairly large asteroids. The gravity of Sgr A* pulled the asteroids apart and pulled in the debris, which was heated to millions of degrees shortly before it crossed the black hole's "surface" — the event horizon — and disappeared from view.

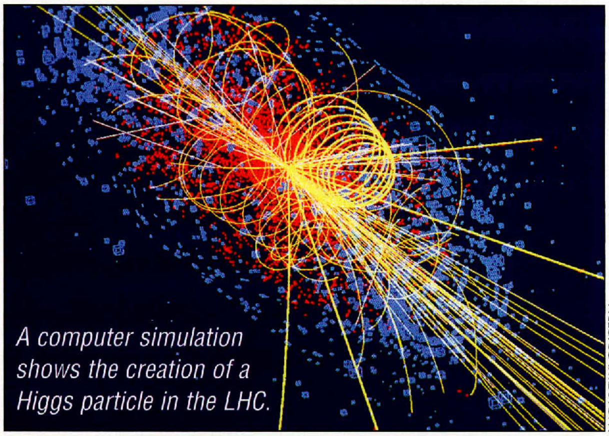
Back to Work

After a two-year upgrade, the world's largest scientific experiment is scheduled to get back to work in March. The Large Hadron Collider (LHC) will continue its quest to help scientists better understand the most basic particles and forces in nature.

The LHC is a 17-mile ring in which particles of matter are accelerated to almost the speed of light. Two beams of matter are aimed at each other, producing spectacular collisions between particles. The temperatures and pressures in these collisions can rival those found shortly after the Big Bang, so they reveal details about what the Big Bang created, and how.

In its first set of experiments, which concluded in 2013, the LHC confirmed the presence of the Higgs boson. This long-sought particle confirmed the existence of a field that gives mass to other particles of matter. The discovery earned a Nobel Prize for the scientist who predicted the Higgs particle and the leader of the team that found it.

The upgraded LHC will operate at higher energy levels than before, allowing it to probe conditions even closer to the Big Bang. Its experiments could reveal the particles that make up dark matter, which produces no energy but accounts for most of the matter in the universe. The experiments also will allow scientists to look for evidence of supersymmetry, a theory that says the Big Bang created heavier counterparts for all the known "normal" particles of matter.



A computer simulation shows the creation of a Higgs particle in the LHC.

LUCAS TAYLOR/CERN

Venus Probe Clocks Out

Venus Express, a European mission that arrived at Venus in 2006, bowed out in November when it used the last of the fuel for its maneuvering thrusters. The craft studied Venus' thick atmosphere, which is 90 times denser than Earth's at the surface and is topped by an unbroken layer of clouds. Venus Express found evidence of active volcanoes on the planet, and discovered that winds at the top of its atmosphere increased from roughly 200 miles per hour to 250 miles per hour (300-400 kph) during its mission. It also found that while the planet's present-day atmosphere consists primarily of carbon dioxide, it once contained large amounts of water, and that lakes or oceans might once have dotted the landscape.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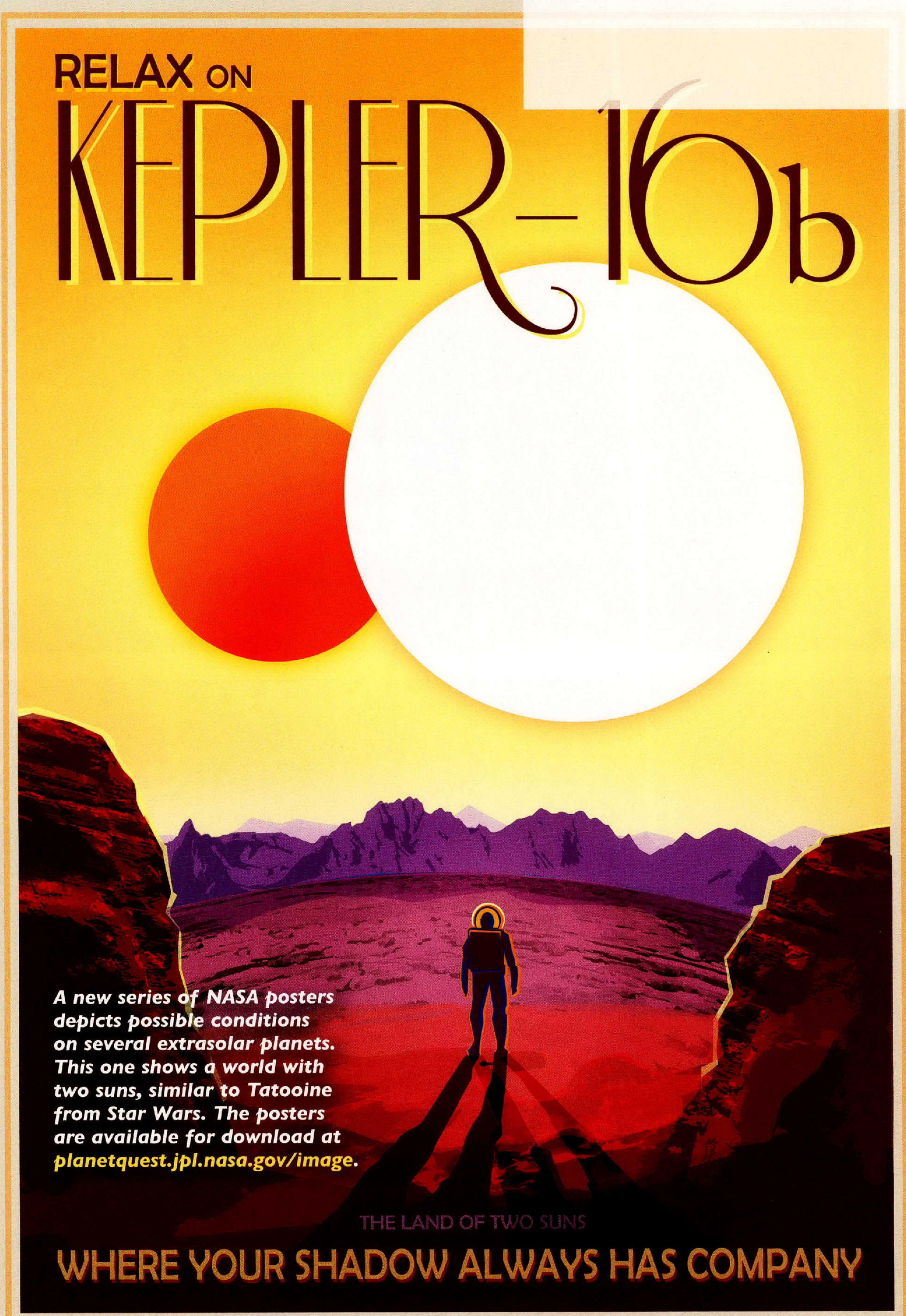

A new series of NASA posters depicts possible conditions on several extrasolar planets. This one shows a world with two suns, similar to Tatooine from Star Wars. The posters are available for download at planetquest.jpl.nasa.gov/image.

NASA/JPL