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MARCH/APRIL 2014 $7

TREASON IN THE STARS
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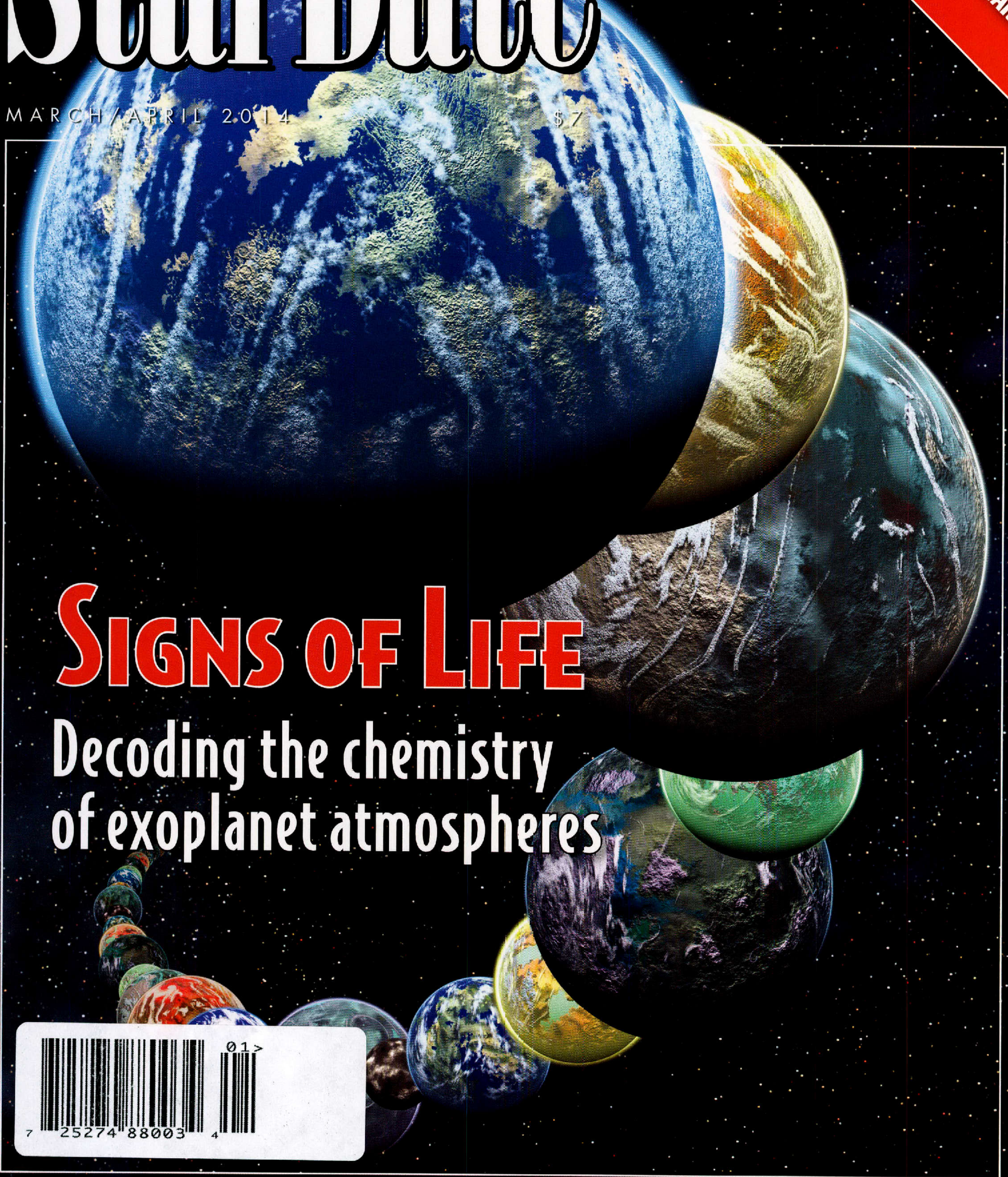

SIGNS OF LIFE

Decoding the chemistry of exoplanet atmospheres

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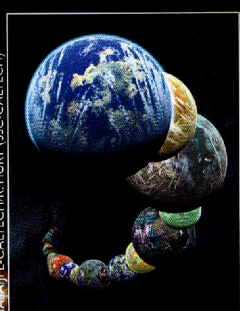
Features

Departments



NASA/JPL-CALTECH/R. HURT (SSC-CALTECH)

On The Cover

Scientists are working out how to probe the atmospheres of rocky Earthlike worlds (like the examples in this artist's concept) for signs of life. Statistics show there are billions of such worlds in our galaxy. For details, see Page 4.

This Page

Bright southern hemisphere star RS Puppis lights up its gossamer cocoon of reflective dust in this Hubble Space Telescope view. A Cepheid variable, RS Puppis brightens and dims every six weeks. Hubble took a series of photos of light flashes rippling across the nebula in a phenomenon known as a 'light echo.'

Coming Up

McDonald Observatory's 75th anniversary is coming up May 5, and we'll look back at the observatory's origins. We'll also bring you summer skywatching tips and charts, the latest astronomy news, and Merlin's answers to your questions.

NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA)-HUBBLE/EUROPE COLLABORATION

MERLIN

Dear Merlin,

Why does the aurora borealis often appear like curtains? How long does a sighting last? Where are good locations in North America to see aurorae? Most examples I have seen are green. What conditions are required for other colors to be visible?

Shanti Thompson
Bedford, Virginia

Merlin's primer on all things auroral will begin with the basics.

An aurora forms when Earth's magnetic field captures electrically charged particles in the solar wind. The particles strike atoms and molecules high in the atmosphere, causing them to glow. Oxygen molecules produce a green glow (the most frequently seen color), oxygen atoms red, and nitrogen molecules blue.

The solar wind particles follow the lines of magnetic force toward Earth's surface. These lines are roughly parallel, so they form glowing streamers. Seen from a great distance (tens to hundreds of miles), the streamers align in such a way that they look like shimmering curtains.

Auroral displays can last anywhere from a few minutes to a few hours. And from North America, the best views generally come in an arc from Alaska through Canada, the northern Great Plains, and into New England. These regions are closer to the north magnetic pole, which is where the lines of magnetic force converge. During periods of high solar activity (when there are a lot of sunspots and solar flares), this arc expands southward. On rare occasions, the aurora borealis can extend as far south as Texas and Florida.

Aurorae are also visible around the south magnetic pole (the aurora australis). Much of the viewing area is over Antarctica and the Southern Ocean, though, so it is more difficult to see.

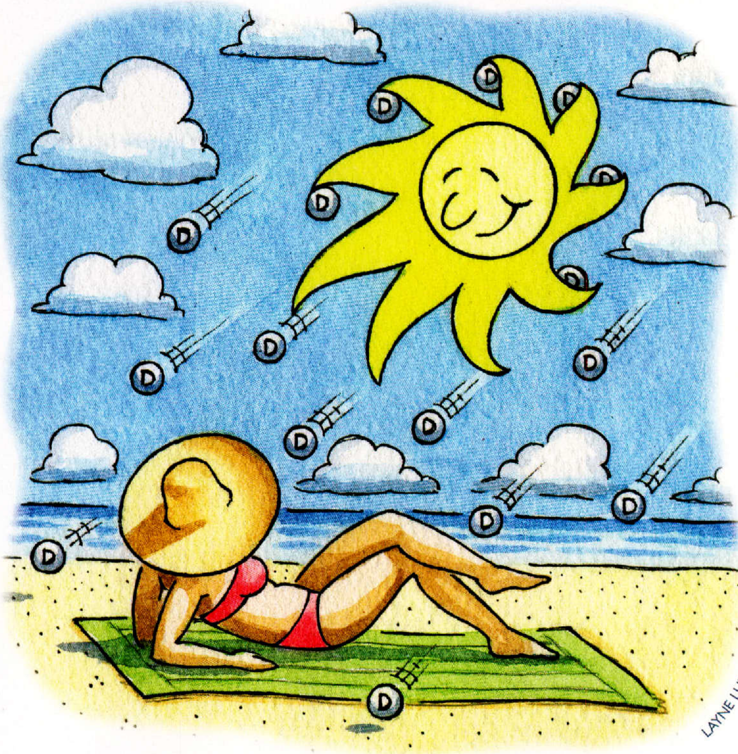
Dear Merlin,

We humans need sunlight to produce vitamin D. If we lived in another star system, would our new star provide us with our RDA of vitamin D, or is it a quality of our star only?

Cherie Hart
West Bend, Indiana

If you're planning a trip outside the solar system, you might want to take along some supplement capsules if you're visiting an especially red star, but otherwise you're fine without them (assuming you can find a planet where you can expose your skin to the star's light).

A type of cholesterol in the skin reacts with ultraviolet energy from the Sun to produce a form of vitamin D, which the body then converts to a usable form. Stars that are especially cool and red produce very little ultraviolet energy, so the skin might not receive enough of it to get the process started. (Most of the galaxy's stars are red, by the way.) Stars that range from a little cooler than the Sun all the way to the top of the temperature scale should produce enough ultraviolet light to help you maintain healthy bones and teeth.



Incidentally, Merlin's medical wizard friends report that exposing your skin to the Sun for a few minutes at a time is enough to keep vitamin D production rolling along. There's no need to prolong the exposure and risk another effect of ultraviolet radiation: sunburn.

Dear Merlin,

In my travels I have seen a Moon calendar with all 28 days listed by name. I have looked, but I can only find the ones with the eight major phases. I know they all have names! Can you help?

Joan Foley
Cameron Park, California

Although Merlin has traveled the cosmos, hobnobbing with fellow wizards and such, he's never seen a calendar with a specific name for each day of the lunar cycle. In fact, Merlin believes that such a calendar would be difficult to create and use.

That's mainly because the Moon's cycle of phases lasts an average of about 29.5 days. Since that's not a whole number of days, you would have to account for the extra half day on your naming scheme.

And because of that half-day addendum, the Moon is not at the same phase at the same time of day from cycle to cycle. In March, for example, the Moon will be full at 12:08 p.m. CDT, while in April it reaches full at 2:42 a.m. So from cycle to cycle, you see the Moon at a slightly different phase at any given time of day.

That leaves us with the names that describe the four major phases of the Moon and the configurations between them: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, and waning crescent.

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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ESA/NASA/M. KORNMESSER (ESA/HUBBLE)/STScI

The atmosphere of extrasolar planet HD 189733b has been probed extensively, revealing water, sodium, carbon monoxide, methane, and more. The giant planet (shown orbiting extremely close to its parent star in this illustration) is too hot to be an abode for life.

Life is in the Air

Astronomers are working on ways to find signs of life in the atmospheres of planets in other star systems

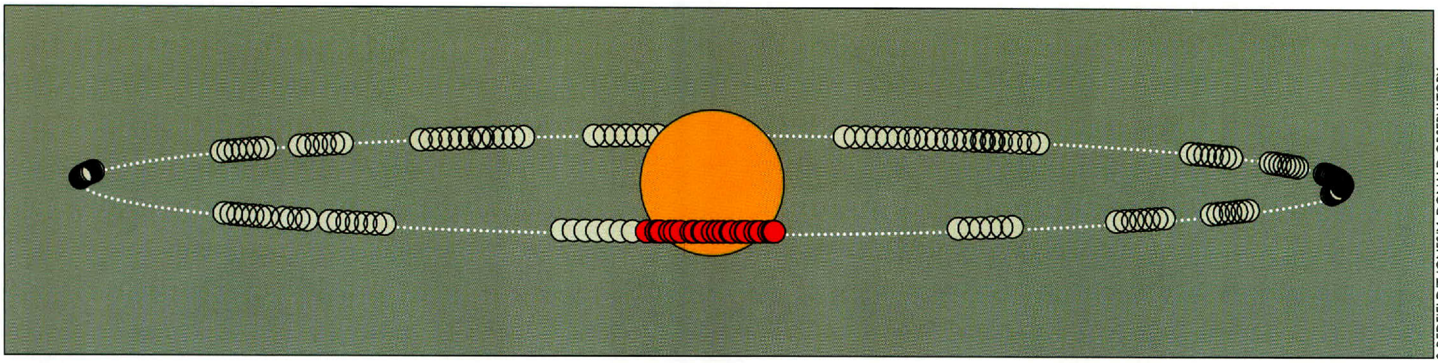
It's been nearly two decades since astronomers found the first planet orbiting a star other than our Sun. More than 1,000 success stories have followed. And while thousands of planet candidates await confirmation and more crop up daily, some astronomers are moving on to the even tougher work of characterizing the known planets. They are asking whether these planets have the right chemical make-up, temperature, and orbit to support life. No confirmed signs of life have yet been found, but astronomers are making headway.

Beyond the 50-year search for extraterrestrial intelligence (SETI), astronomers are now looking for signs of microbial life — or planets with conditions that are ripe for it — as a quicker route to finding ET, even though he might be a bacterium.

SETI is "just looking for a needle in a haystack," says University of Texas at Austin planet-hunting astronomer Michael Endl. "It's much more likely that life in the universe is animal life, even if it's just microbial life. For four billion years, we only had microbes on our planet, and complex life is probably much, much, much rarer. And even within complex life, our kind of *technologicial* intelligence is even much rarer."

If ET can't phone Earth, scientists can do the next best thing: look for signs of alien life in observations of the light from a planet's atmosphere. These telltale signs are called biosignatures or biomarkers.

By Rebecca Johnson



S. REDFIELD/T. JONES/McDONALD OBSERVATORY

Seth Redfield observed planet HD 189733b with the Hobby-Eberly Telescope about 200 times, both in-transit (red circles) and out, over the course of a year. He added these observations together to make the first ground-based probe of an exoplanet's atmosphere.

A planetary atmosphere might show signs of methane or oxygen, both of which are produced in abundance by terrestrial microbes, Endl says. Other clues could include the signatures for nitrogen, water, and carbon dioxide.

Scientists are attacking the biomarker challenge through both theory and observations.

Lee Grenfell of the German space agency's Institute of Planetary Research is working from the theoretical side. At the European Planetary Science Conference in September, he discussed his project to predict what biomarkers could look like to the next generation of giant ground-based telescopes or planet-hunting space missions.

"We developed computer models of exoplanets which simulate the abundances of different biomarkers and the way they affect the light shining through a planet's atmosphere," Grenfell said. "We modeled an exoplanet similar to the Earth, which we then placed in different orbits around stars, calculating how the biomarker signals respond to differing conditions."

The work of Grenfell and others will help scientists and engineers fine tune their designs for future telescopes and instruments that will hunt for biomarkers.

NASA, too, is working on the theoretical side. For two decades, the agency's astrobiology program has studied the conditions needed for life to form and evolve.

The other front in the hunt for biomarkers is the challenge of actual telescopic observations. The first challenge is overcoming the major task of isolating a planet's light from that of its parent star, which is millions or billions of times brighter. Nonetheless, astronomers have found clever ways to isolate the light and have produced some promising results.

One method takes advantage of a chance viewing angle that causes some planets to pass directly in front of, or transit, their parent stars as seen from Earth. Employing a transit to probe a planet's atmosphere is called transmission spectroscopy.

Though the execution can be difficult, the idea is straightforward. Astronomers observe the star both during and between transits. Using computer software, they then subtract the star-only light sample from the star-plus-planet light sample. Voila! Only the planet's light remains. Then they can decode the planet's light, looking for signatures of different elements and molecules, including biomarkers.

Only a few stars are good candidates for transmission spectroscopy, Endl says. Though the Kepler planet-hunting satellite has discovered thousands of possible transiting planets, these are too distant, and thus too faint, for the

Planets of a Certain Size

The Kepler space telescope has discovered thousands of possible planets in other star systems. Some are small, like Earth, while others are big and fluffy, like Jupiter, the giant of our solar system. For many planet hunters, though, the big surprise is what's in between: Most of Kepler's planets are between the size of Earth and the size of Neptune, the smallest of the solar system's giant planets.

"These are planets we never expected based on our own solar system," said University of California-Berkeley astronomer Geoff Marcy at a January press conference. "It's a size range not represented in our own solar system, we don't know what these planets are made of, and we don't know how they form."

Kepler discovered the planets as they passed in front of their parent stars, which revealed the sizes of the planets. Astronomers then used ground-based telescopes to measure the gravitational pull of some of these planets, which revealed their masses. The combination revealed how dense the planets are, providing a rough idea of their composition.

Those that are no more than twice of the size of Earth, known as super-Earths, probably consist of a large rocky core that may be topped by water or a thin atmosphere. Those that are up to four times the size of Earth, dubbed "mini-Neptunes," are much less dense than our planet, suggesting that their cores are surrounded by large envelopes of gas.

Although such worlds are common in the Kepler observations, no one knows how common they are overall because Kepler found only planets that are no farther from their stars than Earth is from the Sun. More-distant regions may be dominated by bigger planets, like Saturn and Jupiter. Yet the unexpected numbers of these worlds adds a new mystery for scientists to ponder as they learn more about planets in other star systems. **DB** technique to work. For this method, "you focus on the bright ones," he says.

One of the "bright ones" is HD 189733, which lies about 63 light-years away in the constellation Vulpecula, the fox. "It's a bright star and the planet is rather large," Endl says "… and the [orbital] period is shorter, so you get more transits" in a shorter period of time than some other candidates for this method. Observations from successive transits can be added together to build a stronger signal.

Several years ago, McDonald Observatory astronomer Seth Redfield (now at Wesleyan University) led a team that studied this star. Over a period of a year, the astronomers made about 200 observations of HD 189733, both in transit and out of transit, with the Hobby-Eberly Telescope at McDonald. In 2007, they published their results: the first transmission spectrum of an extrasolar planet from a ground-based telescope. The observations revealed sodium in the planet's atmosphere. While not a biomarker, the result proved that, given sufficient observation time, this work could be done with large ground-based telescopes.

Results from other teams studying this star soon followed. In 2008, Mark Swain of NASA's Jet Propulsion Laboratory found both carbon dioxide and methane in the planet's atmosphere with Hubble Space Telescope. Swain's methane discovery was the first organic molecule found in the atmosphere of an extrasolar planet, "a crucial stepping stone to eventually characterizing prebiotic molecules on planets where life could exist," he says. In 2010, a team from the California Institute of Technology found water vapor in the planet's atmosphere with Spitzer Space Telescope.

Though HD 189733b may be the most-studied exoplanet yet, with an atmosphere known to contain several biomarkers, scientists are not heralding it as an abode for life. The planet is a "hot Jupiter," with a mass similar to our solar system's giant but orbiting just one-tenth as far from its star as Mercury is from the Sun in our own solar system. In fact, a strong wind from the star is ripping away several tons of the planet's atmosphere every second, so the planet is evaporating.

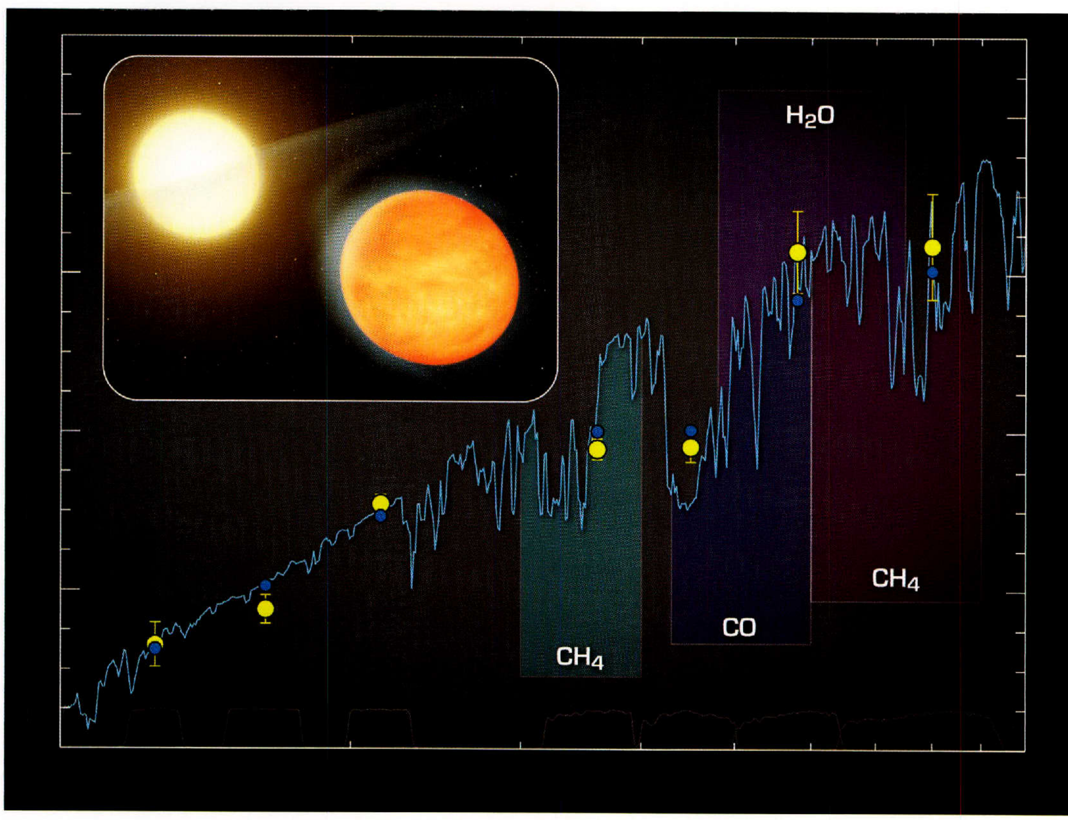
A few other hot Jupiters orbiting nearby stars have had their atmospheres at least partially decoded by astronomers exploiting their transiting orbits.

Water, for example, has been found in the atmospheres of Corot-9b and Gliese 581b. And transits revealed that one strange world is dominated by carbon. MIT astronomer Nikku Madhusudhan's probe of WASP-12b with Spitzer Space Telescope shows "the astounding diversity of worlds out there," he says. An Earth-sized, carbon-rich world would be covered with diamond and graphite rocks, as well as tar, notes collaborator Joseph Harrington of the University of Central Florida. WASP-12b, unfortunately, orbits its star so closely that blistering hot winds heat its day side to 4,200 degrees Fahrenheit — hot enough to melt steel.

Though these targets are hot Jupiters, "these measurements are an important step to our ultimate goal of determining the conditions, such as temperature, pressure, winds, clouds … and the chemistry on planets where life could exist," says JPL's Swain.

The discoveries suggest that future telescopes and instruments may allow astronomers to make the same types of observations on smaller, fainter plan-

Spitzer Space Telescope found molecules of methane (CH_4), carbon monoxide (CO), and water (H_2O) in the atmosphere of exoplanet WASP-12b. The measurements suggest this is the first known carbon-rich planet.



NASA/JPL-CALTECH/N. MADHUSUDHAN (PRINCETON UNIVERSITY) ets orbiting far enough from their stars for liquid water to exist — a realm called the habitable zone.

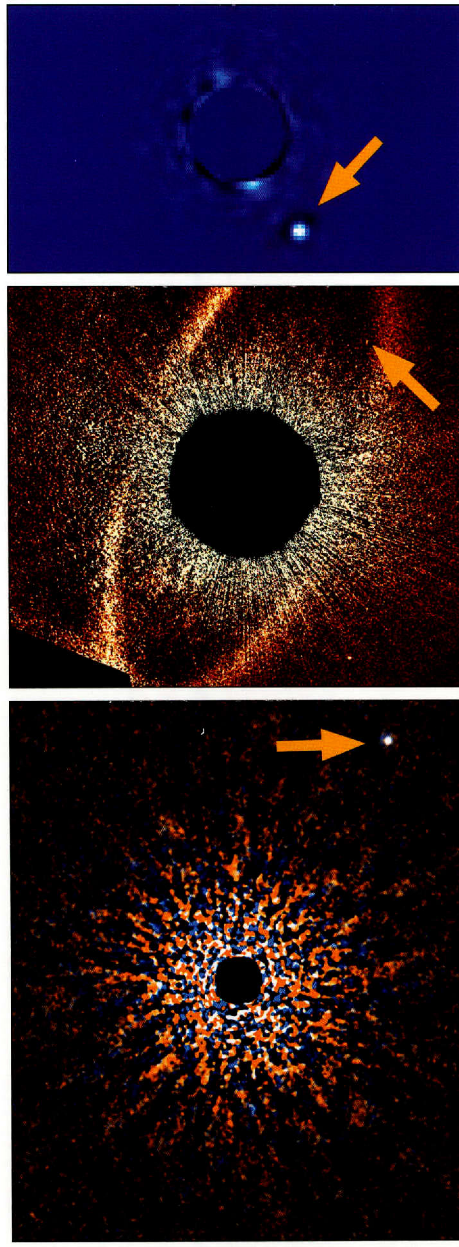
A second technique astronomers use to probe exoplanet atmospheres is even more challenging than transmission spectroscopy, Endl says. This is directly imaging a planet orbiting another star and probing the planet's light for chemical signatures.

Only a handful of extrasolar plants have been directly imaged. Notably, in 2008 Hubble Space Telescope captured an image of the giant planet orbiting Fomalhaut, one of the brightest stars in the night sky.

A few of the largest ground-based telescopes have accomplished similar direct-imaging feats, although not many are equipped for the challenge. "You need a high-powered, high-angular resolution adaptive optics system" Endl says. Adaptive optics allows telescopes to compensate for the blurring effects of Earth's atmosphere, providing extremely sharp views of astronomical objects.

In 2010, Mark Janson of The University of Toronto used the direct imaging technique with the Very Large Telescope in Chile to probe the atmosphere of a giant planet orbiting HR 8799, a young Sun-like star 130 light-years away. The observations relied heavily on adaptive optics. The team found that the chemical signatures in the planet's atmosphere were "not compatible with current theoretical models" of giant planets, says Janson's collaborator Wolfgang Brandner of Germany's Max Planck Institute for Astronomy. These results could cause giant-planet formation models to be reevaluated.

Direct imaging of exoplanets — and especially using the gathered light to decode their atmospheres — is still in its infancy. Astronomers say the future James Webb Space Telescope, which will be much larger than HST and more sensitive to the wavelengths at which astronomers probe planetary atmospheres, could make great strides in studying giant extrasolar planets.



GEMINI/C. MAROIS (NRC CANADA); NASA/ESA/P. KALAS (UC-BERKELEY); NASA GSFC/NOAJ

In each of these direct images of extrasolar planets, the star's light was blocked to allow the planet to show. From top: 2014 Gemini image of Beta Pictoris b, one of the first exoplanets detected; Hubble image of Fomalhaut with planet and asteroid belt; Subaru image of GJ 504b.

Tantalizing hints of future success from direct imaging and a spate of successes via transmission spectroscopy of hot Jupiters don't mean that scientists are ready to start looking for biosignatures in Earth-size planets, though.

"We're not there yet," Endl says. "We first need a sample of suitable targets." The perfect target would be an Earth-mass planet orbiting in the habitable zone of a nearby star.

In recent years, scientists have converged on a plan to get there. In September 2009, a large group of astronomers, planetary scientists, biologists, and others met in Barcelona, Spain. They laid out a roadmap to find habitable planets, known as the Barcelona Process.

The Barcelona Process outlined four milestones to work toward: determine the frequency of exoplanets in the Milky Way and how many are Earth-like, launch a space telescope to survey all of the habitable exoplanets within 50 light-years, launch one or more space missions to do transit observations of Earth-like exoplanets via transmission spectroscopy, and launch a space mission that can characterize habitable Earth-like exoplanets to look for biosignatures.

The first milestone — determining the number of exoplanets in our galaxy and how many are like Earth — has been tackled in several recent studies.

In 2012, Kailash Sahu of the Space Telescope Science Institute published the results of a more than a decade-long search for exoplanets via microlensing — using the gravity of intervening stars as lenses to magnify the view of more-distant objects. Sahu says he found that the Milky Way has at least 100 billion planets. From that, he extrapolated that there must be more than 10 billion small, rocky planets in the galaxy, and at least 1,500 planets within 50 light-years of Earth.

Last year, Kepler scientists working with Keck Observatory announced that statistics gleaned from Kepler's haul of thousands of candidate planets show that 20 percent of all stars in the galaxy probably have an Earth-sized planet orbiting in the habitable zone.

"What this means is, when you look up at the thousands of stars in the night sky, the nearest Sun-like star with an Earth-sized planet in its habitable zone is probably only 12 light-years away and can probably be seen with the naked eye," says Erik Petigura, a graduate student at UC-Berkeley, who led the analysis.

Team member Andrew Howard of the University of Hawaii says this information is crucial "because successor missions to Kepler will try to take an actual picture of a planet, and the size of the telescope they have to build depends on how close the nearest Earth-sized planets are."

The next step in the Barcelona Process is a census to find all of the exoplanets within 50 light-years of Earth. That's exactly what NASA's Transiting Exoplanet Survey Satellite (TESS), which is scheduled for launch in 2017, is designed to do.

Like Kepler, TESS will look for dips in the light of stars that could indicate transiting planets. But unlike Kepler, which scanned a small region of the sky in the constellations Lyra and Cygnus, TESS will survey the entire sky with the goal of identifying small planets with bright host stars in the Sun's neighborhood. Over two years, it will monitor more than 500,000 stars, with mission planners expecting a haul of more than 3,000 exoplanets, including 500 that are roughly as massive as Earth.

What comes next will depend on what TESS finds. Assuming TESS (and other studies) build up a suitable catalog of nearby potentially habitable planets, the next step could be the resumption of planning for the long-delayed Terrestrial Planet Finder (TPF) mission. This high-tech, high-cost space telescope would take direct images of nearby terrestrial planets, feed the light into a spectrograph, and look for biosignatures.

TPF is currently on hold. "The technology doesn't exist," Endl says. "Currently everybody agrees it's much better to wait until we have the first reconnaissance of the solar neighborhood. ... The goal now is really to build up a target catalog for TPF."

Though the search for biomarkers from extrasolar planets seems to be the most likely way scientists will find life outside our solar system, scientists urge caution in interpreting the results. The strategy has its limits.

One of the classic biosignatures astronomers look for in planetary atmospheres, methane, can be produced by geological processes as well as by living organisms, Endl notes. And a study published last year described a process that could produce high levels of another biomarker, oxygen, in the atmospheres of some planets without the presence of life.

"You have to keep in mind, if we find all these spectral signatures, we can only say that 'Yeah, it's quite likely that this planet has an active biosphere,'" Endl says. "But it's not like we can say for sure."

Rebecca Johnson is editor of StarDate *magazine.*

Kepler Rises from the Ashes

Last May, the planetfinding spacecraft Kepler hit a snag: The second of four gyroscope wheels failed, meaning it could no longer point accurately. After months of planning, mission controllers have come up with a way to use the crippled spacecraft to continue to look for transiting exoplanets.

For the new mission, K2, the spacecraft permanently will be oriented to look into Earth's orbital plane (the ecliptic). The pressure of sunlight will combine with the two working gyroscope wheels to stabilize the telescope in three directions.

Periodically, the telescope will need to be maneuvered to switch its sunlit side to prevent sunlight from entering the telescope. This requirement will mean that K2 can hunt for planets in a single field for about 80 days at a time.

"This is a very smart way to still use this space telescope, and of course it will just maximize the science output" says University of Texas at Austin astronomer Michael Endl. He explains that the new process will enable K2 to study changing fields of view in different directions in Earth's orbital plane each 80-day cycle. "Whatever's there, it will find — with orbital periods of less than 80 days." K2 also will study star clusters, active galaxies, and supernovae.

K2 is scheduled to begin testing in March. The 80-day test campaign could study 5,000 to 10,000 targets, mission planners said. **RJ**

Resources

Books

How to Find a Habitable Planet, by James Kasting, 2010

Talking About Life: Conversations on Astrobiology, Chris Impey, editor, 2010

Articles

"Mister Sol's Neighborhood," by Damond Benningfield, *StarDate*, July/August 2013

"The Dawn of Distant Skies," by Michael D. Lemonick, *Scientific American*, July 2013

Internet

Kepler
kepler.nasa.gov

TESS
space.mit.edu/TESS

NASA Astrobiology Program
astrobiology.nasa.gov

Barcelona Process
Pathways2009.net

SKY CALENDAR

by Alan MacRobert

This spring, all five naked-eye planets light up the skies. Mars, Jupiter, and Saturn put on their shows after dark, while Mercury and Venus enliven the pre-dawn hours. Spica seems to travel in tandem with the Red Planet. The bright winter stars Sirius, Procyon, Betelgeuse, Rigel, and Aldebaran maintain their night watch into the new season.

MARCH 1 - 15

Jupiter is still the brightest point in the evening sky this season, shining high overhead in Gemini after dark.

Sirius takes second place for brightness, far below Jupiter in Canis Major.

Three stars nearly tie for third place: Capella, very high toward the northwest; Rigel, in Orion's foot to the right of Sirius; and the "spring star" Arcturus, rising in the east-northeast around 8 p.m. Standard Time (9 p.m. Daylight Saving Time, which begins March 9).

These four bright stars illustrate the extremes of the two factors that can make a star look bright. Sirius is intrinsically unremarkable: it's a run-of-the-mill type-A star, somewhat larger and hotter than the Sun. But it is the *closest* nighttime star that's ever visible to the naked eye from most of the United States — only 8.6 light-years away.

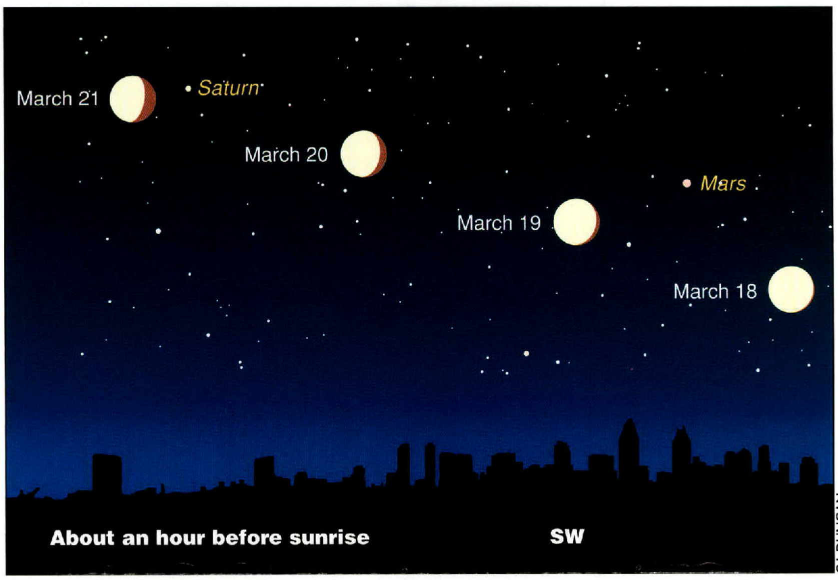
Arcturus and Capella are moderately large stars somewhat more distant, 38 and 45 light-years away, respectively. Rigel, though, is a rare supergiant. It's 85,000 times more luminous than the Sun, shining from a far-off 860 light-years. Although supergiants are rare, they account for quite a few of the leading lights we see.

That's not counting Jupiter, which is only 40 light-minutes from Earth right now, or the Moon, which poses near Jupiter on March 9 and 10. The Moon far outshines anything else in the night because it's ridiculously close: 1.3 light-seconds away, or about 240,000 miles. That's just one percent as far as the next-closest large celestial body, Venus, ever approaches — and it's fewer miles than you may have driven your car.

As the planets creep around the constellations, they form temporary new "constellations" with bright stars. Jupiter now is part of a huge, striking "Winter Diamond" that stands upright after dinnertime. Jupiter is the diamond's top. The rest of it consists of Sirius far below, Betelgeuse to their right, and Procyon nearly the same distance and height to their left.

Sirius, Betelgeuse, and Procyon form the Winter Triangle, which is always in the same place at this time of year. But next year, Jupiter will be one constellation farther east, in dim Cancer.

If you're up before sunrise, step out and look for Venus blazing low in the southeast. And in the mid-part of March, look for Mercury putting in an appearance far to Venus' lower left.



MARCH 16 - 31

As winter turns to spring, Jupiter moves rapidly toward the southwest and west in the evening sky. Meanwhile, another bright planet pops onstage: Mars, rising in the east soon after dark.

Mars comes with a companion this year: Spica, to its lower right. Spica is less bright, twinklier, and icy blue-white. They offer a nice color contrast. Compare them also with Arcturus, pale yellow-orange, farther to their left. All three rise high in the east as evening grows late.

Mars is brightening on the way to its April opposition and closest approach to Earth.

Saturn rises a few hours after Mars. The ringed planet clears the horizon somewhat to the right of where Mars did, and glows somewhat less bright. Around 1 a.m., Antares rises a little farther to the right of where Saturn did.

The waning Moon groups with Mars and Spica late on the evening of March 18. It pairs with Saturn even later on the night of the 20th, and then with Antares on the morning of the 22nd.

By the time spring begins on March 20, Orion has moved off to the southwest in early evening and is tilting down to the right from his high winter upright posture. His three-star belt is becoming nearly horizontal for spring. A horizontal Orion's Belt means you'll find orange-red Betelgeuse straight above it and white Rigel straight below it. And this year, Jupiter shines almost straight above them all. Look up from Jupiter for Castor, completing a very tall line.

Early spring also is when Orion's Belt points left toward Sirius and right more or less toward Aldebaran.

APRIL 1 - 15

Because night is falling later and later, the seasonal turning of the constellations seems to speed up in late winter and early spring. Jupiter remains high over Orion in the southwest during and after dusk

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 in its waxing gibbous phase, so it fills the sky with light for most of the night. It sets a couple of hours before sunrise, though, providing a brief viewing window before morning twilight erases the fireworks.

— but did you really expect to find Leo high in the southeast already, or Cassiopeia low in the north-northwest?

And high in the northeast, the Big Dipper is no longer in its wintertime pose, standing on its handle. Instead, the dipper has begun tilting toward the left, as if dumping water toward the bowl of the Little Dipper below.

Most of the Little Dipper is notoriously dim, but the star marking the end of its handle is easy enough. Look due north for 2nd-magnitude Polaris, the North Star. From this starting point, much fainter stars form a curving arc to the right toward the modestly bright pair forming the end of the Little Dipper's bowl: Kochab and Pherkad. It takes an enviably dark sky to see the rest of the Little Dipper easily.

Mars is the real highlight of the evening. At nightfall, the Red Planet burns low in the east-southeast as brightly as Sirius in the southwest. Spica remains at Mars' lower right, and Arcturus is about four times as far to Mars' left.

April 8 is when Mars reaches opposition (opposite the Sun as seen from Earth). For two weeks after that, Mars is at its closest to Earth until 2016, appearing 15.1 arcseconds wide in a telescope. That's still pretty small. A sharp, high-quality 6-inch scope on a night of fine atmospheric seeing will probably show the planet's North Polar Cap, as well as the dark terrain just beyond the cap's edges, and a few more of Mars' dark surface markings (depending on which side of the planet is facing Earth). One side is bland; the other is more interesting. Look too for white clouds, especially around Mars' edges.

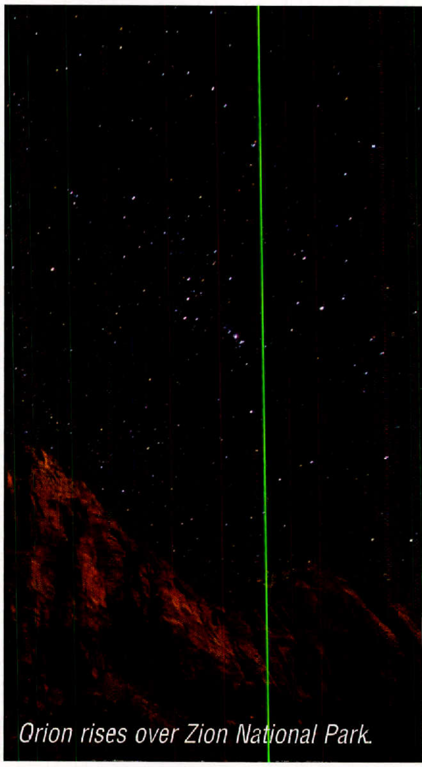
APRIL 16 - 30

Mars now shines invitingly high in the southeast after dark, like a distant campfire burning high in the spring night.

Spica is below Mars. Look to Spica's right, by less than two fist-widths at arm's length, for the springtime constellation Corvus, the crow. Although Corvus has no really bright star, it's something of an eye-catcher with its four stars of second and third magnitude. They form a squashed square, not very large. Some people see it as a four-sided sail. The crow is supposed to be eyeing Spica, to steal it from Virgo's hand.

Look back to Mars. Bright Arcturus shines off to its left. These form the top of a tall isosceles triangle with Saturn far below them. Watch for Saturn rising after dark in dim Libra.

Look far to the left of Saturn, in the northeast, for another bright point rising. Vega is beginning its long spring and summer climb up to the zenith. Keep an eye on it in the coming weeks and months. Vega moves at a leisurely pace in its travels because it's rather far north — farther north than any other first-magnitude or brighter star except for Capella.



Orion rises over Zion National Park.

JOE PARKS

Turning around to the west, you'll find Jupiter still shining in the middle of Gemini. The two Gemini stick figures are now standing upright for their western descent, as if standing in a descending elevator. Their heads, Pollux and Castor, are above Jupiter. Look off to Jupiter's left for Procyon in undistinguished little Canis Minor. Capella shines farther right of Jupiter, in Auriga.

Orion is far below Gemini. If you want to catch the hunter this late in the season, look early — as soon as twilight fades — before it has a chance to sink below the horizon. The same goes for bright Sirius to Orion's left in the southwest, and for dimmer, orange Aldebaran to Orion's right in the west-northwest.

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

TOTAL LUNAR ECLIPSE

APRIL 14-15

A total lunar eclipse will be visible from beginning to end throughout most of North America on the night of April 14-15. The event will last just over 3.5 hours. The Moon will begin to enter Earth's shadow at 12:58 a.m. CDT on April 15, and fall fully within the shadow (a phase called totality) at 1:06 a.m. Totality will last just shy of an hour and 20 minutes, and will end when the Moon begins to exit Earth's shadow at 3:24 a.m. The partial eclipse will end at 4:33 a.m. This photo shows a June 2011 total lunar eclipse seen from Dar es Salaam, Tanzania.

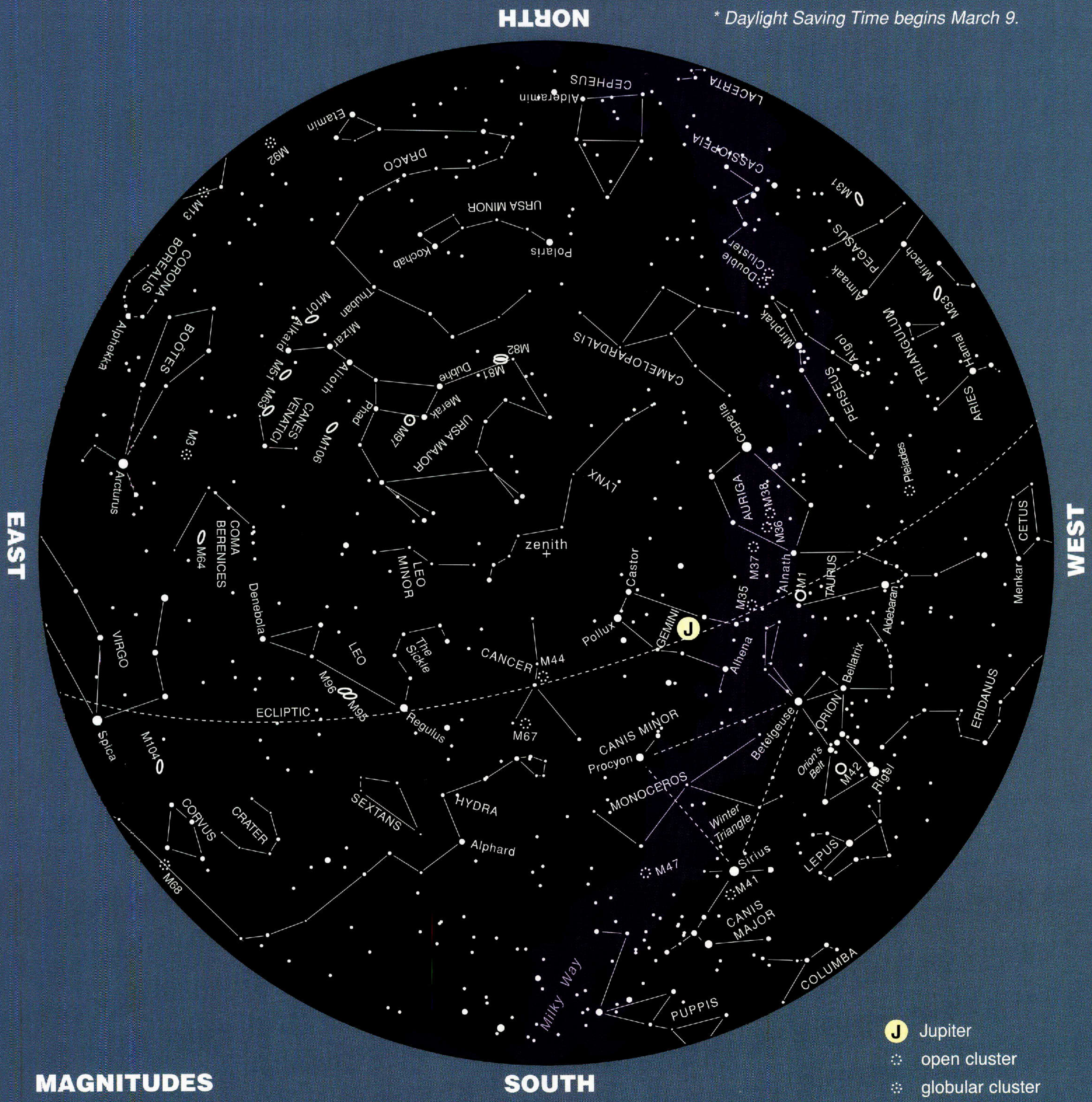
MUHAMMAD MAHDI KARIM/MICRO2MACRO.NET

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 9.*



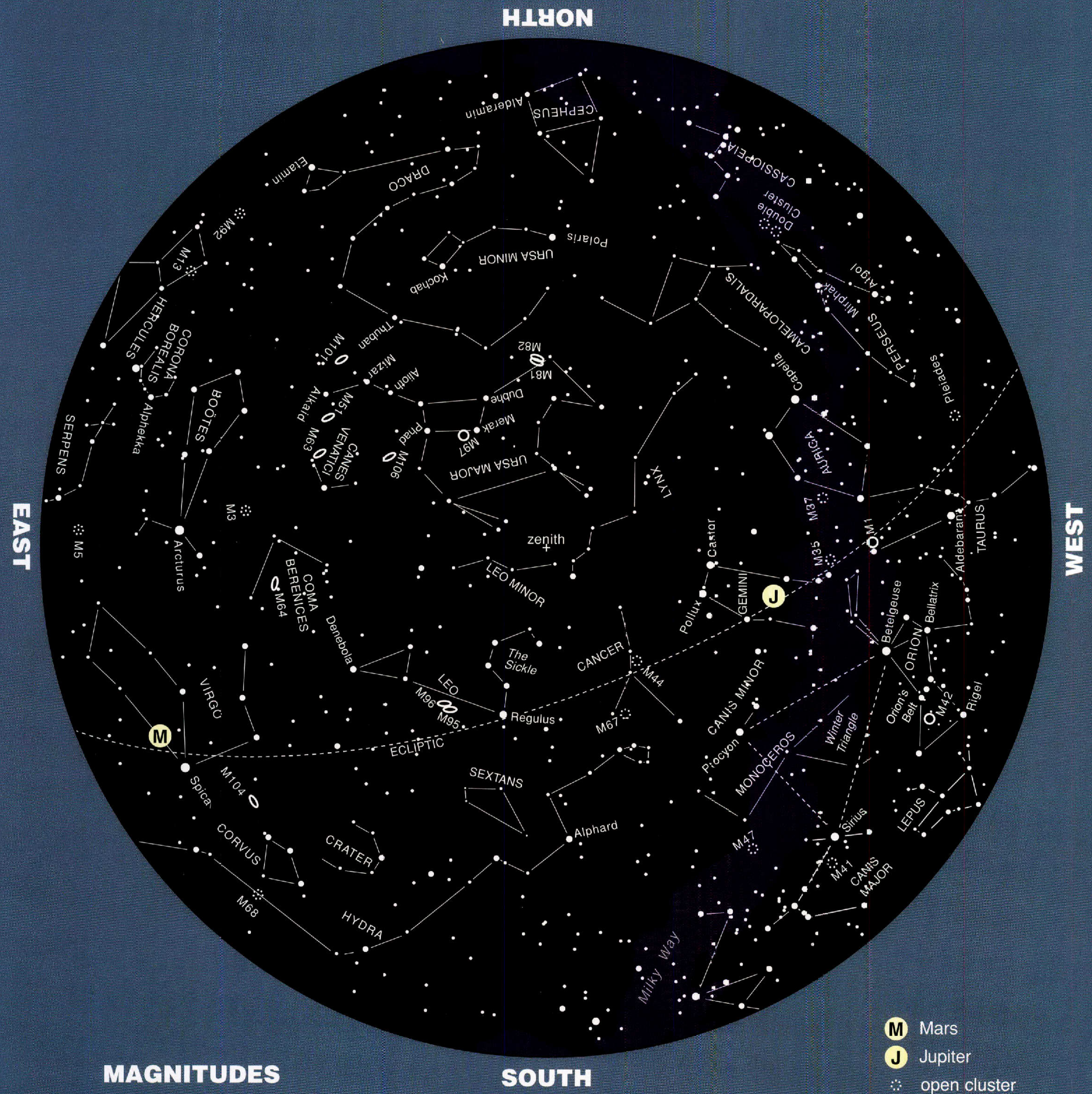
MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

- 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.



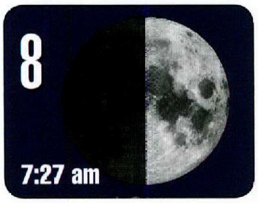
MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

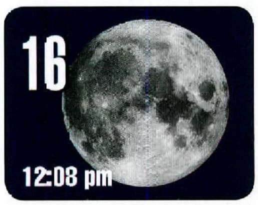
- M Mars
- J Jupiter
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

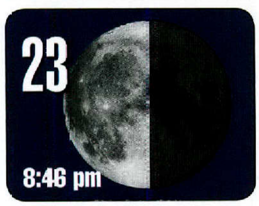
Sky Highlights

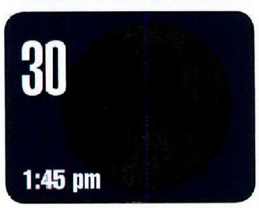
by Damond Benningfield

MARCH









7 The bright star close beneath the Moon at nightfall is Aldebaran, the brightest star of Taurus. The bull's V-shaped face stretches below Aldebaran.

9 Daylight Saving Time begins in the United States at 2 a.m. local time.

9/10 Dazzling Jupiter is close to the upper left of the Moon at nightfall on the 9th, and a little farther to the upper right of the Moon on the 10th.

13 The Moon swings by Regulus, the heart of Leo. Regulus is to the lower left of the Moon at nightfall.

17 Spica and Mars are to the lower left of the Moon as they rise in mid-evening, with Spica closer to the Moon.

18 The Moon, Spica, and Mars form a beautiful triangle as they climb skyward by around 10:30 or 11 p.m, with orange Mars to the upper left of the Moon and Spica to the upper right.

20 The planet Saturn looks like a golden star to the upper left of the Moon at first light, with orange Mars farther to the right of 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 arrives in the northern hemisphere with the vernal equinox at 11:57 a.m. CDT.

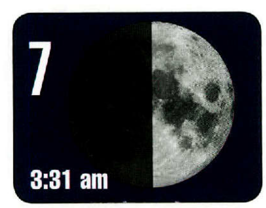
21 Saturn stands just above the Moon as they climb skyward in the wee hours of the morning, and to the Moon's right at first light.

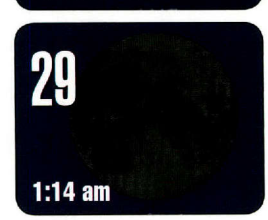
22 Antares, the orange supergiant at the heart of Scorpius, huddles to the lower right of the Moon in the pre-dawn sky.

27 Venus, the "morning star," shines close to the lower right of the Moon at first light, low in the east-southeast.

Moon phase times are for the Central Time Zone.

APRIL





3 Aldebaran, the orange eye of Taurus, gazes down on the Moon at sunset.

5 The brilliant planet Jupiter stands to the upper left of the Moon at nightfall, with the orange star Betelgeuse, the shoulder of Orion, the same distance to the lower left of the Moon.

6 Jupiter is close to the upper right of the Moon this evening.

8 Mars is at opposition today, lining up opposite the Sun in Earth's sky. The bright orange planet rises at sunset and remains in the sky all night.

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			

10 Leo's bright heart, the star Regulus, lurks close to the upper left of the Moon at nightfall.

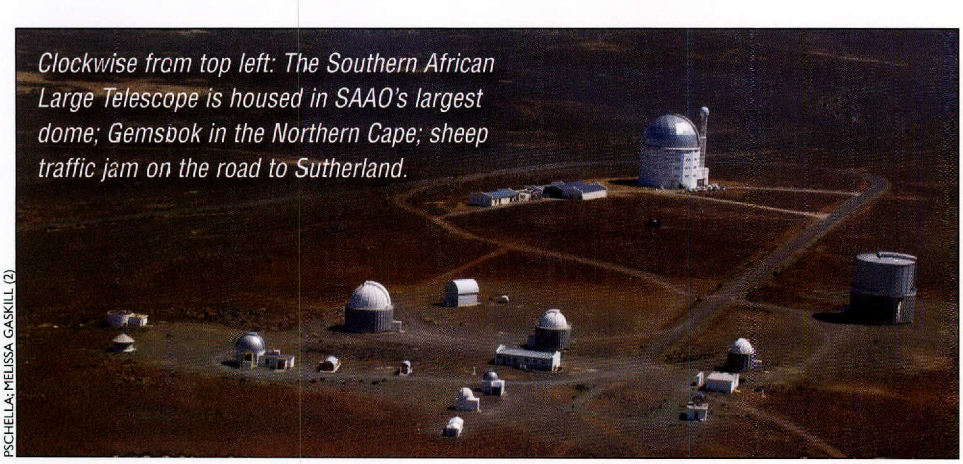
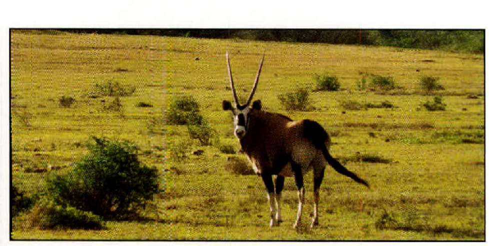
13/14 Brilliant orange Mars, the star Spica, and the full Moon will stage a beautiful encounter, with the Moon undergoing a total eclipse on the second night (see Page 11).

16 The golden planet Saturn is roughly one degree to the left of the Moon as they rise in late evening.

18/19 Antares stands below the Moon as they climb into view in the wee hours of the 18th, and about the same distance to the right of the Moon on the 19th.

21 The Lyrid meteor shower will be at its best tonight.

25/26 Venus, the "morning star," blazes to the lower left of the Moon at first light on the 25th, and to its right on the 26th.


Clockwise from top left: The Southern African Large Telescope is housed in SAAO's largest dome; Gemsbok in the Northern Cape; sheep traffic jam on the road to Sutherland.

PSCHELLA; MELISSA GASKILL (2)

The Stars of the Southern Hemisphere

Stargazing in Sutherland, South Africa

South Africa's Northern Cape is vast, uncrowded, and extremely dark at night. The tiny sheep-farming town of Sutherland, home to the South African Astronomical Observatory (SAAO), lies high in the mountains of the province's southwest corner.

SAAO began as the Royal Observatory at the Cape of Good Hope near Cape Town, founded in 1820 to map southern skies and aid maritime navigation. In 1972, plagued by light and air pollution, it moved to Sutherland to take advantage of dark, cloudless skies and the high elevation. Construction began on the South African Large Telescope (SALT), a modified version of the Hobby-Eberly Telescope at McDonald Observatory, in 2000. It saw first light in 2011. SALT shares the site with 15 other telescopes.

I visited South Africa with two friends, flying into Johannesburg and then to Upington to meet guide Jaco Powell of Cape Fox Tours & Photography. (Guide services in South Africa are affordable, knowledgeable, and include transportation.) We spent three days exploring the northern half of the province, photographing landscapes and wildlife by day and stars by night.

Our lodging was three mountain huts at Naries Namaqua Retreat near Springbok, on a ridge overlooking the Spectacular Mountains. The property and several nearby parks offered hiking trails, exotic wildlife, more than 600 plant species — and starry skies. Each night, Powell helped us shoot perfect photos of the Milky Way and star trails.

We then drove to Sutherland (the last 50 miles on an unpaved road with sweeping views and the occasional sheep traffic jam) for a guided tour of SAAO. The visitors center has exhibits on the electromagnetic spectrum and SALT's abilities to fingerprint starlight by breaking the light into its component parts. The telescope's 11-meter array of 91 hexagonal mirrors detects distant stars and galaxies a billion times too faint to see unaided. Astronomers are using SALT to explore the scale and age of the universe, its earliest galaxies and quasars, the lives and deaths of stars, and planets orbiting other suns. Our tour ended with a peek at those mirrors inside SALT's tall dome.

SAAO
www.saao.ac.za

Skitterland Guest House
skitterland.co.za

Cape Fox Tours & Photography
kalaharisafari.com

After the tour, we relaxed on the covered porch of Skitterland Guesthouse, a stone structure dating back to 1860. My room featured tall windows, an enormous bathroom with heated floors, and a sitting room with a fireplace. At 6 p.m., Powell drove us to Reit Se Eetplek restaurant for a traditional South African meal: mutton, rice, potatoes, vegetables, and dessert.

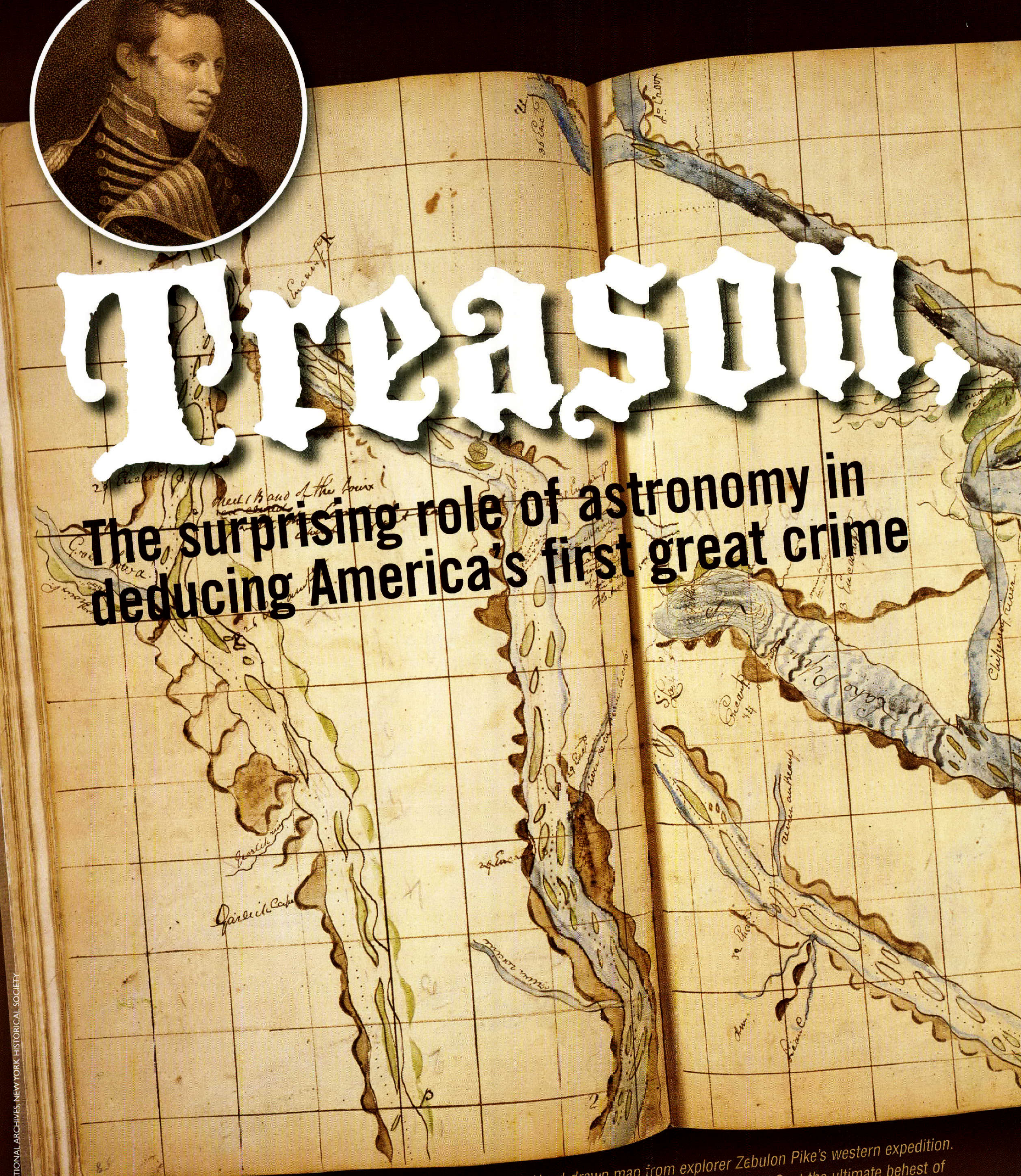
Jurgens and Rita Wagener run the restaurant and our guesthouse, and Jurgens, an enthusiastic amateur astronomer, leads nightly stargazing. The program starts with an orientation and video, then moves to a viewing area with five 11-inch telescopes surrounded by a seven-foot brush wall to keep out lights from the rare passing car. We viewed Saturn's rings, Alpha Centauri, the Jewel Box Cluster, the Omega Centauri globular cluster, the Trifid Nebula, the Swan Nebula, and M22, a globular cluster in Sagittarius. With our unaided eyes, we took in the Southern Cross and an incredible Milky Way stretching across the sky, almost bright enough to throw shadows. (Dress warmly; Sutherland is South Africa's coldest spot and nights can be chilly year-round.)

At more than 274,000 acres, nearby Tankwa Karoo National Park offers plenty of solitude and dark skies. Many animals and birds can be spotted from the roads or by striking out on foot, but the more adventurous may opt to book one of the park's cabins or camp out for a chance to see shyer nocturnal animals.

— Melissa Gaskill

Treason,

The surprising role of astronomy in deducing America's first great crime



Hand-drawn map from explorer Zebulon Pike's western expedition. Pike (top left) explored the western U.S. at the ultimate behest of former Vice President Aaron Burr (bottom right, in an 1802 portrait by John Vanderlyn), who was later tried for treason.

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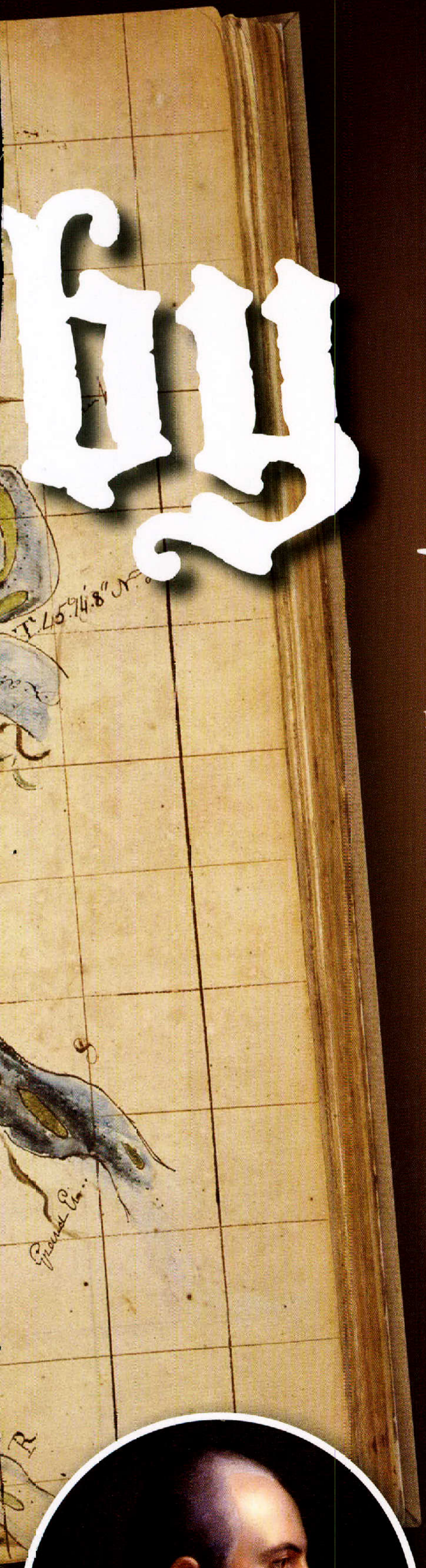


By Jove!

In the days of the United States' westward expansion, explorers like Meriwether Lewis and William Clark routinely used the stars to identify their position and map the growing nation's new lands. In 1807, when former Vice President Aaron Burr was only two years out of office, he was charged with treason against the U.S. for dispatching his own expedition. Accusers said Burr was not out to chart the west, but to steal it! Burr may have intended to found his own nation. Evidence against him included tables of calculations about the planets and their moons.

This colonial whodunit draws together several founding fathers, from Burr (already despised for his duel with Alexander Hamilton), to Thomas Jefferson, our most scientifically literate president. Its outcome hinges on the astronomy of a European nobleman, Giovanni Cassini, whose methods for calculating longitude using the moons of Jupiter made mapmaking possible.

Explorer Zebulon Pike, of Pike's Peak fame, stands at the center of the Burr controversy. He headed Burr's expedition, and was captured by Spanish forces along the Rio Grande River and branded a spy. Pike was found carrying planetary calculations that suggested he might be surveying Mexican lands for conquest. Was Pike lost, or an agent in Burr's conspiracy?

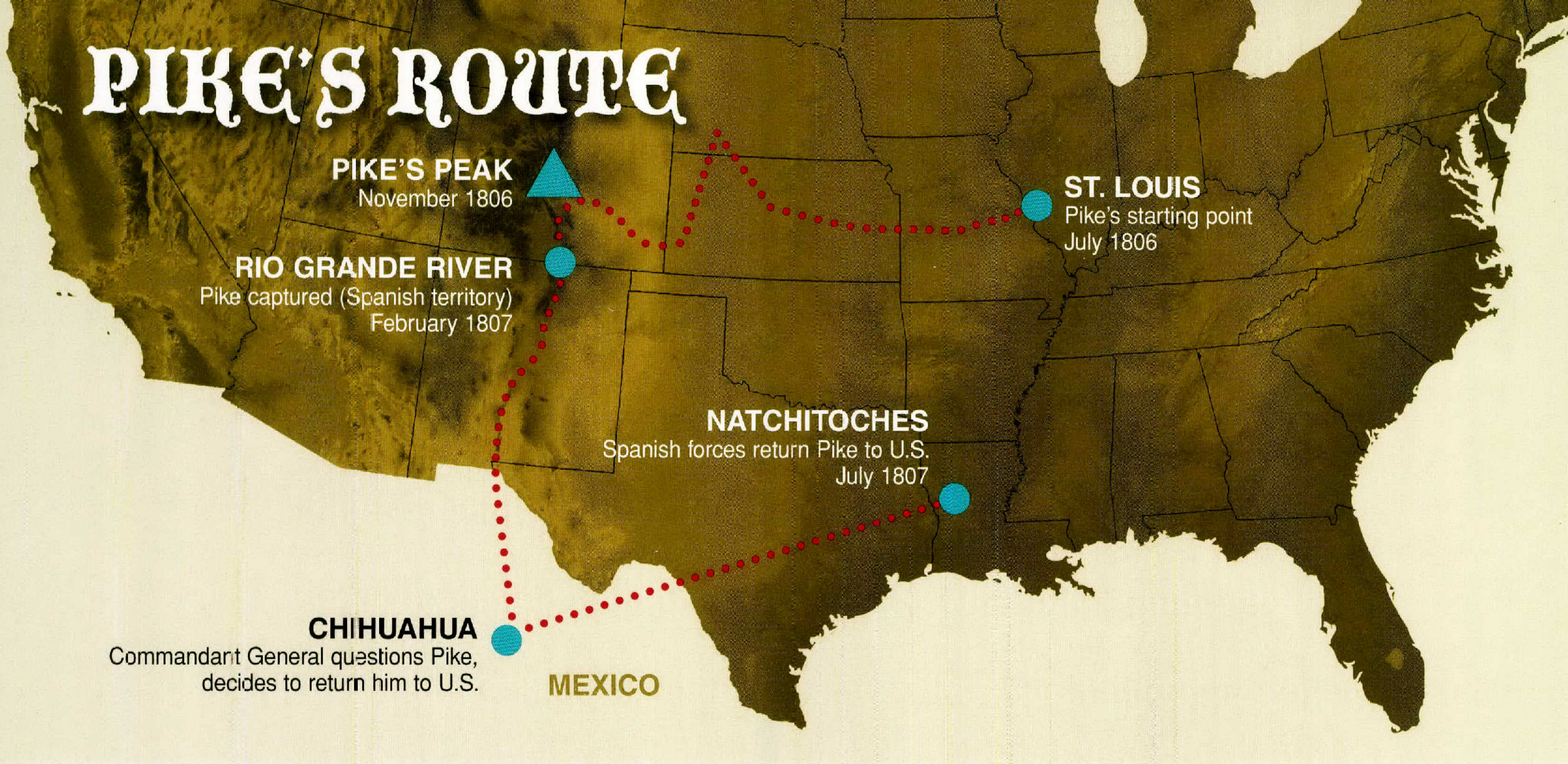
In his travels across the untamed American wilderness, Pike repeatedly made telescopic observations. Along the way, he encountered both American Indian and Spanish settlements, each with its own traditions for using the stars to answer the age-old question "Where are we?"

Lieutenant Pike received his orders for the expedition from General James Wilkinson. "At every remarkable point, I wish you to employ your telescope in observing the eclipses of Jupiter's satellites," Wilkinson wrote. "These observations [will] … enable us, after your return, to ascertain the longitude."

Jupiter and its moons are a beacon for finding longitude. The secret to this method is remembering how Earth turns. A traveler simply need note the local time when one of Jupiter's moons becomes visible in a particular way. Then they must compare that time with the moon's known appearance time at a specific place on Earth (for instance, Greenwich, England). The latter is found by consulting an almanac. The difference between the two times indicates the traveler's east-west position. Each hour marks 15 degrees of longitude, as Earth rotates that far each hour. The method was first suggested by Galileo Galilei, and perfected by astronomer Jean-Dominique Cassini to improve the map of France. This European astronomy would help decide the fate of the American West.

Thomas Jefferson's telescopes at Monticello were not powerful enough to resolve Jupiter's moons, so a new instrument was purchased for Pike's trip. He carried a state-of-the-art achromatic telescope that was four inches wide

By Nick D'Alto



and a bit more than three feet long. It magnified objects 60 times — enough to resolve Jupiter's four then-known moons: Io, Europa, Ganymede, and Callisto. (Discovered by Galileo in 1610, the four often are called the Galilean satellites.)

Pike set out from St. Louis in July 1806. He traveled farther southwest than Lewis and Clark, into unexplored regions of the new Louisiana Territory. He neared today's Texas and New Mexico, which at the time were fiercely defended by Spain.

In his travels, the explorer followed his astronomical orders to the letter. "Since our arrival here," Pike noted on reaching the village of the Osage tribe in modern-day Missouri, "I have ascertained … the variation of the compass to be 6° 30′ E.; the latitude, 37° 26′ 17″ N., and by observation on three different nights … two immersions of Jupiter's satellites."

When one of Jupiter's moons disappears into the planet's shadow, it is called immersion. That moon's reappearance on the other side is called emersion. Moons may also transit, crossing the planet's face as seen from Earth. Orbital periods for Jupiter's Galilean moons vary widely (more than two weeks for Callisto, less than two days for Io). However, because of gravitational interactions with each other (a phenomenon called resonance), the moons' periods are multiples of each other. This means Pike may have witnessed several immersions just hours apart.

Making precise telescopic observations in untamed country presented challenges, sometimes requiring rustic solutions. "To correct your watch, preparatory to observing the satellites," Wilkinson advised Pike, "First [arrange] a basin of water, in some place protected from the motion of the air." The water acted as an artificial horizon to help Pike align his instruments. (Astronomers still do this, although not with pans of water.)

Farther west, Pike reached the settlement of the Pawnee Indians, a vast complex of hundreds of lodges and other structures. Here, his astronomy facilitated a stirring diplomatic act. Certain by the stars that the village stood within U.S. territory, Pike persuaded "a grand council of 400 warriors and their chieftains" to lower the Spanish flag and raise the American flag. While the Pawnee lacked telescopes, Pike's stargazing would make perfect sense to them. The light he called Jupiter was one of many the tribe tracked nightly across sky to measure the seasons and direct religious worship.

The explorer kept meticulous records. "Took equal altitudes," he noted frequently. This a method for sighting the Sun to establish local time, which is vital for timing Jovian immersions. "Established meridional altitude" was a means to fix latitude; Pike carried a reasonably accurate sextant for the purpose. But the realities of trail life often intervened; phrases such as "killed a deer" sometimes intermix with his stargazing notes.

Pike's travels revealed a vast new America, crossing what today are seven states. But as the seasons changed, his expedition turned tragic. "The feet of nine of our men are frozen," Pike recorded "Thermometer, 18½° below zero." "Hungry … without cover … snow four, or five feet deep." His astronomy grew desperate. "Took … angular distances of two stars … do not recollect which." Finally, Pike was confronted by mounted Spanish cavalry. "Am I not on the Red River?" he protested. "This is the Rio Grande," came their reply: Spanish territory. Zebulon Pike and his men were captured.

Perhaps fearing American reprisal, Pike's captors treated him well. Led through Mexico, he wrote of grand mansions and beautiful Spanish ladies. He also mentioned a friar, fascinated by his telescope, who told him that the leaders of New Spain do not permit astronomy, apparently not wishing their subjects to know exactly where they are. Pike's own astronomical notes were impounded. The reason was soon clear: His stargazing made him a spy.

"In one of the documents found upon Pike, there is talk of Jupiter, of telescopes, of sextants," Spain's ambassador protested in letters to James Madison, America's Secretary of State. "In another," he fumed, "there is renewed mention of the said planet, and its satellites." The explorer being lost seemed unconvincing. "Either

Pike knows how to make astronomical observations," the ambassador charged, "or he does not." War with Spain appeared imminent. The Spanish monarch Charles IV became involved, furious that the American with the telescope had seen too much.

For President Jefferson, the situation was more complex. Jefferson knew that Pike was not a spy for the United States. Jefferson had received reports that Aaron Burr, already a political outcast, was gathering men and arms to seize parts of the American West and Mexico for himself. Even more troubling, James Wilkinson, the general who planned and authorized Pike's expedition, admitted to knowing of Burr's plans. The two men had corresponded extensively, allegedly in code.

This cast Pike's expedition and his stargazing in a chilling light. Jefferson, who first advocated using astronomy to chart the American West, may have felt that his own science was turning against him. Were the moons of Jupiter, orbiting millions of miles from Earth, being used to help commit the crime of the century?

"Sundry persons are conspiring … to set ... a military expedition against the dominions of Spain," Jefferson proclaimed in a special address to Congress. "The prime mover in these [is] Aaron Burr."

RESOURCES

Books

Zebulon Pike, Thomas Jefferson, and the Opening of the American West, by Matthew L. Harris and Jay H. Buckley, 2012

American Emperor: Aaron Burr's Challenge to Jefferson's America, by David O. Stewart, 2011

Articles

"Burr versus Jefferson versus Marshall," by R. Kent Newmyer, *HUMANITIES,* May/June 2013

Internet

Jupiter's Moons and the Longitude Problem
lawrencehallofscience.org/pass/passv07/jupmoons.html

Pike National Historic Trail Association
zebulonpike.org

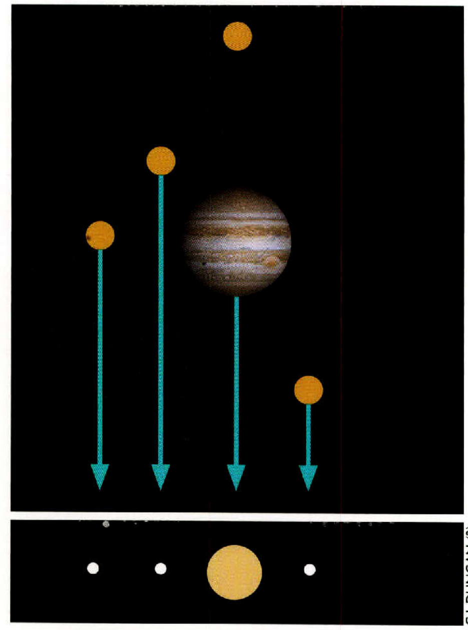
Burr was charged with high crimes against the United States, potentially a hanging offense. Accusers brought a mountain of evidence against Burr. At trial, Burr protested his innocence, and attempted to call Jefferson to the witness stand.

In the end, Burr's scheme was foiled — yet he was found innocent. The Constitution states that to be convicted, a person accused of treason either must admit the crime in court, or two people must testify to witnessing the accused's treasonous act. The lack of witnesses prevented a conviction in this first treason trial in American history. Spared but disgraced, Burr fled to England. His tale of astronomy and greed later inspired a famous work of fiction, *The Man Without a Country*.

A separate military commission exonerated Pike after he was finally released by Spain. Today, he ranks among America's legendary explorers. Yet suspicion has always dogged him.

Forensic astronomy can help solve the riddle of Pike's guilt or innocence. From surviving documents, Pike's capture point can be reconstructed at about 37 degrees north, 105 degrees west — near the modern town of Alamosa, Colorado, and just inside the old Spanish borders (exactly as the cavalrymen told him). Yet from maps Pike likely knew, he believed his position to be about two degrees east of this. That would have placed him just on the American side. At this latitude, the longitudinal discrepancy is about 100 miles. A significant error, but surely understandable, especially for an amateur astronomer making his last sightings under desperate conditions.

General Wilkinson's orders likewise exonerate Pike, and may suggest more about the actual plot. The General's remark, "on your return … to ascertain longitude" revealed a curious detail: He had deprived Pike of vital astronomical tables when the explorer left St Louis, preventing Pike from knowing his precise position in the field. James Wilkinson was likely a Burr collaborator, but Zebulon Pike was not a spy. If his stargazing was planned to aid future treachery, he never knew it.



C.J. DUNCAN (2)

Jupiter's four largest moons change positions as they orbit the planet (top), showing different configurations through a telescope (bottom). By matching the configuration seen via their their telescopes to a known time that configuration appeared at a known longitude like Greenwich, England, explorers could deduce their current longitude.

Ironically, the Spanish lands after which Aaron Burr lusted eventually became part of the United States. The modern U.S.-Mexico border was established in 1898 — by a delegation of astronomers. Pike's seized astronomical notebooks, long believed lost, were finally returned to the United States in 1910.

Pike did mislocate several landmarks we can measure today. Still, his writings offer a pioneering account of following the stars west. Other trailblazers followed, also looking skyward. For them, the moons of Jupiter served as colonial GPS. Pike's most lasting fame resulted from a single climb in November 1806. He had observed an incredibly high point of land through his daytime telescope, writing that it looked like "a small, bluish cloud." Towering 14,115 feet, the lofty summit was later named in his honor. Pike's Peak is the highest point in the western Rockies, and the "purple mountains majesty" proclaimed in the song *America the Beautiful*. Today, a statue of Pike stands in its shadow, with telescope in hand.

Nick D'Alto is a freelance writer in Bellmore, New York.

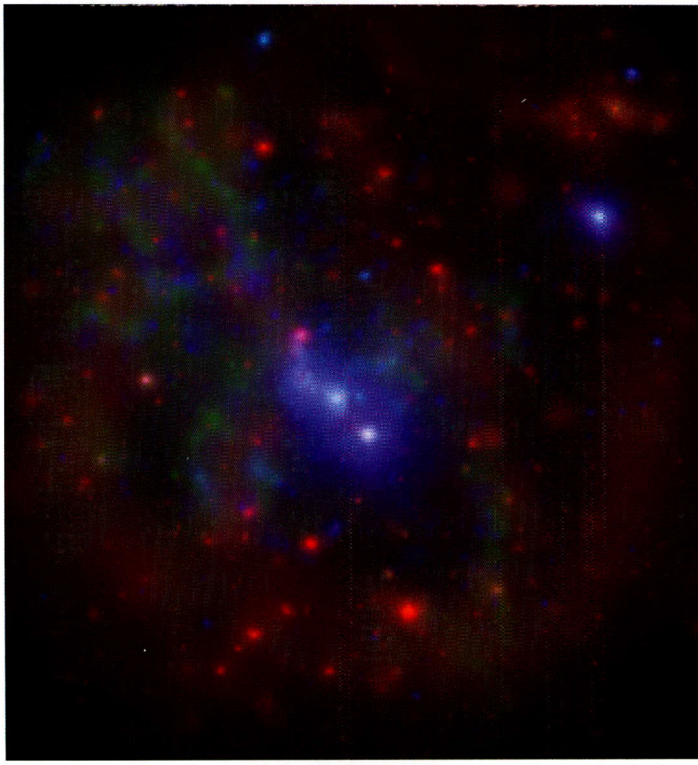
by Rebecca Johnson and Damond Benningfield

Into the Jaws of a Black Hole?

The center of the Milky Way galaxy may be about to set off some fireworks. An object known as G2 is expected to pass close to the supermassive black hole in the galaxy's heart in late March, and astronomers will be watching with several telescopes on the ground and in space to see if the encounter produces a lightshow.

"Even if this isn't super spectacular, we'll learn a lot along the way," said UCLA astronomer Leo Meyer during a January astronomy conference. "Will there be fireworks or not? The definite answer has to be 'maybe.'"

The black hole, known as Sagittarius A* ("A-star"), is more than four million times as massive as the Sun. Its gravity is so powerful that nothing can escape from it, including light. Matter in a swirling disk around the black hole, however, can be heated to millions of degrees, producing X-rays and other forms of energy.



NASA/SWIFT/N.DEGENAAR (UNIV. OF MICHIGAN)

An X-ray view of the center of the Milky Way galaxy from the Swift space telescope. The galaxy's central black hole is in the upper left bright blue blob at the center of the image. The X-rays come from hot gas around the supermassive black hole.

While the black holes in the centers of many other galaxies produce enormous amounts of energy, though, there's not much to see around Sagittarius A*. Space-based X-ray observatories detect an occasional outburst when a bit of gas or rocky debris spirals into the black hole, but otherwise it remains dark.

Astronomers say that could change when G2 passes within about 15 billion miles of Sagittarius A* in March.

G2 was discovered in 2012, and even though astronomers have been tracking it regularly, they are uncertain of its nature. It probably is a giant cloud of gas, although it has not yet been "spaghettified" — ripped apart by the black hole's gravity — as had been expected. That suggests that it could be a ring of gas, or perhaps a disk of gas and dust around a faint star. If the latter, the black hole might disrupt the disk but leave the star unharmed.

Some of G2's material may be pulled into the black hole, causing it to glow brightly before it disappears from view, with the remaining gas heated enough to glow for months or years. On the other hand, G2 might not be as massive as astronomers had anticipated, so "this dietary supplement wouldn't show up," Meyer said. **DB**

Small Galaxies Model 'Massive' Black Holes

Like T-shirts and baseball caps, black holes seem to come in a full range of sizes, from S to XXL. Astronomers recently found evidence for many of the "L" variety in the hearts of dwarf galaxies. They may help explain how other classes of black holes were born.

Astronomers had already discovered many supermassive black holes, which range from a few million to a few billion times the mass of the Sun, in the hearts of large galaxies, such as the Milky Way.

Until a few years ago, however, they had not seen black holes in the centers of dwarf galaxies, which are much smaller than the Milky Way. The sample size grew earlier this year with the revelation of more than 100 additional black holes.

Amy Reines of the National Radio Astronomy Observatory led a team that found evidence of the black holes in observations of galaxies by the Sloan Digital Sky Survey. The black holes are roughly 100,000 times the mass of the Sun, putting them between stellar-mass black holes, which formed from the collapse of individual stars, and supermassive black holes.

These "massive" black holes, as Reines described them, may have formed from the collapse of especially large stars in the early universe, the mergers of smaller black holes, or the collapse of gas clouds. Black holes in this size range then could have formed the "seeds" that gave birth to supermassive black holes in larger galaxies, which could feed more gas and stars into them to make them grow.

Understanding the birth mechanism of the massive black holes could therefore yield new insights into the birth of all black holes more than a few times the mass of the Sun, Reines says, and help astronomers better understand the relationship between a galaxy and its central black hole.

'One-in-a-Billion' System Tests Einstein's Theory of Gravity

A recently discovered triple-star system could help scientists determine whether there's a flaw in Albert Einstein's theory of gravity, known as General Relativity.

The system consists of a neutron star — the ultradense remnant of a massive star — and two white dwarfs, the not-quite-as-dense remnants of stars similar to the Sun. The neutron star rotates 366 times per second, sending out a beam of radio waves with each turn (classifying the star as a pulsar). Astronomers discovered these pulses in 2007 with a radio telescope in West Virginia, and have monitored the pulsar regularly with other radio telescopes. Observations with other types of telescopes helped confirm the companion stars, the masses of all three stars, and the layout of the system.

"It's a one-in-a-billion system," said Scott Ransom of the National Radio Astronomy Observatory, a member of the discovery team, which makes the system a prime laboratory for studying theories of gravity.

Precise timing of the neutron star's pulses reveals details about the interactions among the three stars, all of which have strong gravity. Changes in the timing can tell scientists whether there's a flaw in General Relativity. Although the theory has passed every test to date, it's not compatible with quantum theory, which governs the behavior of matter on the smallest scales. Scientists therefore expect to see a breakdown in relativity under the most extreme conditions, such as those around a neutron star.

A WISE view of a massive stellar nursery, which shines brightly in the infrared. Inset: Artist's concept of a possible Dyson sphere configuration.

NASA/JPL-CALTECH/WISE TEAM; INSET: WIKIMEDIA

Team Looks for Evidence of ET in Stellar, Galactic Warming

A planet may be just the first thing that a technologically advanced civilization warms up. Those that outgrow their planets may harness the power of an entire star or even a galaxy, producing enormous amounts of waste heat. A team of Penn State astronomers is looking for that heat in the observations of a small space telescope that mapped the entire sky.

"Alien civilizations capture starlight to do whatever alien civilizations do," says team leader Jason Wright. "When they're done with it they have to get rid of it, the same way that when your computer's done with its electricity, it's got to have a fan to get rid of all that energy as heat. We are using the WISE satellite ... to look for the traces of that heat coming from stars and galaxies that might have alien civilizations around them."

WISE (Wide-field Infrared Survey Explorer) operated for more than a year, amassing a catalog of more than 500 million distant galaxies, dusty stars, asteroids and comets, and other objects that emit infrared energy.

The WISE observations could reveal alien civilizations by detecting stars that are unexpectedly bright in the infrared. The excess infrared energy could come from Dyson Spheres — star-encircling arrays of giant solar panels that would capture the star's light and convert it to electricity — or other massive structures that emit infrared energy as they are warmed by their parent star.

Most infrared-bright stars are surrounded by dust, which absorbs the starlight and re-radiates it in the infrared, so the astronomers must conduct follow-up observations to more thoroughly understand the source of a star's infrared energy. "As scientists we always reach for nature first," Wright says. "Aliens are the conclusion of last resort. We don't have anything that I'm super excited about yet. But we definitely have candidates." **DB**

Earth Bugs Could Hitchhike to Other Worlds, Study Shows

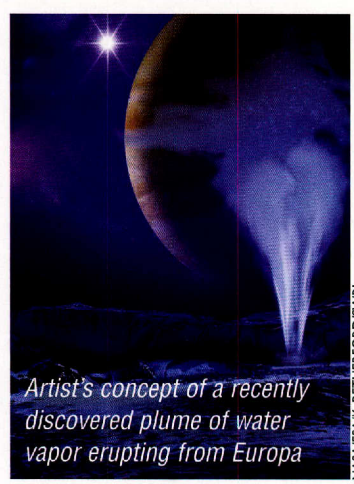
Microscopic life could have caught a lift from Earth to some of the moons of the outer solar system, according to a recent study, perhaps seeding those worlds with life.

"We know that material can be ejected from the surface of a planet by large asteroid impacts," says Penn State graduate student Rachel Worth, the study's lead author, "so we ran simulations to see what would happen to that material — where in the solar system it could end up."

The simulations indicated that perhaps a half-dozen rocks large enough to shield microscopic life against the cold and radiation of deep space could have traveled from Earth to Europa, one of the larger moons of Jupiter. Europa is of particular interest because an ocean of liquid water may lie beneath its icy crust, making the moon a possible abode for life.

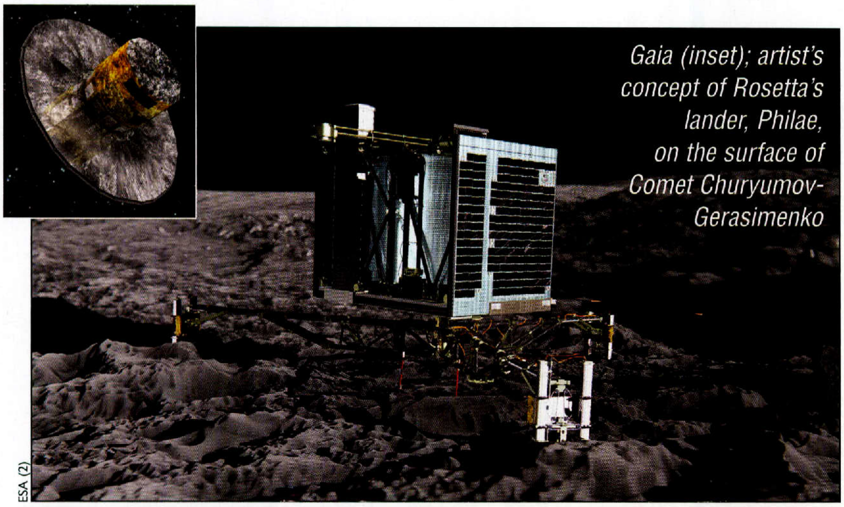
"There's at least the potential for life to have been transferred there," says Worth. "That's interesting because if we find life there with some future mission, we want to determine whether it's from Earth originally, or of independent origin."

The study also found that rocks from Earth could have reached as far as Titan, the largest moon of Saturn, which is surrounded by a dense hydrocarbon-rich atmosphere and that also appears to have an underground ocean of liquid water.



Artist's concept of a recently discovered plume of water vapor erupting from Europa

NASA/ESA/K. RETHERFORD/SWRI



Gaia (inset); artist's concept of Rosetta's lander, Philae, on the surface of Comet Churyumov-Gerasimenko

ESA (2)

Gaia Takes Off, Rosetta Awakens

Two European spacecraft are embarking on ambitious missions — one newly launched, and another waking up after a long cruise and snooze.

Launched December 19 from French Guiana, Gaia now orbits the second Lagrange point (L2), a gravitationally stable point between Earth and the Sun. From there, it will map a billion stars to create the most precise map of the Milky Way to date. Its aim is to help astronomers probe our galaxy's origin and evolution. Mission scientists expect Gaia also will discover thousands of extrasolar planets, brown dwarfs, and supernovae.

Mission controllers awakened Rosetta on January 20 after it spent 31 months in hibernation. Launched in 2004, its 10-year cruise has included three gravity-assist flybys — two of Earth and another of Mars — as well as flybys of asteroids Steins and Lutetia. Rosetta is set to arrive at its final target, Comet Churyumov-Gerasimenko, in August. The craft's 11 science instruments will be checked and reactivated through April. Rosetta will create a global map of the comet, and launch a probe that will attempt the first soft landing on a comet's surface. **RJ**

Taft Armandroff to Direct McDonald Observatory

Taft Armandroff will take the reins of McDonald Observatory on June 1. Currently the director of the W.M. Keck Observatory in Hawaii, Armadroff will succeed David L. Lambert at the helm of McDonald.

McDONALD OBSERVATORY

Taft Armandroff

"I'm tremendously excited to be joining the Texas astronomy program, and to develop the McDonald Observatory further with new instrumentation and research programs, and to continue the observatory's stellar efforts to communicate astronomy discoveries to the public," Armandroff says.

Armandroff's research specialties include dwarf galaxies, stellar evolution, and globular star clusters. Prior to directing Keck Observatory, he worked for the National Optical Astronomy Observatory in Tucson for almost two decades. While there, he spent five years as director of the Gemini Science Center.

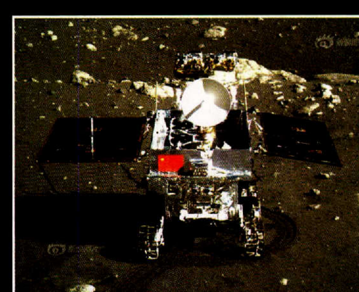
Lunar Rabbit Loses Its Bounce

The first robotic lunar rover in almost four decades apparently lost some of its bounce as it prepared to shut down for its second night on the Moon in late January, just one-third of the way through its planned three-month mission.

The Chinese Chang'e-3 mission landed in Mare Imbrium, a volcanic plain in the Moon's northern hemisphere, on December 14, and quickly deployed the 310-pound Yutu rover (shown at left center of the main image, and in close-up in the inset). (In Chinese lore, Yutu was a pet rabbit for the moon goddess, Change'e.) The rover carried cameras, a ground-penetrating radar to map subsurface layers, and other instruments to measure the chemical and mineral composition of the lunar rocks and soil.

As Yutu prepared to enter hibernation during the frigid lunar night, which lasts 14 Earth days, mission controllers reported a "mechanical control anomaly." The rover was designed to stow its cameras and fold its solar panels over its body to allow nuclear-powered heaters to keep the instruments and electronics warm, but a problem appeared to have interrupted that sequence.

Yutu is the first lunar rover since the Soviet Union's Lunokhod 2 in 1973, and Chang'e-3 was the first successful lander since the Soviet Luna 24 sample-return mission in 1976.



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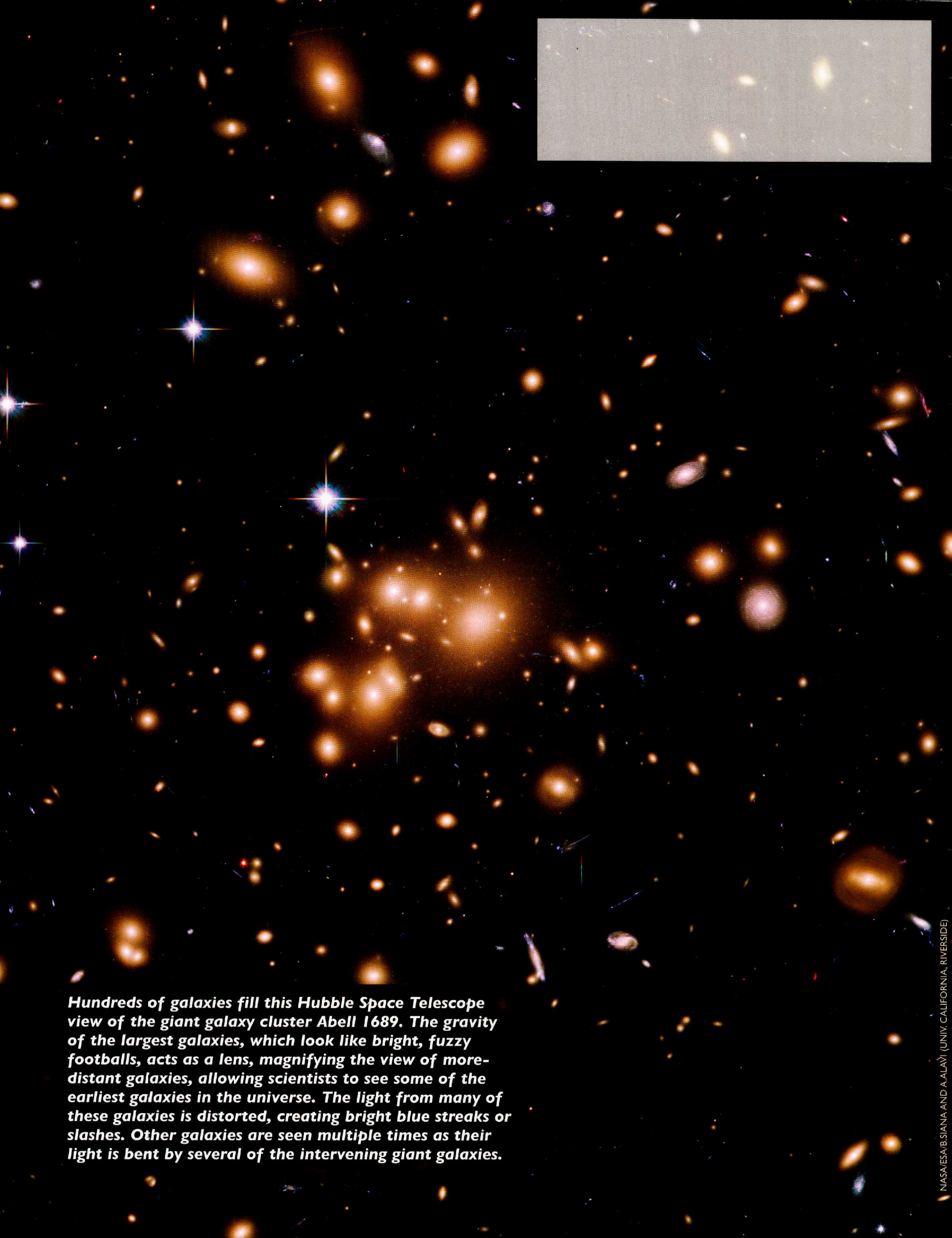

Hundreds of galaxies fill this Hubble Space Telescope view of the giant galaxy cluster Abell 1689. The gravity of the largest galaxies, which look like bright, fuzzy footballs, acts as a lens, magnifying the view of more-distant galaxies, allowing scientists to see some of the earliest galaxies in the universe. The light from many of these galaxies is distorted, creating bright blue streaks or slashes. Other galaxies are seen multiple times as their light is bent by several of the intervening giant galaxies.

NASA/ESA/B. SIANA AND A. ALAVI (UNIV. CALIFORNIA, RIVERSIDE)