BONUS! Guide to the Night Sky 2018

DO **EXOPLANETS** HAVE MOONS? p. 30

LISTEN TO THE **MUSIC** OF THE HEAVENS p. 46

JANUARY 2018

Astronomy®

The world's best-selling astronomy magazine

SPECIAL ISSUE

TOP 10 SPACE STORIES OF THE YEAR

THE LATEST NEWS ON

- Neutron star merger detected
- Seven Earth-sized planets orbiting nearby star
- Mysteries of fast radio bursts
- Cassini's last glory at Saturn

AND MORE p. 20

Two neutron stars merge in a kilonova, throwing out gravitational waves, gamma rays, and other forms of light.

www.Astronomy.com

BONUS ONLINE CONTENT CODE p. 4

Vol. 46 • Issue 1

Discover deep-sky objects in Auriga p. 52

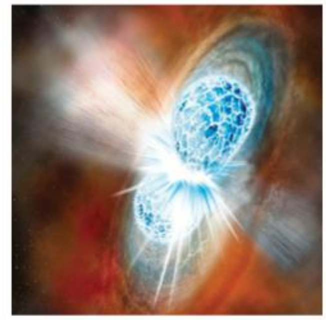
Starmus IV rocks in Norway p. 56

Have questions? We are here to help! Use "Live Chat" today on our website.
ORION®
EVERYTHING FOR THE AMATEUR ASTRONOMER
SINCE 42nd year 1975
FREE SHIPPING on orders of $250 or more
INSTALLMENT BILLING on orders of $350 or more
NO SALES TAX* on most orders
NEW EYE OPENING PRODUCTS FROM ORION
NEW PRODUCT 2017
Orion® SkyQuest™ XT10 PLUS Dobsonian Reflector Telescope #8987 $749.99
Orion® GiantView™ BT-100 Binocular Telescope #51849 $1,599.99
Orion® LHD 80° Lanthanum Ultra-Wide 1.25"/2" Eyepieces $269.99 ea
Orion® ED66 CF Carbon Fiber Refractor Telescope #40905 $749.99
Orion® StarShoot™G4 Color /Monochrome Deep Space Imaging Cameras
Color #53088 $499.99
Monochrome #53087 $499.99
Orion® BX90 EQ 90mm Equatorial Refractor #52588 $229.99
Orion® VersaGo™ E-Series Altazimuth Mount #52587 $99.99
Orion® 70mm White-Light Solar Refractor Telescope #10381 $129.99
Orion® Tritech™ CFX Carbon Fiber Tripod with 3-Way Pan Head #40811 $299.99
Orion® Exploring the Cosmos: An Introduction to the Night Sky #51441 $12.99
Orion® 8x40 Wide-Angle Camo Binoculars #51850 $89.99
Orion® 8-24x25 Compact Zoom Binoculars #51851 $119.99
Orion® Otter™ ED 10x42 Waterproof Binoculars #51847 $269.99
Orion® Otter™ ED 8x42 Waterproof Binoculars #51848 $249.99
Phone not included
Orion® SteadyPix™ Quick Smartphone Photo Adapter #40003 $22.99
Retail prices shown are current as of 10/20/17 from Orion, excluding sale items. Prices are subject to change without notice. Please check OrionTelescopes.com for the most current pricing. Dealer pricing and/or promotions may vary.
OrionTelescopes.com
Orion Telescopes & Binoculars now accepts the following payment options:
Orders: (800) 447-1001
Customer Service: (800) 676-1343
*We only collect sales tax in CA & PA. See website for details.

Online Content Code: ASY1801
Enter this code at: **www.astronomy.com/code**
to gain access to web-exclusive content

CONTENTS

JANUARY 2018
VOL. 46, NO. 1



ON THE COVER

Astronomers recently observed gravitational waves from the long-ago crash of two neutron stars.

ROBIN DIENEL COURTESY OF THE CARNEGIE INSTITUTION FOR SCIENCE

FEATURES

COLUMNS

QUANTUM GRAVITY

IN EVERY ISSUE

ONLINE FAVORITES >>

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

My Science Shop
Perfect gifts for your favorite science geeks.

Picture of the Day
Gorgeous photos from our readers.

Ask Astro Archive
Answers to all your cosmic questions.

News
The latest updates from the science and the hobby.

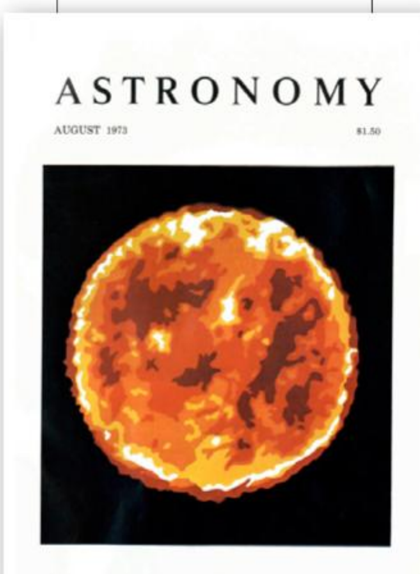
Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, P.O. Box 62320, Tampa, Fla. 33662-2320. Canada Publication Mail Agreement #40010760.

FROM THE **EDITOR**
BY DAVID J. EICHER

45 years of *Astronomy*

This year, our magazine marks an anniversary — 45 years of publication, and still going strong. In August 1973, the title's founder, Steve Walther, produced the first issue, which offered 48 pages and five feature articles, plus information about what to see in the night sky that month. As the '70s transformed into the '80s, and the Voyager spacecraft began exploring Jupiter and Saturn, *Astronomy* became the world's largest publication on the subject, a status it has not relinquished.

Walther died in 1977, but the company he started — AstroMedia Corp. — brought in Richard Berry to become editor and Bob Maas to take the publisher's helm. Together, Berry and Maas forged *Astronomy* into a solid, respectable, and exhilarating package showcasing the best astronomy had to offer throughout the late 1970s and early 1980s. Berry and his co-workers lorded over one of the most exciting periods in the history of modern astronomy, covering the Voyager missions to the planets in spectacular detail. They guided the magazine through the period in which it became the largest-circulation astronomy publication in the world — larger than the long-established, conservative *Sky & Telescope*; larger than the Japanese leader, *Tenmon Gaido*.



August 1973: The first issue

When Berry hired me in 1982, I brought my magazine, *Deep Sky*, now relaunched as a quarterly, and joined the *Astronomy* staff as the most junior of its members. In the mid-1980s, Kalmbach Publishing Co., famous for *Model Railroader* and *Trains* magazines, purchased AstroMedia. We left our building for another part of town, ramping up for the appearance of Halley's Comet and living through the *Challenger* disaster.

Ever since those early days, the magazine has continued furiously, and it now boasts a print circulation of 100,000, three-quarters of a million visitors to our website each month, and a social media following of 1.4 million. Together, this comprises the largest community of astronomy enthusiasts on the planet.

We plan to celebrate this community with you in this anniversary year. Stay tuned for some surprises.

I think Steve Walther would be proud of what the magazine has become. I know that I am.

Yours truly,

David J. Eicher
Editor

Follow the Dave's Universe blog:
www.Astronomy.com/davesuniverse
Follow Dave Eicher on Twitter: **@deicherstar**

Astronomy

Editor David J. Eicher
Art Director LuAnn Williams Belter

EDITORIAL
Managing Editor Kathi Kube
Senior Editors Michael E. Bakich, Richard Talcott
Associate Editors Alison Klesman, Jake Parks
Copy Editors Dave Lee, Elisa R. Neckar
Editorial Assistant Nicole Kiefert

ART
Graphic Designer Kelly Katlaps
Illustrator Roen Kelly
Production Specialist Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Glenn F. Chaple, Jr., Martin George, Tony Hallas, Phil Harrington, Korey Haynes, Jeff Hester, Liz Kruesi, Ray Jayawardhana, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, Sheldon Reynolds, Erika Rix, Raymond Shubinski

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Kalmbach Publishing Co.
CEO Dan Hickey
Senior Vice President, Sales & Marketing Daniel R. Lance
Vice President, Content Stephen C. George
Vice President, Consumer Marketing Nicole McGuire
Art and Production Manager Michael Soliday
Corporate Advertising Director Ann E. Smith
Circulation Director Liz Runyon
New Business Manager Cathy Daniels
Retention Manager Kathy Steele
Single Copy Specialist Kim Redmond

ADVERTISING DEPARTMENT
Phone (888) 558-1544
Advertising Sales Manager Steve Meni
Advertising Sales Representative
Dina Johnston, djohnston@kalmbach.com
Ad Services Representative
Christa Burbank, ads@astronomy.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Phone (800) 558-1544
Outside U.S. and Canada (262) 796-8776, ext. 818
Fax (262) 798-6592
Email tss@kalmbach.com
Website www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
Phone (877) 246-4835
Outside U.S. and Canada (813) 910-3616
Customer Service Astronomy@customersvc.com
Digital Astronomy.Digital@customersvc.com
Back Issues Astronomy.SingleCopy@customersvc.com

CONTACT US
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com
Editorial Phone (262) 796-8776

QG QUANTUM GRAVITY

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES>>

TRENDING TO THE TOP

LIKE CLOCKWORK
An all-mechanical Venus rover could operate without succumbing to instrument degradation as quickly as previous landers.

RESTING PLACE
Lunar probe SMART-1's 2006 crash site was recently discovered in data from the Lunar Reconnaissance Orbiter.

NONE MORE BLACK
The exoplanet WASP-12b's atmosphere traps so much light that the planet is blisteringly hot and appears pitch black.

TERRY HANCOCK; TOP FROM LEFT: NASA/JPL-CALTECH; P STOOKE/B FOING ET AL. 2017/NASA/GSFC/ARIZONA STATE UNIVERSITY; NASA, ESA, AND G. BACON (STScI)

The immense sea of nebulosity surrounding the southern portion of Orion appears when the gas lies close to hot stars that excite it to glow. Some dark nebulae, dust grains that block light from behind, are also visible.

SNAPSHOT

The beauty of nebulous space

The Orion Nebula and its neighbors reveal much about what we see — and don't see — in the cosmos.

Go under a really dark sky, and you can see a vast array of glowing clouds of gas littering the Milky Way Galaxy. Some are visible with the naked eye, others in binoculars, and most require a telescope and a moonless night for visibility. The most famous nebula of all, the Orion Nebula, stands as a case study in what the cosmos shows us.

Nebulae can be nebulous to understand. Glowing clouds of gas that are collapsing into newborn stars, the death shrouds of aged suns, or simply the detritus in the ongoing cosmic recycling program, these clouds of gas play a major role in how galaxies work. They are difficult to gauge; their distances are hard to determine, unless bright stars happen to be lodged conveniently within them. Astronomers know the Orion Nebula is about 1,500 light-years away, but that's an estimate. The whole region of the constellation Orion is swamped in what's known as the Orion Molecular Cloud, a vast bubble stretching several hundred light-years across.

We see the brightest parts of this complex, including the Orion Nebula and the nebulosity surrounding and backlighting the famous dark nebula called the Horsehead, because bright stars energize those parts of the cloud. But large amounts of gas, as well as the dust that makes up dark nebulae, mostly go unnoticed.

This area serves to remind us that what we see in the sky is but the tip of an iceberg. So much more lies in the quiet darkness that we cannot yet tease out of space. — **David J. Eicher**

STRANGE**UNIVERSE**

BY BOB BERMAN

Earth's gravity: A downer?

Gravity's pull influences life — and the potential for death — on the planet.

Every seashore demonstrates the influence of celestial bodies.

It's vivid but old news: Ancient cultures knew that tides are mainly controlled by the Moon, not the Sun. Yet nowadays, many are mystified by this supposed disparity.

Ask your smartest friends, "The Sun's gravity is much greater than the Moon's — we even orbit it, right? Yet the Moon controls the tides, so it boasts a greater *tidal* influence on us. This means tidal and gravitational pulls are different animals. But how?"

You'll find no one who can tell you. Maybe you yourself know, since you're into astronomy. Yes, the Sun pulls on Earth about 175 times more forcefully than the Moon. But its effect on the oceans isn't even half that of the Moon. That's because gravity alone won't make water move. What does the job is the difference in the gravitational pull on various parts of the ocean.

The Moon's extreme nearness is the key. Since gravity's grip falls quickly with distance, a little change in nearness yields a big shift in power. The Moon hovering 3.4 percent closer to one side of Earth yields a 7 percent inequality in its gravitational influence across the globe. This difference doesn't produce the tidal effect; it *is* the tidal effect.

So a tidal effect is a gravity *difference*. There's a 7 percent disparity in lunar strength acting on Earth's hemispheres. But the Sun's great distance yields only a 0.018 percent variation in its pull on opposite hemispheres. That's less than one-twentieth of a percent. Result: comparatively wimpy solar tides.

Even more fun is dealing with Earth's own gravity. Especially in ways often misunderstood, like escape velocity: It's 7 miles per second. That's the speed you'd need, after being shot from a cannon, to keep going and never be pulled back, ignoring air resistance. Many imagine that if a rocket failed to achieve that speed, it could never escape the planet.

In the '90s, I had that debate with the astrophysics chair at Columbia University. That otherwise brilliant man insisted that if a rocket headed upward at only, say, 2 miles per second, its path would invariably curve back down. "That's not true," I told him, in what was surely the only instance of me being right and him being wrong about anything. "You could keep heading upward at even 2 *miles an hour*, and as long as the engines kept firing, you could go clear across the universe."

A little change in nearness yields a big shift in power.

He disagreed because he'd apparently forgotten that escape velocity simply doesn't apply if you're supplying further energy to the job. The concept that a speed greater than the escape velocity is needed is only valid in a one-shot deal, after which your rocket then coasts on its own.

Boats sit directly on the exposed ocean floor during low tide in Gorey Harbour, Jersey. Water levels around Jersey, an island between England and France, can differ by more than 40 feet (12 m) between low and high tide. FOXYORANGE ON WIKIPEDIA

What's cool is that escape velocity equals the impact speed if you fell to the ground from a great distance. If you toss an orange up, it comes back to strike your palm at exactly the same speed you happened to hurl it upward. Up equals down.

Schools teach that falling bodies accelerate by 32 feet (9.8 meters) per second squared. But most people grasp that more easily if we instead say a rock tossed off a cliff falls 22 miles (35.4 kilometers) an hour faster after each passing second. If it falls for two seconds, it hits the ground at 44 mph. Three seconds, and it's 66 mph. Simple.

Air resistance stops the speed gain at some point, which is why rain falls at just 22 mph. And why squirrels have no lethal terminal velocity. It's why an arms-and-legs-out base jumper leaping from any height above 49 stories remains falling at 120 mph. It explains why meteoroids screaming into our atmosphere at 72,000 mph (115,873 km/h) hit rooftops at just 250 to 300 mph (402 to 483 km/h), and penetrate no farther than one or two floors.

Ignoring air resistance, you can find your final falling speed by multiplying your height in feet times 64.4 and then hitting the square root button. The result is in feet per second, which very nearly equals kilometers per hour. For miles per hour, multiply again by 0.68. This equation reveals that jumping from 1 foot (times 64 is still 64, whose square root is 8) makes you strike the ground at 8 km/h or 8 fps. That's 5 mph. From 5 feet up, you'd land at 12 mph. These are typical impact speeds after slipping on ice.

From 10 feet, a single house story, you hit at 17 mph. From two stories it's 24.4 mph, and now you'd better land on something very soft to avoid serious injury. Fatal impacts become more likely than not at around 35 mph, which corresponds to four stories. An old insurance table says the chance of death increases by 1 percent for each additional foot you fall.

Enlightening, perhaps, but we're now getting morbid. Let's stop.

Contact me about my strange universe by visiting **http://skymanbob.com.**

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

ASTRO**LETTERS**

TOM OLSON

Beautiful cloudshine

I read Stephen James O'Meara's article about cloudshine in *Astronomy*'s July 2017 issue. I witnessed the phenomenon one evening leaving the gliderport at Harris Hill near Elmira, New York. I snapped this photo, but it pales in comparison to reality. A rainbow was forming in the glare of the reflection, and the under-cloud landscape stretched into the horizon. I thought I'd send this image and let you know how much I appreciate the observation of planetary science all around us. I've been learning soaring the past three summers at the gliderport. It's been said that weather and wind patterns are fingerprints of Earth's primordial atmosphere after the planet's formation. Learning to sail on these wind currents is fascinating and thrilling, and a direct connection to the forces of the universe.
— Tom Olson, Ithaca, NY

Ready for the next eclipse

I was fortunate enough to witness my first total solar eclipse August 21, and I have to say that it was better than I dreamed it could be! The sight of that pitch-black hole in the sky where the Sun should be, the amazing and indescribable colors around the edges of the eclipsed Sun (something like a hot, reddish, fluorescent pink with orange tints), the diamond rings before and after totality, the view of solar prominences, and the brightly glowing extended corona went together to produce a jaw-dropping, heart-stopping, otherworldly naked-eye view! This incredible view was so colorful, brilliant, and crisp, it looked unreal. It was as if Hollywood had taken an actual total solar eclipse image, enhanced it beyond all reason, and projected it on an overhead screen. Each time I think about it, talk about it, read about it, or watch a TV program about it, my heart starts racing, my hands start shaking, and I get a lump in my throat. I guess it's time to start planning for 2024! **— Larry Russell,** Germantown Hills, IL

The magnificent eclipse

I traveled to Hopkinsville, Kentucky, to view the total solar eclipse August 21. It was magnificent, beautiful, awe-inspiring, and eerie. I almost felt like I was on an extrasolar planet viewing something that was normal there. Being alive at this time to view this rare and spectacular event was special and very memorable. I feel fortunate that I was able to witness it!
— Tom Bryant, Danville, KY

The amazing Moon House

Kudos to Mark Boslough for his Moon House piece, a brilliant exposition of celestial phenomena through the eyes of an ancient Anasazi culture with the time, energy, and incentive to watch the sky very closely, very closely indeed.
— Kenneth Roberts, Tucson, AZ

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

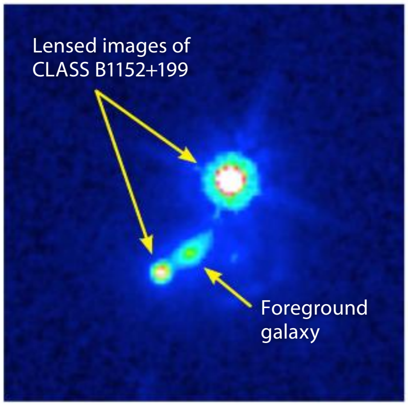
CHIMING IN. The new Canadian Hydrogen Intensity Mapping Experiment (CHIME) will probe nearly the entire observable universe in 3-D while studying dark energy and gravitational waves.

YOUNG GALAXIES MAY HAVE OLD MAGNETIC FIELDS

From prompting star formation to driving accretion around supermassive black holes, magnetic fields influence nearly every astrophysical process. However, one of the biggest hurdles in studying the magnetic fields that pervade galaxies is their lack of strength. Millions of times weaker than Earth's magnetic field, galactic magnetic fields are difficult to measure at great distances.

But in an August 28 paper in *Nature Astronomy*, a team of researchers reported the best measurements yet of a magnetic field in a galaxy located a record-breaking 4.6 billion light-years away. The team, led by Sui Ann Mao of the Max Planck Institute for Radio Astronomy, detected a magnetic field similar to the Milky Way's in a host nearly 5 billion years younger, providing new insight into how these fields have evolved in the universe over cosmic timescales.

The scientists investigated the galaxy using a phenomenon called gravitational lensing, which occurs when a massive object — the galaxy in this study — lines up between Earth and a distant object — in this case, a quasar (CLASS B1152+199). As divergent light rays from the quasar pass by the intervening galaxy, the galaxy's gravity bends their path.

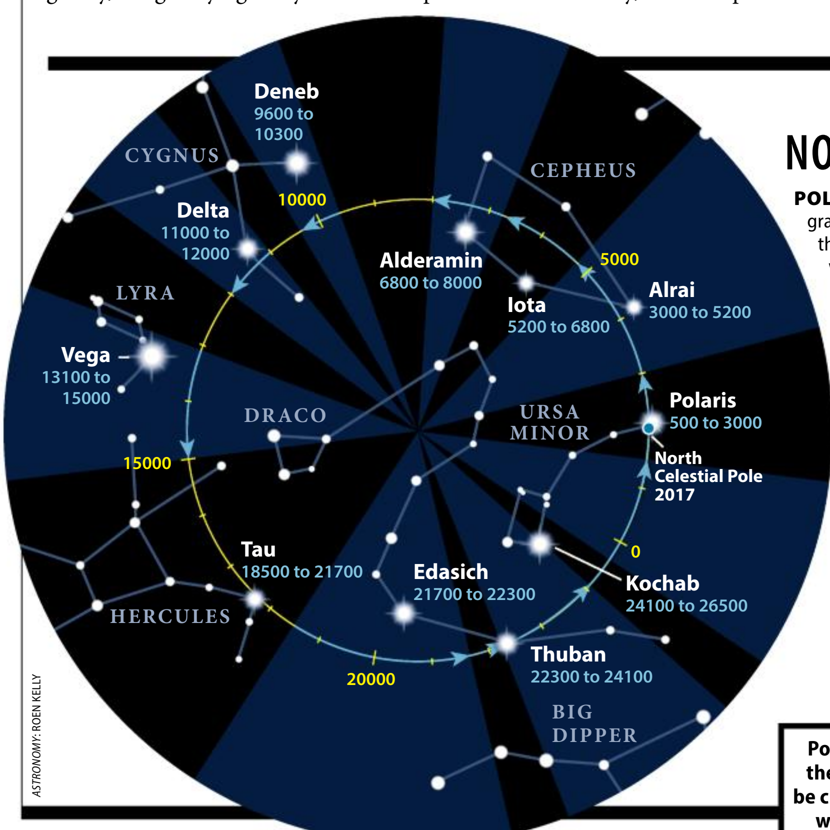


MAGNETIC FINGERPRINTS. The Hubble Space Telescope captured two gravitationally lensed images of a distant quasar behind a young foreground galaxy. The two images are light that has traveled through opposite ends of the galaxy, picking up information about its magnetic field along the way. MAO ET AL., NASA

The light passing through the galaxy's edges is further affected by any local magnetic fields, which can change the light's polarization, or the direction of its vibration. This effect is called Faraday rotation, and the stronger the magnetic field, the more the light's polarization is rotated.

By measuring this rotation in the light received from the background quasar, the researchers determined the young galaxy's magnetic field is similar in size and strength to those found in the Milky Way and other nearby, older galaxies.

One of the leading theories on the evolution of galactic magnetic fields is that they begin scrawny and tangled, then strengthen and organize over time. But that doesn't seem to be the case here. "By catching magnetic fields when they're so young, we can rule out some of the theories of where they come from," Ellen Zweibel, a co-author on the study, said in a press release. — **Jake Parks**



ASTRONOMY: ROEN KELLY

FUTURE NORTH STARS

POLAR EXPRESS. Because of gravitational influences from the Sun and Moon, our planet wobbles like a top with a period of 25,772 years. That means the point above the North Pole (the North Celestial Pole, or NCP) traces a circle in that span. Currently, the closest bright star to the NCP is Polaris, the brightest star in the constellation Ursa Minor the Bear Cub. But 10 other relatively bright stars will lie closer to the NCP before Polaris once again assumes the mantle of North Star.
— **Michael E. Bakich**

FAST FACT

Polaris, currently 0.77° from the North Celestial Pole, will be closest to that point in 2102, when it will lie 0.46° away.

BRIEFCASE

NEIGHBORHOOD WATCH

Coryn Bailer-Jones of the Max Planck Institute for Astronomy has published the first systematic estimate of how often other stars wander into our solar neighborhood. Using data from the European Space Agency satellite Gaia, Bailer-Jones found that every million years, between 490 and 600 stars typically pass within 5 parsecs (16.3 light-years) of the Sun. Astronomers are interested in these close stellar encounters because they can nudge comets out of the Oort Cloud and into the inner solar system, potentially wreaking havoc on unsuspecting planets like Earth.

•

TURBULENCE AHEAD

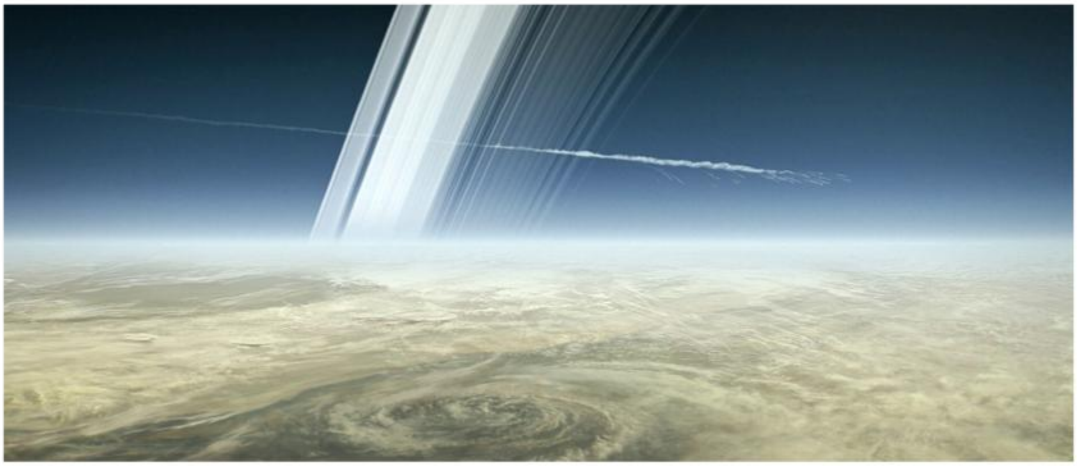
Researchers once thought Jupiter's aurorae were created the same way as Earth's, where energetic particles are accelerated by differences in strength between atmospheric magnetic fields, called electric potentials. But the strongest aurorae on Jupiter are not always associated with the biggest electric potentials, as on Earth. Instead, it appears a different cause is responsible for the most powerful displays. "At Jupiter, the brightest aurorae are caused by some kind of turbulent acceleration process that we do not understand very well," Johns Hopkins University Applied Physics Laboratory researcher Barry Mauk said in a press release. At high energies, he said, "a new acceleration process takes over," which Juno scientists are now working to understand.

•

MIDDLE GROUND

In a paper published September 4 in *Nature Astronomy*, a team of astronomers led by Tomoharu Oka of Keio University in Yokohama, Japan, shows evidence that a gas cloud called CO-0.40-0.22 near our galaxy's center may harbor an intermediate-mass black hole. Gas particles inside CO-0.40-0.22 have motions consistent with an object 100,000 times the Sun's mass. Radio emission measured from the cloud also bears striking similarities to the radio source associated with our galaxy's 4 million-solar-mass supermassive black hole, Sagittarius A*, though 500 times fainter, suggesting a black hole a few hundred times smaller. — **J.P., John Wenz, Alison Klesman**

ASTRO**NEWS** **NOT SO WINDY.** New ALMA observations of young galaxies indicate that the winds generated by new stars aren't strong enough to blow away material and stop star formation.



THE ULTIMATE BREAKUP. Cassini disappeared into Saturn on September 15, ending its 13-year-long mission at the ringed planet. Before breaking up, the spacecraft beamed back valuable data from within the planet's atmosphere. NASA/JPL-CALTECH

Cassini probe sends its last regards

After an amazing 20 years in space — 13 of those years at Saturn — NASA's venerable Cassini spacecraft met its fiery death in the upper atmosphere of the ringed planet September 15.

The craft was launched October 15, 1997. Gravity assists from Venus, Earth, and Jupiter sent it on to Saturn, where it arrived in June 2004. From there, the craft wrote the book on our understanding of the Saturn system. It provided incredible views of Saturn's largest moon, Titan, showing ever-shifting seas of hydrocarbons and revealing a subsurface ocean much like Europa's.

Cassini also followed up on tentative evidence from the Voyager probes of watery activity on the small moon Enceladus, ultimately discovering geysers shooting water hundreds of miles into space. Their source is a global subsurface ocean, elevating the moon to one of the more likely places in the solar system to find alien life. The spacecraft also discovered circumstantial evidence of oceans and cryovolcanism on Dione, as well as inexplicable red streaks on Tethys that might be due to outgassing, fracturing, or perhaps some other process entirely.

In its final months, Cassini skimmed Saturn's rings and traversed the space between the rings and the planet itself. Using a last gravity assist from Titan, NASA set Cassini on a destruction course to disintegrate within minutes in Saturn's atmosphere. The decision was made out of concern that extreme bacterial life from Earth could survive deep inside the craft and contaminate one of the system's habitable moons if an accident were ever to occur.

The spacecraft's signal went out at 4:55:46 A.M. PDT, to a standing ovation. Shortly after, Cassini program manager Earl Maize told his team, "I hope you're all deeply proud of this amazing accomplishment."

Linda Spilker, a Cassini project scientist who has been with the mission since it was first planned in 1982, said, "It felt so much like losing a friend, a spacecraft I got to know so well."

NASA is now reviewing proposals for future missions that could return us to Titan, Enceladus, or Saturn. In the meantime, there are several hundred gigabytes of data for present and future generations to sort through to make amazing discoveries about the Saturn system.

Thanks for everything, Cassini.
— J.W.

Revealing Pluto's first officially named features

NASA/JHUAPL/SwRI/ROSS BEYER

MAPMAKING. New Horizons gave us our first and only up-close look at the Pluto system in 2015. In September, the International Astronomical Union (IAU) announced the first 14 officially named features on the dwarf planet. The names highlight individuals whose work has contributed to our understanding of Pluto, including Clyde Tombaugh and James Elliot. Some names also pay homage to famous explorers and space missions, such as Sir Edmund Hillary and Sputnik 1. Additional regions bear the names of figures or places associated with the underworld in Norse, Australian, Inuit, and Greek mythology. The IAU will continue to consider proposals to name more features on Pluto and its five moons. — **A.K.**

QUICK TAKES

TAKING AIM
NASA plans to use the James Webb Space Telescope to study plume activity on the icy solar system worlds Europa and Enceladus.

MOON PILEUP
Uranus' satellites Desdemona and Cressida are on a future collision course as Cressida destabilizes its sister moon's orbit.

REFLECTION PERFECTION
Gradually applying atom-thin coatings could improve silver-based telescope mirrors by preventing corrosion.

LARGE SURVEY
The Karl Jansky Very Large Array in New Mexico is undertaking its biggest-ever observing campaign, searching the sky for high-energy events over the next 7 years.

FAST AND FURIOUS
Astronomers estimate that one or more mysterious fast radio bursts may pop off every second somewhere in the universe.

SLEEPING BEAUTY
NASA's New Horizons awoke from a five-month slumber September 12, en route to MU_{69} — a primordial Kuiper Belt object.

SPIN DOCTORS
Researchers seeking to understand galaxy shapes now believe a galaxy's rotation speed plays a big role in its appearance.

SEVEN SISTERS
The Pleiades' seven recognizable stars are all variable, according to evidence from the Kepler telescope.

ALIEN AGENTS
Comets and asteroids of interstellar origin may have brought the building blocks of DNA to Earth. **— J.W.**

42
The number of spacecraft that ended their missions on another planet, excluding moons.

ASTRONEWS

GAINING WEIGHT. Astronomers bumped white dwarf 40 Eridani B's mass from 0.42 to 0.57 solar mass after carefully watching it interact with its red dwarf binary companion.

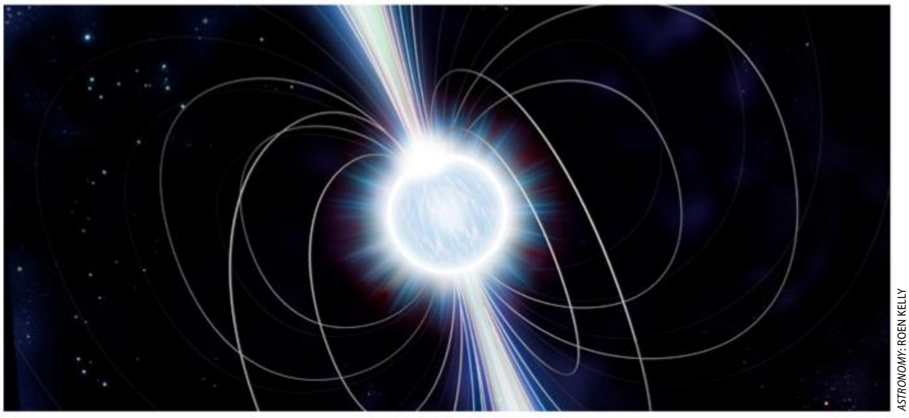
The fastest pulsar in the Milky Way discovered

Even the fastest heavy metal drummers have nothing on the pulsar PSR J0952–0607.

One of two rapidly rotating pulsars recently discovered with the Low-Frequency Array (LOFAR) telescope, PSR J0952-0607 emits more than 700 "beats" (or radio pulses) per second. That makes it the fastest pulsar in the Milky Way and the second-fastest pulsar ever discovered, after PSR J1748–2446ad in the Terzan 5 globular cluster. (See page 17 for more on Terzan 5.) And the other newly discovered pulsar, PSR J1552+5437, is no slouch itself. It rotates 412 times per second.

Pulsars are a subclass of neutron stars, which are objects left behind when a star goes supernova but isn't massive enough to form a black hole. They emit radiation from their poles as they spin, making them a sort of metronome for the universe. These pulsars were discovered using a new technique on the LOFAR telescope, which looks in lower-frequency light than traditional pulsar searches.

Although it's difficult to search for pulsars at low frequencies because their light is disrupted by intervening gas and dust, LOFAR has instruments to filter out noise from any matter between the telescope and the observing target. PSR J0952–0607 and PSR J1552+5437 are both bright at low frequencies but dim at higher frequencies, where traditional pulsar searches occur — perhaps hinting at a previously unseen population that could tell us more about these extreme objects. — **J.W.**

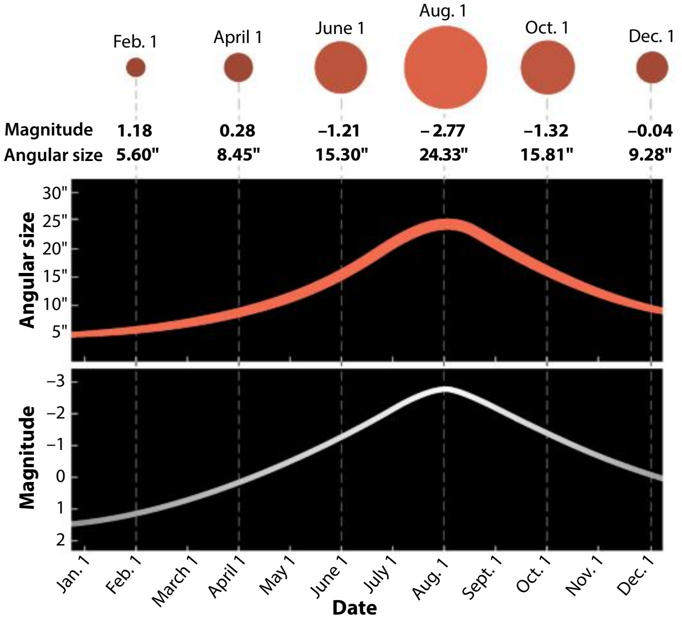


ASTRONOMY: ROEN KELLY

RAPID FIRE. Pulsars such as PSR J0952–0607 are believed to spin so fast because they steal material from a binary companion to boost their spin rates. Such rapidly rotating pulsars beam powerful radio and gamma-ray jets from their poles, destroying those companions over time.

300 The number of asteroids the proposed Asteroid Touring Nanosat Fleet could visit, using 50 tiny spacecraft.

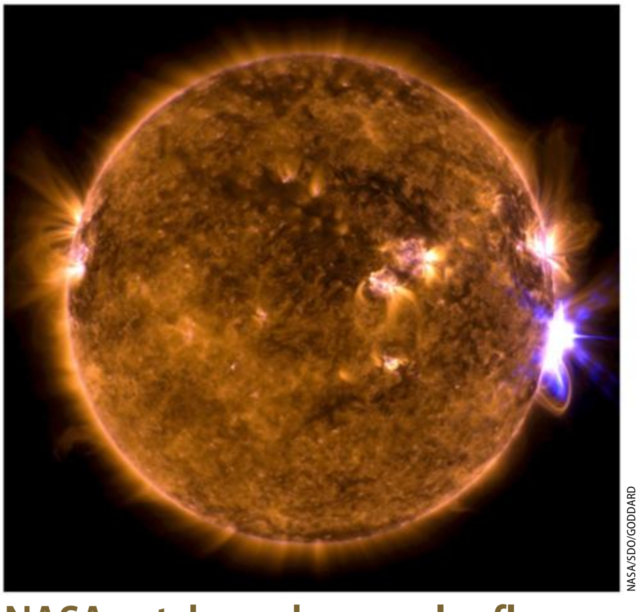
AS GOOD AS IT GETS



ASTRONOMY: ROEN KELLY

FAST FACT At its peak in August 2003, Mars shone at magnitude –2.9 and appeared 25.1" in diameter.

RED PLANET REVIVAL. Mars puts on its best show in 15 years during 2018. At its peak in late July, it will shine at magnitude –2.8 — brighter than any other point of light in the sky besides Venus — and swell to an apparent diameter of 24.3". But Mars will exceed magnitude –1.0 from late May to mid-October and span more than 10" from late April until mid-November. — **Richard Talcott**



NASA/SDO/GODDARD

NASA catches a huge solar flare

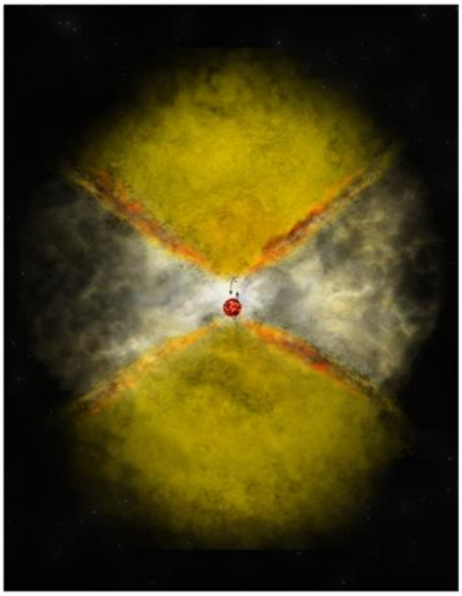
IN A FLASH. In early September, the Sun released its largest solar flare since 2006. NASA's Solar Dynamics Observatory easily spotted it, shown here in the extreme ultraviolet (304 angstroms, or about 30 nanometers). Solar flares typically erupt from or near sunspots — cooler areas on the surface of the Sun that are associated with localized buildups in the star's powerful magnetic field. The magnetic field can become twisted and looped as the Sun rotates, until finally these lines "snap" and trigger a massive eruption of energy in many wavelengths across the spectrum, including X-rays. — **A.K.**


SPECIAL INTEREST
TOURS
MARCH 2018 CHILE
SOUTHERN SKIES TOUR
MARCH 16-21
SAN PEDRO EXTENSION
MARCH 21-24
INCLUDES WILDLIFE, ASTRONOMY AND CULTURAL ACTIVITIES!
THE ORIGINAL CHILE ASTRONOMY AND NATURE TOUR
DON'T MISS OUT,
THE LAST SOUTHERN SKIES TOUR UNTIL 2021!
JOURNEY TO ALASKA
WITH BOB BERMAN
EXPERIENCE THE NORTHERN LIGHTS!
MARCH 11TH-16TH
"FLY TO FAIRBANKS FOR AN AMAZING, ONCE-IN-A-LIFETIME, NORTHERN LIGHTS ADVENTURE."
ENJOY HOT SPRINGS, ASTRONOMY LECTURES, DOG-SLED RIDES AND MORE!
www.specialinteresttours.com
727.330.7738 info@specialinteresttours.com


LUMICON
Own the Lumicon Legend!
Quality Filters
Astrophotography
Visual Accessories
LUMICON COMET USA
www.Lumicon.com
See us at the
26th Annual
NEAF
NORTHEAST ASTRONOMY FORUM™
Suffern, NY • April 8–9


AVAILABLE AT OPT
NEW L-SERIES MOUNTS
• DIRECT-DRIVE
• HIGH-RES ENCODERS
• ALT/AZ OR EQUATORIAL
• SLEWS 50° PER SECOND
PlaneWave INSTRUMENTS
L350
$10,000
100 LB. PAYLOAD
L500
MOUNT ONLY
$18,000
200 LB. PAYLOAD
L600
$29,000
300 LB. PAYLOAD
SEND US YOUR OLD EQUIPMENT FOR CREDIT TOWARDS A NEW L-SERIES MOUNT
EXCLUSIVELY WITH OPT
BUYBACK PROGRAM
WWW.OPTCORP.COM • 800-483-6287

MERCURIAL ICE. A review of MESSENGER data indicates there's enough water ice at Mercury's poles to cover the state of Rhode Island.



Shocks boost nova brightness

Novae occur when a white dwarf, the remnant of a Sun-like star, collects material from a nearby donor star. The resulting runaway nuclear reaction causes a powerful explosion visible from vast distances.

But some novae seem *too* bright. Now, astronomers have shown that such explosions don't defy the laws of physics, but result from amplification making them appear brighter. The findings, published September 4 in *Nature Astronomy*, prove a theory developed by Brian Metzger, an astronomer at Columbia University and co-author on the paper.

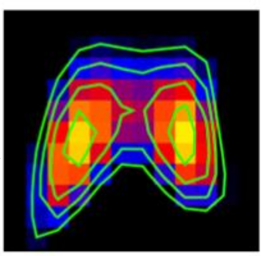
"Astronomers have long thought the energy from novae was dominated by the white dwarf, controlling how much light and energy are emitted," co-author Laura Chomiuk of Michigan State University explained in a press release. "What we discovered, however, was a completely different source of energy — shock waves that can dominate the entire explosion."

"This event shows that shocks are the main event," added Metzger.

White dwarfs in binary systems can pull material from companion stars, and it slowly builds on the stellar remnant's surface. Once a tipping point is reached, a nuclear reaction begins. A wave of material is ejected from the white dwarf, with another wave right after it. The second wave, hotter and faster than the first, collides with the cooler, slower-moving material to produce heat and light that boost the appearance of the nova. "The bigger the shock, the brighter the nova," said Chomiuk. "We believe it's the speed of the second wave that influences the explosion." — **A.K.**

SHOCKING DEVELOPMENT. Material ejected during a nova, colored yellow in this artist's concept, gives off gamma rays as shock waves travel through it. Observing optical light and gamma rays from a recent nova helped astronomers to determine the role shocks play in a nova's brightness. BILL SAXTON, NRAO/AUI/NSF

Supermassive black holes can form tight pairs



TIFR-NCRA AND RIT, USA

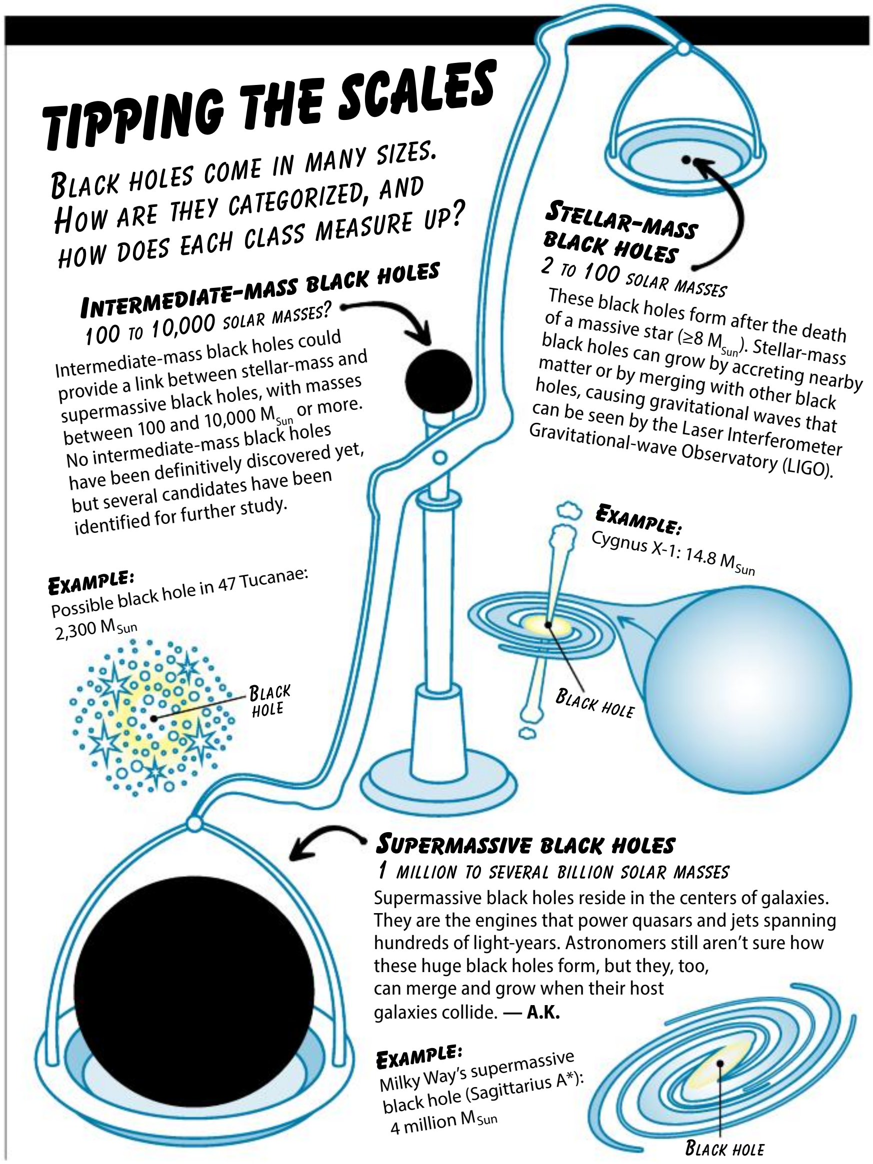
PARTNER DANCE. Located at the center of galaxy NGC 7674, these two compact radio sources are less than a light-year apart and correspond to two accreting supermassive black holes orbiting each other.

Like their smaller counterparts, supermassive black holes weighing in at over 1 million times the mass of the Sun can exist in binary pairs. Scientists believe such pairs most commonly form when galaxies merge — over time, each galaxy's supermassive black hole falls to the center of the resulting larger galaxy, eventually orbiting and merging with each other. But just how closely can two gargantuan black holes orbit each other before they collide?

In September 18's *Nature Astronomy*, an international team of astronomers reported the discovery of the tightest-ever orbiting supermassive black hole system. Located 400 million light-years away near the center of the spiral galaxy NGC 7674, the two black holes are separated by less than 1 light-year. The previous record holder has a separation of nearly 25 light-years.

To resolve such a tiny separation from such a large distance, the team took advantage of a technique called very-long baseline interferometry, which uses multiple radio telescopes networked together to function as one massive telescope. This provided an angular resolution about 10 million times better than the human eye, enough to resolve the two black holes.

The combined mass of the black holes is about 40 million times the mass of the Sun. Though they are tightly bound, their orbital period is a sluggish 100,000 years, meaning it will be a while yet before they merge to create a single object. — **J.P.**



ASTRONOMY: ROEN KELLY

TWEET AWAY. University of Kansas researchers found that social media can help, rather than hinder, young students' ability to argue scientific theories.

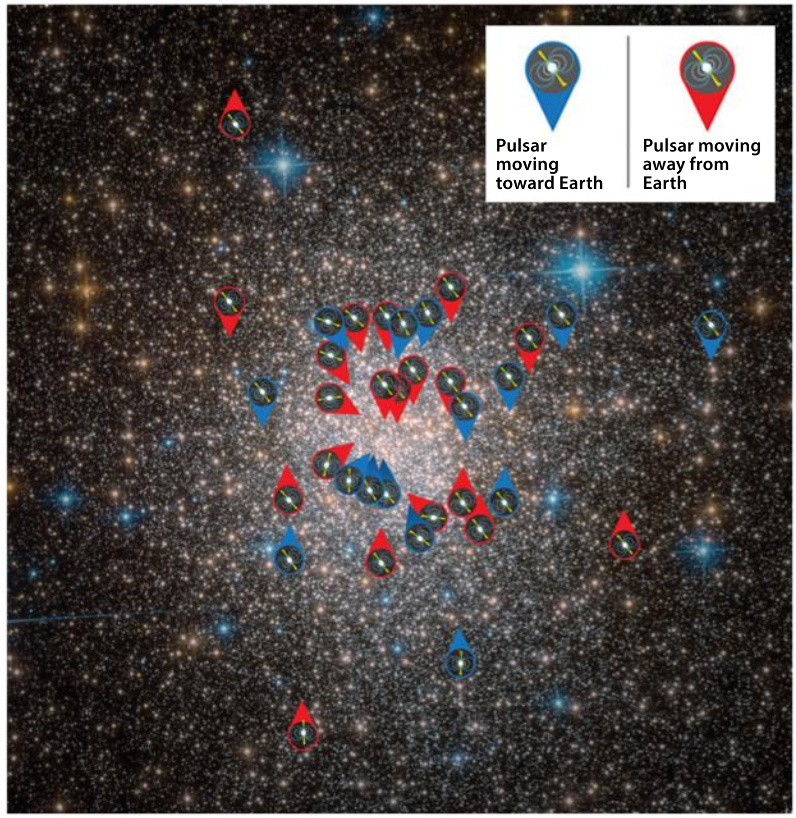
Pulsars reveal origin of a globular cluster

The motions of stars inside globular clusters can help astronomers better understand the cluster's origin to determine whether it originated within the Milky Way, or is the leftover core of a dwarf galaxy that our galaxy gobbled up. Though optical studies are often thwarted by galactic dust, astronomers have now used radio observations to track pulsars in the Terzan 5 globular cluster, finding evidence that it came from within our galaxy.

Terzan 5 has 37 known pulsars, more than any other globular cluster. Brian Prager at the University of Virginia in Charlottesville and his collaborators observed 36 of those pulsars with the 100-meter Green Bank Telescope (GBT) in West Virginia. They watched as the pulsars' regular radio pulses were Doppler shifted (stretched or squished in frequency) by their motion relative to Earth, allowing precise mapping of the cluster's interior. The work was published August 21 in *The Astrophysical Journal.*

"Pulsars are amazingly precise cosmic clocks," co-author Scott Ransom of the National Radio Astronomy Observatory said in a press release. "With the GBT, our team was able to essentially measure how each of these clocks is falling through space toward regions of higher mass. Once we have that information, we can translate it into a very precise map of the density of the cluster, showing us where the bulk of the 'stuff' in the cluster resides."

If Terzan 5 used to be a dwarf galaxy, it might still harbor a central supermassive black hole or show signs that it warped as the Milky Way gobbled most of its stars. The team saw no sign of either, instead finding "better evidence that Terzan 5 is a true globular cluster born in the Milky Way rather than the remains of a dwarf galaxy," said Ransom. — **A.K.**



IN MOTION. Astronomers measured the motion of 36 pulsars in the Terzan 5 globular cluster to map the location of its mass. Blue markers indicate pulsars moving toward Earth, while red markers show those moving away. B. SAXTON (NRAO/AUI/NSF); GBO/AUI/NSF; NASA/ESA HUBBLE, F. FERRARO

Hubble spies asteroid pair sporting a tail

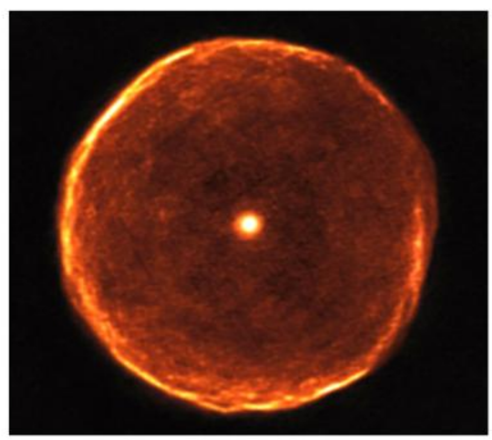
A group of German-led astronomers used the Hubble Space Telescope to study main belt asteroid 288P as it passed Earth in September 2016 on its closest approach to the Sun. The team was surprised to discover the asteroid was actually *two* asteroids, orbiting each other with a separation of about 60 miles (100 kilometers).

Astronomers can easily measure the mass of a binary system by watching the objects orbit each other, and the researchers found that the two asteroids are not only roughly the same size, but also about the same mass. Their work was published in *Nature* on September 20.

Wide asteroid binary pairs are already rare, but 288P appears to be unique. The pair was caught sporting a cometlike tail, making 288P the first binary asteroid also classified as a main belt comet. Team leader Jessica Agarwal of the Max Planck Institute for Solar System Research said the observations showed indications of water ice, a feature that sublimates (turns directly from a solid to a gas) when the comet comes close to the Sun, creating a tail.

The presence of ice, which can't survive long on the surface of an object in the asteroid belt, is a sign this binary system was likely once a single object with ice buried just beneath the surface. The parent asteroid may have broken up to produce the pair as little as 5,000 years ago. — **Nicole Kiefert**

TWO IN ONE. 288P is not one asteroid, but two, orbiting each other as a wide binary pair. This artist's impression shows not only the asteroids' elliptical orbit outlined in blue, but also the diffuse cometary tail spotted by Hubble. ESA/HUBBLE, L. CALÇADA



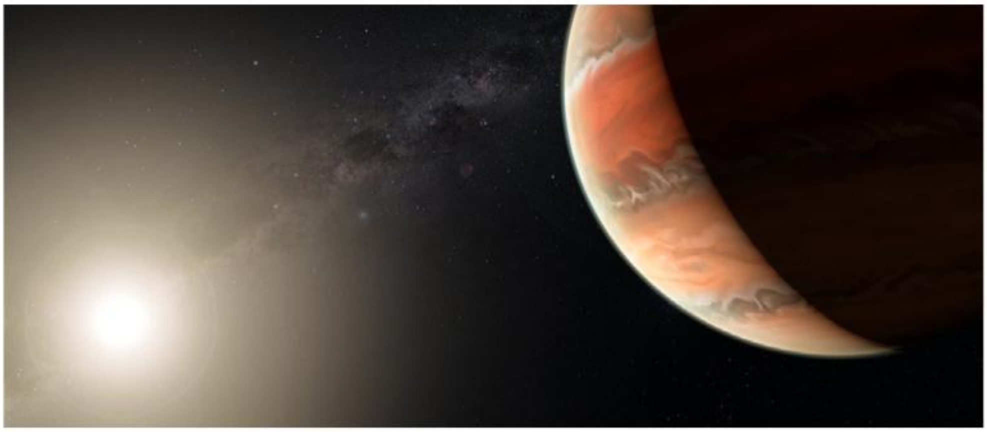
ALMA (ESO/NAOJ/NRAO)/F. KERSCHBAUM

ALMA sees a star blow a bubble

SURROUNDED. U Antliae is a carbon star — a luminous red giant with an atmosphere composed of more carbon than oxygen. With binoculars, the red star is visible in the Southern Hemisphere constellation Antlia the Air Pump. The Atacama Large Millimeter/submillimeter Array (ALMA) recently found that this star is quite unusual: It has a very thin shell of material around it. Only ALMA's ability to take sharp images at multiple wavelengths allows astronomers to see the thin, round shell of material and the wispy clouds, called filamentary substructures, that comprise it. The shell was created when the star ejected the material at high speeds over a brief period 2,700 years ago. Researchers can now use this data to better understand how carbon stars evolve and form these shells. — **N.K.**

 WORKING BACKWARD. Australian National University scientists created the best estimate of Earth's composition, which can now be used to improve solar system formation models.

Hot Jupiter's skies contain titanium oxide



REVERSE THINKING. Astronomers think the titanium oxide in the hot Jupiter WASP-19b's atmosphere leads to a situation called temperature inversion: The upper atmosphere is hot, with cooler temperatures deeper down. ESO/M. KORNMESSER

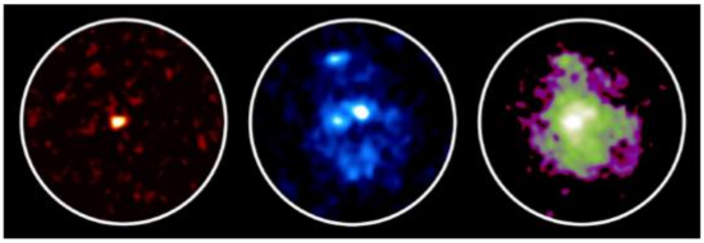
Research into the exoplanet WASP-19b, classified as a hot Jupiter because of its size and proximity to its star, revealed something startling: It has titanium oxide scattered throughout its upper atmosphere.

Astronomers studied WASP-19b's atmosphere, which is measured at 3,600 degrees Fahrenheit (2,000 degrees Celsius), using the FORS2 instrument on the European Southern Observatory's Very Large Telescope. As the planet passed in front of its star, background light filtered through its atmosphere, highlighting some of the molecules and elements present. FORS2 is a spectrograph, which splits light into its constituent parts to identify the signatures of elements and molecules. Using this technique, researchers found titanium oxide, water, and sodium.

Previously, titanium oxide was largely associated with cool stars. But as we learn more about exoplanet atmospheres, we are discovering compounds like titanium oxide are also found there. In this case, titanium oxide may act as a heat absorber, creating a thermal blanket around the planet that traps heat mostly in the upper atmosphere and keeps lower areas cool.

The research, published September 13 in *Nature*, highlights our slowly increasing understanding of exoplanet atmospheres, as we often find that they're vastly different from those of our solar system's planets. So far, all the information we've gathered has been on larger, hotter worlds, but upcoming instruments may be able to finally study Earth-sized planets in distant solar systems enough to detect a holy grail: water vapor on worlds with Earth-like temperatures. — **J.W.**

Birthing stars makes galaxies swell

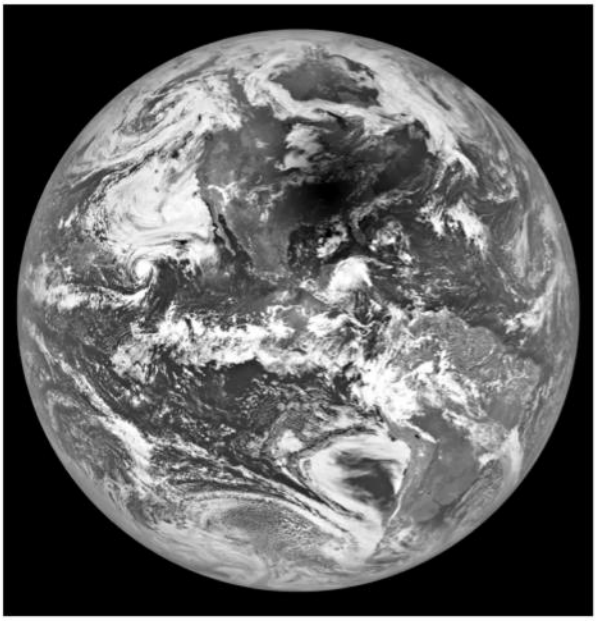


RISE AND SHINE. Infrared light from the Hubble Space Telescope (right) emphasizes the large galactic disk of a young galaxy. Optical light (middle) highlights three young star clusters packed full of freshly formed stars near its center. Submillimeter waves from the Atacama Large Millimeter/submillimeter Array (left) show a dense, star-forming cloud of material in the galactic core. ALMA (ESO/NAOJ/NRAO), NASA/ESA HUBBLE SPACE TELESCOPE, TADAKI ET AL.

The prevailing theory in galactic evolution is that massive elliptical galaxies are formed when smaller disk galaxies collide and merge. However, an international team of astronomers led by Ken-ichi Tadaki of the National Astronomical Observatory of Japan (NAOJ) recently found that this is not always the case.

"Massive elliptical galaxies are believed to be formed from collisions of disk galaxies," said Tadaki in a press release. "But, it is uncertain whether all the elliptical galaxies have experienced galaxy collision. There may be an alternative path."

Tadaki and his team discovered that possible path. They found that intense bursts of star formation can swell disk-shaped galaxies — much like yeast helps bread rise — morphing them into ellipticals without the help of collisions. The researchers used the Hubble Space Telescope and the Atacama Large Millimeter/submillimeter Array to investigate 25 galaxies about 11 billion light-years away, observing them just 3 billion years after the Big Bang, at a time when most galaxies were in their infancy. They looked at both the number of stars already shining and the amount of gas and dust available to form more stars. The team saw a huge available reservoir of gas and dust in the centers of these galaxies, indicating that over time, star formation in the core will dominate the galaxy's appearance — "puffing up" these galaxies and turning them into ellipticals from within. — **J.P.**

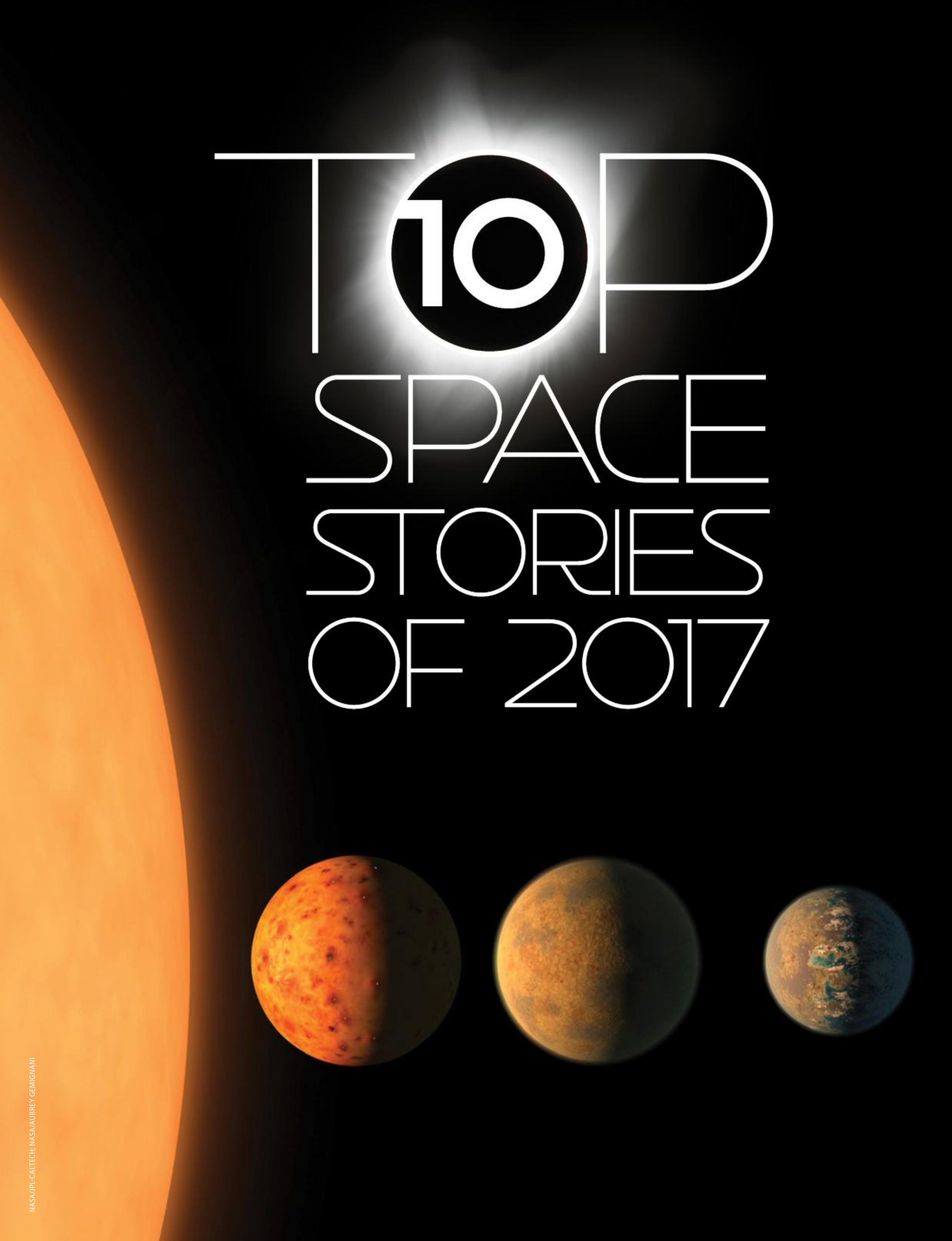


NASA/GSFC/ARIZONA STATE UNIVERSITY

What did totality look like from the Moon?

LUNAR VIEWPOINT. During the August 21 total solar eclipse, NASA's Lunar Reconnaissance Orbiter (LRO) took an image of the eclipse as seen from the Moon. LRO completed a slow 180° turn shortly after passing over the Moon's south pole, allowing it to look back toward Earth and snap a photo as the shadow sped just north of Nashville, Tennessee, moving at 1,500 mph (670 m/s). LRO's Narrow Angle Camera, which is actually two high-resolution cameras, began imaging Earth at 2:25 P.M. EDT and took 18 seconds to complete the image, building it up line by line. The final picture shows the eclipse near the longest duration of totality. — **N.K.**

TOP 10 SPACE STORIES OF 2017



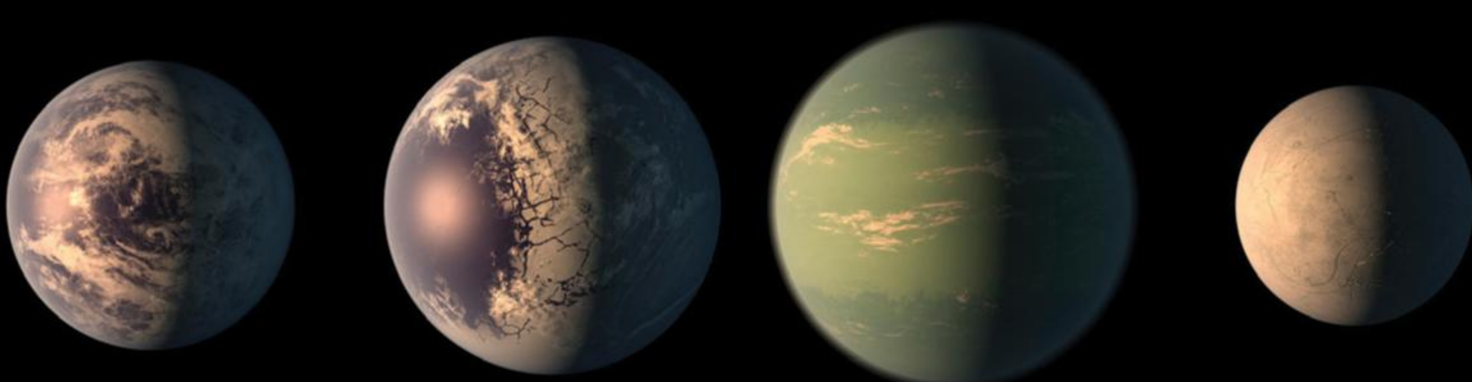
NASA/JPL-CALTECH; NASA/AUBREY GEMIGNANI

Last year, we found a star with seven Earth-sized planets, said goodbye to the Cassini mission, and watched a total solar eclipse race across America. **by Liz Kruesi**

Each year, *Astronomy* ranks the top 10 astronomical discoveries and space stories. Choosing 2017's top stories wasn't easy, as it was a year full of exciting discoveries and unexpected findings. In the end, the detection of a neutron star merger tops the list. For the first time, astronomers spotted a pair of neutron stars spiraling inward and colliding, throwing off gravitational waves, gamma rays, and many other forms of light. Coming in a close second was the discovery of *seven* likely terrestrial planets crammed into their star's habitable zone. The global network of astronomers who pinpointed the location of a weird, mysterious blast of radio waves also makes our top 10.

Not all of the past year's biggest space stories came from outside our solar system. Cassini's final goodbye after 13 years of incredible discoveries brought tears to the eyes of the scientists who have worked with the craft, as well as those who have followed the mission from the sidelines. And closer to home, millions watched as the Moon blocked the Sun and its shadow raced across the continental United States.

Here's how these and the rest of the top 10 stories stack up.



Cassini's high-resolution camera penetrated the haze around Titan and spotted some of the moon's largest seas and lakes of liquid hydrocarbons. These seas could sustain life: Researchers found a signal from vinyl cyanide, a molecule that could act as a cell membrane. NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

10

Titan's complex chemistry — and astrobiology?

Saturn's largest moon, Titan, is one of the solar system's most intriguing worlds. It hosts a thick atmosphere denser than Earth's and harbors lakes and rivers of a methane-ethane mixture on its surface. The saturnian satellite even has a complex weather system that circulates this liquid, which evaporates into the atmosphere, condenses into clouds, and then rains back to the surface. Could Titan even harbor some form of life that relies on hydrocarbons in the way Earth organisms rely on water? Perhaps. Scientists continue to find more complex chemistry at the satellite (although, no aliens).

A July 28 paper in *Science Advances* shows Titan is astrobiologically interesting. While looking for the molecule acetonitrile isotopolog in archived observations taken with the Atacama Large Millimeter/submillimeter Array (ALMA), researchers found a signal from vinyl cyanide, "a more exciting molecule," says Maureen Palmer of NASA's Goddard Space Flight Center and lead author of the discovery paper. Laboratory experiments and computer simulations suggest that this particular molecule would be a stable material from which to form something called a lipid bilayer membrane, a structure that separates and protects a cell's innards from its environment. All living organisms on Earth have such cell membranes.

Palmer and her colleagues looked through several months of ALMA observations of Titan and found three spectral lines associated with vinyl cyanide. Each of these lines is produced as an energized vinyl cyanide molecule settles to a lower energy state, giving off a photon. The brightness of each spectral line relates to the number of photons ALMA received. "And the number of photons is dependent on how many molecules are changing energy levels and releasing these photons," adds Palmer.

The researchers modeled different scenarios to estimate the overall abundance of vinyl cyanide at Titan, but their data weren't sensitive enough to create a map of where in the atmosphere the molecule is most abundant. They've taken more observations of Titan with ALMA and are currently analyzing them.

This type of work — hunting for biologically important chemistry — can begin to address how life forms, at other locales and here on Earth. Perhaps soon, we'll find out we're not alone.

A perfectly positioned standard candle

On September 5, 2016, the 48-inch telescope at Palomar Observatory captured a stellar explosion, dubbed iPTF16geu. Astronomers published the discovery April 21 in *Science*.

This isn't just any type of explosion — it's one that's used as a ruler to measure cosmic distances, called a type Ia supernova (or type Ia SN). Each of these blasts has a nearly identical light curve, which measures brightness over time. The fainter the explosion, the farther it must lie from us. Astronomers can calculate distances to high precision by comparing these blasts because of their similarities. Scientists used this type of measurement in the late 1990s to show the universe's expansion is speeding up, as some type Ia SN explosions are fainter than expected, meaning they are farther than expected.

But iPTF16geu is more than just a type Ia supernova. Astronomers found four images of that same blast at the site of a galaxy lying about 2 billion light-years away. It turns out the supernova lay directly behind that galaxy as viewed from Earth. When objects line up like this, background light is bent around the foreground object — in this case, the massive galaxy. (Think of putting a straw into a glass of water; the straw looks like it bends.) As a result, the light from the blast took four separate paths around the galaxy, leading to four images of the same stellar explosion. And with four images, there's more science that can be done. That's because the light in each image traveled a slightly different path around the intervening galaxy. Slightly different paths equate to different distances and different amounts of time. "If you measure the arrival times of the different images, that turns out to be a good way to measure the expansion rate of the universe," lead author Ariel Goobar said in a press release.

Astronomers expect this is the first of many similar discoveries, as new surveys come online and software better understands how to pick out multiply lensed explosions. Not only will finding more lensed supernovae improve our ability to measure the expansion rate of the universe, new gravitational lenses will also allow astronomers to more accurately map the distribution of normal and dark matter throughout the cosmos.

A distant supernova, iPTF16geu lit up the sky not once, but four times, thanks to the phenomenon of gravitational lensing. The Hubble Space Telescope caught this image of the lensed supernova, which appears as four bright spots surrounding a blue foreground galaxy. The supernova itself occurred at a distance of 4.3 billion light-years. ESA/HUBBLE, NASA

Earth rises just over the lunar horizon in this image taken by the Apollo 17 crew. When SpaceX sends humans back to the Moon, they'll enjoy similar views. NASA

8

A trip around the Moon

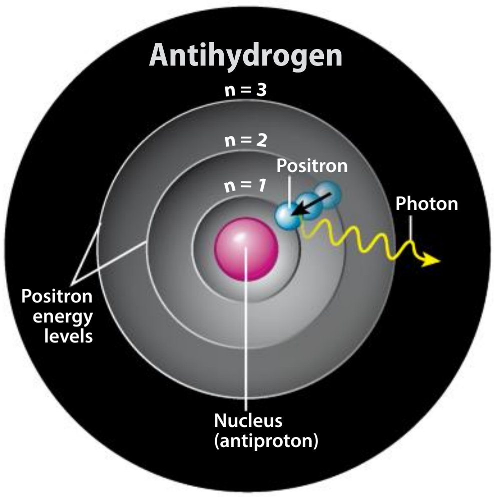
SpaceX certainly has big goals. In 2012, the aerospace company was the first private corporation to dock with the International Space Station. And in 2015, SpaceX was the first organization, government agencies included, to bring a rocket safely back to Earth after sending a payload of supplies to the space station. Yet the goal SpaceX announced in February 2017 could be even more difficult to reach, because it involves the safety of human lives.

The aerospace giant announced its plans to send two private citizens — who will likely pay an enormous sum of money — on a trip around the Moon. At the time, the company set a date of late 2018, but that goal is hard to believe, considering SpaceX hasn't sent humans into space yet. In its February announcement, SpaceX said its first crewed flight will take place in late spring of 2018. In July 2017, the company announced via social media that its heavy-lift rocket, the Falcon Heavy, would have its first test flight in November.

A mission around the Moon will certainly need that powerful rocket. SpaceX has launched its Falcon 9 dozens of times, but that rocket's payload goes into orbit to rendezvous with the ISS — a target only about 250 miles (400 kilometers) above Earth's surface. The Moon is much farther away (238,900 miles [384,500 km]).

It'll take a lot more power to launch humans and supplies to the Moon before returning to Earth. For a crewed trip around the Moon to occur, there's still technology that must be fully developed. Many doubt it can happen by the end of 2018, but if it does, SpaceX will see itself in our top 10 again.

Pad 39A at the Kennedy Space Center will become the home of SpaceX Falcon Heavy launches. The rocket, shown in this artist's rendition, is the company's chosen vehicle to transport two humans around the Moon in early 2018. SPACEX

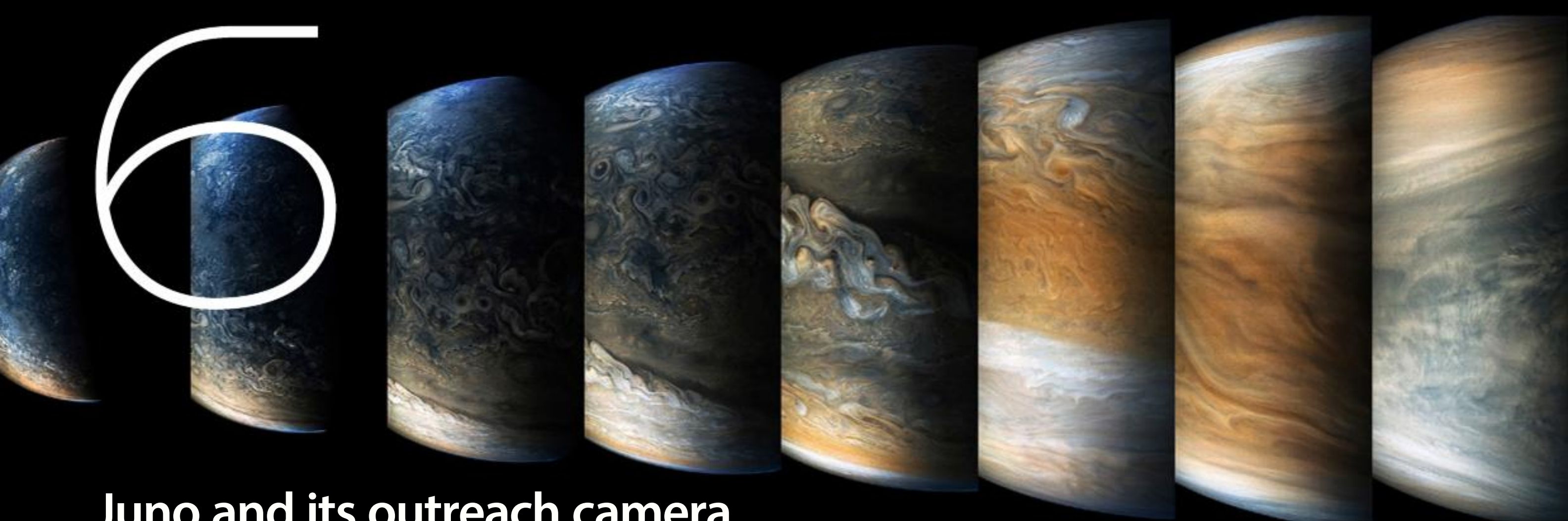


7 Spying light from antimatter

When electrons transition between energy levels in an atom, they either absorb or release specific wavelengths of light. The ALPHA collaboration has measured a positron transition in antihydrogen, and found its wavelength identical to hydrogen. *ASTRONOMY*: ROEN KELLY

When the universe came into existence 13.8 billion years ago, equal amounts of matter and antimatter should have been created. Look around the cosmos now, and it's obvious matter stuck around, and antimatter didn't. While scientists don't know why there's a preference for matter, learning more about antimatter will help reveal the answer.

But it's not easy. Whenever antimatter encounters its matter match, the two annihilate. (For example, when an electron encounters an antielectron, called a positron, they are converted into a burst of radiation.) So scientists have to find a way to isolate antimatter from matter.



6 Juno and its outreach camera

Swirls and waves of red-tinged clouds, white oval-shaped storms mixed with tan-toned vortices — these are some of the incredible details that the JunoCam instrument is capturing at Jupiter. The images made a splash across the news and social media in 2017, and for good reason: Never before have human eyes seen the features JunoCam is revealing. And it's all because of a late decision to add this public outreach instrument.

Like all NASA space missions, Juno has a set of science objectives, but none of those objectives requires a visible-light camera. The craft is equipped with seven other instruments to reveal the deep layers of Jupiter's atmosphere, map the planet's magnetic and gravitational fields, and study its aurorae. However, those instruments and their collected data don't always resonate with the public. A chart showing the abundance of water at different depths of Jupiter's atmosphere doesn't have the same impact on non-scientists as a stunning photograph of Jupiter's Great Red Spot.

The mission leader, Scott Bolton, recognized that fact. Prior to launch, Juno got one more instrument: a small camera to engage the public. JunoCam has fewer resources than the science instruments. There's no large dedicated planning or processing team. "Our concept was that the public would be our virtual imaging team," says Candice Hansen, the scientist responsible for planning and operating JunoCam. That means the public recommends imaging targets, then discusses and votes on which ones to study — all via the internet. Once JunoCam captures the images, members of the public process them. The entire concept has been successful "beyond our wildest dreams," says Hansen.

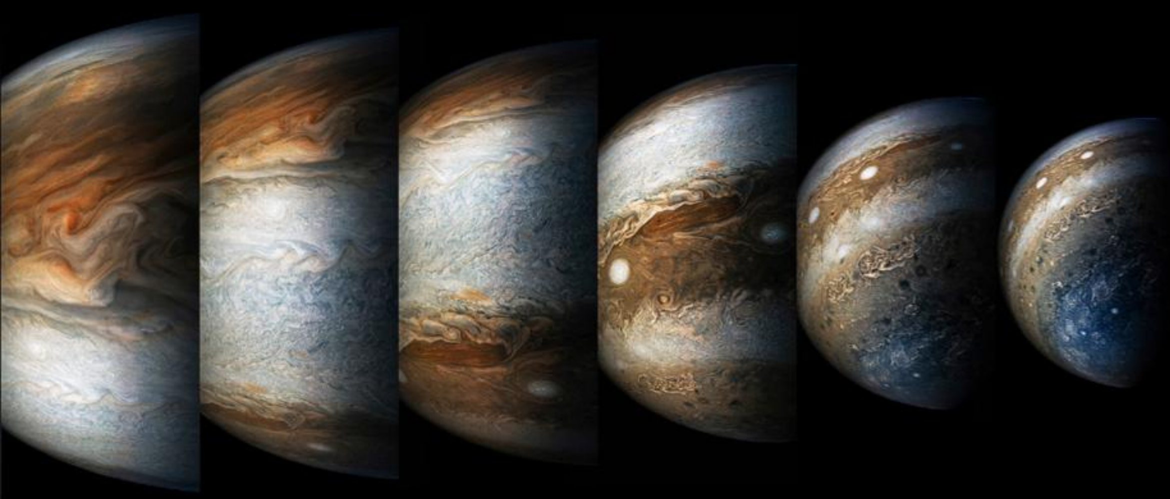
JunoCam has received the most attention, but Juno's other instruments have also been hard at work. In May, the mission team released the first science results. Scientists knew Jupiter has a strong magnetic field — that's why Juno's electronics have to be well-shielded to protect against radiation damage — but Juno has found it is twice as strong as expected. The magnetic field is also "lumpy" — it's stronger in some places than others. Researchers think that could mean the field is generated not at the very center of the planet, but closer to the surface.

Juno flies by Jupiter every 53 days, skimming a few thousand miles above the cloud tops at each pass. Its primary mission includes 12 of these 53-day orbits and continues through July 2018. NASA could then opt to extend the mission.

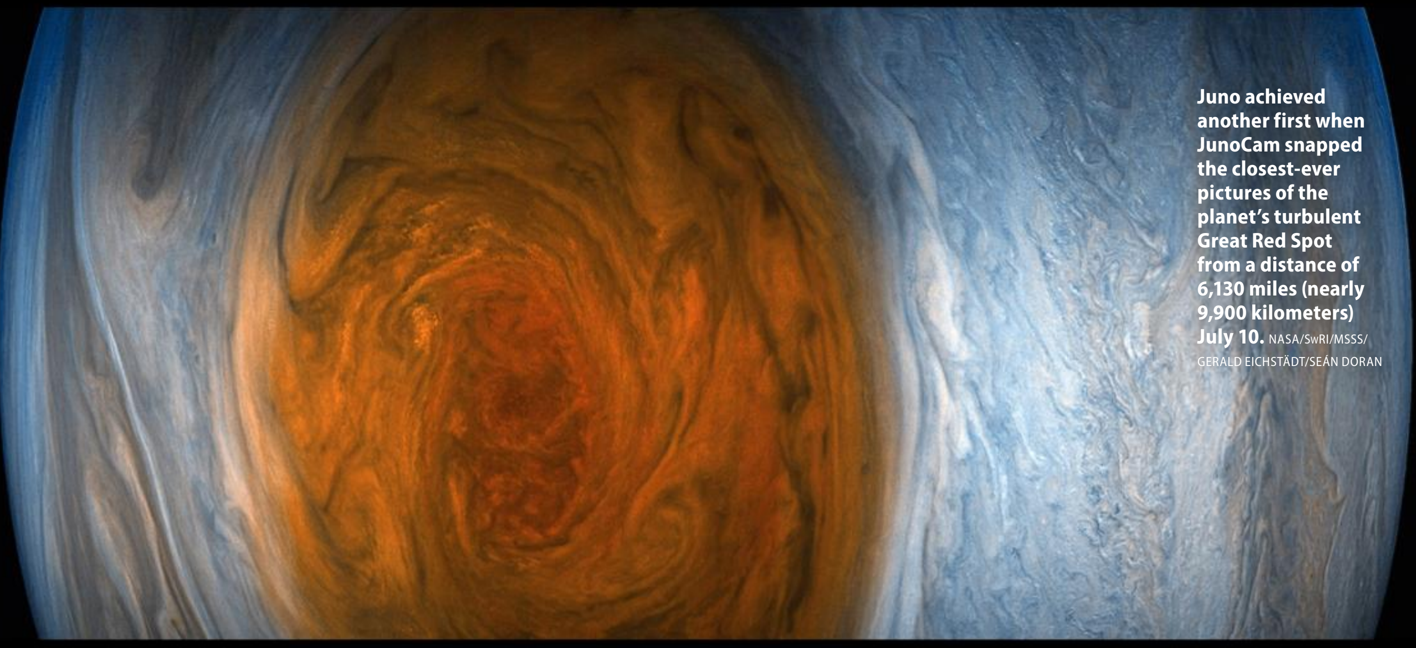
In 2011, physicists with the ALPHA experiment at Europe's CERN laboratory were able to create and trap antihydrogen — consisting of an antiproton and a positron — for 16 minutes, long enough to study the material. And in December 2016, that same group announced it had measured the glow of antihydrogen for the first time.

Every chemical element — whether it's hydrogen, carbon, or copper — glows at specific colors when energized. Each specific color corresponds to the amount of energy that an electron needs to absorb to jump to another energy level within an atom. Conversely, if the electron is at one of those higher energy levels and falls down, it releases that same color of light. (For example, the red color of hydrogen-alpha radiation, commonly observed by astronomers, corresponds to an electron in a hydrogen atom moving between the third and second energy levels.) Understanding the colors each element glows at is crucial to identifying the material and learning about its physics. Scientists know every color that a hydrogen atom gives off. Does antihydrogen differ? And if it does, what does it mean about the reason our universe picked matter over antimatter?

The ALPHA group is working on detecting all the different colors at which antihydrogen glows. In December 2016, they announced they've observed one. The light the atom emits when its positron bounces between two specific energy levels is the same as the light emitted from a regular hydrogen atom, meaning so far, matter and antimatter appear to give off identical colors. This agreement shows that antimatter does indeed appear to be matter's exact but opposite twin, confirming predictions made by the current Standard Model of particle physics — and special relativity — so far.



On May 19, Juno zipped past Jupiter. The spacecraft's two-hour close approach is captured in this sequence of 14 color-enhanced JunoCam images, beginning with the planet's north pole (left), then crossing the equator (middle images), and ending with the south pole (right). NASA/SwRI/MSSS/GERALD EICHSTÄDT/SEÁN DORAN



Juno achieved another first when JunoCam snapped the closest-ever pictures of the planet's turbulent Great Red Spot from a distance of 6,130 miles (nearly 9,900 kilometers) July 10. NASA/SwRI/MSSS/GERALD EICHSTÄDT/SEÁN DORAN

5

During its plunge into Saturn on September 15, the Cassini spacecraft kept its antenna pointed at Earth until 4:55 A.M. PDT. Shortly after its signal was lost, the spacecraft ended its mission as a meteor streaking across Saturn's sky. NASA/JPL-CALTECH

Cassini's kiss goodbye

On September 15, the Cassini spacecraft took its last bow. It grazed Saturn's atmosphere, burned up due to friction, and became part of the planet it had spent 13 years exploring.

The craft arrived at the ringed planet in summer 2004 after a seven-year journey. Since then, Cassini has revealed not just the planet itself in more detail than ever before, but also has shown Saturn's moons as a diverse bunch, with a few possibly capable of supporting life. "We've changed how you look at the Saturn system," says Linda Spilker, Cassini's project scientist. "I'm just so proud of Cassini and all its wonderful discoveries."

The end of this historic mission went precisely as planned. The primary mission took four years, but after two mission extensions, the spacecraft was running out of fuel. The Cassini team decided to make the final few months memorable via a mission plan they named the Grand Finale.

On April 22, as Cassini flew by Saturn's largest moon, Titan, the moon's mass tweaked the spacecraft's orbit. As a result, four days later Cassini dove between Saturn's inner rings and its upper atmosphere. After that close flyby, the spacecraft followed a six-day elliptical orbit to its farthest point before swinging back through that gap again May 2. In total, Cassini passed between Saturn's inner rings and its atmosphere 22 times before finally diving into the ringed planet's upper atmosphere and disintegrating.

During each close crossing, Cassini was between about 1,000 miles and 2,400 miles (1,700 km and 3,900 km) above the planet's cloud tops. The spacecraft's imaging camera continued to take incredible photographs, while its other 11 instruments also recorded data. The craft was traveling too fast at each orbit's closest approach — some 75,000 mph — to snap photos at those precise moments, but the camera system could focus well enough to take images at other times in the orbit. It captured atmospheric vortices, the great hexagon at the planet's north pole, and features in the rings. Crossing inside the rings also meant that Cassini could measure precisely the mass of the rings and even sample a few ring particles, something never done before. And by flying so close to the planet, the spacecraft's magnetometer was able to take detailed measurements of the strength and direction of the planet's magnetic field. Scientists can use that information to learn about the rotation and size of Saturn's core, plus determine how fast the cloud tops are moving with respect to the core.

In one of the last few photos taken by Cassini, the moon Enceladus sinks behind Saturn September 13. NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

Cassini imaged its impact site in monochrome just hours before its 13-year mission at Saturn ended. This is the last image taken by the spacecraft's cameras, recorded at 19:59 UTC (spacecraft time) September 14.

After those 22 orbits, Cassini completed a final half orbit. On the night of September 14 and into the early hours of September 15, scientists and engineers gathered at NASA's Jet Propulsion Laboratory and held a vigil. "I think of Cassini almost like a person," says Spilker. On September 15, Cassini plunged into Saturn's atmosphere; the final signals arrived at 4:55 A.M. local time. And then the Cassini mission team said goodbye to a friend of nearly 20 years.

Totality crosses America

August 21 marked the first time a total solar eclipse crossed the continental United States in nearly 100 years. As millions of people watched the Moon blot out the disk of the Sun, the brilliant solar corona appeared. NASA/AUBREY GEMIGNANI

One of nature's greatest spectacles arrived at the Oregon shore at 10:16 A.M. PDT on August 21. The midmorning light turned to darkness as the Moon blocked the Sun's disk from view. The Sun's million-degree outer atmosphere, the solar corona, then took center stage. And for the millions of people in that 70-mile-wide (115 km) shadow, the corona looked like fire sprouting from a gray disk. The shadow then continued across 13 more states before the South Carolina coast ushered it into the Atlantic Ocean.

There was nothing *surprising* about the August 21 solar eclipse. Astronomers understand eclipse geometry very well, and they can predict these events millennia in advance. But this eclipse was historic for other reasons. It crossed the entire continental United States, the first eclipse to do so in almost a century.

More than 12 million people lived along the path of the 2017 eclipse. An additional 20 million people traveled to get a better view, according to the University of Minnesota's Jon Miller. Talk of traffic nightmares, like gridlock on interstates, began circling months beforehand. Some hotels and camping sites were booked several years in advance. Twenty-one national park units and seven scenic national trails lay in the path of totality — including Grand Teton in Wyoming and Great Smoky Mountains in Tennessee and North Carolina — and some of them experienced full capacity that August day.

Whether people made their observing plans years out or waited until the day before, August 21, 2017, presented an act of beautiful celestial geometry to those along the Moon's umbral path. It's likely no other astronomical observing event in history has garnered so much attention.

The case of the mysterious radio waves

One of the most mysterious signals encountered in modern astrophysics is a blast of radio waves lasting only milliseconds. The first of these fast radio bursts (FRBs) was discovered about a decade ago, but several years elapsed before astronomers detected another. Now, they know of around 20 FRBs, and yet these bizarre signals remained mysterious because astronomers couldn't figure out precisely where any of them were originating.

What scientists needed was to pinpoint a signal's location on the sky with enough precision to find out how far away the source was. In the past year and a half, the universe has obliged.

It all hinged on a discovery made a few years ago. Scientists found an FRB that actually seemed to repeat, though not with any noticeable pattern. Now they knew a rough location in the sky. A coordinated effort of several radio telescopes across the globe followed. Using the Very Large Array (VLA) to take 83 hours of observations in 2015 and 2016, astronomers figured out roughly where the blast — called FRB 121102 — is located on the sky. The VLA captured the repeating signal nine times.

"The FRB was extremely generous to us," said Casey Law of University of California, Berkeley, during a January 4, 2017, press conference announcing the observations. The scientists found a varying source of radio waves at that rough location. Was that source connected to the FRB signals?

Astronomers used additional radio instruments to zoom in on the suspected sky site. The European Very-Long-Baseline Interferometry Network, which connects 21 radio telescopes scattered mostly across Europe, isolated the location further. The FRB signal was originating just 130 light-years away from another source of both radio waves and optical light. It looked like the two might be related.

Next, scientists used an optical telescope to identify where in three-dimensional space the signal was coming from. They learned that a small, faint galaxy hosts this FRB. This dwarf galaxy has 1,000 times less mass than the Milky Way and is physically 10 times smaller than our home galaxy. It lies so far away that the radio waves traveled some 2.4 billion light-years to reach our telescopes.

Now that astronomers have pinpointed the precise location, the next step is to figure out what process is producing this repeating radio signal. For that, astronomers may need the universe to cooperate again.

The fast radio burst FRB 121102 is the only known repeating FRB. Astronomers used this property to track down the burst's host galaxy: an unassuming dwarf galaxy nearly 3 billion light-years away. GEMINI OBSERVATORY/AURA/NRC/NSF/NRAO

2 Terrestrial planet plethora

The TRAPPIST-1 system contains at least seven planets circling an M-dwarf star. All seven appear Earth-sized and terrestrial in nature, prompting astronomers to wonder whether they might also host life. NASA/JPL-CALTECH

One of humanity's greatest discoveries will be the confirmation that life exists elsewhere in our universe. We haven't made this discovery yet, but each year, astronomers move closer to that goal. This past year was no exception.

In February, a team of planetary scientists announced — both at a press conference and in a *Nature* article — that it had found seven Earth-sized planets orbiting a nearby star. All seven were within the so-called habitable zone. Inside this region, the amount of starlight the exoplanets receive could lead to ideal temperatures for liquid water on those worlds' surfaces. (Though just because a planet is in the habitable zone doesn't mean there's water.) The researchers also ran computer models and estimated that three of those exoplanets could harbor water oceans on their surfaces, provided those worlds also have Earth-like atmospheres.

To find these seven worlds, astronomers used several ground-based telescopes in addition to the infrared Spitzer Space Telescope to focus on the star known as TRAPPIST-1. They watched as its starlight flickered. From their hours of data, the researchers determined the flickering was due to multiple planets crossing in front of the star, blocking a tiny amount of starlight at each crossing. As of February, they could confirm six exoplanets in orbit around TRAPPIST-1. Confirmation of the seventh world, which orbits farthest from the star, came in May. And there could even be more exoplanets in the system.

From the amount of light each exoplanet blocked, the astronomers could calculate its diameter. By analyzing the amount of time that passed between subsequent transits of the same exoplanet, and comparing the six different inner worlds' orbits, the scientists could also estimate those exoplanets' masses. With diameter and mass, you can calculate density. The calculations suggest the six inner worlds are rocky like Earth, Mars, Venus, and Mercury, although the numbers are still highly uncertain. (The seventh exoplanet's density has even greater uncertainty.)

While the exoplanets might be rocky and Earth-sized, their star is nothing like the Sun. TRAPPIST-1 holds only 8 percent of the Sun's mass and is about 12 percent of the width of our star. It is also much cooler, giving off a red glow instead of our Sun's yellow-white light. This planetary system is also far more condensed than our solar system. The innermost planet completes an orbit around TRAPPIST-1 in 1.5 days, whereas the most distant one takes 18.8 days. Even though astronomers haven't found an exact solar system analogue, the discovery of seven likely terrestrial planets orbiting a star only 40 light-years away is a good indication that an Earth twin may be out there.

STORIES TO WATCH FOR IN 2018

- BepiColombo, the European-Japanese collaborative mission to Mercury, is set to launch in October.
- SpaceX is still hoping for crewed missions to start up in 2018.
- NASA's next space-based exoplanet observatory, the Transiting Exoplanet Survey Satellite (TESS), launches in early 2018.
- The agency's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission to Mars has a launch window beginning May 5, and a landing date of November 26.
- The X-ray satellite Spectrum-Roentgen-Gamma (SRG) will launch in 2018. This Russian and German collaboration project will scan the entire sky and is expected to discover millions of supermassive black holes. — *L.K.*

Astronomers spotted gravitational waves, gamma rays, and several other forms of light from a pair of merging neutron stars August 17. The event, called a kilonova, produced heavy elements such as gold and platinum. ESO/ L. CALÇADA/M. KORNMESSER

1 The day multi-messenger astronomy burst forth

August 17, 2017, began like any other day. But at 8:41 A.M. EDT, everything changed. For 100 seconds, ripples in the fabric of space-time stretched and squished Earth's extremely precise gravitational wave telescopes. A bright flash of gamma rays followed shortly afterward. And so began weeks of intense analysis by 3,500 astronomers and physicists using 70 observatories scattered across all seven continents and in space.

Scientists announced the results of that analysis October 16 during several press conferences and in more than three dozen papers. They had spotted gravitational waves from a source never before detected: two neutron stars spiraling together and merging. The collision also let out a gamma-ray burst (GRB), thus proving a long-held assumption that neutron star mergers cause at least one type of GRB. But this event also emitted other forms of light: visible light, infrared radiation, radio waves, ultraviolet light, and X-rays, all of which astronomers examined for details.

On the morning of August 17, the gravitational waves reached Earth first. The Laser Interferometer Gravitational-wave Observatory (LIGO) in Louisiana — composed of fine-tuned lasers, mirrors, and detectors — saw a strong signal, as did its twin in Washington state just milliseconds later. The European gravitational wave observatory, Virgo, uses similar technology and had come online just weeks before, but it couldn't make out the August 17 event even though the signal should have been visible. "The event happened in one of the very few areas on the sky that they have low sensitivity to," says LIGO team member Amber Stuver of Villanova University. "That gave us information that made us better able to pinpoint where on the sky the source could have come from."

While gravitational wave scientists were alerting their colleagues, gamma-ray astronomers were processing a signal that arrived at the Fermi gamma-ray space observatory. "We were absolutely sure we had a gamma-ray burst," says Eric Burns, a team member with Fermi's Gamma-ray Burst Monitor (GBM). The GRB arrived 1.74 seconds after the gravitational wave signal ended. Once the LIGO/Virgo scientists narrowed the location of their source on the sky, it lined up with the GBM's signal. "That's when all of us were certain it was the same thing," says Burns.

The observatories had seen two neutron stars spiraling toward one another, circling some 1,500 times before merging. And they saw the resulting energetic light. What else could we learn about this incredible event?

That region of sky hosts some 50 galaxies. Pinpointing the signal's origin required other forms of light. Eleven hours after the LIGO and Fermi events, the area came into view of the Swope Telescope at Las Campanas Observatory in Chile. It spied a new source of light in the outskirts of galaxy NGC 4993. Several other telescopes confirmed the find.

By spreading out the received optical and infrared light by wavelength, astronomers found chemical fingerprints of heavy elements, including those heavier than iron — elements like gold. While researchers know that stellar explosions called supernovae produce these elements, which then diffuse throughout the cosmos and provide material for new stars and planets, supernova blasts account for only part of the universe's heavy element content. Neutron star collisions, it turns out, create the rest.

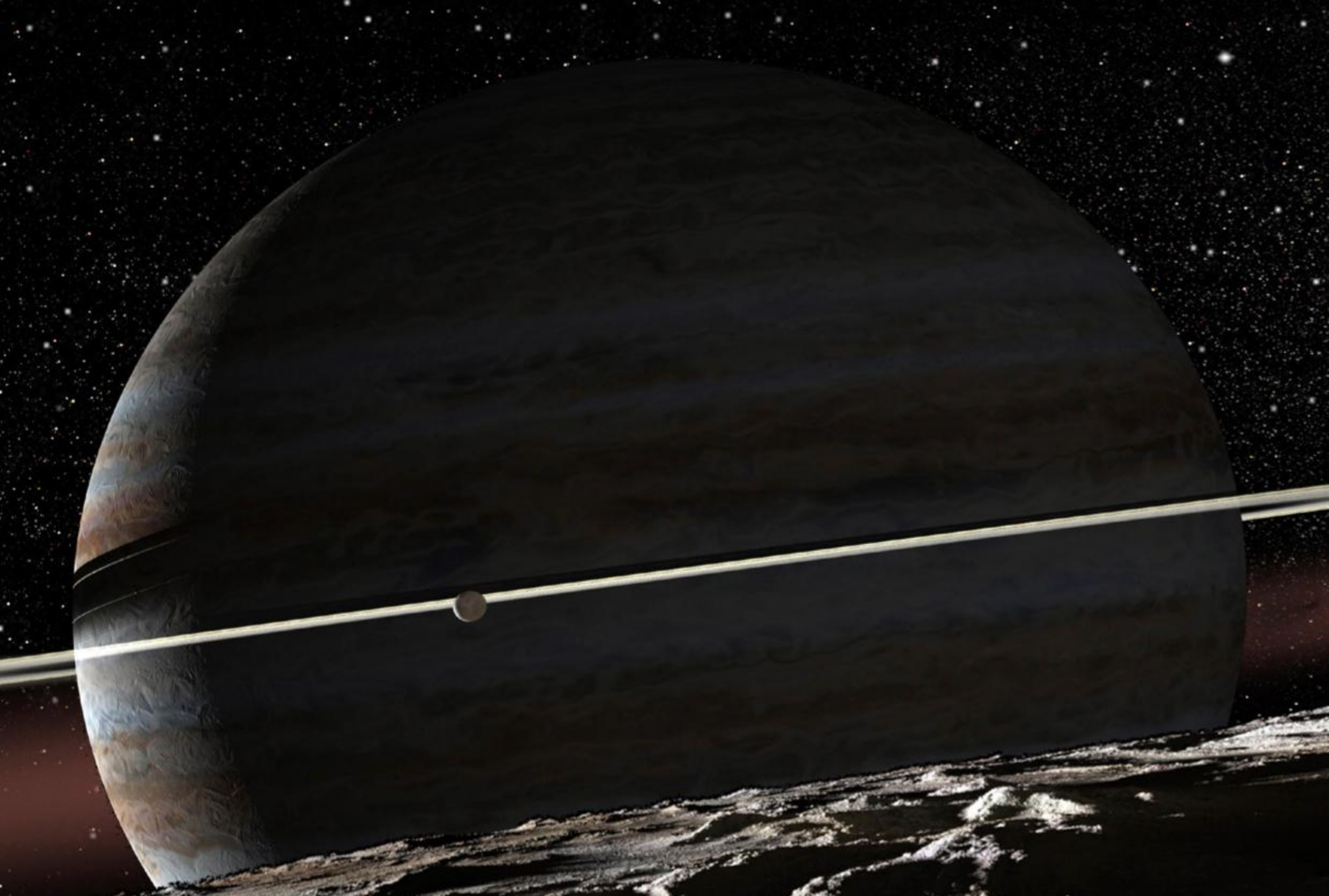
Plenty of questions remain. This round of analysis was just the first, says Burns. "Now it's time for the community to come in and figure out what really happened by combining all of this information, hopefully into a single coherent picture," he says. Perhaps the neutron star merger marks the beginning of multi-messenger gravitational-wave astronomy and the future of the field, in which the entire astronomical community studies all forms of light and gravitational waves together to reveal how the universe's most energetic events work.

Liz Kruesi, *a contributing editor to* Astronomy, *writes about our universe from the sunny locale of Austin, Texas.*

Do exoplanets have moons?

Our solar system harbors at least 180 moons. Now astronomers have launched a quest to find satellites in another system.

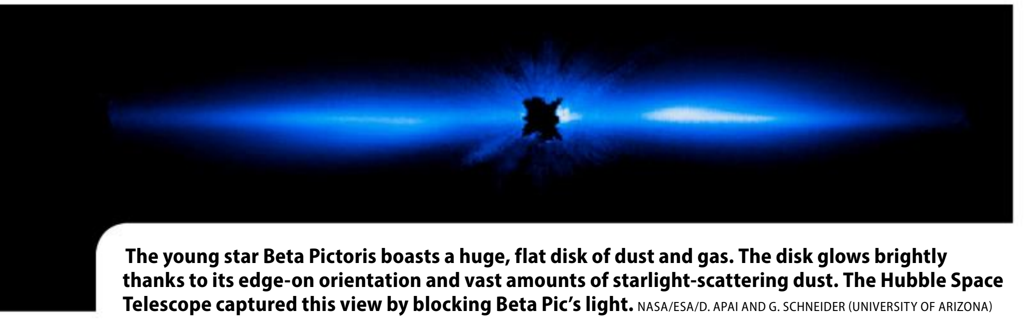
by Nola Taylor Redd



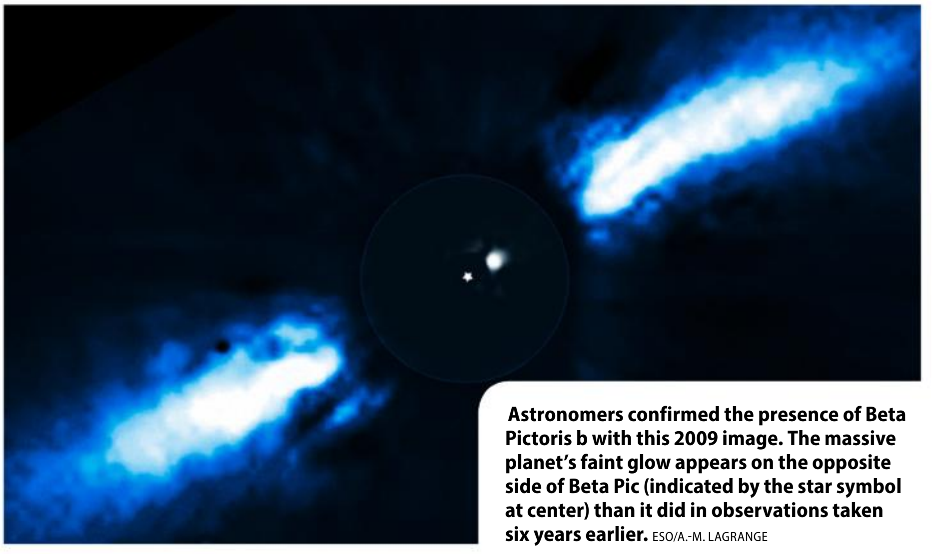
On the African savanna, a tiny telescope with owl-like eyes peers at the heavens. Amid Antarctic ice, a larger instrument stares at the same slice of sky. The two are part of an international hunt to discover the first moon beyond the solar system.

In 2017, a slew of telescopes turned their eyes toward Beta Pictoris, a modest star in the southern sky just 6° from brilliant Canopus. More specifically, astronomers are scrutinizing Beta Pictoris b, one of the few exoworlds discovered through imaging. The star's massive planet barely avoids passing directly between its sun and our planet from April 2017 to January 2018. The near miss opens up a rare opportunity to study any material surrounding the planet, which could boast rings visible from Earth. With a little luck, it may also reveal an exomoon, a planetary satellite beyond the solar system.

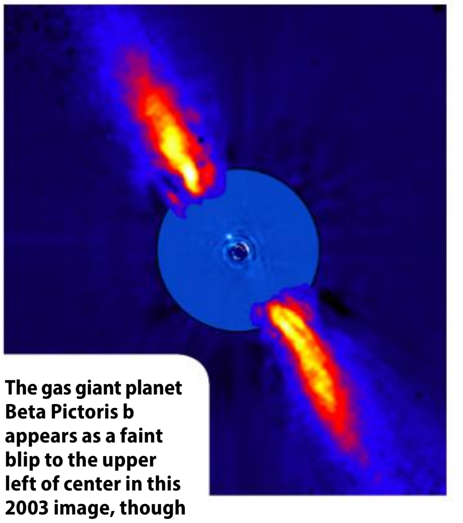
Astronomers are hunting for possible moons and rings around the gas giant planet Beta Pictoris b. Beta Pic itself, enveloped in a dusty disk, lurks in the background. RON MILLER FOR *ASTRONOMY*



The young star Beta Pictoris boasts a huge, flat disk of dust and gas. The disk glows brightly thanks to its edge-on orientation and vast amounts of starlight-scattering dust. The Hubble Space Telescope captured this view by blocking Beta Pic's light. NASA/ESA/D. APAI AND G. SCHNEIDER (UNIVERSITY OF ARIZONA)



Astronomers confirmed the presence of Beta Pictoris b with this 2009 image. The massive planet's faint glow appears on the opposite side of Beta Pic (indicated by the star symbol at center) than it did in observations taken six years earlier. ESO/A.-M. LAGRANGE



The gas giant planet Beta Pictoris b appears as a faint blip to the upper left of center in this 2003 image, though confirmation did not come until 2009. Astronomers carefully subtracted the light of Beta Pic itself to reveal the planet's glow. ESO/A.-M. LAGRANGE ET AL.

Among the Sun's family, moons are abundant. Only two planets — Mercury and Venus — lack orbiting companions. It's not unreasonable to think that moons might be plentiful around exoplanets. So far, however, they've dodged detection. Part of the trouble is technological. Small rocky worlds are barely discernible, and tinier moons present even greater challenges. Luck also plays a role. Although scientists are hunting for exomoons using a variety of techniques, each requires a specific alignment between the candidate object and Earth. And even then, the largest search has targeted hot Jupiters, massive gas giants that circle their host stars in days or even hours. If these giants traveled inward from the outskirts of their system, as many scientists suspect, they may have shed their moons along the way or lost them in a gravitational tug-of-war with their star.

For Beta Pic, however, the stars — and planets — seem to be aligned. The system boasts a gas giant orbiting at about Saturn's distance from the Sun, far enough away that it should be able to hold on to any satellites. Also, the star is only about 20 million years old, so even if the violent interactions common to adolescent systems wind up stripping its moons, there's a good chance they're still orbiting today.

Even more important, the region around the planet where any rings or moons could exist is passing between Beta Pic and Earth over the course of 10 months, with its closest brush in late August 2017. Any moons or rings hiding around the gas giant may well be revealed.

A limited opportunity

When Jason Wang turned his eye toward Beta Pictoris in 2016, he was far from the first astronomer to find it intriguing. Since scientists discovered a disk of gas and dust orbiting the young star in the 1980s, it has garnered plenty of attention. In the 1990s, astronomers detected a warp in this disk that suggested an unseen planet. But it was not until 2009 that Anne-Marie Lagrange of Grenoble Observatory and her colleagues confirmed Beta Pic b through direct imaging. The gas giant holds about 10 times the mass of Jupiter.

Later photos revealed the world drawing closer to our line of sight to Beta Pic. If the planet should cross in front of its sun, the light that it blocked would reveal more information about the world. NASA's Kepler space telescope used this technique, known as the transit method, to discover thousands of exoplanets. With the hope that Beta Pic b would make a similar transit, Wang, a graduate student at the University of California, Berkeley, calculated the planet's path.

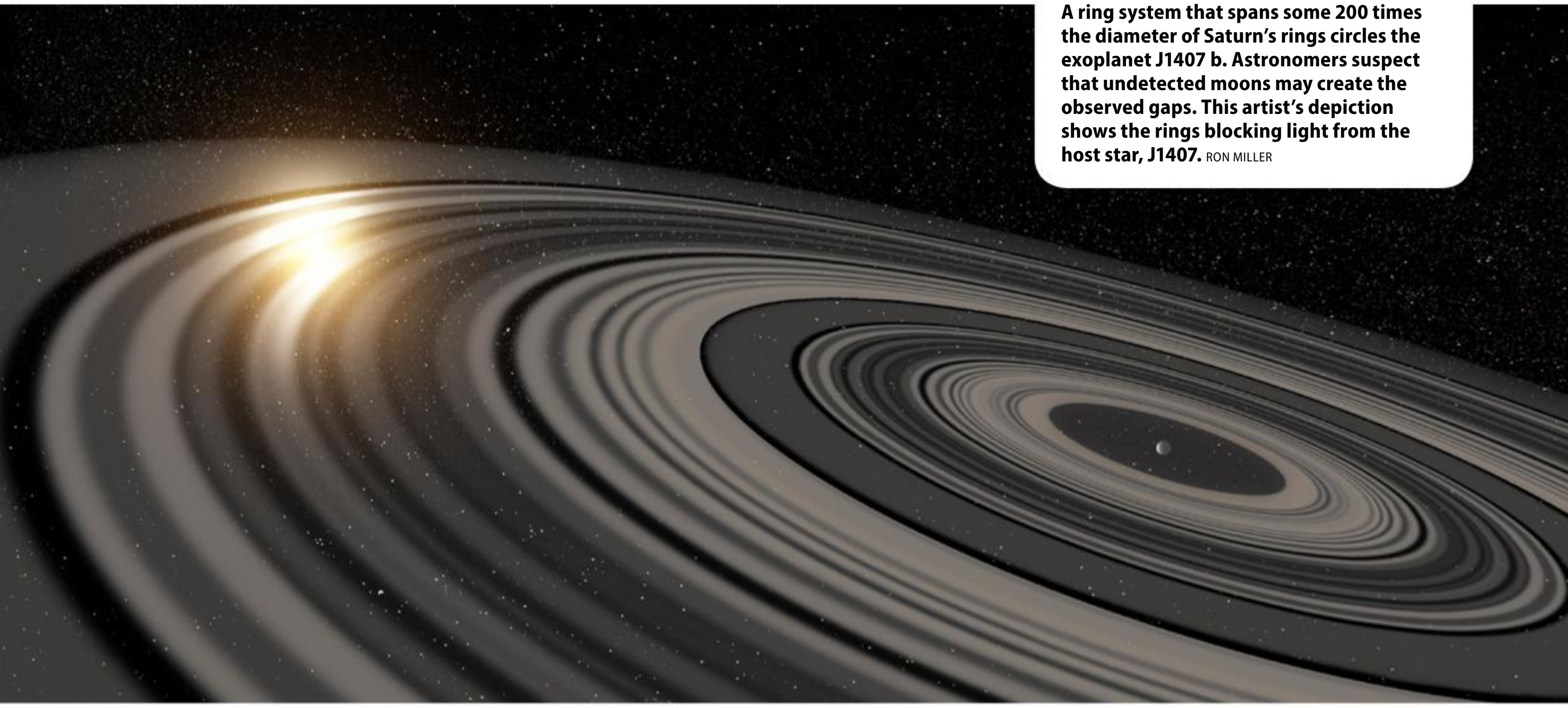
To his disappointment, Wang learned that Beta Pic b dances just outside our line of sight to the star. But he quickly realized that its Hill sphere — the region where a planet's gravity dominates that of its host star and where any rings or moons could orbit — would cross. If the planet carries a massive ring system tilted with respect to Earth, it could be visible, as could a massive moon.

But it can be spotted only if astronomers are looking.

Moons near and far

The solar system's moons play an important role in helping scientists understand how planets form and evolve. For example, Jupiter's four big moons — Io, Europa, Ganymede, and Callisto — help track how water surrounded the gas giant when it was young.

"These four moons, they serve as tracers — or records — of the water or temperature distribution in the circumplanetary accretion disk, which has long gone today," says René Heller of the Max Planck Institute for Solar System Research in Germany. To Heller, these objects could reveal similar characteristics about other planetary systems. Scientists still aren't sure just how planets form; exomoons could help clarify the process. "We can take these moons as yardsticks to calibrate our models of giant planet formation," he says.



A ring system that spans some 200 times the diameter of Saturn's rings circles the exoplanet J1407 b. Astronomers suspect that undetected moons may create the observed gaps. This artist's depiction shows the rings blocking light from the host star, J1407. RON MILLER

An exomoon alone could be a challenge to detect. While Beta Pic b's entire Hill sphere will take from early April 2017 to late January 2018 to transit, a massive moon detectable from Earth would zip by in two days, says Wang. And it may make only a single transit. To confirm an exoplanet, scientists typically have to view at least three transits to rule out other possibilities. Since Beta Pic b takes more than 20 years to orbit its star — and the moon may not be visible during some transits, according to Heller — it could take a century to confirm a moon this way.

Massive rings could be quite a bit easier to spot. Saturn boasts the solar system's most massive ring system, but all the giant planets have rings. Saturn's set remains an enigma, however, because its expected lifetime is much shorter than the age of the solar system, says Heller. Fragments from colliding moons are one possible source, and exoplanets presumably could host similar systems. And a young planet like Beta Pic b may still possess a dazzling, pristine ring system that could put Saturn's to shame.

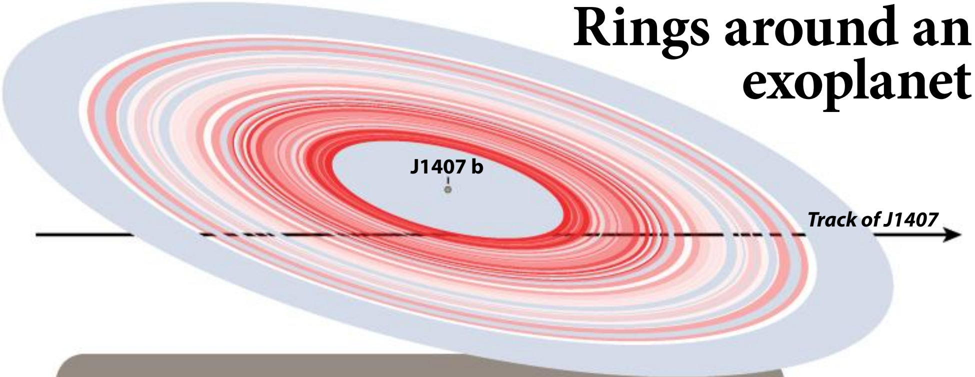
Matthew Kenworthy of Leiden Observatory in the Netherlands knows about rings. In 2007, he and his colleague, Eric Mamajek of the University of Rochester, spotted a massive ring system around a planet circling another star, J1407, only a few million years younger than Beta Pic. The enormous rings stretch nearly 200 times farther than Saturn's, and they have gaps that the researchers tentatively identify with the gravitational pull of exomoons in much the same way that Saturn's moons sculpt its rings.

Ironically, although the rings are visible, the planet has yet to be discovered. The moons also have evaded direct detection; the evidence for them remains circumstantial. Nor have the strange rings eclipsed J1407 again, although Kenworthy and his colleagues are keeping their eyes on the star. But without seeing a planet, there's no way to determine an orbit to know when the geometry might repeat.

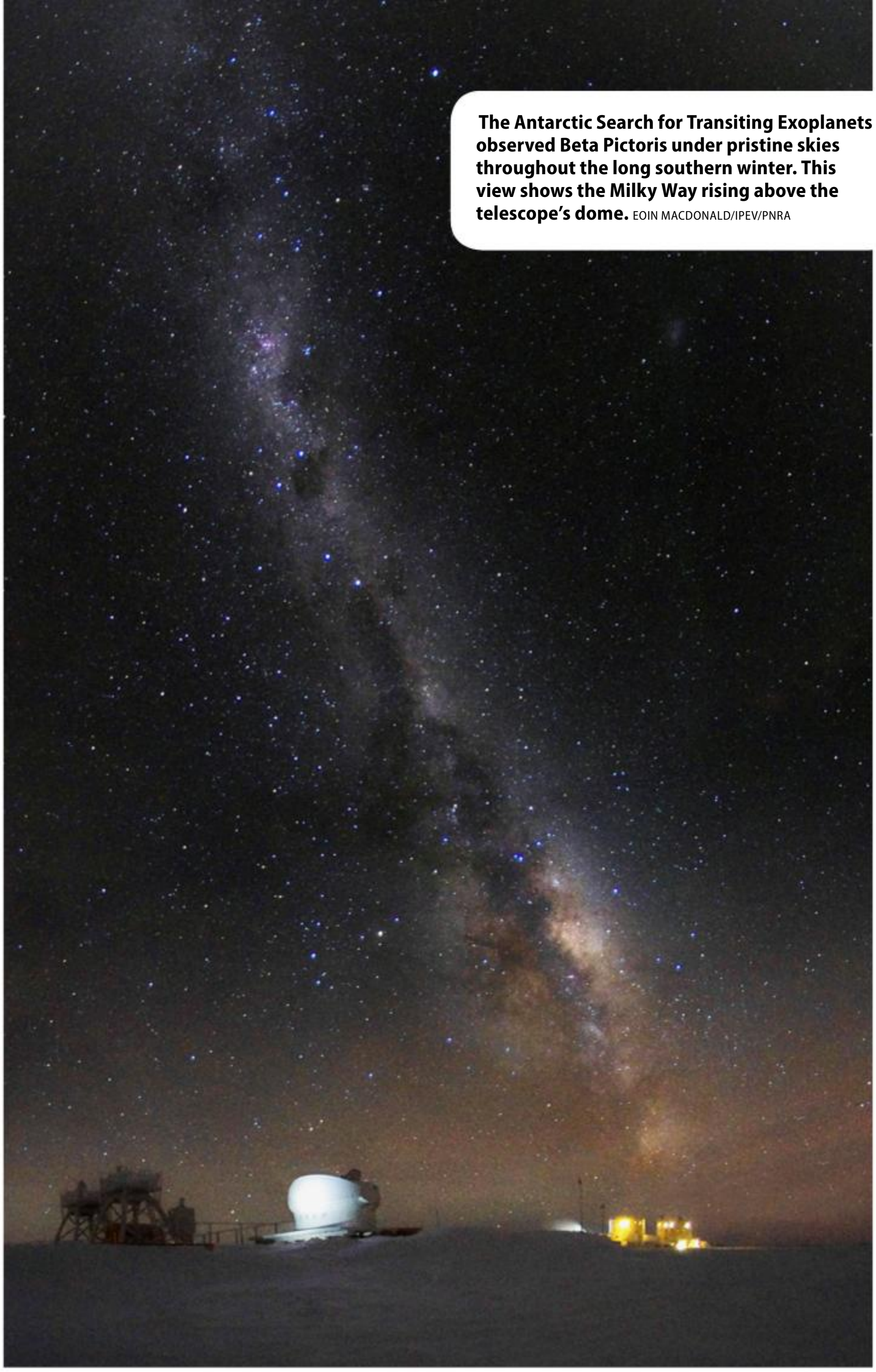
"We think that the same thing may happen with Beta Pic and its planet," says Kenworthy. And this world might provide even better signs of its rings than J1407 did. "The difference is that we know when the planet is moving between us and its star."

There's another reason Kenworthy is mildly optimistic about finding rings. Because Beta Pic is reasonably bright — at 4th magnitude, it's easily visible to the naked eye from a dark site — astronomers have long used it as a standard star to help calibrate observations of other objects. In 1981, a strange fluctuation changed the star's usually steady light over a two-week period, creating a pattern that puzzled astronomers. According to Wang's calculations, there's a good chance that Beta Pic b's Hill sphere transited the star at that time, suggesting that something associated with the planet blocked the star's light. So when Kenworthy heard that the planet itself wasn't going to transit, he began wondering if perhaps a set of massive rings could produce a signal.

Rings around an exoplanet



Astronomers deduced the presence of J1407 b's ring system from the rapid brightness variations it caused as the rings passed in front of the Sun-like star J1407 in 2007. In this plot, the intensity of the red color corresponds to how much light each ring blocked. *ASTRONOMY*: ROEN KELLY, AFTER KENWORTHY AND MAMAJEK



The Antarctic Search for Transiting Exoplanets observed Beta Pictoris under pristine skies throughout the long southern winter. This view shows the Milky Way rising above the telescope's dome. EOIN MACDONALD/IPEV/PNRA

Beta Pic b's Hill sphere stretches roughly the distance between the Sun and Earth. Any rings would have to be enormous for astronomers to spot them from our world. And if any gaps like those seen in the rings around J1407's planet show up, they could be clues to the presence of exomoons. "The potential for seeing exomoons by seeing the path they cleared is very exciting and very plausible," says Kenworthy.

A worldwide hunt

Beta Pic's southern location limits observations because the Southern Hemisphere houses far fewer telescopes than its northern counterpart. So Wang decided to take the search to space. Working with his adviser, Paul Kalas, also from UC Berkeley, Wang has targeted the transit with the Hubble Space Telescope several times. Hubble got its first glimpse in mid-June, when it searched for material orbiting the infant planet. The space observatory took its second look in early August. Wang says their initial analysis of the data shows nothing. But the team has three more observations scheduled between early October and late November (after this issue went to press), and Wang remains optimistic about finding material around Beta Pic b.

Wang isn't the only one studying the planet with Hubble. Paul Wilson, a researcher at France's National Center for Scientific Research, is using the instrument to study the makeup of comets around the distant star. His project searches for the absorption signatures of exocomets imprinted in the spectrum of Beta Pic. Wilson is intrigued to see if the amount of water and other ingredients varies within the Hill sphere, much as lighter compounds in Earth's atmosphere drift higher above our planet's surface. To spot atoms like hydrogen, nitrogen, carbon, and oxygen, Wilson must probe at far-ultraviolet wavelengths, which are visible only from space because Earth's atmosphere absorbs them. Wilson and his colleagues also hope to study the motion of gas and dust around Beta Pic b. If a moon orbits this planet, the team could help determine its natal material.

Far smaller than Hubble is the Bright Target Explorer Constellation (BRITE-Constellation), an array of nanosatellites studying the brightest stars in the sky. The first of the five 8-inch (20 centimeters) telescopes launched in February 2013 to study stellar quakes. Just like earthquakes help reveal the internal structure of our planet, starquakes can reveal what's happening inside a star.

Konstanze Zwintz, a stellar scientist at Austria's University of Innsbruck, previously studied Beta Pic with BRITE-Constellation. Now she has the star in her sights again. Her goal was to map its oscillations precisely before the transit began. Observations of the Hill sphere need to account for Beta Pic's pulsations. Zwintz's models should help other researchers remove the variations of light that come from the star, leaving behind only traces of a ring or moon. Although she won't actually study the star during the transit, the oscillations should remain constant over the short period. "In principle, the mechanism acts like a clock for a very long time," says Zwintz.

Although Hubble could catch a glimpse of a moon as large as Io or Ganymede, two of Jupiter's largest satellites, the odds are against it. Astronomers would have to be incredibly fortunate to spot a two-day transit while the space telescope is pointed at Beta Pic b.

And ground-based observatories couldn't provide a lot of help, particularly during the transit's early stages. Beta Pic climbs highest in the Southern Hemisphere sky late in the calendar year, so it was essentially beyond the reach of earthly instruments until August.

View from a frozen desert

There is one place on Earth where the star remains visible throughout the Southern Hemisphere winter: Antarctica. The winter season keeps the frozen continent shrouded in darkness, so from May to July, it is the only land on Earth where the transit can be viewed. Kalas reached out to Chinese astronomers, who run a handful of modest telescopes in Antarctica, and they planned to observe the transit. He also spoke with Tristan Guillot at the Observatoire de la Côte d'Azur in Nice, France, about a telescope that had only recently left the continent.

The Antarctic Search for Transiting Exoplanets spent four years hunting for exoplanets as they transited their faint host stars before the telescope came home at the end of 2013. But when asked, the French group responsible for the 16-inch (40 cm) instrument was willing to return it to the southern continent.

"This system being so extraordinary, IPEV, the French Polar Institute, was willing to make a really important effort to allow this telescope to be flown back to Antarctica," says Guillot. "This is something really special."

Operating in Antarctica isn't without its challenges. Standard electric cables become as fragile as glass once temperatures plunge to –58 degrees Fahrenheit (–50 degrees Celsius), says Guillot, so you have to be extremely careful with connections. And electronics and parts built to withstand –4 F (–20 C) begin to have problems when they reach –112 F (–80 C), even when heated.

While it rarely snows on the continent, ice can form. The base sits on a plateau at an elevation of 10,000 feet (3,000 meters), and when the wind blows, it can carry ice to cover the instruments. Frost and condensation are concerns, too. And any technical problems must be resolved from a distance. Only about a dozen people remain on the base over the winter, and they aren't astronomers; they can fix any mechanical issues, but they can't address scientific concerns.

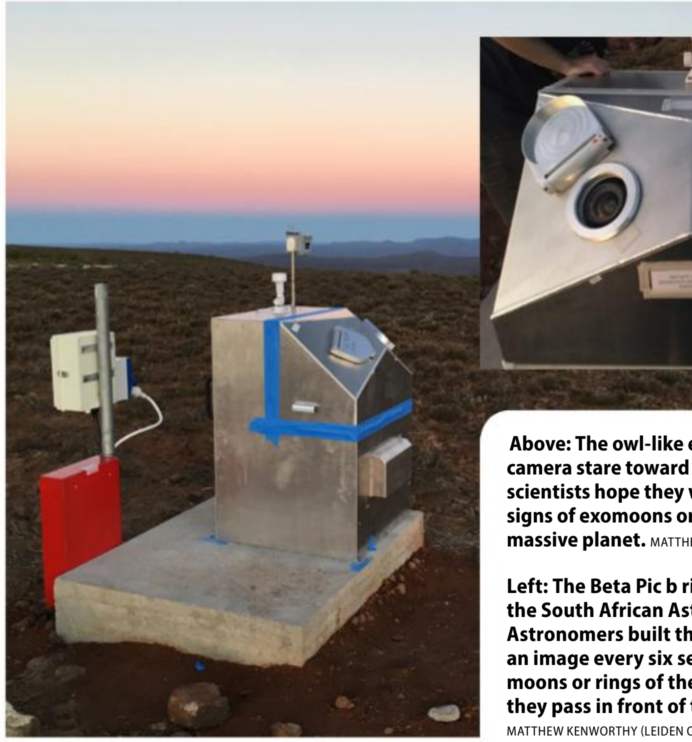
"It's not easy, but once you overcome all that, then you have the reward of a night that can be really, really nice with extremely good conditions," Guillot says.

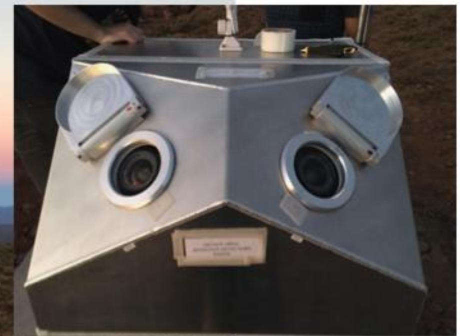
While Antarctica was the only continent where Beta Pic was well placed throughout the southern winter, it won't be the only site viewing the transit's latter stages. Telescopes in Chile and South Africa were set to peer at the star after August, once it put some distance between itself and the Sun.

Kenworthy has built a ground-based telescope just for the event. In January 2017, he installed the Beta Pic b ring camera — bRing for short — on the African savanna at the South African Astronomical Observatory. About the size of a mini-fridge, the telescope sits off to the side of larger instruments, its camera eyes peering toward the south. The scope takes an image every six seconds, and three computers inside the instrument crunch the data before transmitting it back home. A second bRing, supervised by Mamajek, has been set up in Australia, and the two should provide nearly continuous coverage of the night sky. If a large series of exorings exists within Beta Pic b's Hill sphere, the bRing team should know pretty quickly.

"We're pretty sure we'll see something, but we're not sure when we'll see it or how big the signal will be," says Kenworthy.

This loose-knit band of astronomers is working together, each on their own individual projects, to reveal the secrets of Beta Pictoris. "This is a worldwide effort," Kalas says. If one of the teams spots something unusual, it will immediately share the news with everyone else, including other astronomers who don't have their eyes trained on the bright young star. They hope any find will galvanize even more astronomers to turn their attention to Beta Pic. "It's quite an exciting and unusual time," says Kenworthy.





Above: The owl-like eyes of the Beta Pic b ring camera stare toward the southern sky, where scientists hope they will pick up the telltale signs of exomoons or exorings around the massive planet. MATTHEW KENWORTHY (LEIDEN OBSERVATORY)

Left: The Beta Pic b ring camera operates from the South African Astronomical Observatory. Astronomers built the camera, which takes an image every six seconds, to record any moons or rings of the gas giant planet as they pass in front of their host star. MATTHEW KENWORTHY (LEIDEN OBSERVATORY)

The 16-inch telescope of the Antarctic Search for Transiting Exoplanets and its dome rest on the frozen desert of Earth's southernmost continent. This December 2016 view shows the instrument before it began its Beta Pictoris observing campaign. DJAMEL MEKARNIA AND ABDELKRIM AGABI/IPEV/PNRA

Nola Taylor Redd *is a freelance science writer who writes about space and astronomy while home schooling her four kids.*

MARTIN RATCLIFFE and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

January 2018: Totality over America

On October 8, 2014, the Full Moon passed into Earth's umbral shadow and created this stunning total lunar eclipse. On January 31, observers across more than half the globe can witness a similar event. DAMIAN PEACH

All of January's naked-eye planets congregate in the morning sky. Mars and Jupiter lead the way, and they provide the month's planetary highlight when they pass within 1° of each other during the New Year's first week. The pair makes a stunning backdrop for the Moon when it slides by a few days later. Mercury and Saturn also shine brightly from their positions lower in the predawn sky.

But the Moon deserves top billing in January's sky show. On the 31st, our satellite dives completely into Earth's umbral shadow, bringing a total lunar eclipse to viewers in much of North America, the Pacific Ocean, Asia, and Australia. This is the first total eclipse since September 2015.

From North America, the eclipse occurs before dawn and delivers better views to those who live farther west. East of a line that runs from the Ohio-Indiana border to New Orleans, the eclipse starts after the onset of twilight and the Moon sets before totality begins. The Full Moon enters Earth's umbral shadow at 6:48 A.M. EST (3:48 A.M. PST). Within 10 minutes, the lunar orb looks like a giant sugar cookie with a bite taken out of it.

The geometry of the Sun, the Moon, and Earth drives itself home during lunar eclipses in twilight. With the Sun just below the eastern horizon before dawn and the eclipsed Moon hanging low in the west, you can almost feel the giant rock you're standing on casting its shadow all the way to its only natural satellite.

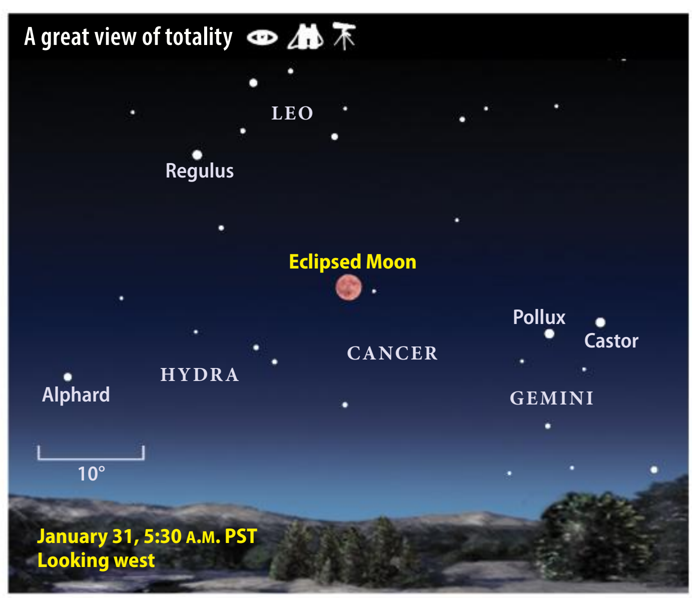
Those in the continent's western two-thirds can view at least some of totality, which gets underway at 6:52 A.M. CST (4:52 A.M. PST). Totality lasts 76 minutes and can be seen in its entirety west of a line that runs from central North Dakota to New Mexico. The eclipsed Moon hangs among the stars of Cancer the Crab with the Beehive star cluster (M44) 4° to its northwest.

Observers in Northern California, Oregon, and Washington get to witness the concluding partial phases, which wrap up at 7:11 A.M. PST. Fortunately, we don't have long to wait for the next total lunar eclipse. Earth will cast its shadow on the Moon on July 27 (though this time the eclipse won't be visible from North America), and again the night of January 20/21, 2019.

The eclipse isn't Luna's only distinction during January. Totality occurs at the month's second Full Moon, so it also earns recognition as a Blue Moon. Our satellite reaches its first Full phase on New Year's Night. This is the closest Full Moon of 2018, so it is also the biggest (33.5' across), and many people will feel compelled to label it a "Super Moon."

Although no planet rises to the level of "super" this month, most will reward your viewing efforts. The evening sky offers the two outermost and dimmest members of the solar system's family. Despite their faintness, both Uranus and Neptune are within range of binoculars. **Neptune** lies lower and should be your first target. In early January, the ice giant stands 30° above the southwestern horizon at the end of twilight.

Neptune glows at magnitude 7.9 among the background stars of Aquarius. You can find it near



Viewers in western North America won't want to miss the spectacular total lunar eclipse in January 31's predawn sky. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

RISING**MOON**

Reading ages from a crater's structure

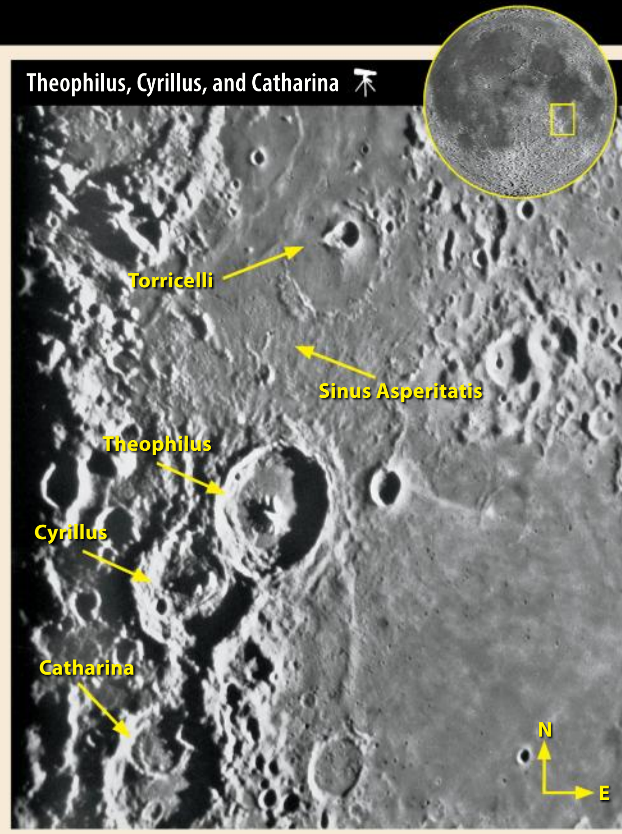
If there's a best face to the Moon, the thick waxing crescent phase has to be it. Large waves seem to swell across smooth seas, big craters take your breath away, and small impacts stand out by casting long shadows. On the evening of January 22, the Serpentine Ridge grabs your attention as a couplet of light and darkness snaking across Mare Serenitatis (Sea of Serenity) north of the equator. Although it looks like a frozen wave rippling through the lava, it's actually a compression feature formed when the mare lavas contracted.

Scanning southward, you'll cross Mare Tranquillitatis (Sea of Tranquility) before running into the crater Theophilus. This 60-mile-wide, sharp-edged impact feature presents a complex jumble of central peaks and slumped terraces on the rim's inside slopes. Just to its south lies Cyrillus. Although this crater is the same size as Theophilus, its softer edges imply an older age.

Still farther south rests ancient Catharina. Its lower, rounded rim signifies a longer history of pummeling. The impact that created Theophilus spread a rugged debris apron north into the Sea of Tranquility. Selenographers named this bleak landscape Sinus Asperitatis (Bay of Roughness).

The unusual double crater Torricelli lies in this bay. Planetary scientists think its weird shape arose from a single glancing blow instead of two unrelated events. A fraction of a second after the initial impact, what was left of the projectile blasted through the back wall of the developing main crater. Torricelli — named after the Italian scientist who invented the mercury barometer — sits off-center in a low-profile, battered bowl filled to the brim with solidified lava.

Theophilus, Cyrillus, and Catharina



This trio of lunar craters on the waxing crescent Moon tells a tale of advancing age, from Theophilus in the north to Catharina in the south. *CONSOLIDATED LUNAR ATLAS*/UA/LPL; INSET: NASA/GSFC/ASU

4th-magnitude Lambda (λ) Aquarii. On the 1st, the planet lies 0.5° southeast of Lambda. By the 31st, Neptune stands 1.1° due east of the star. While binoculars reveal the world as a dim pinpoint, a telescope shows the planet's blue-gray disk, which spans 2.2".

Uranus shines brighter and lies farther east, against the backdrop of eastern Pisces. Although the planet is an easy binocular object at magnitude 5.8, Pisces has few bright stars to guide you. Your best bet is to home in on 5th-magnitude Mu (μ) Piscium. Uranus remains nearly stationary during January some 3° north of the star. And no other object in the area shines so brightly.

Uranus stands nearly 60° above the southern horizon as darkness falls. That's the best time to target the distant

— Continued on page 42

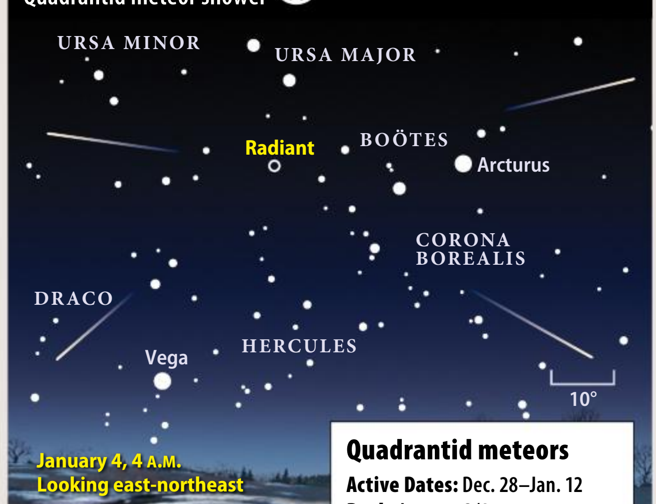
METEORWATCH

The Super Moon's unwelcome impact

Although the Quadrantids rank among the year's strongest showers, the 2018 edition likely won't be memorable because of the January 1 Super Moon. At the peak before dawn on the 4th, bright moonlight will wash out faint meteors and make the brighter ones less impressive. The hourly rate can top 100 meteors in good years, but observers may be lucky to see 20 this year.

Observers shouldn't give up, however. Bright meteors still show up through moonlight, and the nice planet grouping before dawn makes an early morning observing session all the more worthwhile.

Quadrantid meteor shower



Bright moonlight mars the peak of January's best meteor shower, rendering it less impressive than in most years.

Quadrantid meteors
Active Dates: Dec. 28–Jan. 12
Peak: January 3/4
Moon at peak: Full Moon
Maximum rate at peak: 110 meteors/hour

OBSERVING HIGHLIGHT The Full Moon on January 31 slides deep into Earth's shadow, bringing a total eclipse to observers from North America to Asia.

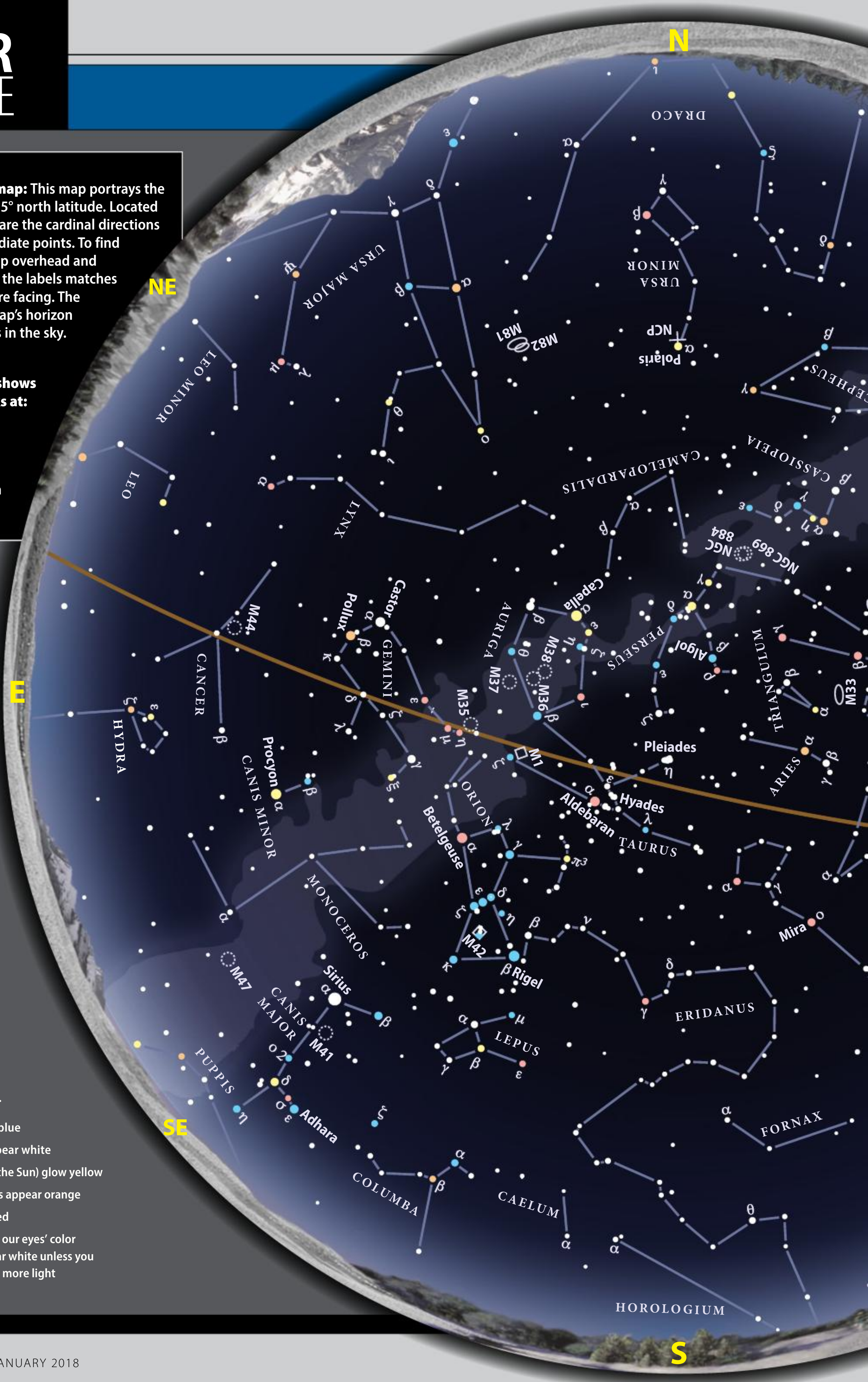
STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. January 1
8 P.M. January 15
7 P.M. January 31

Planets are shown at midmonth



STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

JANUARY 2018

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	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			

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

1 Mercury is at greatest western elongation (23°), 3 P.M. EST

The Moon is at perigee (221,559 miles from Earth), 4:49 P.M. EST

Full Moon occurs at 9:24 P.M. EST

2 Asteroid Flora is at opposition, 1 P.M. EST

Uranus is stationary, 4 P.M. EST

3 Earth is at perihelion (91.4 million miles from the Sun), 1 A.M. EST

Quadrantid meteor shower peaks

5 The Moon passes 0.9° north of Regulus, 3 A.M. EST

SPECIAL OBSERVING DATE

7 Mars passes 0.2° south of Jupiter before dawn.

8 Last Quarter Moon occurs at 5:25 P.M. EST

9 Venus is in superior conjunction, 2 A.M. EST

Pluto is in conjunction with the Sun, 5 A.M. EST

11 The Moon passes 4° north of Jupiter, 1 A.M. EST

The Moon passes 5° north of Mars, 5 A.M. EST

11 The Moon passes 0.4° south of asteroid Vesta, 11 P.M. EST

13 Mercury passes 0.6° south of Saturn, 2 A.M. EST

14 The Moon passes 3° north of Saturn, 9 P.M. EST

The Moon is at apogee (252,565 miles from Earth), 9:10 P.M. EST

15 The Moon passes 3° north of Mercury, 2 A.M. EST

16 New Moon occurs at 9:17 P.M. EST

20 The Moon passes 1.6° south of Neptune, 3 P.M. EST

23 The Moon passes 5° south of Uranus, 8 P.M. EST

24 First Quarter Moon occurs at 5:20 P.M. EST

27 The Moon passes 0.7° north of Aldebaran, 6 A.M. EST

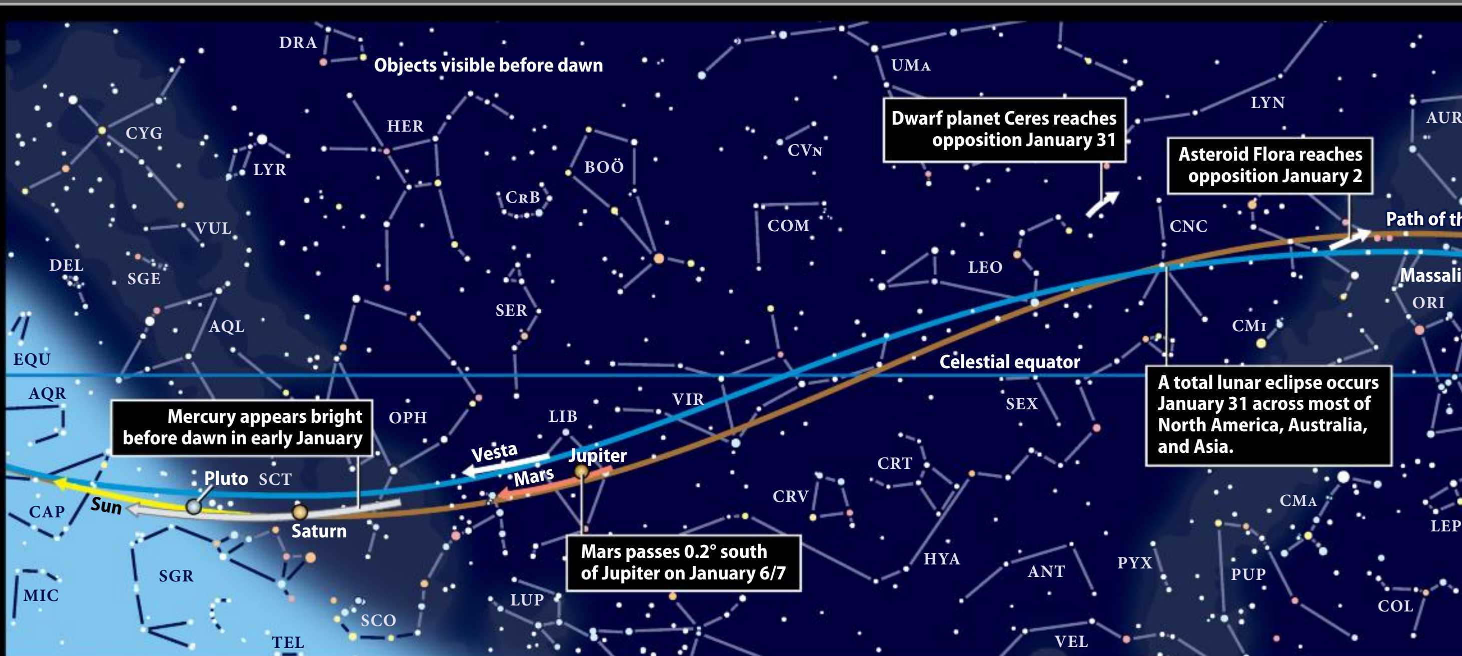
30 The Moon is at perigee (223,068 miles from Earth), 4:57 A.M. EST

31 Dwarf planet Ceres is at opposition, 8 A.M. EST

Full Moon occurs at 8:27 A.M. EST; total lunar eclipse

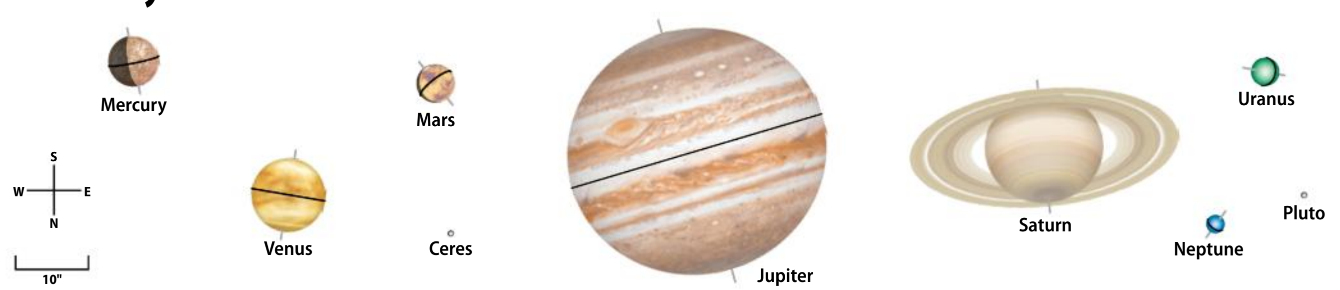
BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

The planets in January 2018



The planets in the sky

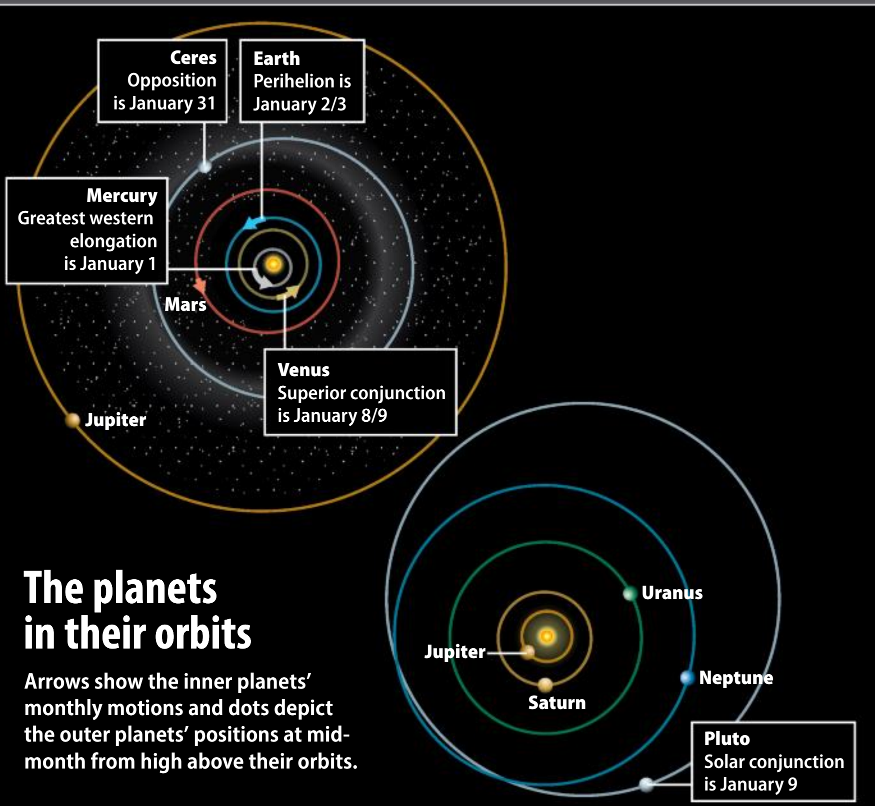
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Jan. 1	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15
Magnitude	–0.3	–4.0	1.4	7.1	–1.9	0.5	5.8	7.9	14.3
Angular size	6.7"	9.8"	5.1"	0.8"	34.2"	15.1"	3.5"	2.2"	0.1"
Illumination	62%	100%	92%	99%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.999	1.711	1.830	1.645	5.761	10.972	19.879	30.601	34.464
Distance (AU) from Sun	0.389	0.728	1.619	2.576	5.430	10.065	19.901	29.945	33.485
Right ascension (2000.0)	17h07.4m	19h52.3m	15h21.8m	9h26.0m	15h06.9m	18h11.9m	1h31.2m	22h55.0m	19h22.1m
Declination (2000.0)	–20°52'	–21°54'	–17°39'	28°00'	–16°24'	–22°31'	8°56'	–7°54'	–21°40'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

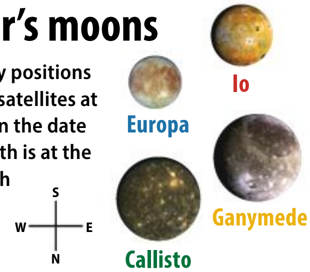


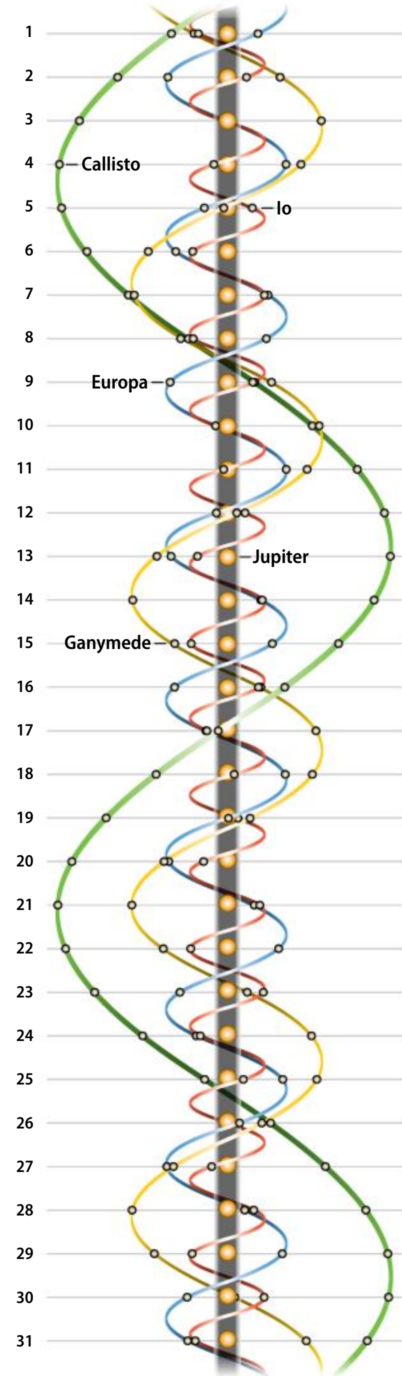
The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EST on the date shown. South is at the top to match the view through a telescope.





ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

— *Continued from page 37*

WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Uranus (south)	Uranus (west)	Mercury (southeast)
Neptune (southwest)		Mars (southeast)
		Jupiter (south)
		Saturn (southeast)

Jupiter's moons on the verge of eclipse

On January 10, Io and Europa simultaneously disappear into Jupiter's shadow just a few minutes after the scene depicted here.

world through a telescope. A view at medium power reveals Uranus' 3.5"-diameter disk and distinct blue-green color.

The rest of the visible planets congregate in the morning sky. **Mars** already has begun its long trek toward an outstanding opposition in July. Or, more accurately, Earth has started to catch up to Mars as our planet speeds around the Sun a bit more quickly than its outer neighbor. The Red Planet will linger in the morning sky for several months, at first growing slowly in brightness and apparent size as Earth draws closer. The snail's pace will pick up this spring as Mars gets ready for a spectacular summer show.

On January 1, Mars stands 2.6° west of **Jupiter** and the pair rises more than four hours before the Sun. Mars shines at magnitude 1.5 while Jupiter dazzles at magnitude –1.8. The two straddle Libra's second-brightest star, magnitude 2.8 Zubenelgenubi (Alpha [α] Librae), which itself is a fine double.

The planets shift eastward relative to the background stars during January, with Mars moving faster in its inner orbit. Watch every morning as their positions change relative to Zubenelgenubi and to each other. On the 2nd, Mars passes 0.6° north of Alpha. And on the 7th, the two solar system worlds stand just 16' apart. This is the closest they've been since September 2004, but they were then just a few degrees from the Sun and invisible. They haven't been this close and visible since January 1998.

A telescope shows both planets in a single low-power field of view. Mars spans 5" compared with Jupiter's 34". Yet Jupiter lies three times farther away, a testament to its status as a giant planet.

Just four mornings after this fine conjunction, a waning crescent Moon joins the two in a stunning predawn display. On January 11, Mars stands 4.6° south of the Moon while Jupiter lies 2.1° west of the Red Planet. Use binoculars for a close-up view or just enjoy the scene with your naked eye.

Although the planets rise earlier with each passing morning, the gap between the two grows wider. Slowpoke Jupiter remains in Libra all month, while Mars speeds across that constellation and enters Scorpius on the 31st. Having brightened to magnitude 1.2, the Red Planet stands 9° northwest of the

COMETSEARCH

A snowball in the winter sky

Comet PANSTARRS (C/2016 R2) shares the sky with dozens of deep-sky gems sprinkled across the winter Milky Way. It glides past the head of Taurus the Bull during January as it heads north, and it remains on view for most of the night.

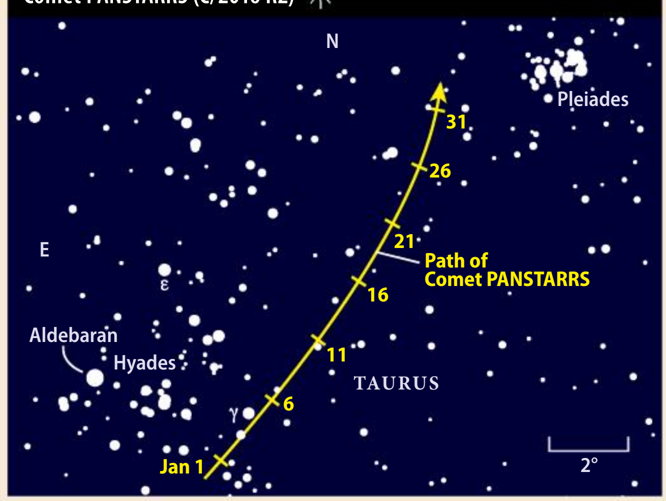
A small ball of dust and ice, PANSTARRS simultaneously is out of place and at home. Visually it appears much like a 10- or 11th-magnitude elliptical galaxy, at odds with the sparkling open star clusters and amorphous gas clouds in this area. Yet the fingers of obscuring dust and gas in the background are every bit like the nursery that gave birth to our solar system and its shell of comets, the Oort Cloud.

C/2016 R2 should be within reach of 4-inch telescopes under a dark sky. From the suburbs, you'll likely need a 10-inch scope to spot it. On a positive note, it should be compact and well-defined, making it a good target at medium or high power.

Astroimagers will want to capture PANSTARRS in this photogenic region near the Hyades and Pleiades (M45) star clusters. Deeper exposures also will record the wisps of galactic dust and gas that thread through the Milky Way's outer spiral arm. Imagers should skip the first few days of January and the month's final week when the Moon interferes.

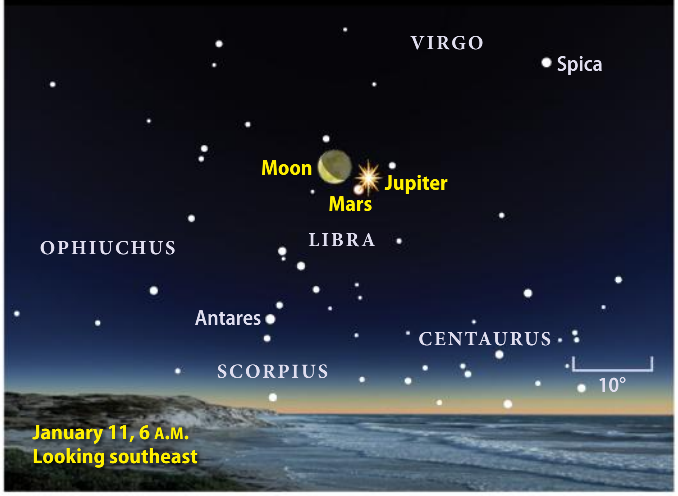
Although the first few months of 2018 don't show much promise for bright comets, things should pick up this summer. And if predictions hold, Comet 46P/Wirtanen could become visible to the naked eye next autumn.

Comet PANSTARRS (C/2016 R2)



This first-time visitor to the inner solar system should glow around 10th magnitude as it travels between the Hyades and Pleiades star clusters.

The Moon slides past Mars and Jupiter



A waning crescent Moon stands above Mars and Jupiter in the predawn sky January 11. Brilliant Jupiter shines 20 times brighter than ruddy Mars.

Scorpion's brightest star, magnitude 1.1 Antares. The star's name literally means "rival of Mars," and the similarities between their brightnesses and hues this month will help you understand why ancient astronomers made the comparison.

This new season of Jupiter observations promises some splendid views through a telescope. The best observing comes shortly before twilight starts to paint the sky. In mid-January, the giant planet stands some 30° high in the southeast at that time, and its 34"-diameter disk should look impressive through any telescope. Notice the two dark equatorial belts that sandwich a brighter zone coinciding with Jupiter's equator.

The jovian satellites are also worth a look. You'll typically see the four brightest — Io, Europa, Ganymede, and Callisto — arrayed beside the planet's disk, though occasionally one or more will hide in front of or behind Jupiter. A good example of vanishing moons comes January 10. At 5:28 A.M. EST, Io and Europa simultaneously disappear into the giant planet's shadow. Track the two moons for the half-hour leading up to the eclipse and then watch them fade over several minutes.

You can find **Mercury** to the lower left of Mars and Jupiter during January's first three weeks. The innermost planet reaches greatest elongation on the 1st, when it lies 23° west of the Sun and stands 11° high in the southeast 30 minutes before sunrise. It shines at magnitude –0.3, more than a full magnitude brighter than ruddy Antares 11° to its right. A view through a telescope reveals the planet's disk, which spans 6.7" and appears 62 percent lit.

Mercury loses altitude each morning. On January 10, it's still a decent 8° high a half-hour before sunup, but that drops to just 4° by the 20th. Although the planet remains at magnitude –0.3 throughout this period, it becomes progressively harder to see in bright twilight. Its disk also shrinks and becomes more fully illuminated, making telescopic views less appealing.

But you'll want to be sure to look for Mercury on January 13 because **Saturn** then lies just 0.6° north of the inner world. You'll probably need binoculars to spot the magnitude 0.5 ringed world in the bright twilight.

But unlike its neighbor, Saturn climbs higher with each passing day. By the end of the month, the planet appears 10° high in the southeast an hour before sunrise. You should be able to spot it easily among the background stars of Sagittarius. Unfortunately, Saturn's low altitude means it won't look that great through a telescope. You're better off waiting a month or two for it to return to glory.

The last of the solar system's major planets remains out of sight all month. **Venus** reaches superior conjunction January 8/9, when it passes on the opposite side of the Sun from Earth. Look for it to reappear low in the evening sky in late winter.

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

LOCATING**ASTEROIDS**

Out of darkness comes the light

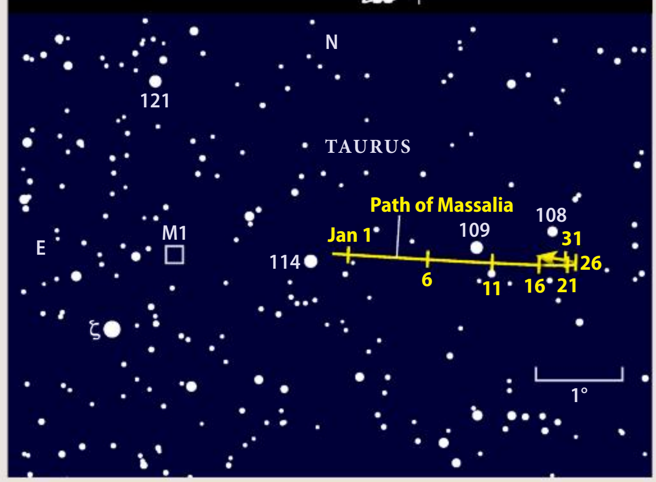
Asteroid 20 Massalia reached opposition in mid-December, which places it high in January's evening sky and not far from its peak brightness. Massalia glows at 9th magnitude this month as it treks across eastern Taurus.

Although you might think the asteroid would be difficult to locate among the swarms of faint Milky Way stars, it fortuitously passes in front of the dark clouds of dust and gas in this region. Only a relative handful of stars shines through, leaving the 90-mile-wide asteroid in the open.

Avoid looking for it on the first few and last few nights of the month when the Full Moon lies nearby. Start at 3rd-magnitude Zeta (ζ) Tauri, the star that marks the tip of the Bull's southern horn.

Take a quick look at the Crab Nebula (M1) 1° to the northwest before targeting 5th-magnitude 114 Tau 1.6° farther west. Just three stars matching Massalia's brightness reside near the path to 5th-magnitude 109 Tau, which lies 2° west of 114. Your best bet for seeing Massalia move during a single observing session comes the evenings of January 10 and 11, when the asteroid slides 0.2° south of 109 Tau.

Massalia horns in on Taurus the Bull



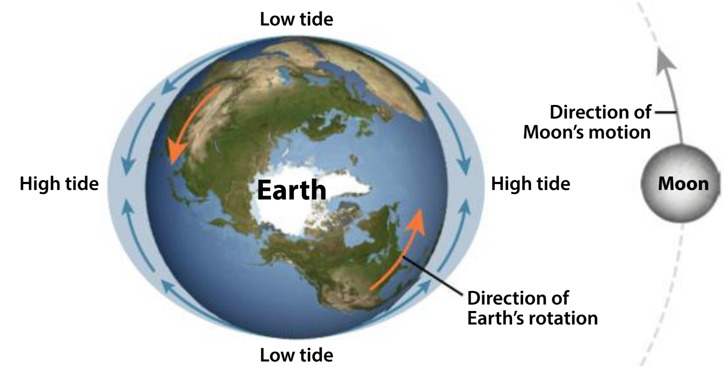
This 9th-magnitude asteroid should be easy to find during January as it moves slowly against the backdrop of eastern Taurus.

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

CELESTIAL MOTION

Q: I SAW A PROGRAM THAT SHOWED THE MOON REVOLVING AROUND EARTH, CAUSING THE OCEANS TO SWELL ON BOTH SIDES OF THE PLANET. SHOULDN'T THE OCEAN OPPOSITE THE MOON BE SHALLOWER THAN THE SIDE FACING IT?

Michael Gamble, *New Berlin, Illinois*



The ocean nearest the Moon bulges outward in a high tide because of increased gravitational attraction. On the other side of Earth, the ocean bulges outward as the rest of the planet is pulled toward the Moon. Low tide occurs at the two points on Earth between the bulges. *ASTRONOMY*: ROEN KELLY

A: Tides occur because of the uneven pull of the Moon's gravity on different parts of Earth. Portions closer to the Moon are pulled more strongly than those farther away. As the Moon pulls on the portion of the planet nearest its location, the water deforms and bulges toward the Moon more easily than the seafloor beneath. On the far side of Earth, the water is "left behind" as the rest of the Earth feels a stronger attraction to the Moon, causing the water to pile up and bulge away from the planet. Earth's rotation causes most locations to experience these two bulges each day, approximately 12 hours apart.

The Sun also influences tides on Earth, though its effect is slightly less than half as strong as the Moon, due to its greater distance. During the Full and New Moon phases when Earth, the Moon, and the Sun are aligned, these gravitational interactions reinforce each other. This gives us the highest high tides and lowest low tides (called spring tides). During the First and Last Quarter Moon, the tidal forces from the Sun and Moon are working in different directions, leading to smaller tidal bulges (neap tides).

Tides are even more complex than this; not all places on Earth have two equal high and low tides per day (called semidiurnal tides). Some places, such as the Gulf of Mexico, only have one high and one low tide per day because the surrounding landmasses prevent the free flow of water throughout the globe. As a result, more complex patterns occur in particular regions.

April Russell
Visiting Professor, Siena College, Loudonville, New York

ESA/HUBBLE AND NASA

The globular cluster Messier 68 is 33,000 light-years from Earth and spans about 100 light-years. At least 2,000 bright stars are easily visible, but this cluster likely contains several tens of thousands more.

Q: WHAT ARE THE MOTIONS OF STARS RELATIVE TO EACH OTHER IN A GLOBULAR OR OPEN CLUSTER? DOES THE CLUSTER MOVE AS A UNIT OVER TIME?

George Haskins
Auburn, Washington

A: Globular clusters are compact groups of up to a million or so stars held together by their mutual gravitational attraction, with a nearly spherical distribution and high density in the center. Our own galaxy has approximately 170 globular clusters separated into two subsystems associated with the galactic disk and halo. The movement of halo star clusters traces the galactic gravitational field at large scales, and their spatial distribution provides stringent constraints for models of dark matter distribution in the outer parts of the galaxy.

In a globular cluster, star motions are determined by the sum of the mass of all stars within the cluster. The cluster's internal dynamics are also affected by its "relaxation time," which is the time it takes for random encounters between stars to erase information about their initial orientation. For globular clusters, the average relaxation time is shorter than their age, so it can be argued that they are close to a relaxed state, like air molecules at room temperature. This is the physical reason why the orbits of member stars do not have a preferential orientation (i.e., their distribution is "isotropic") around the center of mass of the cluster itself. This is even more pronounced in open clusters, which are typically smaller systems of only a few thousand stars.

Measuring the motions of the stars in a given globular cluster is beyond the capabilities of small telescopes. The European Space Agency's Gaia observatory is currently measuring the positions and velocities of thousands of star clusters in our galaxy with unprecedented accuracy. This data, coupled with decades-long observational campaigns by the Hubble Space Telescope and other surveys (e.g., the Gaia-ESO survey, conducted with the Very Large Telescope in Chile), will soon enable us to study the distribution of globular clusters' individual stars in position and velocity space. Stay tuned for the many interesting discoveries that will surely emerge!

Anna Lisa Varri
Marie Skłodowska-Curie Research Fellow, Institute for Astronomy, University of Edinburgh, Scotland

Q: HOW FAR CAN A PAIR OF STARS BE SEPARATED AND STILL MAINTAIN A STABLE ORBIT AROUND EACH OTHER?

Robert Bobo
McKenzie, Tennessee

A: There are two issues here: First, how far apart can two stars form and remain bound? And second, once formed, how far apart can they survive as a pair? There are a number of ideas being debated for how very wide binaries can form. The Gaia satellite will, with its precision measurements, identify many thousands of ultra-wide binaries that we can study, and their properties will help astronomers to determine the most likely formation mechanism behind them.

The second issue is better understood. If the two stars in a very wide binary were the only stars in the universe, the pairing could survive forever. But the universe is a busy place, and our Milky Way alone contains more than 100 billion stars moving around its center. A very wide binary has a very weak gravitational bond, so if another star passes near the binary, the pair can break apart. Eighty years ago, Armenian astronomer Victor Ambartsumian calculated that a wide binary rarely breaks apart as the result of a single close encounter with another star, but rather through numerous distant passages that each gently tug on the binary until it imperceptibly passes from being bound to being unbound.

For a very long time, the two stars will still travel together through space until eventually they part ways. An ultrawide binary with a separation of 0.5 parsec (1.6 light-years) is statistically likely to break up within just 100 million years, while a slightly less extreme binary with separation around 0.1 pc (0.3 light-years) may survive for more than 1 billion years.

In summary, there is no known fixed upper limit for binary separations, but the wider a binary is, the more difficult it will be to find.

Bo Reipurth
Institute for Astronomy, University of Hawaii

Q: HOW DO WE KNOW WHAT STARS ARE BEHIND DARK NEBULAE (IF THEY ABSORB THE LIGHT FROM BACKGROUND STARS)?

Margaret Lucero
Baldwinsville, New York

A: You've actually answered your own question here. The key word is "absorption."

Interstellar space is not a perfect vacuum. The mean density in interstellar space in our part of the galaxy is about 1 particle (mostly hydrogen atoms) every 0.6 cubic inch (10 cubic centimeters). Amid this gas is a smattering of dust grains; on average, 1 percent of the interstellar mass is in the form of solid silicate or carbonate grains. Astronomer Robert Trumpler showed in 1930 that interstellar gas and dust absorbs light at a typical rate of 2 magnitudes per kiloparsec (3,262 light-years).

Barnard 68 is a nearby molecular cloud with higher density than the space around it. Left: The cloud absorbs light from the stars behind it at optical (short) wavelengths, appearing dark. Right: At infrared (longer) wavelengths, background stars become visible through the cloud. ESO

All gas and dust in the interstellar medium absorbs (or scatters) light that passes through it, resulting in the extinction of light from background stars. Most of the extinction at optical wavelengths is due to dust grains, which have typical sizes of 0.01 to 1 micron. A photon with a wavelength smaller than the size of the dust grain can be physically absorbed by the grain, heating the grain up. Longer wavelengths of light can diffract (which causes the light to bend or spread) around the grain.

Optical light (about 400 to 700 nanometer wavelengths) is strongly dimmed by these dust grains. The amount of dimming is proportional to the cross sectional area of the grains times the number of grains in the line of sight. The size of the grain affects the wavelength of light that will be dimmed. Extinction is strongest at short wavelengths and its effects decrease with increasing wavelength.

William Herschel noted the apparent lack of stars in certain directions back in the 18th century, and may be the discoverer of dark nebulae (although he didn't understand what they were). These dark, or absorption, nebulae are localized enhancements in the density of the interstellar medium by factors of 1,000 to 100,000. A density enhancement of 10,000 means a 1-magnitude attenuation occurs over a fraction of a light-year.

To tell which stars are in the background, look at their colors. Stars whose light passes through the absorption nebula will be reddened — their blue light will be preferentially absorbed and scattered. Be careful though — some stars are naturally red. You really need to have a spectrum (or spectral type) that will tell you what the colors of the star should be.

Frederick Walter
Professor of Physics and Astronomy, Stony Brook University, Stony Brook, New York

Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

The real MUSIC OF THE SPHERES

The sky is an endless source of inspiration for artists and composers. Here's a look back at how the stars have influenced music. **by Joel Davis**

DO THE MOON AND THE PLANETS SING as they move through the sky? The idea of the "music of the spheres" is at least 2,500 years old. The Greek philosopher Pythagoras of Samos (ca. 570–490 B.C.) noticed that simple mathematical ratios exist among harmonious frequencies. He proposed that the Moon, Sun and *planētes asters* ("wandering stars") all produced a kind of metaphysical "hum" as they moved in their paths around Earth. These sounds, the "music of the spheres," were undetectable by the human ear, but influenced the quality of all life on Earth.

Today, the music of the spheres is nothing more than a fascinating piece of archaic philosophy. But another kind of celestial music has been around for centuries: songs and other music about or inspired by astronomical objects or events. They include classical oratorios, jazz standards, folk songs, and even a few rock 'n' roll tunes.

Handel's total eclipse

A total solar eclipse occurs when the Moon passes in front of the Sun as seen from Earth, and completely blocks the Sun's disk. The dark inner lunar shadow races across Earth's surface, cutting a narrow path of totality in which night briefly falls. Totality lasts only a few minutes for observers along the path. For example, at its longest, the total eclipse of August 21, 2017, lasted for 2 minutes, 41.6 seconds near Carbondale, Illinois. For most of human history, solar eclipses were mysterious, terrifying events, omens of disaster. But they also might have been sources of artistic inspiration — it is quite possible that a solar eclipse (or maybe two!) influenced one of the greatest Baroque composers and one of his most famous works.

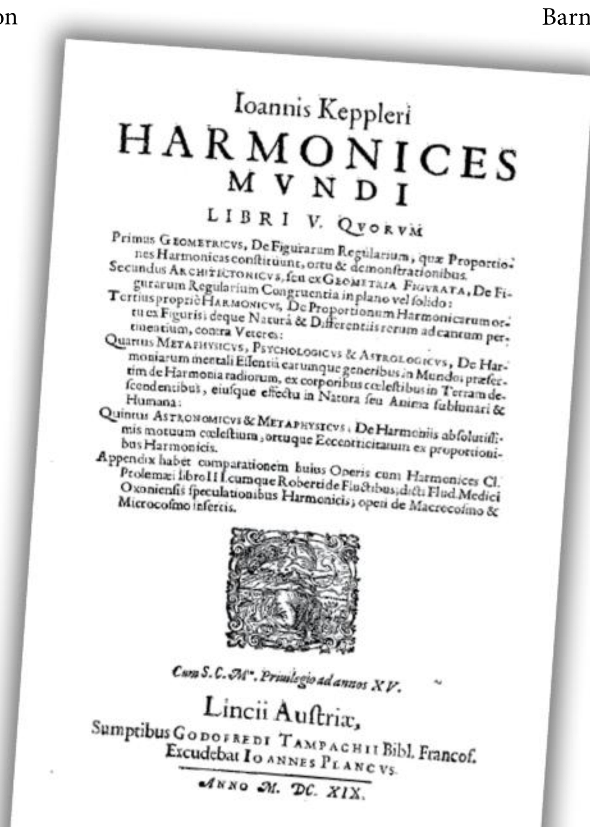
On May 3, 1715, a solar eclipse traced a path of totality in England from Cornwall across London to Norfolk. Totality lasted for 3 minutes, 33 seconds in London. On May 22, 1724, another total solar eclipse was visible at sunset from southern Wales to Sussex. The path of totality ran south of London. At the time both eclipses occurred, George Frideric Handel was among London's citizens.

George Frideric Handel is one of many artists struck by inspiration upon viewing a total solar eclipse. The composer likely witnessed at least one, if not both, of the total solar eclipses that crossed England in 1715 and 1724. THOMAS HUDSON; WIKIMEDIA COMMONS: PHROOD

Handel was born in 1685 in Germany, and while still a boy he showed great musical talent. After attending university, he took positions as a cathedral organist, a violinist and harpsichordist, and later a composer and performer for Catholic cardinals in Italy. Handel moved to England in 1710, and by 1713 he was living in Barnes, about 6 miles (10 kilometers) southwest of central London. Four years later, he had moved to the northwest part of London, and in 1723, he bought a mansion in the exclusive Mayfair district of central London, where he lived for the rest of his life.

It was in London that Handel became famous, and his magnificent *Messiah* sealed his fame for the ages. When Handel finished *Messiah* in 1741, he immediately began another project. Like *Messiah*, this would be an oratorio, a large musical composition for orchestra, choir, and soloists, with identifiable characters and arias. He titled the new project *Samson*. The text (by Irish writer Newburgh Hamilton) was based on John Milton's dramatic poem *Samson Agonistes*, a retelling of the famous

Left: The Leonid meteor storm of April 1833 produced hundreds of thousands of meteors and struck awe and wonder into all who saw it. Among them was Joseph Harvey Waggoner, whose account inspired artist Karl Jauslin to paint the storm. This image, in turn, is an engraving produced by Adolf Vollmy, based on Jauslin's painting. ADOLF VOLLMY



Ioannis Keppleri
HARMONICES MVNDI
LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiones Harmonicas constituunt, ortu & demonstrationibus.
Secundus ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel solido:
Tertius propriè HARMONICVS, De Proportionum Harmonicarum ortu ex Figuris; deque Naturâ & Differentiis rerum ad cantum pertinentium, contra Veteres:
Quartus METAPHYSICVS, PSYCHOLOGICVS & ASTROLOGICVS, De Harmoniarum mentali Essentiâ earumque generibus in Mundo; præsertim de Harmonia radiorum, ex corporibus cœlestibus in Terram descendentibus, eiusque effectu in Natura seu Anima sublunari & Humana:
Quintus ASTRONOMICVS & METAPHYSICVS, De Harmoniis absolutissimis motuum cœlestium, ortuque Eccentricitatum ex proportionibus Harmonicis.
Appendix habet comparationem huius Operis cum Harmonices Cl. Ptolemæi libro III. cumque Roberti de Fluctibus, dicti Flud Medici Oxoniensis speculationibus Harmonicis, operi de Macrocosmo & Microcosmo insertis.

Cum S. C. M^tis. Privilegio ad annos XV.

Lincii Austriæ,
Sumptibus GODOFREDI TAMPACHII Bibl. Francof.
Excudebat IOANNES PLANCVS.
ANNO M. DC. XIX.

Right: In 1619, Johannes Kepler published *Harmonices Mundi* (Harmony of the Worlds). In it, he looks for "harmonies" analogous to those between musical notes in the distances and speeds of planets in the solar system. While no such harmonies appeared to exist with regard to planetary distances, he did discover a pattern governing a planet's speed with respect to its position in its orbit — this would become Kepler's third law. JOHANNES KEPLER: *HARMONICES MUNDI*, LINZ 1619; WIKIMEDIA COMMONS: URS WERRA

Bible story of a super-strong Israelite hero brought low by the treacherous Dalila. *Samson*'s first act begins with Samson blinded and in chains, a prisoner of the hated Philistines. He bemoans his fate in an aria that uses the image of a total solar eclipse to symbolize his loss of sight. *Samson* premiered in February 1743 at London's Covent Garden Theatre, and it was a smash hit.

Why a solar eclipse as a metaphor for blindness? Did Handel witness the total eclipse of 1715? It's more likely than not that he did. After all, he lived near or in London from 1713 onward. He could have easily made the journey to see both the 1715 and 1724 eclipses. Both were witnessed by thousands of people, and their memories of the events would have been vivid when *Samson* and its dramatic aria, "Total Eclipse," premiered in 1743. Talk about a gripping opening, a dramatic hook! *Samson* was a favorite of audiences throughout Handel's life, and it remains popular to this day.

In his later years, "Total Eclipse" would often bring the composer to tears as he sat listening to the performance, but unable to see it. For the last 10 years of his life, Handel himself was blind, trapped in the shadowy path of his own "total eclipse."

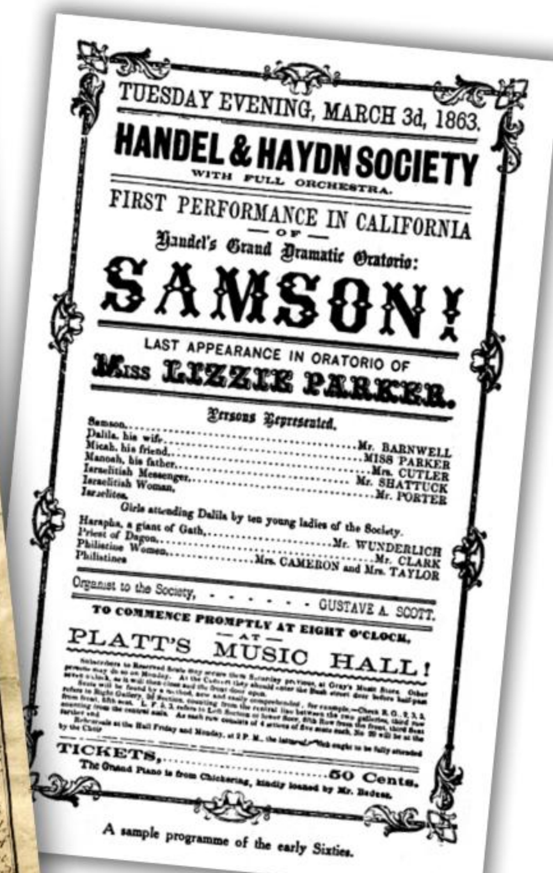
Stars fell

Comets eject gas and dust as they approach the Sun and their surfaces heat up. They leave a meteoroid stream of dust particles in their wake, with some areas denser than others. The gravitational influence of the planets — especially Jupiter — as well as the pressure of sunlight perturb the streams, so the orbits of the particle trails are not quite the same as their comets of origin. Meteor showers occur when Earth moves through these clouds of cometary dust. Older meteoroid trails are fairly sparse and produce few meteors per hour, while newer trails are denser and the meteor showers are more impressive. Outbursts greater than 1,000 meteors per hour are called meteor storms.

The Leonid meteor shower graces the night sky every November. Named for the constellation Leo, from which it appears to radiate, the Leonids are famous for their occasional spectacular outbursts. The Leonid meteor storm of November 1833 was truly epic. For nine hours on the night of Thursday, November 12, people across eastern North America saw thousands of meteors streaking through the sky each minute. Observers later estimated the number of meteors from 100,000 to nearly 240,000 per hour. Newspapers and magazines around the country ran stories about the event, complete with illustrations based on observers' reports.

Left: Edmond Halley's map of the predicted path of the 1715 eclipse visible over England was printed and sold as a broadside (a type of advertisement or poster). Its widespread availability and affordable price created excitement and encouraged people to view the event; one of them may have been Handel. UNIVERSITY OF CAMBRIDGE, INSTITUTE OF ASTRONOMY LIBRARY

Below: Handel's *Samson* included an eclipse-inspired piece, aptly named "Total Eclipse." The oratorio premiered in 1743 to great success and remained hugely popular. This playbill advertises a performance in San Francisco in 1863. MARGARET BLAKE ALVERSON: *SIXTY YEARS OF CALIFORNIA SONG*, 1913



Through the end of the 18th century, meteors had been commonly considered a purely atmospheric phenomenon, like lightning. The 1833 Leonid storm changed all that, and kick-started the scientific study of meteors. Shortly after the storm, astronomer Denison Olmsted proposed a cosmic origin of meteors, suggesting they came from a cloud in space. The Leonids returned the following November, though not at "storm" levels. Astronomer Heinrich Olbers predicted in 1837 that the Leonids would have especially large displays every 33 or 34 years. Sure enough, the November 13–14, 1866, display was spectacular. At about the same time, astronomers Wilhelm Tempel and Horace Parnell Tuttle independently discovered the comet that bears their name. Giovanni Schiaparelli soon determined that Comet Tempel-Tuttle was the source of the Leonids.

In 1934, American writer Carl Carmer published an autobiographical account of the six years he spent living and teaching in Alabama. He included stories of the 1833 Leonid meteor storm based on both old newspaper accounts and stories he heard from children and grandchildren of eyewitnesses. "Many an Alabamian to this day reckons dates from the year the stars fell," Carmer wrote, "though he and his neighbor frequently disagree as to what year of our Lord may be so designated. All are sure, however, that once upon a time stars fell on Alabama." Folks would recall that their son or daughter was born "about the time the stars fell," or that they got married "a week after the stars fell." Carmer's book, *Stars Fell on Alabama*, quickly became a best-seller.

One of the book's fans was music publisher Irving Mills. He was sure there was a song in it, something that could be based on or inspired by the meteor shower story. Mills turned to Frank Perkins to write the tune and Mitchell Parish to write the lyrics. Perkins was a solid but otherwise undistinguished composer. Parish, though, was one of jazz's great lyricists. Among other classics, Parish wrote "Sophisticated Lady" (Duke Ellington), "Moonlight Serenade" (Glenn Miller), and "Stardust" (Hoagy Carmichael). The lyricist turned the shared memories of the 1833 meteor storm into a song about romance: Boy fell for girl the night the stars fell on them both. "We lived our little drama / We kissed in a field of white / And stars fell on Alabama / Last night …"

Like so many of Parish's other pieces, "Stars Fell on Alabama" streaked across the musical sky like, well, a meteor — a meteor that's never stopped blazing. More than a hundred artists have covered the song, including Guy Lombardo, Bing Crosby, Ella Fitzgerald and Louis Armstrong, Cannonball Adderley and John Coltrane, Billie Holiday, Anita O'Day, Stan Getz, Dean Martin, Frank Sinatra, Doris Day, Kate Smith, Mel Torme, Ricky Nelson, and even Jimmy Buffett.

3C 273, a quasar located in an elliptical galaxy 2.5 billion light-years away, lies in the constellation Virgo. While some once believed quasars might be generated by alien civilizations, astronomers now know they are the accretion disks surrounding supermassive black holes. ESA/HUBBLE AND NASA

The 1833 night when "stars fell on Alabama" and the song it later inspired were so memorable that the phrase was featured on the state's license plate between 2002 and 2009.
WIKIMEDIA COMMONS: ROGUE FALCONER

A quasar for The Byrds

Quasars, short for "quasi-stellar objects," are regions immediately surrounding supermassive black holes at the centers of distant galaxies. Their gravitational fields suck surrounding matter onto their accretion disks, releasing enormous amounts of electromagnetic energy. "Radio-loud" quasars (about 10 percent of all known quasars) emit radio waves and visible light up to a hundred times as bright as our entire Milky Way Galaxy.

In 1959, no one had a clue what these mysterious cosmic radio sources were. Their measured redshifts implied they were billions of light-years distant, but that meant their energy output was gargantuan. Perhaps the objects were much closer, and the large redshifts were caused by light escaping from a deep gravitational well. That year, radio astronomers from the California Institute of Technology found one they named CTA-102 — the 102nd entry in the Caltech Survey, Part A.

In 1963, Russian astrophysicist Nikolai Kardashev offered a novel suggestion: CTA-102 could be the product of a highly advanced extraterrestrial civilization. Two years later, Gennady Sholomitskii found its radio emissions were variable. Perhaps this strange celestial object *was* the powerful radio beacon of an advanced alien race. This was a wondrous suggestion — with nothing to support it. The "ET hypothesis" was still making the rounds in 1966 when it captured the fancy of a 24-year-old musician named Roger McGuinn.

McGuinn is the guitarist, singer, and songwriter who founded The Byrds, one of

The Great January Comet of 1910 (pictured) grew brighter than Venus and dazzled viewers with a long, arcing tail visible in daylight; Halley's Comet would appear just months later. The close timing of the comets could have confused people's later recollections — including those of John S. Stewart.
UNIVERSITY OF CHICAGO PHOTOGRAPHIC ARCHIVE, [APF6-02103], SPECIAL COLLECTIONS RESEARCH CENTER, UNIVERSITY OF CHICAGO LIBRARY

the most influential bands of the 1960s. He's also an enthusiastic — if not always well-informed — astronomy fan. With collaborator Bob Hippard, McGuinn wrote "C.T.A.-102." The space-themed song appeared on the group's early 1967 album *Younger Than Yesterday.*

In a 1973 interview, McGuinn said of the inspiration for the song, "At the time we wrote it, I thought it might be possible to make contact with quasars." It was not until later, he added, that he learned they "were stars which are imploding at a tremendous velocity … sending out tremendous amounts of radiation." He mistakenly thought that the signals were audible as an electronic impulse detected by radio telescopes "in rhythmic patterns."

We've been singing songs about the awe-inspiring worlds of the night sky for a very long time.

The song's tune is jaunty, the lyrics upbeat: "We're over here receiving you / Signals tell us that you're there … on a radio telescope / Science tells us that there's hope." And the group went to considerable lengths to produce some spacey sound effects. At a time when computers weren't yet available, they got creative. They used audio feedback, an oscillator connected to a telegraph key, a piano keyboard repeatedly pounded with their fists, and nonsense sounds laid down on audiotape that was speeded up or played backward to achieve the desired effect. As McGuinn later said, "That was a big fad at the time, to play things backwards."

A 1968 paper published in *The Astrophysical Journal* ("Quasi-Stellar Radio Sources: 88 GHz Flux Measurements") actually referenced McGuinn and The Byrds. Referring to aspects of CTA-102's spectrum, the authors wrote: "The spectrum … [gives] no indication of an upturn at short wavelengths. … [W]e have been unable to detect it." In a wry reference to the rock band's song they added, "Therefore we are unable to comment on the discussion by McGuinn, Clark, Crosby, Clarke and Hillman."

"C.T.A.-102" isn't the only science- or science-fiction-inspired rock song. David Bowie's 1969 "Space Oddity," Elton John and Bernie Taupin's 1972 "Rocket Man," Brian May and Queen's 1975 space-travel folk song "'39," and Rush's 1977–78 two-part "Cygnus X-1" are other examples. But "C.T.A.-102" is the first song inspired by a quasar, the first to reference a radio telescope in music — and possibly the first to garner a rock band a mention in a refereed scientific journal.

An account of a comet

1P/Halley is arguably the most famous comet of all time. Its regular visits to the inner solar system have been reliably recorded since at least 240 B.C. In 1066, the comet was seen in England and its appearance recorded in the famed Bayeux Tapestry, a 230-foot (70 meters) textile depicting the Norman conquest of England. None of its apparitions were identified contemporaneously as the same comet, however, until its appearance in 1682, when English astronomer Edmond Halley successfully predicted its return in 1758. Halley's Comet returned again in 1835, and then again in 1910.

That was actually a year of two great comets. Halley's was one, and people around the world were eagerly awaiting its return to our cosmic neighborhood after 75 years. But C/1910 A1, better known as the Great January Comet of 1910 or the Daylight Comet, dazzled the world first. It was already a magnitude 1 naked-eye object when it was spotted January 12. The comet was visible in broad daylight in the Southern Hemisphere, and by February it was visible at twilight in the Northern Hemisphere as a spectacular object with a long, curved tail.

Two months later, Halley's Comet was a naked-eye object in the night sky, reaching perihelion April 20. It then passed within 0.15 AU (13.9 million miles [22.4 million km]) of Earth. So while not quite as

awesome as the Great January Comet, Halley was still a spectacular sight.

It certainly made an impression on a boy named John S. Stewart, who was living with his parents near Lexington, Kentucky, at the Transylvania Inn, where his father was a horse trainer. The young boy's experience seeing Halley's Comet remained with him the rest of his life. Some 60 years later, his son tape-recorded his memories of that long-ago spring in 1910.

His son was John C. Stewart, a folk singer and songwriter probably best known as a member of the Kingston Trio and the composer of the Monkees' hit "Daydream Believer." But Stewart also had a successful solo career that stretched from the late 1960s to his death in 2008. He was an acknowledged and continuing influence on contemporary folk music's so-called "Americana" sound. An enthusiastic supporter of the U.S. space program, Stewart wrote "Armstrong," a tribute to the first lunar landing with not-so-subtle references to troubling social issues still with us today. His song about his father and a comet, though, is particularly touching, both for its subject matter and its lyrics.

The Byrds (pictured in 1970; from left are Roger McGuinn, Skip Battin, Clarence White, and Gene Parsons) found musical inspiration in the radio-loud quasar CTA-102. Their song of the same name communicates a positive message of hope that the quasar is an alien beacon. JOOST EVERS/ANEFO; COURTESY OF THE NATIONAAL ARCHIEF, THE DUTCH NATIONAL ARCHIVES, AND SPAARNESTAD PHOTO

Stewart began with his father's tape-recorded recollections. To them he added a musical arrangement with a string section and a simple but driving chorus. The result was "An Account of Haley's [sic] Comet." It opens with John S. narrating his personal story. "It must have been in the late spring or early summer, my mother came to me and said, 'Let's go upstairs on the veranda.' She said, 'I want you to see Haley's Comet.'" At first it looked like a bright star, but as it came closer to Earth, it "started to take on the look of a ball of fire with a tail behind it." John C. and several backup singers then sing the refrain: "Kentucky light shine / Will it fall from the sky? / Kentucky light shine / Stranger in the sky."

His father continues his story, recalling how the comet got larger and brighter until one night "it was over the Tattersall's barn. … The horses were restless … [and] my father … went to the barn to try and quiet" them. The young John S. runs to his mother and tells her he's afraid, and she replies, "So am I." He describes the light as "eerie" and so bright the eaves of the barn cast shadows. The refrain cuts back in: "Kentucky light shine / Will it fall from the sky?"

Some of the senior Stewart's memories may have been colored by the passing years. He may have confused the spectacular twilight sight of the Great Comet a few months earlier with his experience of Halley. In the end, though, it doesn't matter much. In 1910, John S. Stewart saw Halley's Comet during one of its most impressive appearances. Sixty years later, his folk singer son turned his memories into a moving "music of the spheres" account of an astronomical experience most of us will have only once in a lifetime.

We've been singing songs about the awe-inspiring worlds of the night sky for a long time, maybe as long as we've been human. From meteor storms to comets, from solar eclipses to quasars — and much more — the night sky continues to inspire us to make celestial music right here on Earth.

Joel Davis *has worked as a technical writer at Microsoft and WideOrbit. He blogs regularly at notjustminorplanets.blogspot.com.*

Halley's Comet also lit up the sky in 1910, during an especially close pass to Earth; in fact, Earth passed through the comet's extensive tail in May that year. This photo was taken during the comet's subsequent apparition in March 1986. NASA/W. LILLER

EXPLORE AURIGA's DEEP-SKY WONDERS

Flaming Star Nebula (IC 405)

Open cluster M36

LEFT: GERALD RHEMANN. UPPER RIGHT: BERNHARD HUBL

Bright star clusters, challenging nebulae, and even a distant globular cluster await you in one of winter's great constellations.

by Stephen James O'Meara

Auriga, a wreath of stars within the larger wreath of the Winter Hexagon, possesses some of the most disparate deep-sky objects in the heavens — from dazzling Capella (the most northern 1st-magnitude star) to the dim and distant globular cluster Palomar 2 (among the most visually demanding deep-sky objects). Beyond the bright showpiece open star clusters **M36**, **M37**, and **M38** — which all observers should admire for their rich diversity in visual splendor — Auriga has a cache of objects that can satisfy your desires.

FOLLOW THE "LEAPING MINNOW"

Beyond Capella and its Kids — Epsilon (ε), Zeta (ζ), and Eta (η) Aurigae — the first object to catch my eye in this constellation under a dark sky is the tight and "hazy" ellipse of starlight east of Iota (ι) Aurigae on the western bank of the Milky Way; it may be among the most unsung naked-eye objects in the night sky. Binoculars will show this delightful grouping as what *Sky & Telescope*'s Alan M. MacRobert likens to a "leaping minnow." The brightest minnows are 5th-magnitude 16, 19, and IQ Aurigae.

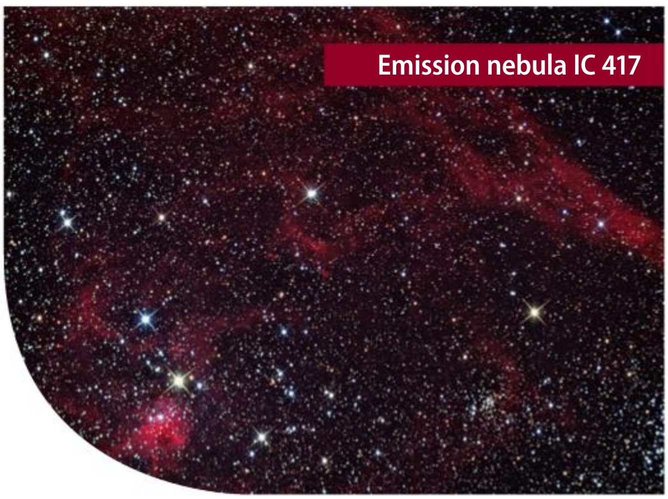
About 1° southwest of the leaping minnow you'll find **14 Aurigae**. This wide double star is visible through small telescopes. The pale white pair consists of a 5th-magnitude primary and a magnitude 7.5 secondary 14.6" to the southwest. The trick is to resolve the 5th-magnitude primary, which also has a 10th-magnitude "companion" 12" to the north; I put "companion" in quotes because the two are not physically related, being most likely a chance line-of-sight pairing.

Now return to the leaping minnow and look immediately northwest of 19 Aurigae for a naked-eye star at the edge of visibility: **AE Aurigae**. This variable star fluctuates erratically between magnitudes 5.8 and 6.1. Born in a binary system some 200 million years ago in the Trapezium star cluster in the Orion Nebula (M42), AE Aurigae was ejected to its present location after its system had a close encounter with another binary star system.

Today we still see AE Aurigae "running away" to the north, only now it is passing through and illuminating an interstellar cloud of dust and gas known as the **Flaming Star Nebula** (IC 405). Under dark Hawaiian skies, I've spied AE Aurigae and the brightest part of IC 405 that surrounds the star, using averted vision through 10x50 binoculars. Small telescope users should try low power first, and plan to gently sweep in a general north-south


Open cluster M37


Open cluster M38


Emission nebula IC 417


Emission nebula NGC 1931

direction along the nebula's 30'-by-20' length while keeping your eyes relaxed and your mind alert. The nebula's most prominent portion is a kite-shaped wedge extending southeast from AE, followed by a long, thin streamer that runs along the nebula's northeastern edge.

If you are under a dark sky, use 10x50 binoculars to scan about 1° southeast of the leaping minnow, and see if you can detect the soft and tiny (12') glow of the magnitude 7.5 cluster **NGC 1893** that illuminates the surrounding 20'-wide diffuse emission nebula **IC 410**. I mention this latter object specifically for astroimagers because the nebula reminds me of a little Rosette Nebula and is part of the larger one that lies at the core of the Auriga OB2 association. The embedded cluster has about 20 members, the brightest of which shine around 9th magnitude and dip down to about 13th.

SAID THE SPIDER TO THE FLY …

If you're out admiring M36 and M38 with binoculars, look for two curious threads of starlight that seem to connect the two clusters to 5th-magnitude **Phi (φ) Aurigae**, an orange K-class giant flanked by two 6th-magnitude attendants. As a whole, this star-and-cluster stream forms an open V asterism that New York City skywatcher Ben Cacace refers to as the Cheshire Cat (an allusion to *Alice's Adventures in Wonderland*).

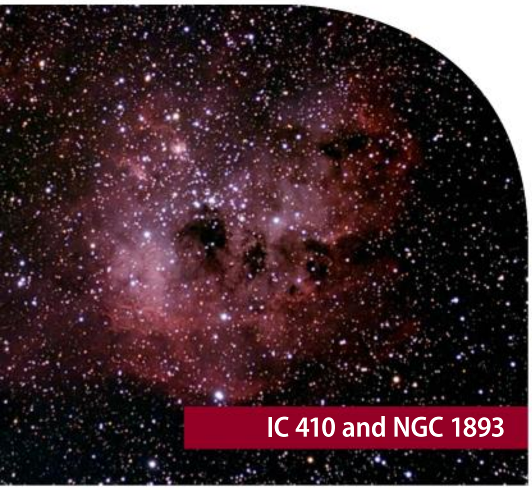
Now peer at Phi Aurigae through a larger looking-glass — your telescope. That crisp, golden star has numerous fainter stars sprinkled around it from northeast to southwest, while a smaller collection of jewels hugs Phi to the southeast.

All these stellar gems belong to the largely "silent" **Stock 8** — a 2 million-year-young cluster embedded in its nascent nebula **IC 417**, which washes through the entire region. Wide-field imaging reveals that IC 417 is a vast cloud of glowing hydrogen with long, spindly legs that stretch across 1½° of sky. When Boston amateur astronomer Steve Cannistra scanned one of his wide-field images of the region, he nicknamed IC 417 "The Spider," and our next target — the tiny (4') nebulous cluster **NGC 1931** (about 5' to the east-southeast) — "The Fly."

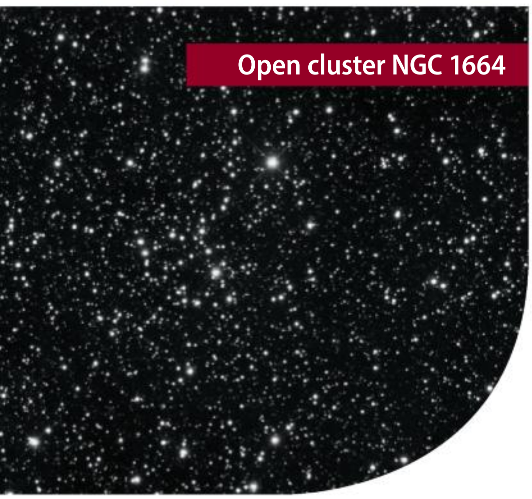
NGC 1931 is a beautiful little cluster that's easily seen through small scopes. Only 10 million years old, the cluster is 7,000 light-years distant — or about five times farther away than the Orion Nebula, of which it is a remarkable miniature.

Telescopically, at low power and with direct vision, NGC 1931 is so dense that it appears like a fuzzy star. With averted vision, however, it immediately swells into a distinct nebulous knot. The trick to seeing the cluster within is to use high magnification (start with 165x and work your way up) to resolve its central triad of suns. Concentration will bring out several other fainter jewels. But these may swim in and out of view as you move your eye while using averted vision and pass over the nebulosity, which is brightest on the southern side. The stars appear to be embedded in knots or nebulous folds, from which thinner tendrils stream — including a graceful sweep of reflection nebulosity stretching southward from the main nebula.

CLOCKWISE FROM UPPER LEFT: ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA; ANTHONY AYIOMAMITIS; MARK HANSON; MARTIN C. GERMANO; AL AND ANDY FERAYORNI/ADAM BLOCK/NOAO/AURA/NSF; ADAM BLOCK/NOAO/AURA/NSF



IC 410 and NGC 1893



Open cluster NGC 1664

About midway between Phi and Nu (ν) Aurigae is a great visual challenge object: the collision site of two giant molecular clouds, **Sharpless 2–235**. If you're a skilled observer using a 5-inch or larger telescope, try to visually swallow this kidney bean-shaped emission nebula; a deep-sky or ultra-high-contrast filter will help show this 10'-wide pale oval glow. The challenge for large telescope users is to not only resolve the dark band that separates the nebula's bright northern half from its dimmer southern portion, but also the two "knots" of nebulosity immediately to its south: **Sharpless 2–235A** and **B**. How small a telescope will show them?

HIDDEN CLUSTERS

Auriga sports some of the brightest (M36, M37, and M38) open star clusters, and also some of the faintest. The latter group includes 7th-magnitude **NGC 1857**, a 5' cluster centered on a 7.5-magnitude star about 45' south-southeast of Lambda (λ) Aurigae. Through a small telescope, the cluster is a little polygon of about a half-dozen dim stars — which itself lies on the southern skirt of an even larger (18'-wide) and much more discrete cluster, **Czernik 20**. Telescopes 12 inches (30.5 centimeters) and larger may show up to four dozen roughly magnitude 13.5 stars within NGC 1857, transforming it into a blizzard of faint starlight. The alignment of NGC 1857 and Czernik 20 appears to be by chance because recent estimates place NGC 1857 about 3,000 light-years farther away.

Heading farther "upstream" toward the northwest border of Auriga and Perseus, we arrive at the magnitude 7.6 open star cluster **NGC 1664**. This little explosion of about 100 stars sprays outward to the northwest for about 20' from a magnitude 7.5 star about 2° west of Epsilon Aurigae. I find the cluster most appealing at low power as it seems to play with the Milky Way, appearing as if it were the cloudy aftermath of an oblique meteorite strike into that milky river. Higher powers show its irregular loop and tail of starlight as a stingray swimming, or an earring dangling under moonlight.

Now we've nearly hit rock bottom in the magnitude range for decent cluster viewing. **NGC 2126** lies in the remote regions of far northern Auriga and shines at a dismal magnitude 10.2. Fortunately, not only is the cluster compact (6') but it has an unrelated 6th-magnitude star superimposed on its northeastern flank. Through small telescopes, the cluster appears simply as an elliptical fog of faint light oriented northeast to southwest. With averted vision and high power, it appears granular — like an unresolved globular cluster. For those using larger instruments, the cluster contains 40 stars of 13th-magnitude and fainter.

We'll end our cluster scan on a high note, with the bright (5th-magnitude) open cluster **NGC 2281**. It's a largely overlooked treasure hiding in the remote far-eastern corridor of Auriga, in one of the seven lashes of the Charioteer. Yet the cluster is bright enough to blossom forth in 7x50 binoculars as a diffuse glow nestled between a 7th- and an 8th-magnitude star; both have dramatic golden hues, so the binocular scene is quite pleasing. Telescopically, the cluster looks like a tortured stellar system, one that's been "stretched on the rack," in all four directions, creating Gumby-like arms in the process. NGC 2281 has about 120 members of 8th magnitude and fainter, with many of the dimmest stars hovering around 13th magnitude. The question is, can you spy it without optical aid?

EXTRAGALACTIC DENIZENS

If you'd like a galaxy challenge, Auriga has two "visually reasonable" island universes for you to seek out: **NGC 2208** and **NGC 2303**. The magnitudes are faint and both are small, but they are highly condensed, making them decent targets. So when you look for them, search for a "star" in the right position and use high power and averted vision to see their diffuse disks.

American astronomer Lewis Swift discovered both galaxies visually in 1886 using the 16-inch refractor at Warner Observatory in Rochester, New York. Today, however, a telescope as small as a 4-inch will show them from a dark site, with time and patience. NGC 2303 is a round (1.5' across) magnitude 12.6 elliptical galaxy 270 million light-years distant that has a starlike appearance. NGC 2208 is a round (1.6' by 1.1') magnitude 12.8 lenticular galaxy 265 million light-years distant.

TWO VISUAL PECULIARITIES

IC 2149 is an unusual planetary nebula in northeastern Auriga, just 40' west-northwest of 4th-magnitude Pi (π) Aurigae. A longtime enigma, IC 2149 defied classification until 2002. In images, the compact 8"-wide ellipsoidal nebula surrounding an 11th-magnitude central star (visible in large binoculars) appears to be a bipolar planetary nebula still in the process of forming. I got the best view between 165x and 180x, though powers of 300x and greater will start to show it more and a trivial bit of "fuzz."

Hopping far to the southwestern corner of the constellation, we come to our final challenge. **Palomar 2** is an incredibly dim (magnitude 13) and distant (90,000 light-years) denizen of our galaxy's outer halo, a distant globular cluster. First, you'll need precise coordinates to find it (R.A. 4h46m06s, Dec. 31°22'51"); next, you'll need perhaps a 12-inch or larger telescope to see it; and third, you'll need to use averted vision and tube-tapping techniques, and eat lots of carrots. But don't let this dissuade you. You'll be looking for a 2'-wide amorphous round glow, which, as the 17th-century comet hunter Charles Messier would have said (if he were using a 24-inch Dobsonian at 170x), "resembles a comet, just beginning to shine."

Stephen James O'Meara *is a contributing editor of* Astronomy *and an author of many books on observing.*

A panel of 11 Nobel Prize laureates discusses the future of science. Pictured from left are Edvard Moser, Adam Riess, Chris Pissarides, Finn Kydland, George Smoot, May-Britt Moser, moderator Adam Smith, Tim Hunt, Robert Wilson, Stefan Hell, Susumu Tonegawa, and Torsten Wiesel. MAX ALEXANDER/STARMUS

Snapshots from

The fourth Starmus Festival, a celebration of science and the arts, took place in Trondheim, Norway, in June 2017. **by David J. Eicher**

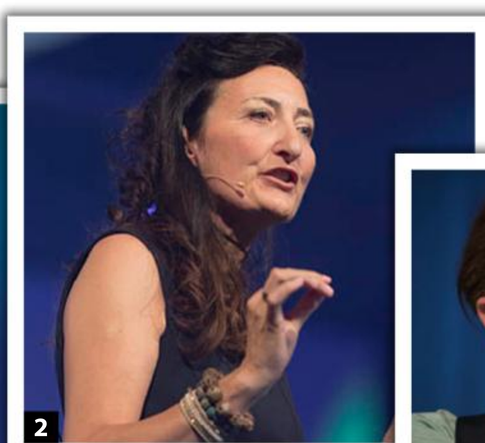
FOUR STARMUS FESTIVALS HAVE taken place since 2011. The international science celebration, the creation of astronomer Garik Israelian, grew out of his friendship with astrophysicist Brian May, also the founding guitarist of the rock group Queen. The festival is dedicated to stars and music, thus the name, but has expanded to highlight important scientists from all disciplines.

In 2017, the event showcased 11 Nobel Prize winners, an astronaut panel of moonwalkers (Buzz Aldrin, Charlie Duke, and Harrison Schmitt), talks by Larry King and Oliver Stone, many important scientific lectures, and a Sonic Universe Concert led by the amazing guitarist Steve Vai. Starmus was hosted in Trondheim by the Norwegian University of Science and Technology, and occurred June 18–23.

The following pages present postcards from Starmus, glimpses of what the 2,500 attendees experienced. For more information, visit www.starmus.com.

David J. Eicher *is editor of* Astronomy *and a member of the Starmus Festival Board of Directors.*

Starmus

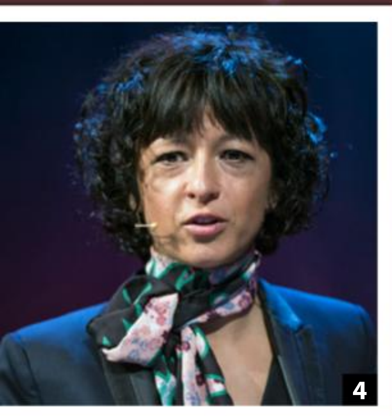


1. Garik Israelian, Starmus' founder and director, describes the effort that went into assembling Starmus IV. THOR NIELSEN/NTNU

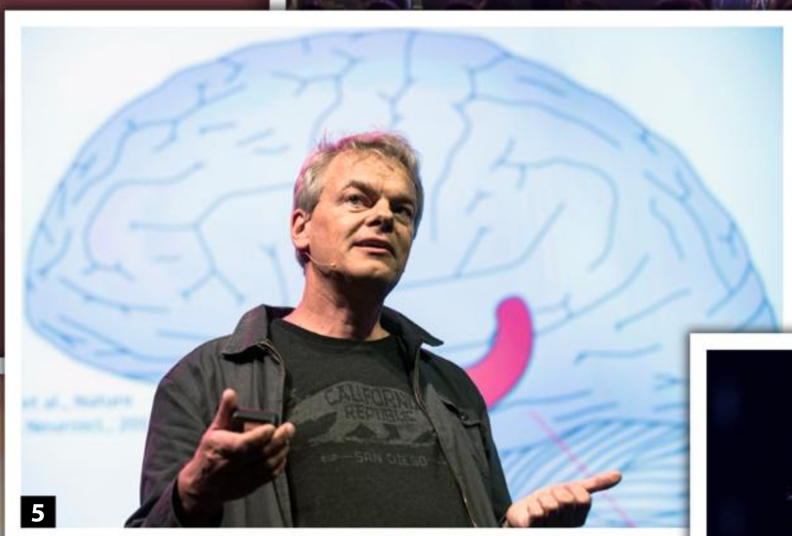
2. May-Britt Moser, who helped to bring Starmus to Trondheim, talks about her neurological research during a multimedia show. THOR NIELSEN/NTNU

3. Well-known TV and radio host Larry King commands a discussion on post-truth and fake news. MAX ALEXANDER/STARMUS

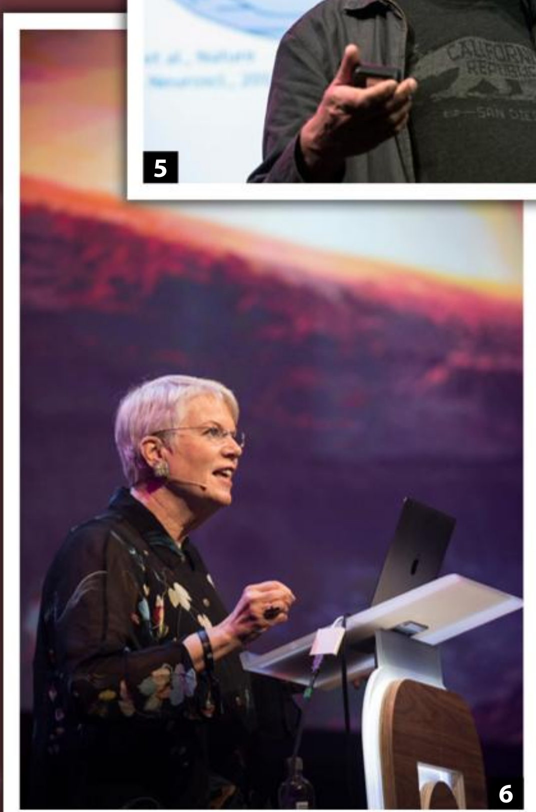

STARMUS
THE SCIENCE FESTIVAL
STARMUS
HOSTED BY
NTNU
Norwegian University of Science and Technology



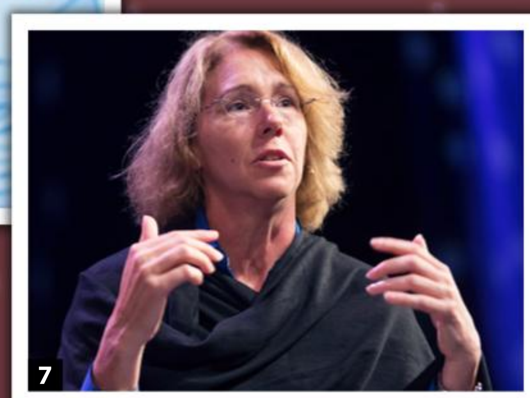
4



5



6



7


STARMUS

8

4. Emmanuelle Charpentier describes her groundbreaking work on CRISPR-Cas9, gene editing technology that will revolutionize the life sciences. MAX ALEXANDER/STARMUS

5. Edvard Moser talks about his amazing research on how the brain maps space, which happens in the hippocampus. MAX ALEXANDER/STARMUS

6. Jill Tarter delivers a landmark "state of the union" address on where we stand with the search for life in the universe. MAX ALEXANDER/STARMUS

7. Space shuttle and International Space Station astronaut Sandy Magnus recalls her experiences in orbit and the perspective they provide on Earth below. MAX ALEXANDER/STARMUS

8. Apollo 16 astronaut Charlie Duke describes the science he and John Young conducted on the lunar surface. MAX ALEXANDER/STARMUS

9. Stephen Hawking addresses the Starmus audience remotely from Cambridge, England, carefully weighing the prospects for the future of humanity. MAX ALEXANDER/STARMUS

10. David Eicher opens the festival with a welcome and an introduction, and commences hosting the first day. THOR NIELSEN/NTNU

11. Climate scientist Katharine Hayhoe gives a spectacular lecture on the realities of global warming. MAX ALEXANDER/STARMUS

12. Harrison "Jack" Schmitt describes his exploration of the lunar surface during Apollo 17 and reflects on being in the last group of explorers to the Moon. MAX ALEXANDER/STARMUS

13. Columbia University economist Jeffrey Sachs delivers a commanding performance in his exposé on dark money in American politics, garnering a standing ovation from the festival crowd. MAX ALEXANDER/STARMUS

14. Guitarist Steve Vai, left, jams with Grace Potter and Nuno Bettancourt during the Sonic Universe Concert. MAX ALEXANDER/STARMUS

Explore Scientific's 12-inch Truss Tube Dobsonian offers a large aperture at a reasonable cost.

This telescope offers top-notch construction and high-quality optics, and is easy to set up and use, as well.

text and images by Mike Reynolds

Explore Scientific's 12-inch Truss Tube Dobsonian

The Dobsonian, John Dobson's sidewalk telescope mount design more commonly referred to as a Dob, has evolved significantly since its first commercial introduction in the 1980s. Many of us remember the blue tube Coulter Optical Dobsonian telescopes, the first of which contained a 13.1-inch primary mirror.

Soon, amateur telescope makers and companies began producing larger and more innovative Dobs. The simplicity of the mount, coupled with a large mirror, made them popular telescopes. The Dob rage brought on what many referred to as "aperture fever."

The basic Dobsonian mount carries a Newtonian reflector with its concave primary mirror and flat secondary mirror mounted at a 45° angle to the primary. As the Dob evolved over the years, innovations such as shorter focal lengths for the big scopes, primary mirror cooling fans, equatorial tracking tables (an accessory that serves as a motor drive), and numerous others appeared.

Truss tube Dobs were also one of these early innovations, brought on by need and by mirror-size evolution. As the primaries became larger, solid tubes of either cardboard concrete column tubing or metal became impractical due to weight. This led to the truss tube: a set of rigid poles to connect the lower part of the Dob — referred to as the rocker box, which contains the primary mirror — to the Dob's upper cage, which holds the secondary mirror and focuser. This design, and the use of innovative connectors, means the telescope quickly disassembles into the rocker box, the mirror box, the secondary cage assembly, and the truss tubes.

Opening it up

Explore Scientific, known for its apochromatic refractors and wide-field eyepieces, has entered the market with three new Dobsonian telescopes. The trio features a number of traits standard to most Dobs along with a few surprises.

The Explore Scientific 12-inch Truss Tube Dobsonian arrived in one box. This was the first surprise; previously reviewed Dobs have always needed at least two boxes. I appreciated that the included user manual was well-written, and even contained pictures!

Assembly of the telescope was easy, and this would hold true even for a beginner. I found the construction solid, from the mirror box to the secondary mirror cage. The finishes appear nice and should last through many an observing session. The weight of the

PRODUCT INFORMATION

Explore Scientific 12-inch Truss Tube Dobsonian
Type: Newtonian reflector
Aperture: 12 inches
Secondary mirror obstruction: 24 percent
Focal length: 1,525mm
Focal ratio: f/5
Weight: 66.2 pounds (30 kg)
Price: $1,199.99

Contact:
Explore Scientific
1010 S. 48th St.
Springdale, AR 72762
866.252.3811
www.explorescientificusa.com

12-inch components is reasonable, and they easily fit into my Camry's back seat or trunk.

The next surprise was the collimation tool for the mirror. Collimation (the alignment of a telescope's optics) is usually tedious or takes two people. Explore Scientific has designed a system so the user can employ the collimation tool, a rod that lets you collimate the scope from the focuser. Usually you are back and forth to the rear of the telescope, or telling someone, "No, the other screw; tighten not loosen." What a great innovation!

The focuser is a 2" two-speed (10-to-1 reduction) model. The finder included is a red dot finder. I prefer an optical finder scope on my Dobs, but the red dot finder is adequate and reduces the secondary mirror cage's weight. Yet if that weight becomes an issue, or you want to use one of these heavy wide-angle eyepieces, Explore has included threaded counterweights. This was another unexpected surprise.

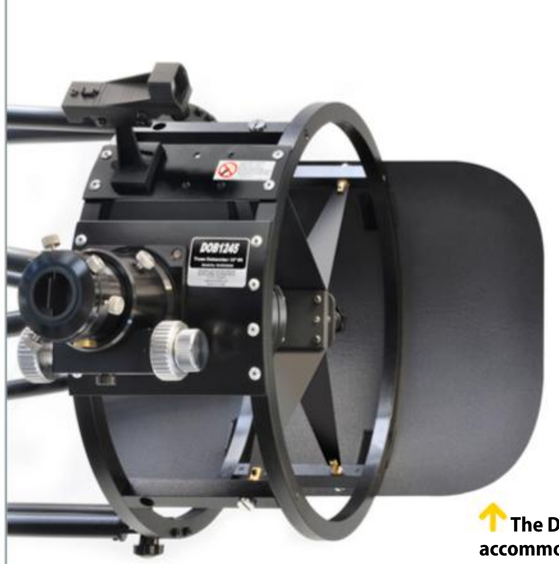
You should know that no eyepieces are included; most purchasers of scopes this large will already have at least one eyepiece. However, if this is your first telescope, make certain you order an eyepiece or two with it. I would suggest a wide-field 25mm as a starter. You might also want an 18mm for a little higher magnification, or a longer focal length eyepiece for a wider field of view and lower power.

Taking it for a spin

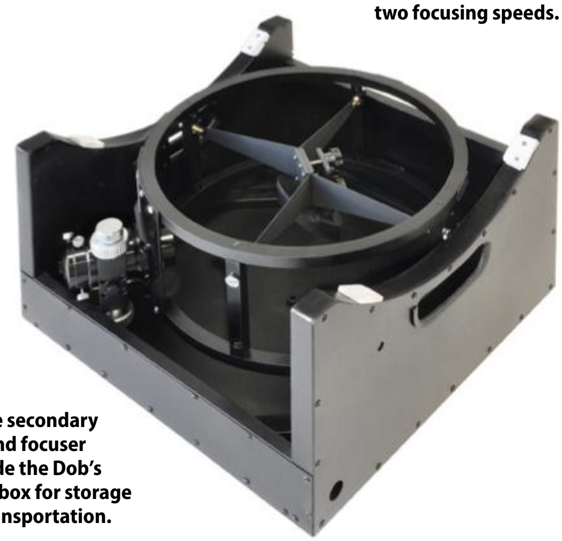
Under the night sky, the telescope performed well. It was easy to move around to its final observing spot. Once at the eyepiece, I also found it easy to adjust the tube's position while observing. The focuser works well. I always appreciate the 10-to-1 reduction. It allows for getting the focus just right, especially at higher magnifications. And the focuser held my fairly heavy wide-angle eyepiece with no slippage.

There are several general observational tests I do on all telescopes. Even though I was expecting no color issues, I like to test telescopes on the Full Moon. I detected no color issues, but our satellite was overwhelmingly bright, so I had to use a filter. The Explore Dob also performed nicely on the waning crescent Moon, providing a crisp image.

On a good night, a contrast between two telescopes can be established. My yardstick is a tough one here; I compare Dobsonians to my personal 18-inch f/6 Dob, a high-quality one that used to belong to a close friend. The Explore Dob views were excellent; I pushed the telescope to 90x with a 17mm eyepiece and then to 127x with a 12mm with no problems and a great image. I did try a 2x Barlow lens, but found my local sky conditions were not good enough to give a fair test. I noted that the image of Jupiter was OK, but not as good as at 127x.



The Dob's focuser accommodates 2" eyepieces and offers two focusing speeds.



The secondary cage and focuser fit inside the Dob's rocker box for storage and transportation.

Deep-sky objects were excellent, from the brighter ones like the Orion Nebula (M42) to some of the season's dimmer and more elusive targets. I also spent some time looking at double stars. One of my favorites this time of year is Albireo (Beta [β] Cygni) because it's easy to see and colorful.

Conclusions

All in all, I was pleased with the telescope's performance. I did not note any visual issues like coma, astigmatism, or other distortions.

Many of us Apollo program-era kids considered ourselves fortunate if we had an opportunity to look through someone's 12.5-inch reflector. And you were quite advanced if you owned an 8-inch Newtonian reflector. Today, if you catch aperture fever and want to see many of those subtle deep-sky object colors, faint wisps, and nebulosity, or if you want Jupiter to appear like you've never seen it in smaller scopes, a Dobsonian just might be for you. And Explore Scientific's new trio of Dobsonian truss tube telescopes gives you a selection with excellent optical performance and great mechanical quality at good prices, with convenience of setup and use — just know that even the largest of these will eventually leave you wanting something bigger. In the meantime, explore as much of the night sky as you can with one of Explore Scientific's fine new telescopes.

Mike Reynolds *is a contributing editor of* Astronomy *who observes through a variety of scopes from his home in Jacksonville, Florida.*

Astrophysicist Neil deGrasse Tyson and composer Jean-Michel Jarre pose with their awards at the 2017 Starmus Festival. The producers of *The Big Bang Theory* also won an award but were unable to attend. MAX ALEXANDER

Starmus awards 2017 Stephen Hawking Medals

The prestigious prize recognizes popularizers of science from around the world. **by Jake Parks**

During the 2017 Starmus Festival, founder Garik Israelian presented the Stephen Hawking Medal for Science Communication to three worthy recipients. Astrophysicist Neil deGrasse Tyson won for science writing, French electronic composer Jean-Michel Jarre captured the prize for music and arts, and the producers of the CBS sitcom *The Big Bang Theory* were honored for films and entertainment.

In addition to the medal, each winner received a uniquely engraved, 18-karat yellow gold Speedmaster Moonwatch from Omega — the official watchmaker for NASA since the 1960s.

Encapsulating the spirit of the Starmus Festival, the Stephen Hawking Medal was established in 2016 to acknowledge and honor those scientists, artists, musicians, and filmmakers who work tirelessly to promote science to the general public. "I firmly believe that if there is one thing for us all to strive for," said Selda Ekiz, host of the award ceremony, "it is to spread our burning desire to understand the world and the universe that we are a part of."

The back of the medal combines an image of Russian cosmonaut Alexei Leonov's trail-blazing spacewalk with Queen guitarist Brian May's iconic guitar — the "Red Special" — to highlight the connection between science and art. MAX ALEXANDER

Tyson, the first American to receive the award, used his acceptance speech to explain that every human being is born innately inquisitive. "This is affirmation that there is a hunger out there for people to continue to learn long into adulthood," Tyson said. "There is a curiosity that still burns within us, even if we have forgotten it is there."

Jake Parks *is an associate editor at* Astronomy *who greatly enjoys playing guitar and drums despite his lack of talent.*

NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

4-inch scope

Stellarvue
Auburn, California

Stellarvue's SV102T f/7 APO Triplet Refractor Telescope incorporates an apochromatic, air-spaced triplet lens and a focal length of 714 millimeters. It weighs 11.2 pounds (5.1 kg) with the 2.5" focuser, 2" adapter, and dual hinged rings. The scope measures 19¼" long (49 centimeters) with the focuser unthreaded.

Price: $2,195
530.823.7796
www.stellarvue.com

Solar scope

Coronado Instruments
Irvine, California

Coronado's SolarMax III 70mm Solar Telescope is an f/5.7 Hydrogen-alpha scope with a focal length of 400 millimeters. It includes the company's RichView tuning system, which uses a 10 mm blocking filter and has a bandpass of less than 0.7 angstrom. A hard carry case is included.

Price: $2,299
800.626.3233
www.meade.com

10x42 binoculars

Orion Telescopes & Binoculars
Watsonville, California

Orion's ShoreView Pro II 10x42 ED Waterproof Binoculars feature optics made from extra-low dispersion glass. The unit offers a 6.1° field of view and 16 millimeters of eye relief. The company includes tethered objective lens caps, a single-piece eyepiece cap, a neck strap, and a soft carry case.

Price: $199.99
800.447.1001
www.telescope.com

9mm eyepiece

Orion Telescopes & Binoculars
Watsonville, California

Orion's 9mm LHD 80-Degree Lanthanum Ultra-Wide Eyepiece contains eight fully multicoated elements. This 1¼" eyepiece offers 20 millimeters of eye relief and an 80° apparent field of view. The unit has an aluminum body, and the barrel is threaded to accept 1¼" filters. It weighs 19 ounces (539 grams).

Price: $269.99
800.447.1001
www.telescope.com

SEE REPORTS ON 350+ PRODUCTS AT **www.Astronomy.com/equipment.**

OBSERVING**BASICS**

BY GLENN CHAPLE

What's my true field?

Try these three methods to determine an eyepiece's true field of view.

The Full Moon has an apparent diameter of about 0.5°, a convenient reference for calculating an eyepiece's true field of view. JOHN CHUMACK

Last summer, I received an email from 13-year-old Adriana Baniecki in Chandler, Arizona. She wrote, "I have just started viewing the sky with my new telescope, which has an aperture of 114mm (4.5 inches) and a focal length of 910mm. I have 25mm, 12.5mm, and 4mm eyepieces, as well as a 3x Barlow. I was wondering, given my eyepieces, what magnification would be needed to view the Moon and planets.

"Also, in your January *Astronomy* column, 'January's top 10 targets,' I noticed references to both the angular size of an object and the magnification needed to view it. [Author's note: I had mentioned that the Pleiades star cluster (M45), which spans 2°, is best viewed with low power.] Given the angular size of any object, could you simply calculate the magnification needed to view it? If so, how?"

I responded by suggesting that she always start with the 25mm eyepiece, which yields 36x with a 910mm focal length scope, because its large field of view makes it easier to key in on sky objects. I also recommended this eyepiece for deep-sky objects wider than 0.5°, such as the Pleiades and the Andromeda Galaxy (M31), adding that the 12.5mm eyepiece (73x) and 25mm eyepiece with 3x Barlow (109x) would work fine on the Moon and planets.

What about the magnification needed for an object of given angular size? I pointed out that an eyepiece's true field of view, not its magnification, is the ultimate determining factor. This caused me to do a little soul-searching. During my nearly five decades as an avid backyard astronomer, I've become familiar with the magnifying power all my eyepieces produce with my various telescopes, but I knew next to nothing about their true fields of view. With my 10-inch f/5 reflector, for example, I normally use three eyepieces: a 32mm (40x), a 16mm (79x), and a 6mm (212x). Spurred to action by Adriana's email, I went outside with scope and eyepieces and went to work determining their true fields of view.

CALCULATING THE FIELD OF VIEW

Eyepiece	Mag.	Apparent Field	TRUE FIELD Moons	TRUE FIELD Star-drift	TRUE FIELD Calculation
32mm	40x	70°	1.7°	1.8°	1.8°
16mm	79x	82°	0.8°	1.0°	1.0°
6mm	212x	60°	0.3°	0.3°	0.3°

The author calculated the true field of view of three eyepieces when attached to his 10-inch f/5 reflector. The three methods he used — estimating how many Moons would fit in the field, star-drift timings, and mathematical calculations — gave pretty consistent results.

True to your field

There are three basic ways to figure out the true field of view an eyepiece provides. One is to use the Moon, which has an apparent diameter of 0.5°, as a measuring tool. So if an eyepiece captures a chunk of sky three Moon diameters across, it has a true field of view of 1.5°. With each eyepiece, I measured how many Moons, or what fraction of a Moon, I could fit in the field. Because this is the most subjective of the three methods and I didn't want to bias my results, I used this method first.

My tool for the next method was our spinning planet. Because Earth rotates once every 24 hours, covering 360° of sky, a star near the celestial equator will drift 1° every 4 minutes. If you time how many minutes it takes the star to enter the field of view, cross the center, and exit on the opposite side, then divide that time by 4, you have the true field of view in degrees. If the transit time is 6 minutes, for example, the true field is 1.5°. My star of choice was 3rd-magnitude Sadalmelik (Alpha [α] Aquarii), located just 19' south of the celestial equator. I ran several trials for each eyepiece.

The final method can be done mathematically while indoors. An eyepiece's true field of view equals its apparent field of view (AFOV) divided by the magnifying power it yields with a given scope. An eyepiece with a 60° AFOV that magnifies 40x has a true field of 1.5°. Calculator in hand, I worked out the true field for each eyepiece. The results for all three methods appear in the table below.

Some final thoughts: Because the Moon's angular size varies with its distance from Earth (0.49° when farthest away, 0.56° when closest), it's not an ideal measuring tool. Nevertheless, the ballpark figure you get is better than nothing, as my results show. Also, by the time this issue reaches the newsstands, Sadalmelik won't be as easy to use for star-drift timings. Work instead with 2nd-magnitude Mintaka (Delta [δ] Orionis), the northernmost and westernmost of the three stars in Orion's Belt and just 18' south of the celestial equator.

Finally, the AFOV of an eyepiece depends on its design. Here are approximate AFOVs for traditional types: Huygens or Ramsden (labeled "H" or "R" on the barrel), 30°; Kellner, achromatized Ramsden, or modified achromat ("K" or "Ke," "AR," or "MA"), 40°; orthoscopic ("Or" or "Ortho"), 45°; Plössl, 50°; and Erfle (ER) or König, 60°. For newer designs, especially super- and ultrawide types, refer to the manufacturer's website for specifics.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: another 13-year-old and her eclipse adventure.

Glenn Chaple has been an avid observer since a friend showed him Saturn through a small backyard scope in 1963.

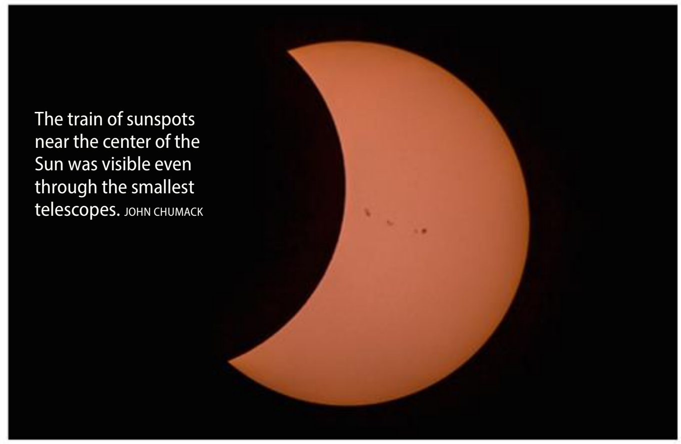
BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**

SECRET**SKY**

BY STEPHEN JAMES O'MEARA

The 'black drop' effect of sunspots

Can this well-known phenomenon during planetary transits also be observed with sunspots?



The train of sunspots near the center of the Sun was visible even through the smallest telescopes. JOHN CHUMACK

The Great American Eclipse has come and gone, and many observers have already shared their impressions of totality with me. And now I'd like to pass those exciting stories on to you.

A sunspot train

Observers using safely filtered binoculars and telescopes enjoyed views of a sunspot "train" with roughly a dozen umbral (dark inner) cores stretching some 140,000 miles (225,000 kilometers) along the Sun's equator. Another sunspot group near the Sun's eastern limb joined the train — a pleasant surprise for an eclipse during a solar minimum.

At the Oregon Star Party (OSP), which lay in the path of totality, the plethora of spots gave observers several opportunities to witness an optical phenomenon I had proposed might be visible during the partial phases. During a talk the night before the main event, I had asked observers for their help searching for it. And on eclipse day, several of them took on the challenge and reported success.

A parade of illusions

The phenomenon I had mentioned is akin to the "black drop" effect that observers have reported during transits of Mercury and Venus. Torbern Bergman first noticed it during the 1761 transit of Venus from Uppsala, Sweden, reporting that a dark "ligature" (resembling a narrow bridge) joined the silhouette of Venus to the inky background of the sky beyond the Sun. Imagine the black drop as gum on a hot pavement that clings to a shoe — until it breaks free as the shoe lifts.

Astronomers still debate the cause of the effect. Theories include atmospheric turbulence, aberrations in optical systems, and eye-brain visual deceptions. In the *Proceedings of the International Astronomical Union Colloquium*, No. 196 (2004), Jay Pasachoff, Glenn Schneider, and Leon Golub demonstrated how the Sun's limb darkening is a principal culprit. Now observations made at OSP during the 2017 solar eclipse add yet another dimension to the effect.

During the eclipse's partial phases, observers using telescopes viewed the black drop effect whenever the dark lunar limb encountered a sunspot's umbral core. Several observers saw the effect independently using telescopes with apertures ranging from 6 to 16 inches.

Judy and Chuck Dethloff, my wife, Deborah Carter, and Richard Just all saw the effect as the Moon covered the length of the sunspot train and the eastern group before totality, and uncovered them afterward. As the Moon passed over the spots, it created a parade of illusions mostly near the center of the Sun's disk — away from any limb darkening.

A black bridge, teardrops, and more

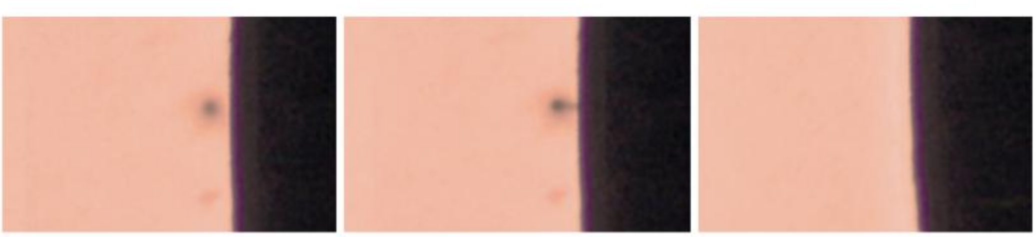
I got to see only one event (through Judy's 16-inch Dobsonian-mounted reflector), but it was dramatic enough to convince me of the effect's reality. As the Moon's limb approached the core of one spot, a thin ligament appeared like a narrow bridge that joined the spot's core and the Moon's advancing silhouette. Over the course of seconds, this thread of darkness vanished and reappeared repeatedly before becoming a solid bridge that rapidly melted into the lunar limb.

In addition to this phenomenon, Chuck, Judy, and Deborah also observed the larger sunspot cores transforming into either a pencil-tip or teardrop shape before the advancing limb covered them all. Deborah described the re-emergence of the last sunspot core before third contact as a mirage.

"First, the spot appeared flattened above the dark limb of the Moon separated by a narrow gap," she said. "Darkness from the spot then dripped into the lunar limb as the spot transformed into a teardrop before separating from the lunar limb and appearing as a normal spot."

It's important to note that the observers deemed the atmosphere steady during many of these events, with occasions of imperfect seeing. So these effects were observed under stable air, through sizable telescopes, and mostly near the center of the Sun's disk. Is it possible, perhaps, that a sunspot's penumbra serves equally well as limb darkening to help cause the effect?

As always, if you observed similar phenomena, send your reports to sjomeara31@gmail.com.



The photographs at left and right show the approach and disappearance of a sunspot near the lunar limb during the 2017 solar eclipse. The middle image has been altered with software to show what the author saw visually. STEPHEN JAMES O'MEARA

Stephen James O'Meara is a globe-trotting observer who is always looking for the next great celestial event.

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

BINOCULARUNIVERSE

BY PHIL HARRINGTON

Wonders of the Big Dog

Canis Major holds the sky's brightest star and one of the most beautiful open clusters.

A blaze of brilliant stars decorates the January sky, ushering in 2018. Brightest of all is **Sirius** (Alpha [α] Canis Majoris) in Canis Major, the Big Dog. Aptly nicknamed the Dog Star, Sirius stands obediently by its master, Orion the Hunter.

Swing your binoculars Sirius' way, and it puts on an astonishing show. If you can, catch it as it is just rising above the southeastern horizon. Since you look through more of Earth's atmosphere when viewing near the horizon, temperature layers and intertwining wind currents play havoc with Sirius' light, bending and refracting it into a firestorm of rapidly changing colors. When our atmosphere is especially turbulent, resulting in "poor seeing," Sirius' color shifts are stroboscopic.

As it rises higher in the sky, the colorful show slowly calms down to reveal that the star's true color is a radiant white. Winter skies often remain turbulent through the night, with upper-level winds still creating mayhem with distant starlight. The brighter the star, the greater the twinkling effect. In the case of Sirius, the effect can be almost hypnotic.

Sirius shines at magnitude –1.4. But while it appears bright in our sky, it is not an especially luminous star. True, it does radiate 26 times more energy than our Sun, but it is not nearly as powerful as, say, Rigel, seen 27° to the northwest. No, Sirius appears so bright primarily because of its distance from our solar system. Sirius lies only 8.6 light-years away, while Rigel is almost exactly 100 times more distant. Were they to swap places, Sirius would shine at only 9th magnitude. Rigel, however, would blaze at a staggering magnitude –10.

The brightest star in the sky, Sirius, harbors a dim companion called Sirius B just 4" away (below left). It is quite a challenge to see visually. DAMIAN PEACH

Sirius is accompanied by a white dwarf companion star known as **Sirius B**, or the Pup. Trying to spot Sirius B is one of backyard astronomy's greatest challenges. The problem is not that Sirius B is so faint. In fact, it shines at magnitude 8.5, which is within reach of most binoculars. No, the problem is Sirius. The same effect that causes stars to twinkle — scintillation — also blurs the view by scattering their light. Sirius so completely overwhelms the observer's eye that poor Sirius B, some 10,000 times fainter, is usually obliterated. The two are separated by only 4", which also confounds observers.

Shift Sirius toward the top (north) of the field and then take a look near the bottom (south) for a clump of faint stars. That's the open cluster **M41**. I think of it as the "Dog Tag Cluster" for its position near Canis Major's "neck."

The bright star cluster M41 in Canis Major is one of the most sparkling star groups when viewed with a good pair of binoculars. ANTHONY AYIOMAMITIS

Many astro history buffs credit the Greek scientist Aristotle (384 B.C.–322 B.C.) with discovering M41. That credit is based on his description in *Meteorologica* (325 B.C.) in which he writes, "one of the stars of the Dog has a tail, though a dim one; if you looked hard at it, the light used to become dim, but to a less intent glance it became brighter."

The first person to associate this statement with M41 was John Ellard Gore (1845–1910) in an article he authored in the August 1902 issue of *The Observatory*. Others have since adopted the same interpretation, although some suggest it actually points to a trail of faint stars farther south, near Wezen (Delta [δ] Canis Majoris). There is no way to know for sure.

From Aristotle's words, however, there seems little doubt that whatever he saw, he used averted vision to see it more distinctly. You can, too. But to see M41 with the unaided eye, it takes especially dark, transparent skies.

It's much easier through binoculars. Swing your binoculars toward the cluster, and you will immediately see a compact collection of stellar pinpoints. Some 80 stars call M41 home, with 16 of them breaking the 9th-magnitude "binocular barrier." The rest blend together to create a soft glow.

The brightest star in M41, designated **HD 49091**, lies nearly dead center in the pack. A type K3 orange giant, it shines at magnitude 6.9 and puts on a fine show through binoculars. Try defocusing the image ever so slightly to accentuate the color. How many other red and orange stars can you count in M41?

Also try your luck at resolving a double star found northwest of the cluster's center. Known as **h2341**, its component stars shine at magnitudes 8.3 and 9.1 and are separated by 45". That's wide enough to be resolved at 10x, but their faintness will likely require you to use a tripod or other support to steady the view. Then, by using Aristotle's technique of averted vision, they may just pop into view.

I'd love to hear about your binocular adventures and conquests. Contact me through my website, philharrington.net.

Until next month, remember that two eyes are better than one.

Phil Harrington is a longtime contributor to Astronomy *and the author of many books.*

STATEMENT OF OWNERSHIP, MANAGEMENT, AND CIRCULATION

(Required by 39 USC 3685)

1. Publication title: ASTRONOMY
2. Publication no.: 531-350
3. Filing date: October 1, 2017
4. Issue frequency: Monthly
5. Number of issues published annually: 12
6. Annual subscription price: $42.95
7. Complete mailing address of known office of publication: 21027 Crossroads Circle, Waukesha, WI 53187-1612
8. Complete mailing address of headquarters or general business office of publisher: Same
9. Publisher: Dan Lance, 21027 Crossroads Circle, Waukesha, WI 53187-1612. Editor: David J. Eicher, same.
10. Owner: Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612. Stockholders owning or holding 1 percent or more of total amount of stock are: Deborah H.D. Bercot, 22012 Indian Springs Trail, Amberson, PA 17210; Gerald and Patricia Boettcher Trust, 8041 Warren Ave., Wauwatosa, WI 53213; Alexander & Sally Darragh, 145 Prospect Ave., Waterloo, IA 50703; Melanie J. Kirrene Trust, 9705 Royston Ct., Granite Bay, CA 95746; Harold Edmonson, 6021 N. Marmora Ave., Chicago, IL 60646-3903; Laura & Gregory Felzer, 3328 S. Honey Creek Dr., Milwaukee, WI 53219; Susan E. Fisher Trust, 3430 E. Sunrise Dr., Ste. 200, Tucson, AZ 85718; Bruce H. Grunden, 255 Vista Del Lago Dr., Huffman, TX 77336-4683; Linda H. Hanson Trust, P.O. Box 19, Arcadia, MI 49613; Mary Kay Herrmann, 1530 Tallgrass Circle, Waukesha, WI 53188; George F. Hirschmann Trusts, P.O. Box 19, Arcadia, MI 49613; James & Carol Ingles, 1907 Sunnyside Dr., Waukesha, WI 53186; Charles & Lois Kalmbach, 7435 N. Braeburn Ln., Glendale, WI 53209; Kalmbach Profit Sharing/401K Savings Plan & Trust, P.O. Box 1612, Waukesha, WI 53187-1612; James & Elizabeth King, 2505 E. Bradford Ave., #1305, Milwaukee, WI 53211-4263; Mahnke Family Trust, 4756 Marlborough Way, Carmichael, CA 95608; Milwaukee Art Museum, Inc., 700 N. Art Museum Dr., Milwaukee, WI 53202; James W. Mundschau, N24 W30420 Crystal Springs Dr., Pewaukee, WI 53072; Lois E. Stuart Trust, 1320 Pantops Cottage Ct., #1, Charlottesville, VA 22911-4663; David M. Thornburgh Trust, 8855 Collins Ave., Apt. 3A, Surfside, FL 33154-0436.
11. Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities: N/A
12. Tax status (for completion by nonprofit organizations authorized to mail at nonprofit rates): N/A
13. Publication title: ASTRONOMY
14. Issue date for circulation data below: September 2017
15. Extent and nature of circulation:

15. Extent and nature of circulation	Average no. copies each issue during preceding 12 months	No. copies of single issue published nearest to filing date
a. Total number of copies (net press run)	130,628	127,446
b. Paid circulation (by mail and outside the mail)		
1. Mailed outside-county paid subscriptions	85,051	83,090
2. Mailed in-county paid subscriptions	-0-	-0-
3. Paid distribution outside the mails including sales through dealers and carriers, street vendors, counter sales, and other paid distribution outside USPS	11,678	11,919
4. Paid distribution by other classes of mail through the USPS	-0-	-0-
c. Total paid distribution [sum of 15b (1), (2), (3), and (4)]	96,729	95,009
d. Free or nominal rate distribution (by mail and outside the mail)		
1. Outside-county	-0-	-0-
2. In-county	-0-	-0-
3. Other classes mailed through the USPS	237	230
4. Outside the mail	142	-0-
e. Total free or nominal rate distribution [sum of 15d (1), (2), (3) and (4)]	379	230
f. Total distribution (sum of 15c and 15e)	97,108	95,239
g. Copies not distributed	33,520	32,207
h. Total (sum of 15f and g)	130,628	127,446
i. Percent paid (15c divided by 15f times 100)	99.61%	99.76%
16. Electronic copy circulation:		
a. Paid electronic copies	6,314	5,118
b. Total paid print copies (15c) plus paid electronic copies (16a)	103,043	100,127
c. Total print distribution (15f) plus paid electronic copies (16a)	103,422	100,357
d. Percent paid, both print and electronic (16b divided by 16e times 100)	99.63%	99.77%

17. Publication of Statement of Ownership: Publication required. Printed in the January 2018 issue of this publication.
18. I certify that all information furnished on this form is true and complete. Nicole McGuire, Vice President Consumer Marketing. Date: September 29, 2017.

INDEX *of* ADVERTISERS

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

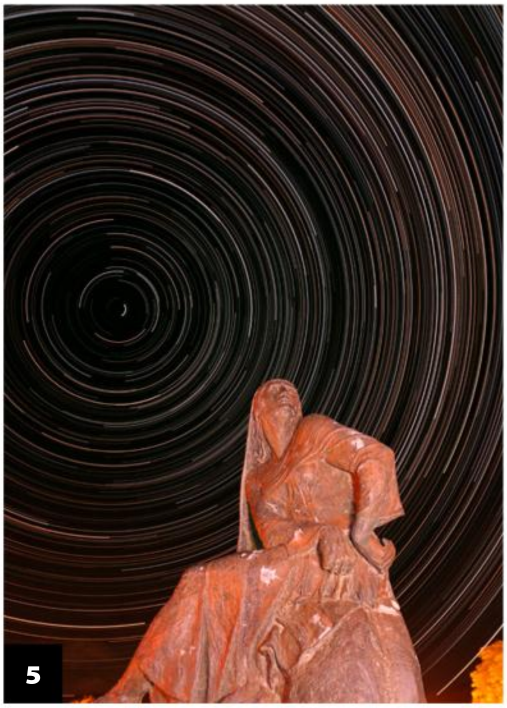
MARKETPLACE

1

2

1. RIGHT PLACE, RIGHT TIME
This photographer was on Pensacola Beach, Florida, shooting the Moon setting August 2, 2017, when a brilliant fireball flashed overhead. He called it "the luckiest shot of my life."
• Austin Houser

2. REMEMBER THE CLUSTER
M92 is often called the "forgotten" globular cluster in Hercules because its brighter counterpart — the Hercules Cluster (M13) — is so well known. But M92 isn't that much fainter. It shines with 60 percent of its counterpart's brilliance. ***• Georges Chassaigne***



3. RED SKY AT NIGHT
Sharpless 2–126 in the constellation Lacerta the Lizard is a magnificent section of sky. This large star-forming region lies some 1,200 light-years from Earth. The energy that makes the cloud emit the characteristic reddish color of emission nebulae comes from the blue main sequence star 10 Lacertae (below and left of center). • ***Richard Sweeney***

4. SEVEN ISN'T ENOUGH
The Pleiades (M45) is the brightest and closest celestial object on French comet hunter Charles Messier's list of 109 objects that were not comets. M45 is also known as the Seven Sisters; images push the total number of stars in this open cluster into the hundreds. • ***Terry Hancock***

5. STARGAZER
This monument in Eretria, Greece, shows a woman viewing the sky overhead. To complement the statue, this photographer captured and stacked seven hundred forty-three 30-second exposures of the background sky, showing how much it appears to move in more than 6 hours. The smallest curved streak belongs to Polaris (Alpha Ursae Minoris). • ***Anthony Ayiomamitis***

6. MAN IN THE CASTLE
A skywatcher observes a majestic group of sunspots in this carefully planned single shot taken September 7, 2017, 1.3 miles (2.1 km) from the Castle of Noudar Park, Portugal. On September 6, the Earth-sized sunspot AR2673 — seen at the right side of the man´s silhouette — unleashed an X9.3-class solar flare, the strongest in more than a decade. • ***Miguel Claro***

7. COAXING OUT DETAILS
Spiral galaxy M100 in the constellation Coma Berenices is difficult to photograph because of its wide dynamic range. Its arms are faint while the galaxy's core is tiny and bright. M100 does lie in a colorful star field. *• Rodney Pommier*

8. GO FLY A KITE
The Kite Cluster (NGC 1664) lies against a rich star field in the constellation Auriga. You'll find this attractive open cluster 2° west of Epsilon (ε) Aurigae. It lies some 4,000 light-years away. *• Jaspal Chadha*

9. DISH IT OUT
This two-exposure panorama shows one of the antennas of the Very Large Array in New Mexico. The Northern Hemisphere summer Milky Way lies behind it. The brightest star to the right of the dish is Antares (Alpha [α] Scorpii). *• John Vermette*


7


8


9

10. I FELL IN LOVE
The Heart Nebula (IC 1805, right) pairs with the Soul Nebula (IC 1848) in the northern constellation Cassiopeia. The pair lies roughly 7,500 light-years away. This image is a combination of 19 hours of exposures through six filters. • ***Kfir Simon***

11. FIVE FOR OBSERVING
This photographer captured a lineup of four solar system objects and a bright star at 6:24 A.M. EDT, September 17, 2017, from East Dayton, Ohio. • ***John Chumack***

Send your images to:
Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

BREAK THROUGH

A tale of three cities

The beauty of the Orion Nebula (M42) belies the firestorm of star birth taking place within its nebulous folds. But this vast stellar nursery shrouds another secret: The young stars within appear to have formed in three separate bursts. Astronomers uncovered these populations by analyzing the data in this image taken through the European Southern Observatory's VLT Survey Telescope in Chile. The researchers measured the colors and brightnesses of the thousands of stars in the nebula's core and discovered what appears to be three successive generations born about 2.87 million, 1.88 million, and 1.24 million years ago.
ESO/G. BECCARI

STELLARVUE HAND CRAFTED APOCHROMATIC TRIPLET REFRACTORS

SV70T F/6 APO TRIPLET

SV80ST F/6 APO TRIPLET

SV102T F/7 APO TRIPLET

SVR102T F/7 APO TRIPLET

SVA130T F/7 APO TRIPLET

SV152T F/8 APO TRIPLET

STELLARVUE®

WWW.STELLARVUE.COM

11820 KEMPER ROAD
AUBURN, CA 95603
(530) 823-7796

SPECIAL Pull-out section

Astronomy's 2018 Guide to the Night Sky

LUNAR PHASES

New	First Quarter	Full	Last Quarter
		Jan. 1	Jan. 8
Jan. 16	Jan. 24	Jan. 31	Feb. 7
Feb. 15	Feb. 23	March 1	March 9
March 17	March 24	March 31	April 8
April 15	April 22	April 29	May 7
May 15	May 21	May 29	June 6
June 13	June 20	June 28	July 6
July 12	July 19	July 27	Aug. 4
Aug. 11	Aug. 18	Aug. 26	Sept. 2
Sept. 9	Sept. 16	Sept. 24	Oct. 2
Oct. 8	Oct. 16	Oct. 24	Oct. 31
Nov. 7	Nov. 15	Nov. 23	Nov. 29
Dec. 7	Dec. 15	Dec. 22	Dec. 29

All dates are for the Eastern time zone. A Full Moon rises at sunset and remains visible all night; a New Moon crosses the sky with the Sun and can't be seen.

THE MOON is Earth's nearest neighbor and the only celestial object humans have visited. Because of its changing position relative to the Sun and Earth, the Moon appears to go through phases, from a slender crescent to Full Moon and back. The best times to observe our satellite through a telescope come a few days on either side of its two Quarter phases. For the best detail, look along the terminator — the line separating the sunlit and dark parts. NASA/GSFC/ARIZONA STATE UNIVERSITY

MARS remains visible for all of 2018, though it appears most conspicuously from April through November. The Red Planet rises around 2 A.M. in mid-April, but comes up earlier with each passing day. It peaks at opposition in late July, when it shines at magnitude –2.8, swells to an apparent diameter of 24", and remains on view all night. Mars hasn't appeared this bright and big since 2003. A telescopic view reveals subtle features that show up as contrasting shades of orange and brown. NASA/JPL-CALTECH/USGS

JUPITER always shows a dramatic face. Its atmosphere displays an alternating series of bright zones and darker belts pocked by the Great Red Spot. Even through a small telescope, the planet's four big moons appear prominent. You often will see them change positions noticeably during the course of a single night. Jupiter reaches its peak in early May, when it shines brightest (magnitude –2.5) and looms largest (45" across), though it's a fine sight through September and again in late December. NASA/JPL/USGS

SATURN and its rings provide a spectacular attraction for telescope owners during most of 2018. The ringed planet is on display from late January through November, but it appears best around the time of opposition in late June. Saturn then shines at magnitude 0.0, and its disk measures 18" across while the rings span 42" and angle 26° to our line of sight. Even a small telescope reveals the dark, broad Cassini Division that separates the outer A ring from the brighter B ring.

NASA/ESA/E. KARKOSCHKA (UNIVERSITY OF ARIZONA)

WINTER

The sky

Winter boasts the brightest stars of any season. Orion the Hunter dominates the evening sky this time of year. Its seven brightest stars form a distinctive hourglass pattern. The bright blue star marking Orion's left foot is Rigel, and the ruddy gem at his right shoulder is Betelgeuse. The three stars of the Hunter's belt point down to Sirius, the brightest star in the night sky, and up to Aldebaran, the eye of Taurus the Bull. To Orion's upper left lies the constellation Gemini.

Deep-sky highlights

The Pleiades (M45) is the brightest star cluster in the sky. It looks like a small dipper, but it is not the Little Dipper.
The Orion Nebula (M42), a region of active star formation, is a showpiece through telescopes of all sizes.
The Rosette Nebula (NGC 2237–9/46), located 10° east of Betelgeuse, presents an impressive cluster of stars and a nebula.
M35 in Gemini the Twins is a beautiful open cluster best viewed with a telescope.
Castor (Alpha [α] Geminorum) is easy to split into two components with a small telescope, but the system actually consists of six stars.

SPRING

The sky

The Big Dipper, the most conspicuous part of the constellation Ursa Major the Great Bear, now rides high in the sky. Poke a hole in the bottom of the Dipper's bowl, and the water would fall on the back of Leo the Lion. The two stars at the end of the bowl, called the Pointer Stars, lead you directly to Polaris, the North Star: From the bowl's top, simply go five times the distance between the Pointers. Spring is the best time of year to observe a multitude of galaxies. Many of these far-flung island universes, containing hundreds of billions of stars, congregate in northern Virgo and Coma Berenices.

Deep-sky highlights

The Beehive Cluster (M44) was used to forecast weather in antiquity. It is a naked-eye object under a clear, dark sky, but it disappears under less optimal conditions.
M5, a conspicuous globular cluster, lies between the figures of Virgo the Maiden and Serpens Caput the Serpent's Head.
The Whirlpool Galaxy (M51) is a vast spiral about 30 million light-years away.
M81 and **M82** in Ursa Major form a pair of galaxies that you can spot through a telescope at low power.

Jan. 1 Mercury is at greatest western elongation

Jan. 31 Dwarf planet Ceres is at opposition

Jan. 31 Total lunar eclipse

March 15 Mercury is at greatest eastern elongation

April 2 Mars passes 1.3° south of Saturn

April 22 Lyrid meteor shower peaks

May 6 Eta Aquariid meteor shower peaks

May 8 Jupiter is at opposition

June 19 Asteroid Vesta is at opposition

June 27 Saturn is at opposition

July 12 Mercury is at greatest eastern elongation

STAR MAPS BY *ASTRONOMY*: ROEN KELLY

July 12
Pluto is at opposition

July 27
Mars is at opposition

Aug. 12
Perseid meteor shower peaks

Aug. 17
Venus is at greatest eastern elongation

Aug. 26
Mercury is at greatest western elongation

Sept. 7
Neptune is at opposition

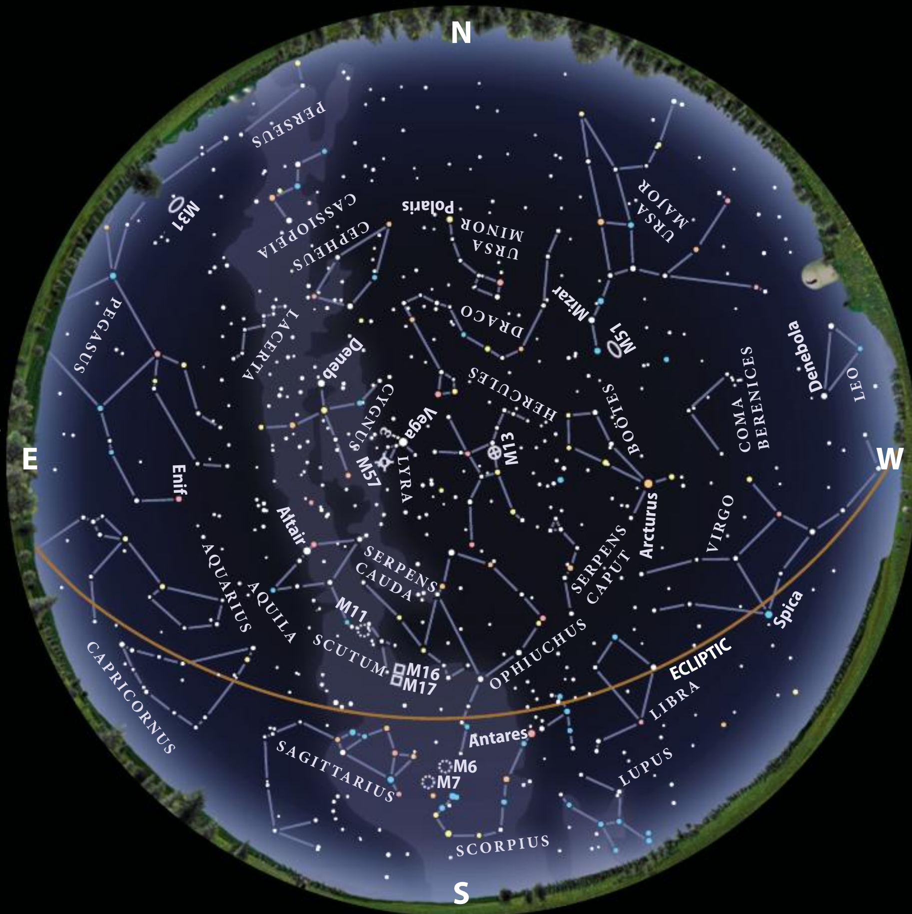
Oct. 21
Orionid meteor shower peaks

Oct. 23
Uranus is at opposition

Nov. 17
Leonid meteor shower peaks

Dec. 14
Geminid meteor shower peaks

Dec. 15
Mercury is at greatest western elongation



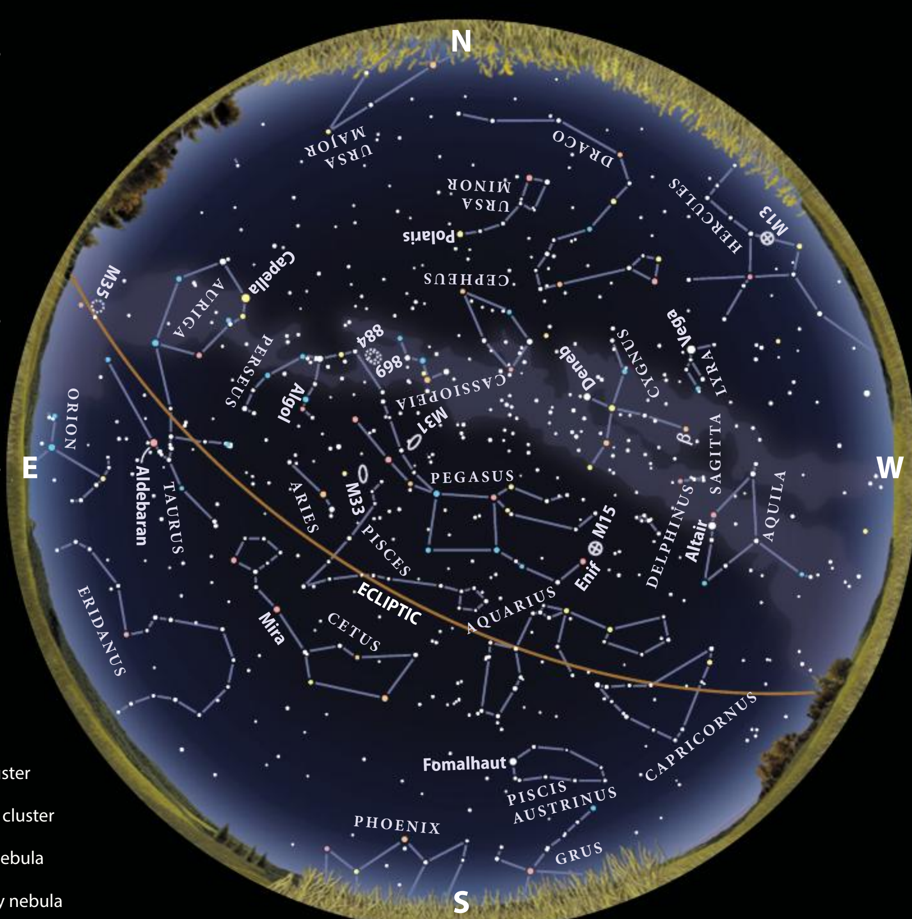
SUMMER

The sky

High in the sky, the three bright stars known as the Summer Triangle are easy to spot. These luminaries — Vega in Lyra, Deneb in Cygnus, and Altair in Aquila — lie near the starry path of the Milky Way. Following the Milky Way south from Aquila, you'll find the center of our galaxy in the constellation Sagittarius the Archer. Here lie countless star clusters and glowing gas clouds. Just west of Sagittarius lies Scorpius the Scorpion, which contains the red supergiant star Antares as well as M6 and M7, two brilliant clusters that look marvelous at low power.

Deep-sky highlights

The Hercules Cluster (M13) contains nearly a million stars and is the finest globular cluster in the northern sky.
The Ring Nebula (M57) looks like a puff of smoke through a medium-sized telescope.
The Omega Nebula (M17) looks like the Greek letter of its name (Ω) through a telescope at low power. This object also is called the Swan Nebula.
The Wild Duck Cluster (M11) is a glorious open star cluster. On a moonless night, a small scope will show you some 50 stars.



AUTUMN

The sky

The Big Dipper swings low this season, and from parts of the southern United States, it even sets. With the coming of cooler nights, Pegasus the Winged Horse rides high in the sky as the rich summer Milky Way descends in the west. Fomalhaut, a solitary bright star, lies low in the south. The magnificent Andromeda Galaxy reaches its peak nearly overhead on autumn evenings, as does the famous Double Cluster. Both of these objects appear as fuzzy patches to the naked eye under a dark sky.

Deep-sky highlights

The Andromeda Galaxy (M31) is the brightest naked-eye object outside our galaxy visible in the northern sky.
The Double Cluster (NGC 869 and NGC 884) in Perseus consists of twin open star clusters. It's a great sight through binoculars.
M15 in Pegasus is a globular cluster containing hundreds of thousands of stars, many of which can be glimpsed through a medium-sized telescope.
Albireo (Beta [β] Cygni), the most beautiful double star in the sky, is made up of suns colored sapphire and gold.

Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

Astronomy magazine

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

March 2018: The evening planets return

The early evening sky has been devoid of bright planets all summer, but that comes to an end as autumn approaches. Unfortunately, the first two solar system residents to appear at dusk don't climb very high in March, particularly from more southerly latitudes. Blame the shallow angle of the ecliptic — the apparent path of the Sun across the sky that the planets closely follow — to the western horizon after sunset at this time of year. A planet's elongation from the Sun translates more into distance along the horizon and less into altitude.

Venus makes the better appearance. In late March, it lies 20° east of the Sun, and from mid-southern latitudes, it appears 4° above the western horizon a half-hour after sunset. (Conditions improve closer to the equator. From Darwin, Australia, for example, the planet appears twice as high at the same time.) Venus shines brilliantly, at magnitude –3.9, and should show up clearly in the twilight if you have an unobstructed horizon.

Mercury doesn't fare as well. The best time to look for the innermost planet is when it reaches greatest elongation March 15. It then lies 18° east of the Sun but climbs just 1° high a half-hour after sundown for those at mid-southern latitudes. (Observers in Darwin see Mercury at an altitude of 5°.) You'll need binoculars to pick up the planet's magnitude –0.4 glow.

If these early evening views leave you unimpressed, just wait a few hours. **Jupiter** rises around 10 P.M. local time in early March and some two hours earlier by month's end. The planet appears nearly stationary against the backdrop of central Libra the Scales. Jupiter brightens from magnitude –2.2 to –2.4 during March, which makes it 100 times brighter than Libra's luminary, which glows at magnitude 2.6.

The view of Jupiter through a telescope is no less impressive. The giant planet's equatorial diameter swells from 39" to 43" during March, delivering exquisite eyepiece images in any instrument. Look for an alternating series of bright zones and darker belts, perhaps punctuated by the ruddy cloud tops of the Great Red Spot, if it happens to be on the Earth-facing hemisphere. Your sharpest views will come as Jupiter climbs high after midnight; it reaches a peak altitude of 70° around the time morning twilight commences.

A couple of hours after Jupiter rises, **Mars** pokes above the eastern horizon. The Red Planet moves steadily eastward against the background stars during March, crossing from Ophiuchus the Serpent-bearer into Sagittarius the Archer in the month's second week. Mars brightens by more than 50 percent during March, climbing from magnitude 0.8 to 0.3, and noticeably outshines the stars of its host constellations.

The rapid brightening goes hand in hand with the planet's increasing diameter. Mars' disk spans 6.7" on March 1 and reaches 8.4" across by the 31st. This is big enough that you might catch a fleeting glimpse of surface detail during moments of good seeing, when Earth's atmosphere steadies and the light from celestial objects snaps into sharp focus.

Saturn rises a little more than an hour after Mars in early March, but the gap shrinks to 10 minutes by the 31st. At the end of the month, they appear 2° apart and make a fine pair through binoculars. (The two will pass within 1.3° of each other April 2.) Saturn shines at magnitude 0.5 and appears a touch dimmer than its neighbor. They'll be easier to tell apart by their colors: Mars shines with a distinctive orange-red hue while Saturn appears golden yellow.

It's always worth exploring Saturn through a telescope, though your sharpest views will come when it climbs high in the east as dawn starts to paint the sky. In mid-March, the planet shows a 16"-diameter disk surrounded by a ring system that spans 37" and tips 26° to our line of sight. The large tilt delivers excellent views of the inky-black Cassini Division that separates the outer A ring from the brighter B ring.

The starry sky

One of the surprises for many first-time telescope users is "discovering" that so many stars are double or multiple. The list of such systems is long, and includes some of the night sky's brightest stars.

Probably the first double that beginners aim their telescopes toward is Alpha (α) Centauri, which is arguably the most famous double star in the southern sky. It is also the nearest star system to our own, with faint Proxima Centauri, the system's third member, the closest of the three. But it is the brighter pair that makes a spectacular telescopic sight. Only 4.5" separate the two suns, and the gap is gradually widening.

Next, turn your attention to Orion the Hunter. Center your scope on Rigel, the bright, blue-white star at the upper left of the constellation these March evenings. At medium and high magnification, the magnitude 6.8 secondary shows up nicely 9" from the primary. Although the companion is also a double, the two stars are a fraction of an arcsecond apart and invisible through backyard scopes.

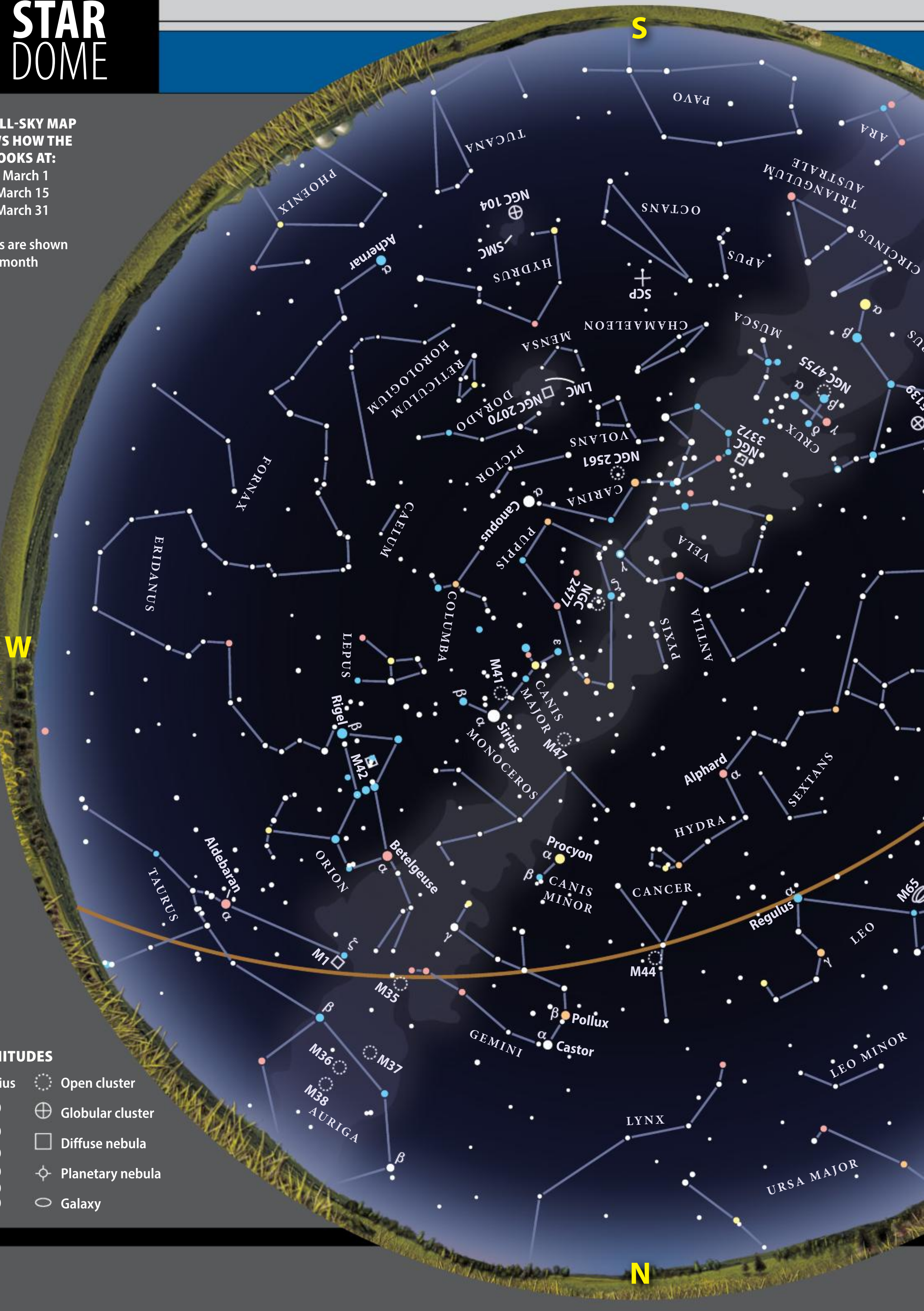
If you want to see a beautiful multiple star system, look no further than Sigma (σ) Orionis. It resides 0.8° south-southwest of Zeta (ζ) Ori, the easternmost star in Orion's Belt. Small scopes reveal four stars. In addition to the 4th-magnitude primary, you'll see stars of magnitudes 10.3, 7.5, and 6.5 in order of their increasing distance. The primary itself is a very close double, but you won't be able to split it.

Our final stop these March evenings is across Orion's eastern border into Monoceros the Unicorn. Beta (β) Monocerotis is a stunning triple star with components glowing at magnitudes 4.7, 5.2, and 6.1. The second-brightest star resides 7" from the primary, while the third-brightest member lies another 3" farther away in nearly the same direction.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
10 P.M. March 1
9 P.M. March 15
8 P.M. March 31

Planets are shown at midmonth



MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

MARCH 2018

Calendar of events

1 The Moon passes 0.9° north of Regulus, 6h UT

2 Full Moon occurs at 0h51m UT

4 Neptune is in conjunction with the Sun, 14h UT

5 Mercury passes 1.4° north of Venus, 18h UT

7 The Moon passes 4° north of Jupiter, 7h UT

9 Jupiter is stationary, 10h UT

Last Quarter Moon occurs at 11h20m UT

10 The Moon passes 4° north of Mars, 1h UT

11 The Moon passes 2° north of Saturn, 2h UT

The Moon is at apogee (404,678 kilometers from Earth), 9h14m UT

15 Mercury is at greatest eastern elongation (18°), 15h UT

17 New Moon occurs at 13h12m UT

18 Mercury passes 4° north of Venus, 1h UT

The Moon passes 8° south of Mercury, 18h UT

The Moon passes 4° south of Venus, 19h UT

19 The Moon passes 5° south of Uranus, 16h UT

20 March equinox occurs at 16h15m UT

Dwarf planet Ceres is stationary, 21h UT

22 Mercury is stationary, 17h UT

The Moon passes 0.9° north of Aldebaran, 23h UT

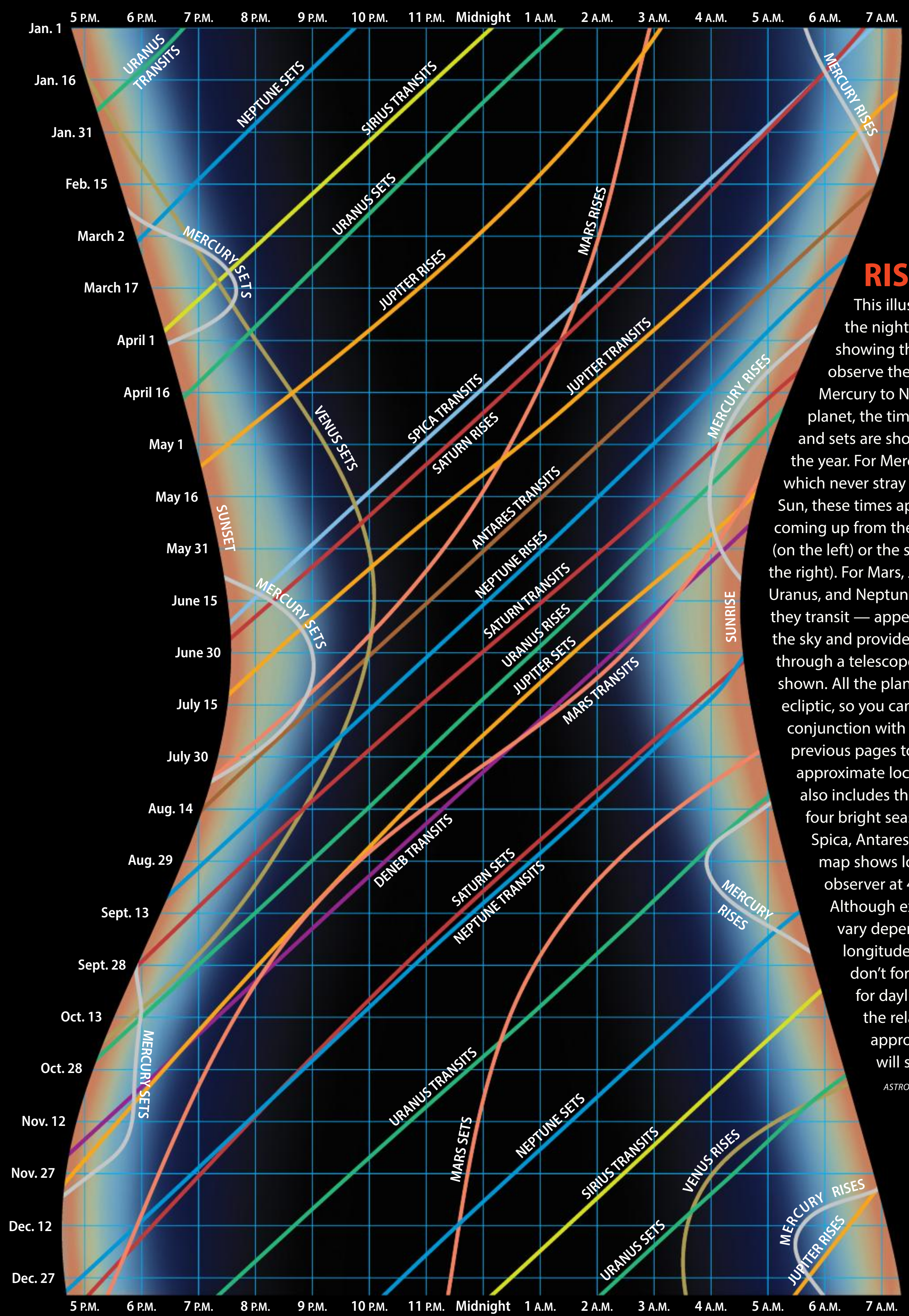
24 First Quarter Moon occurs at 15h35m UT

26 The Moon is at perigee (369,106 kilometers from Earth), 17h17m UT

28 The Moon passes 1.0° north of Regulus, 14h UT

31 Full Moon occurs at 12h37m UT

A+ BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



RISE & SET

This illustration presents the night sky for 2018, showing the best times to observe the planets from Mercury to Neptune. For each planet, the times when it rises and sets are shown throughout the year. For Mercury and Venus, which never stray too far from the Sun, these times appear as loops coming up from the sunset horizon (on the left) or the sunrise horizon (on the right). For Mars, Jupiter, Saturn, Uranus, and Neptune, the times when they transit — appear highest in the sky and provide the best view through a telescope — also are shown. All the planets lie near the ecliptic, so you can use this chart in conjunction with the maps on the previous pages to find a planet's approximate location. The chart also includes the transit times of four bright seasonal stars: Sirius, Spica, Antares, and Deneb. This map shows local times for an observer at 40° north latitude. Although exact times will vary depending on your longitude and latitude (and don't forget to add an hour for daylight saving time), the relative times and approximate positions will stay the same.

ASTRONOMY: RICK JOHNSON