

SPECIAL **40**TH ANNIVERSARY ISSUE

AUGUST 2013

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40
greatest
astronomical
discoveries
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COSMIC MYSTERIES p. 32

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CANADA-FRANCE-HAWAII TELESCOPE/CELEUM

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The beautiful Orion Nebula (M42) graces our cover for the 15th time in *Astronomy's* 40-year history.

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Picture of the Day
Astroimages from around the world

where do you celestron?

As an Oscar- and Emmy-nominated writer, director, and producer, John Davis is familiar with all sorts of stars. But the ones that truly captivate him are those of the celestial variety. In 2007, soon after purchasing a Celestron CPC 800—his first telescope—John became enthralled with the art of astrophotography. He's now a published imager who creates stunning high-resolution star mosaics with a 14-inch Celestron under the dark skies of Texas Hill Country.

We invite you to join our global community of people like John, who are passionate about astronomy, discovery, and the outdoors. Send us your stories and share the cool places you use Celestron products. It could be a star party in your town, a favorite hiking trail, or your own backyard.



"My name is John Davis, and
I Celestron at BuckSnort Observatory."



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Astronomy's 40th anniversary

With this issue, *Astronomy* magazine celebrates its 40th anniversary. The editors have designed a package of special stories we hope you will enjoy, from the 40 greatest discoveries in astronomy to a look ahead at the field's future, and everything in between. It's a special edition that puts forth the best of what the magazine's founder, Steve Walther, would have wanted.

Little did Walther know that his brainchild would turn into the greatest magazine about astronomy in the world. At 29, the ambitious graduate of the University of Wisconsin-Stevens Point launched a periodical about his first love, the stars. The first issue, August 1973, held 48 pages and five feature articles, plus information about what to see in the night sky that month. Walther had grown up in the Milwaukee area and taken jobs in public relations after college, always at least dabbling in his beloved pursuit of astronomy. He worked part time as a planetarium lecturer at the University of Wisconsin-Milwaukee and developed a keen interest in photographing constellations.

Astronomy magazine, his gift to the world, would live

on, but, sadly, he would not. With the magazine catching on rapidly, Walther threw a party for contributing authors, photographers, and sponsors in the summer of 1976. Beside a pool, surrounded by drinks and hors d'oeuvres, talking his best game with his closest friends, Walther collapsed, insensible. He died the following year, the victim of a brain tumor.

I never met Walther. As he toiled through his illness, I was hundreds of miles away — a teenager — working on my own little publication, *Deep Sky Monthly*, a journal about observing galaxies and clusters with small telescopes. But I have been fortunate to meet and make friends with many who knew him, many who had worked with him.

Reeling from the loss of leadership, the company Walther had started — Astro-Media 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.

These people guided the magazine through the period in which it became the

largest-circulation astronomy publication in the world — larger than the conservative, long-established *Sky & Telescope*; larger than the Japanese leader, *Tenmon Gaido*. A highlight of that period was the magazine's detailed coverage of one of the most exciting times in the history of modern astronomy, the Voyager missions to the planets.

Throughout its history, *Astronomy* magazine has really been a story of the people behind it. Obsessed with the subject, they have been driven to assemble the most absorbing material relating to astronomy with every page they have had. Names such as Walther, Berry, Maas, and Robert Burnham established the magazine's stable foundation; the future will expand on this terrific first 40 years. Names you see in the magazine today will carry on this tradition of excellence. Keep a close eye on their work in the pages of *Astronomy*; they are the stars of tomorrow. I think Steve Walther would be proud of them. I know I am.

Yours truly,

David J. Eicher
Editor

Editor David J. Eicher

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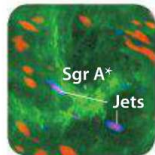
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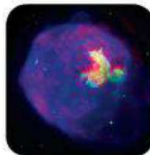
EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH...

HOT BYTES >>

TRENDING TO THE TOP



SURPRISING SIGN
ALMA spied jets of material emanating from dense dust and gas regions within 2 light-years of our galaxy's central black hole, indicating star formation.



SILICA FOUND
On May 1, astronomers reported the discovery in primitive meteorites of two silica grains (SiO_2) likely created in a core-collapse supernova.



ISON IMAGED
The Hubble Space Telescope imaged Comet ISON (C/2012 S1) on April 10 when it was 386 million miles, or 4.2 astronomical units, from the Sun.

SNAPSHOT

What makes a comet "great"?

With ISON on the way, we remember "Great Comets" of the past.

There are comets, and then there are comets. I didn't know that when I caught my first glimpse of Comet West (C/1975 V1) back in the spring of 1976, but as I gazed at the brilliant nucleus and twin tails of that magnificent visitor, I was looking at a "Great Comet."

Great Comets belong to an exclusive club. Over the past 2,000 years of recorded observations, humans have seen 70 such spectacular visitors. The 1990s brought us two — Hale-Bopp (C/1995 O1) and Hyakutake (C/1996 B2). Before then, we had West in the 1970s and Comet Ikeya-Seki (C/1965 S1) in the '60s.

A number of factors influence how bright and well-developed a comet will become. First and foremost is how close the comet will be to the Sun at perihelion. The closer the comet is to the Sun, the brighter it will be. Will Comet ISON (C/2012 S1) become a great comet? We really won't know until October. But it might. We're due for one. Let's keep our fingers crossed and hope for dark skies.

— David J. Eicher



Comet Hale-Bopp (C/1995 O1) wowed observers in 1996 and 1997.

MICHAEL STECKER (COMET HALE-BOPP); ALMA (ESO/MNRAO) (SURPRISING SIGN); X-RAY: NASA/CXC/RUTGERS/J. WARREN, ET AL.; OPTICAL: NASA/STS-61/L. Y. CHU; RADIO: ATCA/U. ILL./J. DICKEL, ET AL. (SILICA FOUND); NASA/ESA/J.-Y. LI (PLANETARY SCIENCE INSTITUTE)/THE HUBBLE COMET ISON IMAGING SCIENCE TEAM (ISON IMAGED)

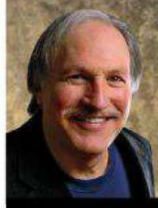
Bright light, black hole

Dark dust lanes and ruddy pockets of star formation highlight M77, a galaxy that lies about 45 million light-years from Earth in the constellation Cetus.

A quick glance at this Hubble image, released March 28, reveals a beautiful, if rather pedestrian, spiral. But looks can be deceiving. M77 is the nearest and brightest Seyfert galaxy, a type in which the central region radiates strongly at many wavelengths. The emission stems from material swirling rapidly around a supermassive black hole. In M77's case, this central monster holds some 15 million solar masses.

NASA/ESA/ANDRE VAN DER HOEVEN





STRANGEUNIVERSE

BY BOB BERMAN

Planet quirks

Our celestial neighbors are anything but ordinary.

The famous Perseid meteor shower unfolds under ideal circumstances this month. On the 11th, a harmless crescent Moon sets before midnight, providing dark skies just as the shooting stars begin cranking up. But unlike last year, something else is happening, too. During the first half of August, all seven planets stand visible in the sky at some point during the night.

To celebrate, our topic: planet oddities. We're talking about truly weird stuff, beyond the more familiar curiosities. Many folks already know that Venus is upside down, Saturn would float in a large-enough lake, and broiling Mercury has tons of ice, providing winter sports to a world badly needing it. Now let's go to the next level of weirdness.

Start with this question, guaranteed to stump your physics teacher or parole officer: "Which planet is brightest when it's farthest away?"

Doesn't seem possible. Yet Mercury, in a move opposite to Venus, grows most brilliant when on the far side of the Sun, like it is this month.

Mercury's also the darkest planet. It's blacker than an asphalt road. Yet it profoundly alters its brightness in the sky, varying a thousandfold. This past year, Mercury went from magnitude 5.3 — invisible from most locations — to a dazzling -2.4, brighter than Jupiter is this summer.

In addition, that second-densest world (Earth is the most) spins exactly three times while it orbits the Sun twice. This gearlike resonance of its

day and year creates odd consequences. We are accustomed to having one sunrise per day. But three leisurely 59-day spins must pass before dawn recurs on Mercury. That's one sunrise every two Mercury years. They're 177 days apart. Birds singing at daybreak: Nice here, but a lot rarer on Mercury.

There's more. Mercury boasts a region resembling nothing else. It's called the "Weird Terrain." Apparently, shock waves or else debris from the colossal meteor impact that formed the planet's huge Caloris Basin traveled halfway around the planet and then collided at the exact antipodal point to wreak havoc and create an unusually hilly and rutted environment.

Mercury's orbit, already the most eccentric, will get even more lopsided thanks to the influence of distant Jupiter, of all unlikely villains. Its path

JUPITER'S GREAT RED SPOT FLOATS 5 MILES ABOVE EVERYTHING ELSE LIKE A SCI-FI CITY.

might stretch out enough to make it collide with poor Venus, destroying both worlds in the next 5 billion years.

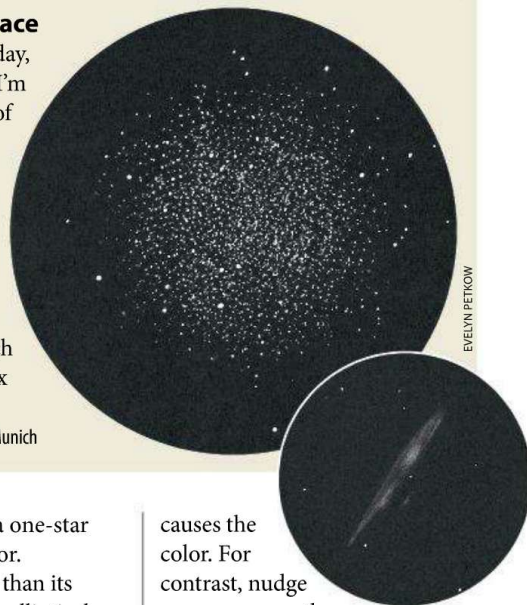
Venus has lots of oddities, too, but my favorite is the bizarre white "snowfall" that can make the planet's tallest mountains temporarily resemble the Coors beer logo. Of course, at a steady 850° Fahrenheit (450° Celsius), enough to burn pot roast in a few seconds, it can't be snow. Best guess is some form of white lead, like galena, that condenses from vapor below the planet's thick clouds, themselves made of concentrated sulfuric acid. No

FROM OUR INBOX

Celebrating space

Happy 40th birthday, *Astronomy* team! I'm sending a couple of my sketches of deep-sky objects — M13 (top) and NGC 4631/4627 — as a birthday present. I viewed these treasures through an 18-inch Dobsonian at 147x magnification.

— Evelyn Petkow, Munich



EVELYN PETKOW

wonder Venus gets a one-star rating on TripAdvisor.

With Mars, other than its freaky dust devils, its elliptical orbit deserves a look. We always wait 26 months for Earth and Mars to meet again, but the rendezvous can happen at a slim or wide gap in our orbits. The narrowest occur during a late August opposition. Remember 2003? Mars looked larger through a 75-power telescope than the Moon appeared to the naked eye. All sorts of intriguing detail emerged. The fascinating rarity of those very close approaches makes them precious. The next

causes the color. For contrast, nudge your scope north to Jove's equator to see giant holes in the clouds revealing gorgeous patches of blue sky. Really.

Saturn? Well, that giant persistent hexagon at its north pole, 60 miles (100km) high, takes the prize. Aliens must have used slave labor to build it so sturdily. It's now aimed our way and will tilt maximally toward us in 2017. That high-tilt setup also will make the rings' shiny ices double Saturn's brightness.

Yet Saturn cognoscenti prefer the rings' opposite surface. Whenever its south side fully slants our way (2003, 2032), Saturn is nearest to the Sun and nearly twice as bright, plus maximally high in the zodiac's northernmost suburbs. The planet then outshines even the bright stars Vega and Arcturus. Saturn's unrelated orbital shape, axial tilt, and declination work strangely in sync, like gears meshing. But whenever they make the ringed world most brilliant, the alien hexagon is hidden.

Turns out the Perseid meteors, delivering their reliable oohs and aahs, blaze through a solar system as wonderfully strange as any we could ever imagine. ☿

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



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

KEPLER FINDS SMALLEST PLANETS YET IN HABITABLE ZONE

The superstar space telescope Kepler bested itself once again when it found the smallest known exoplanets that could host liquid water.

Kepler-69c sits squarely in its Sun-like star's habitable zone. Although it is 70 percent larger than Earth (in terms of radius), it is the closest scientists have come to finding an Earth-sized planet around a Sun-like star.

Meanwhile, Kepler-62f and 62e are much closer to their star than planets in our solar system could be without having temperatures above water's boiling point. They orbit a dwarf star that is only two-thirds the Sun's size and one-fifth its brightness. Kepler-62e is on the fringe of the habitable zone and is 60 percent larger than Earth, but Kepler-62f is only 40 percent bigger than our planet and is farther out than its larger companion.

Astronomers have not determined these planets' masses yet — only their radii — so their compositions remain unknown. Scientists will need to calculate density, which requires both mass and radius, to determine the planets' makeups.



KEPLER • NASA/KEPLER MISSION

"Finding a planet in the habitable zone around a star like our Sun is a significant milestone toward finding truly Earth-like planets," says Thomas Barclay of the Bay Area Environmental Research Institute in Sonoma, California, and lead author of the Kepler-69 system discovery paper published in the May 10 issue of *The Astrophysical Journal*.

The discovery of super-Earth-sized planets around Kepler-62 appeared May 3 in *Science*.

Since Kepler's launch in 2009, it has produced more than 2,700 planet candidates. As the mission has accumulated observations,

scientists have been able to find

smaller and smaller planets, increasing the possibility of finding an Earth analog. However, the astronomical powerhouse is in trouble. On May 12, one of three stabilizing wheels failed, preventing the telescope from pointing properly. Scientists are unsure whether the craft can be revived. The good news is that even if Kepler cannot be fixed, the existing data will require years more analysis. — **Sarah Scoles**

BRIEFCASE

MISSION MATTERS

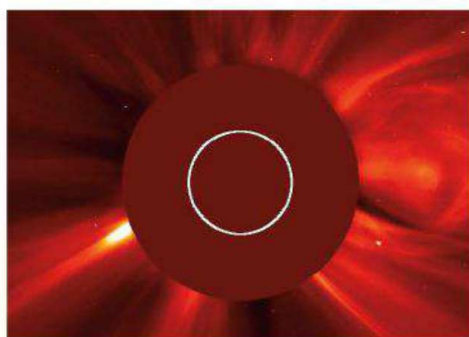
NASA announced April 5 that it has chosen two Explorer missions for 2017 launches. The Transiting Exoplanet Survey Satellite (TESS) will search for nearby planets, surveying 400 times the area of previous missions. The Neutron star Interior Composition Explorer (NICER) will investigate exotic matter inside compact stellar remnants, where densities exceed those in atomic nuclei. The Explorer Program supports scientist-led, (relatively) low-cost endeavors. — **S. S.**

ROCKETS ROCKED IT

On April 21, Orbital Sciences took its Antares rocket for a test drive and delivered a simulated payload in preparation for transporting real payloads to the International Space Station. Likewise, SpaceX's SpaceShipTwo "rocket plane" had a successful test flight April 29. Its carrier dropped it off at 47,000 feet (14.3 kilometers), after which its engines blasted it supersonically to 56,200 feet (17.1km). — **S. S.**

ACTIVE ATMOSPHERE

Curiosity, though on martian ground, has discovered that the planet's atmosphere is dynamic, NASA announced April 8. Measurements of argon isotopes (atoms with different numbers of neutrons) show that the atmosphere has preferentially lost its lighter argon atoms, but the air that remains causes the planet to have geographically dependent humidity and, potentially, whirlwinds, both of which Earth experiences regularly. — **S. S.**



Sun sent three bursts of material into space in two days

POWERFUL PLASMA. The Sun released three coronal mass ejections (CMEs) between April 20 and 21. Each sent billions of tons of charged particles into space at speeds from 500 miles/second (805 kilometers/s) to 625 miles/s (1,000 km/s). Scientists believe CMEs occur when entangled magnetic fields break each other's closed loops, releasing the material that is flowing along them. In this image taken April 21, the third CME in 32 hours expands from the right side of the Sun, whose disk is blocked so that the corona is visible.

— **S. S.** ESA/NASA/SOHO

WHAT'S THAT ROCK IN SPACE CALLED?

Asteroid ▶

Stony or metal-rich rock in space; smaller than a planet and bigger than a meteoroid

Comet

A block of frozen gases and dust; forms a coma as it approaches the Sun

Meteoroid

Stony or metallic debris in space; can range up to about 10 meters

Meteor

The streak of light in Earth's skies formed by infalling debris burning up

Fireball

An exceptionally bright meteor that can cast a shadow

Bolide

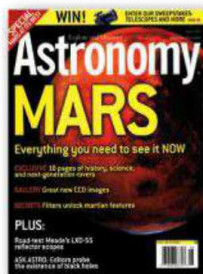
A fireball that explodes in Earth's atmosphere

Meteorite

The solid portion of a meteoroid that lands on Earth's surface



Earth



25 years ago in Astronomy

In the August 1988 issue of *Astronomy*, Ken Croswell described evidence for and against a 10th planet in the article "The Pull of Planet X." A scientist named Robert Harrington believed Planet X existed because the outer planets did not orbit as predicted. "I am confident enough that it's out there that I'm willing to spend a fair amount of my time and the Navy's money to look," he said.

Scientists would not start a systematic search for trans-Neptunian objects, like Planet X and what scientists now call "dwarf planets," for another four years. But in 1990, scientists used data from Voyager 2 to show that Uranus' orbital anomalies arise solely from Neptune's disturbing presence. Today, most scientists think it is safe to put Planet X to rest.

10 years ago in Astronomy

In August 2003, Jim Bell, now the author of three books about Mars and a prominent member of the Curiosity science team, wrote "Blazing a new path," which described the Mars Exploration Rovers that were launched that year: Spirit and Opportunity. While the former no longer roves, the latter is still exploring 10 years after its launch.

Bell saw the rovers as precursors to human exploration of Mars, which the American government aims to do by the 2030s, but which private spaceflight companies plan to begin by the mid-2020s. "Manned missions to Mars will be risky, but there is no shortage of people willing to face these risks," Bell wrote. If the tens of thousands of people who have applied for Mars One's one-way trip are any indication, he was correct. — **S. S.**



POSITRON DETECTOR. The Alpha Magnetic Spectrometer (AMS) has collected more than 30 billion cosmic rays since its deployment at the International Space Station on May 19, 2011. Using AMS, scientists have confirmed that there are more positrons in space than current theories can account for. NASA

Extra antimatter confirmed

Astronauts with the final space shuttle flight delivered the Alpha Magnetic Spectrometer (AMS) to the International Space Station (ISS) on May 19, 2011. Following 18 months of AMS data collection, scientists released their first analysis in a paper published in the April 5 issue of *Physical Review Letters*. They confirmed that space seems to hold too many positrons (the electron's antiparticle) but gave no hints of what's causing this excess.

AMS detects cosmic rays — like electrons, protons, and heavier nuclei — with energies of 0.5 to 350 billion electron volts. (For comparison, visible light has energy between 2 and 3 electron volts.) Using the instruments aboard the ISS, along with complex analysis, scientists then determined the mass, charge, and energy of each collected particle.

The AMS group studied data from about 6.8 million electrons and positrons collected from May 19, 2011, to December 10, 2012. They then looked at the positron fraction, which is the ratio of positrons to both electrons and positrons in different energy "bins." From this fraction, they found too many positrons with the highest energies that AMS detects. This confirms what previous experiments over the past two decades had indicated.

Particles at these higher energies, however, are rarer than those at lower energies. Thus, scientists need many more years of data to learn what is causing the excess. (Luckily, the AMS team expects the detector to last at least 10 years.) Some astronomers think these positrons arise from rapidly rotating stellar remnants called pulsars that create antimatter, while others hypothesize dark matter particles that annihilate each other might create these extra positrons. — **Liz Kruesi**

QUICK TAKES

KEPLER FIND

NASA's Kepler spied a white dwarf eclipsing and bending the light from its companion red star, say astronomers in the April 20 issue of *The Astrophysical Journal*.

LIGHTING THE WAY

Scientists describe in the April 1 issue of *The Astrophysical Journal* how "green pea" galaxies leak ultraviolet radiation and why similar objects may have been responsible for ionizing the young universe and ending the cosmic "Dark Ages."

STELLAR FORMATION

Mid-infrared observations of G35.20-0.74, a massive protostar some 8,000 light-years away, suggest that high-mass stars form in the same way as Sun-like ones. The study appeared in the April 10 issue of *The Astrophysical Journal*.

SENSOR PASSES TEST

A proposed asteroid-hunting telescope's Near Earth Object Camera passed a design test in a space-mimicking environment, said NASA on April 25.

FAR STAR

SDSS J122952.66+112227.8, a possible blue supergiant star, is 54 million light-years distant. According to the April 20 issue of *The Astrophysical Journal Letters*, it could be the farthest star if confirmed.

MOON ENVIRONMENT

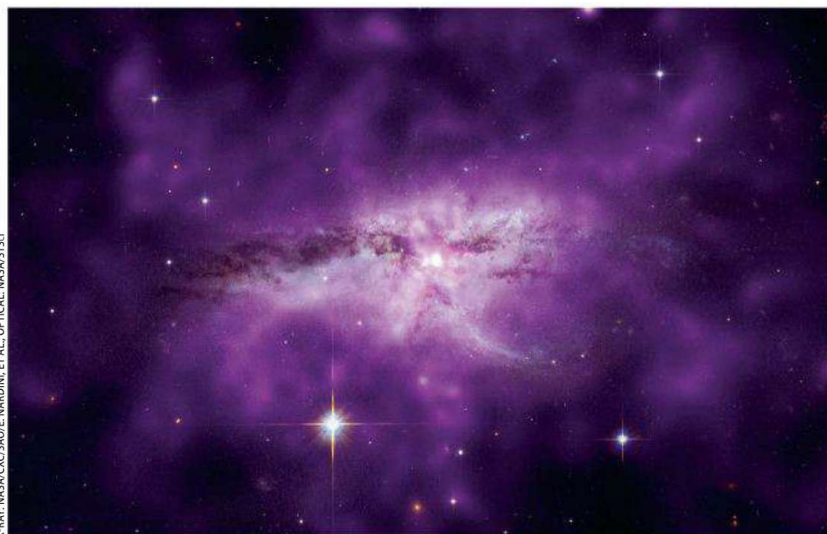
A *Space Weather* article published online April 3 describes how scientists used the Lunar Reconnaissance Orbiter's CRATER instrument's data to simulate the effects of radiation at the Moon's surface on biological and electronic materials.

BIG COMPANIONS

R144 in the Large Magellanic Cloud's Tarantula Nebula is a binary, with components weighing up to 170 and 200 solar masses, according to a March 27 online paper in *Monthly Notices of the Royal Astronomical Society: Letters*.

CLOUDS' SOURCES

The occasional dusty clouds above Saturn's rings are due to streams of material from meteoroids that had broken up before entering the planet's gravity and interacted with the rings, say scientists in the April 26 issue of *Science*. — **L. K.**



X-ray vision of a merger

GASSY GALAXIES. NGC 6240 illustrates what happens when two large spiral galaxies merge. The collision mixes the gas of both galaxies, and a burst of star formation begins. Some of those stars are massive and thus speed through stellar evolution to explode as supernovae. They spew heavy-element-rich gas into the collision product. In this image, which the Chandra X-ray Observatory released April 30, X-ray observations of the 7 million degree gas (due to supernovae and the burst of star formation) glows purple. — **L. K.**



OBSERVING BASICS

BY GLENN CHAPLE

Elvis and the alphabet

The cosmos is full of images of letters, numbers, and even celebrities if you just use your imagination.

News flash! Elvis Presley has been found! You'll no longer glimpse the king of rock 'n' roll slipping out of a KFC with a bucket of fried chicken in hand, and you won't spot him buying a Slurpee at the local 7-Eleven. No, sir. Elvis has a new hangout — the Moon! Here's the story.

My description of the Lunar X and V in the September 2012 issue of *Astronomy* prompted several reader responses, including one from Brian Swartz of Walkersville, Maryland, who came upon the X just nights before reading about it in my column. "I wasn't even looking for it, but it stuck out like a sore thumb," he wrote. "It's always nice to find little jewels hiding in plain sight."

Some readers went through files of lunar images they had taken to see if they might have serendipitously captured the X or V. Glenn Holland of Marina del Rey, California, reported, "I began looking through my archives of cellphone shots of the Moon and, to my amazement, found exactly what you described. I guess I was in the right place at the right time." Joseph W. Jackson of Lowndesboro, Alabama, recalled his initial reaction upon discovering an X on an image he took in May 2012: "When I saw the X, I thought it was a defect or a reflection that I could not explain." The X and V appeared prominently on a photo Chris Theumen of Pembroke, Ontario,

Canada, snapped in December 2008. "I am amazed," he wrote, "that with pure luck I was able to capture both in the same image without foreknowledge of the existence of either. Neat!"

And then Elvis entered the building. Science-fiction author Jerry Olton reported seeing the outline of a rock guitarist in the shadowed part of the Lunar V. Then, *Astronomy's* own Alister Ling made an independent sighting and went so far as to identify the mystery rocker as none other than Elvis himself!

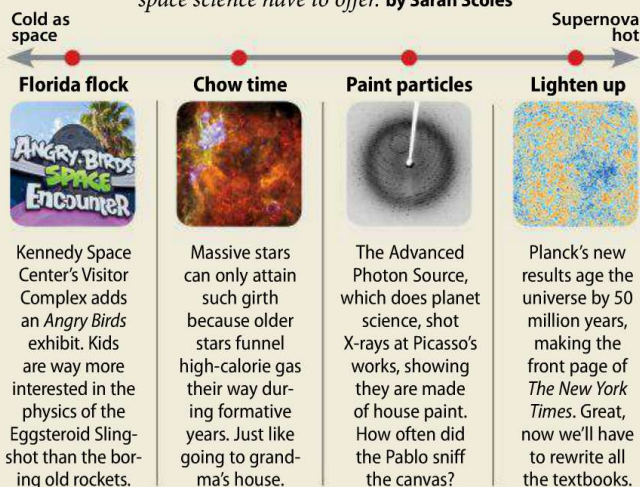


Some readers reported seeing the outline of a rock 'n' roll guitarist, specifically Elvis, in the shadows of the Lunar V. Do you see the king? ALISTER LING

Before we relegate Olton and Ling to the ranks of Elvis fanatics who swear aliens abducted the king (maybe they did — how else could he have gotten on the Moon?), let's examine the photograph on this page that Ling sent me. The shadowy region within the Lunar V certainly seems to outline the figure of a rock 'n' roller in wide open stance, guitar in hand. Just to be sure, though, let's view Elvis and the Lunar V for ourselves. Upcoming windows of opportunity for spotting the V (and X) occur August 13 at 2:57 P.M. EDT, September 12 at 2:53 A.M. EDT, October 11 at

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. by Sarah Scales



NASA/KIM SHLETT (FLORIDA FLOCK); ESA/PACS/SHREYA RIVERA-INGRAM/P. G. MARTIN/HOBYS KEY PROGRAMME (CHOW TIME); JEFF DAHL (PAINT PARTICLES); ESA/PLANCK (LIGHTEN UP)

3:57 P.M. EDT, November 10 at 5:06 A.M. EST, and December 9 at 7:59 P.M. EST (the best window for U.S. observers). Remember, the V and X are visible only for an hour or two before and after these times. Do you see the king in the shadowy region of the Lunar V?

All of these lunar letter responses got me thinking. When I was a science teacher at a local middle school, I used to marvel at a poster one of my colleagues taped to his classroom wall. It showed the entire alphabet plus the numbers 0 to 9 in patterns that appear on the wings of moths and butterflies. The "Butterfly Alphabet" was compiled by Norwegian photographer Kjell B. Sandved, who worked at the Smithsonian Institution's National Museum of Natural History in Washington, D.C. If you've never seen this remarkable poster, look it up at <http://butterflyalphabet.com>.

If we can assemble an alphabet from butterfly wings, why not piece together a cosmic version? We've found a few letters on the Moon. Perhaps more exist on the moons of other planets. And how about the planets themselves? Is an A or B hiding in the Valles Marineris region of Mars? Have the turbulent cloud patterns of Jupiter or

Saturn ever shaped a C or D? We might find letters on the Sun in the form of dark filaments, sunspot groups, or prominences. Think of the letters we might spot within constellations, asterisms, or star clusters. If we search through photographs of nebulae and galaxies, we might even encounter the most colorful and beautiful letters of all. (For inspiration, check out <http://mygalaxies.co.uk>.)

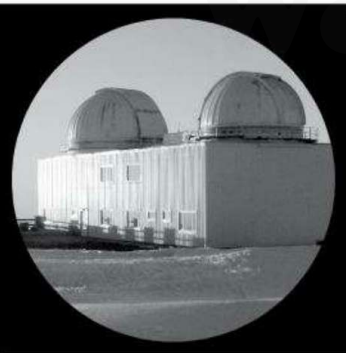
I found the idea so intriguing that I began searching the Internet for astroimages that contain letters. I even contacted some of the staff and contributors of *Astronomy* for suggestions. The alphabet we assembled is sparse indeed, but it's a start.

Perhaps you can help. I'd appreciate any cosmic letters (or numbers) you can locate — either from astroimages you've taken or from items gleaned off the Internet. Be sure your image sources are in the public domain — we don't want any copyright infringements! Email them to me (include the source — yourself or a website). I'll assemble your submissions, and we'll consider publishing the final result.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: a Sagittarius cluster-hop. Clear skies! ☽



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To determine the diameters for eight neutron stars, Andrew W. Steiner and colleagues targeted three X-ray telescopes on clusters like 47 Tucanae (shown at lower left).

FAST
FACT

WHAT CAN NEUTRON STARS TEACH US ABOUT ATOMIC NUCLEI IN OUR BACKYARD?

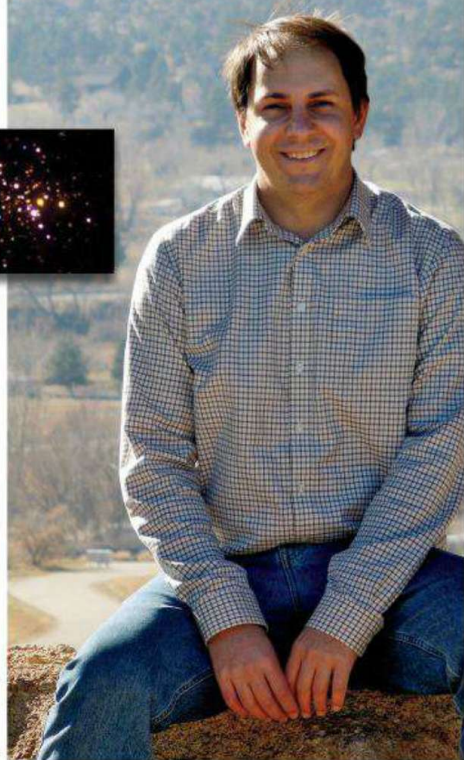
Neutron stars, close cousins of black holes, are incredibly dense objects with the mass of the Sun and the size of a city. They form in cataclysmic supernova explosions at the end of the lives of some massive stars. You can think of a neutron star as a spherical fluid of neutrons and protons, not much different from the atomic nucleus at the center of all atoms. (Neutron stars also have electrons, but unlike atoms, where electrons are mostly outside the nucleus, the electrons are inside.) In fact, you can take this picture even further: The same fundamental nuclear forces that control how neutrons and protons work in a nucleus also control how big neutron stars are.

Because neutron stars are far away, scientists find it difficult to determine their size from observations alone. Until recently, our understanding of neutron star sizes came mostly from mathematical models. Together with colleagues James Lattimer and Edward Brown, however, I just completed a recent

Andrew W. Steiner
Research assistant professor of physics at the Institute for Nuclear Theory, Seattle

analysis of neutron star observations. We determined the diameter of eight neutron stars to be between 13 and 16 miles (21 and 26 kilometers) — one of the first measurements free from some of the complicated mathematical modeling required previously.

Because the same nuclear force controls both neutron stars and nuclei, this observation also helps physicists understand nuclei here on Earth. For example, a typical lead nucleus has 82 protons and 126 neutrons and, because of the 44 extra neutrons, is surrounded by a neutron “skin.” Our neutron star diameter measurement concludes that this neutron skin must be smaller than some models predict, and thus those models are now ruled out.

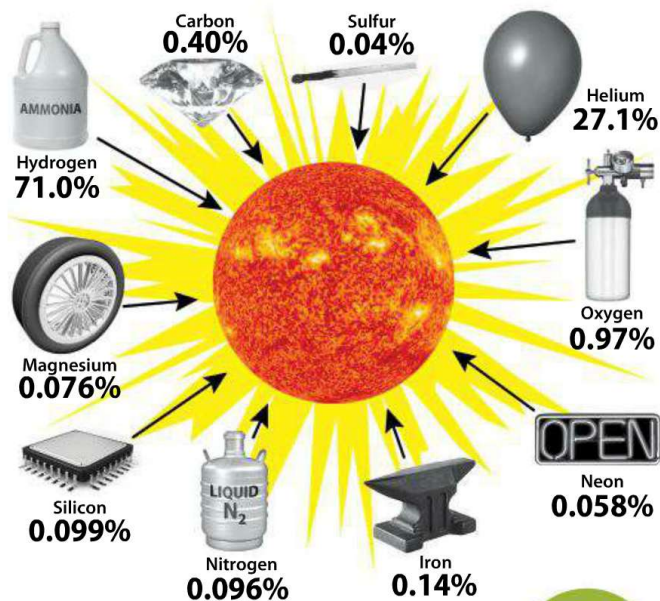


COURTESY ANDREW W. STEINER (PORTRAIT); NASA/CXC/NICHIGAN STATE/A. STEINER ET AL. (47 TUCANA)

ASTRONOMY

BUILDING BLESSING. The Thirty Meter Telescope consortium announced April 13 that the Hawaiian Board of Land and Natural Resources has granted it approval to build and operate the observatory on Mauna Kea, Hawaii.

WHAT'S THE SUN MADE OF?



EVERYDAY ELEMENTS. So far, astronomers have identified more than 70 chemical elements in our Sun. This diagram illustrates the top 10 by mass.

ASTRONOMY: MICHAEL E. BAKICH AND ROEN KELLY

Nuclear fusion in the Sun's core converts 600 million tons of hydrogen into helium each second.

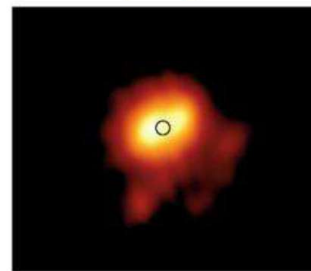
FAST
FACT

Hot spots on a cool red supergiant

A recent Betelgeuse image from the e-MERLIN radio telescope array in the United Kingdom has provided new information on the atmosphere of the nearby red supergiant. According to a paper published online April 23 in the *Monthly Notices of the Royal Astronomical Society*, radio data of the star, which lies 650 light-years away in the constellation Orion, show two areas of surprisingly hot gas — some four times higher than the average temperature of its radio surface — within Betelgeuse's outer atmosphere. The new image also reveals an arc of cool gas that extends even farther out.

This is the first direct image showing hot spots so far out in Betelgeuse's atmosphere, according to lead author Anita Richards from the University of Manchester in England. The two areas appear on opposite sides of the red supergiant.

Richards and her team aren't yet sure what causes Betelgeuse's hot spots, but studying the atmospheres of supergiant stars is key to understanding how such objects lose matter, which ultimately creates new material from



HOT AND COLD. A radio image of Betelgeuse taken using the e-MERLIN array has revealed two hot spots in the outer atmosphere of the red supergiant. The colors represent brightness ranging from red at the faintest to white at the brightest, with the visual size of the star indicated by the black circle. UNIVERSITY OF MANCHESTER

which future stars and planets form. The group therefore plans to follow up this image with further observations using e-MERLIN and other telescope arrays. “This won't just tell us how the elements that form the building blocks of life are being returned to space,” Richards says. “It will also help determine how long it is before Betelgeuse explodes as a supernova.” — **Karri Ferron**

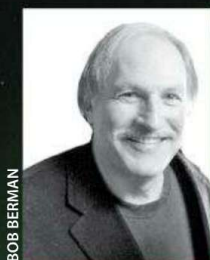
ASTRONOMY

Early galaxy made 3,000 new stars per year

Astronomers have discovered a galaxy undergoing a "maximum starburst," forming new stars at a rate 2,000 times that of the Milky Way. As if that were not impressive and puzzling enough, this galaxy, called HFLS3, contains 140 billion times the mass of the Sun and is a star-formation factory observed as it was just 880 million years after the Big Bang.

According to current ideas about structure formation, galaxies so large should not have existed so long ago. Astronomers thought the earliest galaxies would need to collide and combine with other galaxies in order to grow and work their way up from their initial few billion solar masses. They believed these processes would take much longer than 880 million years. So where did the material to make these early stars come from? How did this galaxy form? The research team, which published its results April 18 in *Nature*, is excited to investigate those questions.

"This is the most detailed look into the physical properties of such a distant galaxy ever made," says lead author Dominik Riechers of Cornell University in Ithaca, New York. "Getting detailed information on galaxies like this is vitally important to understanding how galaxies, as well as groups and clusters of galaxies, formed in the early universe." — S. S.



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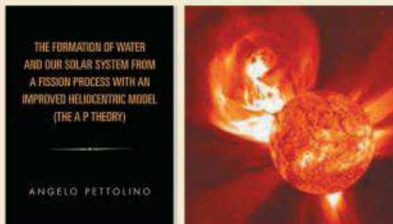
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Test out your visual acuity

The summer sky holds several naked-eye double stars that, once observed, can tell you something about the sharpness of your eyesight at night.

Resolving naked-eye double stars presents an unusual visual challenge. To see fine detail, we usually look directly at the object of study so that light falls onto the eye's fovea centralis — the pit in the retina that is responsible for sharp vision. But the fovea does not have rods, and the cones populating this tiny region are largely ineffective at night. Because some of the stars in this exercise may be too faint for you to detect in the dark with direct, foveal vision, you may have to explore the eye's twilight zone. This area, which is about 12° away from the fovea's center, includes not only cone cells near the fovea's outer edge but also some night-sensitive rod cells that surround them.

Your eye's hot spot

The best way to test your visual acuity with naked-eye doubles is to do so in stages, working from the easiest to the most difficult objects. Try starting with Alpha¹

(α¹) and Alpha² Capricorni, now in the southeastern sky after sunset. These stars form the northwestern tip of the constellation's Delta Wing asterism. Alpha² shines at magnitude 3.6, and Alpha¹ is its magnitude 4.3 companion 6.6' to the west-northwest. While these stars are not difficult to resolve, spend time with them and see where in your field of vision they appear most distinct; this will be your eye's hot spot.

Once you determine your hot spot, position in it our next target: magnitude 3.8 Omicron¹ (ο¹) Cygni and its line-of-sight companion, magnitude 4.8 30 Cygni, 5.6' to the northwest. This attractive pair lies about 5° west and slightly north of Deneb (Alpha Cygni), which marks the tail of Cygnus the Swan. Not only are these stars slightly fainter than Alpha¹ and Alpha² Capricorni, but they're also 1' closer together. Again, take time to study these stars, and see if you need to adjust their placement in your field of vision.



Resolving a visual binary such as Alpha¹ (α¹) and Alpha² Capricorni (the bright stars near center) requires exploring the eye's "twilight zone" about 12° away from the area of sharpest vision. SLOAN DIGITAL SKY SURVEY

FROM OUR INBOX

Lunar observing guide

The Moon is one of my favorite objects to observe in the night sky, which is why I very much enjoy reading the "Rising Moon" section in *Astronomy*'s "Sky this Month" department. Earth's natural satellite never ceases to amaze me with its endless levels of detail and hidden treasures, and I usually make an effort to view whatever feature the current month's issue describes.

I missed the January 2013 issue's suggested viewing date to observe the area around Montes Apenninus (Apennine Mountains) due to poor weather, but was able to see it January 20. I am glad I made the effort to get outside; although it was one of the coldest nights we had this past winter (−13° Fahrenheit [−25° Celsius]), it was by far the best seeing conditions we'd had in Ottawa for many months.

I was able to clearly see the features described in the "Rising Moon" passage as well as many others that I never thought possible with my setup, an 8-inch Meade LX10 with 2x Tele Vue Powermate eyepiece (f/20). I saw numerous rifts running parallel to Montes Apenninus, including a very prominent squiggly Rima Hadley. It also was interesting to compare the appearance of the Imbrium impact debris "skirt" to those of the younger craters Archimedes, Timocharis, and Eratosthenes.

Please continue your "Rising Moon" section. It has inspired me to explore new parts of Earth's satellite each month, and I'm sure the same is true for many others. — **Jim Thompson**, Ottawa, Ontario, Canada

Probing deeper

If you are under a dark sky, shift your gaze high overhead to the Keystone of Hercules. Just 4.5° northwest of Zeta (ζ) Herculis (the southwesternmost star in the Keystone), you'll find the neglected double Nu¹ (ν¹) and Nu² Coronae Borealis. Here, we have two 5th-magnitude stars separated by only 5' and oriented roughly north-south.

These stars are, in fact, perfect test subjects for anyone wanting to try to resolve our next target: Epsilon¹ (ε¹) and Epsilon² Lyrae. You'll find this famous naked-eye pair less than 2° east-northeast of brilliant Vega. Like slightly fainter Nu Coronae Borealis, 4th-magnitude Epsilon Lyrae consists of two equally bright stars in a north-south orientation; but these little gems lie only 3.5' apart. They are, in fact, near the limit of resolution for many naked-eye observers. Seeing them may require watching in the deep twilight when the cone cells are still active.

If you have trouble with Epsilon Lyrae, turn your gaze to

Zubenelgenubi (Alpha Librae), which lies about as high above the horizon as Alpha Capricorni but in the southwest. It is a slightly wider pair (3.9') with a brighter primary (magnitude 2.8) and a magnitude 5.2 secondary to the northwest.

Near impossible?

Return to Alpha Capricorni and then drop your sights to Beta (β) Capricorni. While I often have seen this star referred to as a naked-eye double, I have yet to find an actual account of a positive sighting. I've tried several times and could only muster an elongation of the star. But I do think someone with younger or better eyes could achieve success. While Beta¹ shines at 3rd magnitude, its partner star, Beta², is a magnitude 6.1 sun only 3.4' southwest of Beta¹.

Of course, remember, if you don't see any of these stars with your unaided eyes, they all make striking pairs when binoculars give them clarity. Let me know how you do. Send any reports to someara@interpac.net. ☛



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PRIZE**



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SPACE SCIENCE UPDATE

HERSCHEL CEASES OBSERVATIONS

The Herschel Space Observatory made its last detection April 29. On that day, the liquid helium that cooled the onboard instruments had completely evaporated. In May, mission team members moved the spacecraft to a stable solar parking orbit.

Herschel observed infrared and submillimeter radiation, which is lower energy and cooler than visible light. (The observatory specifically studied dusty objects, which glow in this range.) Over nearly four years, that infrared eye spied early stages of star formation, water in unexpected environments (such as in the Orion Nebula and around the cold prestellar core Lynds 1544 in Taurus), and distant young galaxies vigorously making suns.

To successfully detect these long wavelengths, Herschel's instruments had to remain at just 1.7 kelvins above absolute zero, or -456.6° Fahrenheit (-271.5° Celsius).

The Heterodyne Instrument for the Far Infrared (HIFI) collected information about atoms and molecules by splitting the light from objects into its constituent wavelengths. Within these "spectra," lines correspond to specific elements. Thus, scientists use HIFI data to learn about composition — this is the primary tool that enabled astronomers to find water in numerous locations and also detect spectral lines never seen before.



COOL REGION. The Aquila Rift is an example of a region in the Gould Belt that holds filaments dense enough to collapse into stars. Herschel imaged this area during its Gould Belt survey. The blue regions in this picture show gas heated by young suns, and the long "streamer" from the top-right to bottom-left holds hundreds of compact cores. ESA/HERSCHEL/SPIRE/PACS/GOULD BELT SURVEY



LIGHTS OUT. The Herschel Space Observatory stopped collecting radiation April 29. ESA

The Photodetector Array Camera and Spectrometer (PACS) imaged objects across the far-infrared wavelengths, whereas the Spectral and Photometric Imaging Receiver (SPIRE) covered the longer submillimeter wavelengths.

One of Herschel's most important discoveries resulted from a "key program." The Gould Belt survey incorporates PACS and SPIRE images of star-forming regions in the Gould Belt, a collection of molecular clouds that traces a ring across the sky. While analyzing some of the 460 hours of exposures,

astronomers found that filaments of material above a specific density created young stars while those less dense couldn't form suns. That density (about five times the Sun's mass per light-year length) would allow the filament to collapse into a star.

The Herschel team says that although the observatory has ceased detections, there's still plenty of information to sift through — the craft collected more than 25,000 hours of data. So far, more than 600 scientific articles have resulted from observations made with the Herschel telescope. — L. K.



Alpha Centauri C

4.24 light-years

Alpha Centauri A-B

4.37 light-years

Barnard's Star

5.96 light-years

Wolf 359

7.78 light-years

Lalande 21185

8.29 light-years

Sirius A and B

8.58 light-years

Not to scale

HOW NEAR IS YONDER STAR?

STELLAR NEIGHBORS. All stars lie at tremendous distances from Earth. Some, however, are closer than others. This diagram reveals the six closest star systems. Scientists also recently spied binary brown dwarfs WISE J1049-5319 just 6.6 light-years from the Sun. They aren't shown here because they're technically not stars. ASTRONOMY: MICHAEL E. BAKICH AND ROEN KELLY

FAST
FACT

At magnitude -1.47 , Sirius, the luminary in the constellation Canis Major the Big Dog, is the night sky's brightest star. Sirius A is an A-type main sequence star while its companion is a faint white dwarf.

WHERE ARE THE GOOGLE LUNAR X PRIZE TEAMS?



THEY'RE EVERYWHERE. Twenty-three teams are competing to build the best robotically controlled rover, land it in one functional piece on the Moon, command it to rove 1,640 feet (500 meters) and have it actually listen, and then receive its data — all before the end of 2015. The first teams to succeed will receive \$30 million. This map shows the locations of the contending groups and their official logos. *ASTRONOMY: SARAH SCOLES AND ROEN KELLY*

FAST FACT

Since 1966, 15 landers and rovers have set foot on the Moon. Six have had human beings on board. The Google Lunar X Prize winner will be the first rover since 1973.

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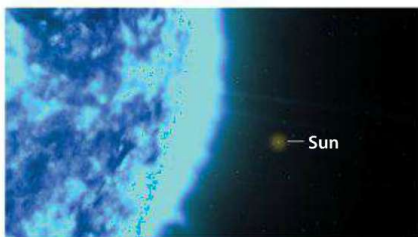
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NEW CATEGORY OF GRBS SEEN

Three mysteriously long bursts of gamma rays, the most energetic form of electromagnetic radiation, likely arose from the explosion of a star some thousand times the size of the Sun, say astronomers. They announced this new class of gamma-ray bursts (GRBs) April 16.

Until scientists studied these three blasts, they thought that GRBs came in two flavors: short duration (those lasting less than two seconds) and long duration (those lasting two seconds to a few minutes). The gamma-ray signals of these newly discovered ultra-long-duration blasts last hours.

A short-duration burst likely glows after two compact objects — either two neutron stars or a black hole and a neutron star — merge and high-speed jets drill through the product. Those jets slam into nearby material, causing it to emit gamma rays. Long-duration GRBs arise from the death of a star some 10 times the Sun's mass. Jets that begin at the core exit the star's surface and react with nearby material, producing a gamma-ray signal that lasts a



STELLAR SCALE. Astronomers think blue supergiant stars (an example is illustrated here to scale with the Sun) could feed a new class of "ultra-long-duration" gamma-ray bursts. NASA'S GODDARD SPACE FLIGHT CENTER/S. WIESSINGER

number of seconds. The size of the initial object affects the length of the burst: Smaller objects have less material and thus produce shorter blasts. Therefore, the thinking goes, a three-hour GRB must arise from a huge star.

The three ultra-long-duration bursts — GRB 101225A, GRB 111209A, and GRB 121027A — were spied by Swift in the past few years. — **L. K.**



RAINING RING PARTICLES. Scientists have discovered that charged water-rich ring particles (shown in blue in this illustration) are "raining" down on Saturn's upper atmosphere along magnetic field lines, neutralizing ions and producing bands of reduced infrared brightness that mimic the patterns of the ring system.

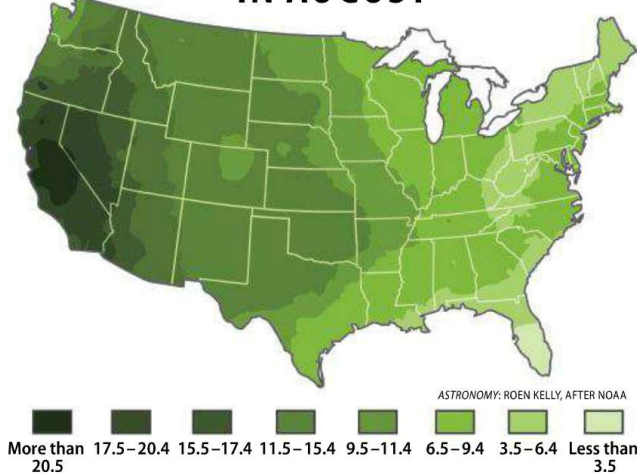
Ring "rain" impacts Saturn's atmosphere

Recent data from the Keck telescopes atop Mauna Kea in Hawaii indicate that Saturn's tiny water-based ring particles are having an unexpected effect on an area of the planet's upper atmosphere known as the ionosphere. According to a study in the April 11 issue of *Nature*, this ring "rain" floods between 30 and 43 percent of the ionosphere, influencing its composition and temperature structure.

In Saturn's ionosphere, just like in Earth's, charged particles result when the planet's otherwise neutral atmosphere comes in contact with a flow of energetic particles or solar radiation. When studying the emission patterns of a particular hydrogen ion with three protons (triatomic hydrogen), the team originally expected to observe a uniform infrared glow similar to that seen on Jupiter. "Where Jupiter is glowing evenly across its equatorial regions, Saturn has dark bands where the water is falling in, darkening the ionosphere," says co-author Tom Stallard of the University of Leicester in England. The pattern of these bands mimics that of the rings.

The team concludes that charged water particles in the ring system are "raining" down on Saturn along the planet's magnetic field lines and neutralizing the glowing triatomic hydrogen ions, resulting in the dark bands. The scientists plan to continue analyzing the bands with the Cassini spacecraft. — **K. F.**

AVERAGE NUMBER OF CLEAR DAYS IN AUGUST



**6230
KELVIN**
**10,800°
FAHRENHEIT**
(6000° Celsius)

The melting temperature of iron at Earth's core-mantle boundary, according to a study published in the April 26 *Science*.

Pulsar system validates Einstein

A newly discovered pulsar-white dwarf binary system has proven that Albert Einstein's general theory of relativity holds even in this extreme circumstance, says the April 26 issue of *Science*.

Astronomers discovered this pulsar — a fast-spinning neutron star left behind in a supernova explosion — and its companion with the Green Bank Telescope in West Virginia. Then, they monitored the pair's orbits with optical telescopes in Chile and the Canary Islands and radio telescopes in Puerto Rico and Germany. Einstein's theory predicts how quickly the pair's orbits will decay as they ripple space-time with gravitational waves, which carry energy away. Astronomers watched the orbits to see if, in such extreme conditions, general relativity still gives accurate forecasts.

Even in this immoderate gravitational circumstance, Einstein's predictions stood fast. "We thought this system might be extreme enough to show a breakdown in general relativity, but instead Einstein's predictions held up quite well," says Paulo Freire of the Max Planck Institute for Radio Astronomy in Germany.

Still, scientists suspect that in an even more exotic system, the traditional theory of gravity will break down. Because this large-scale theory of gravity is not compatible with quantum theory, which describes how the universe works on the smallest scales, astronomers hope to find an overarching idea that accurately reflects the universe at all levels.

That Einstein's gravity holds up in the pulsar-white dwarf system, though, means that scientists



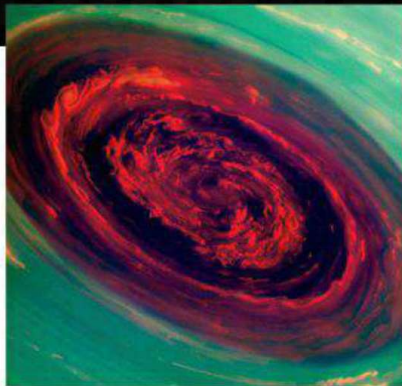
THAT'S HEAVY, MAN. A binary system comprising a pulsar and a white dwarf has provided scientists with a high-mass test of general relativity's predictions about the gravitational waves that should carry energy away from the system. ESO/L. CALÇADA

searching for gravitational waves are watching for undulations of the right strengths and with the right frequencies. If directly detected, gravitational waves would open a whole new window on the universe. — **S. S.**

ASTRONNEWS

Storm on Saturn

VIOLENT VORTEX. Cassini scientists released the first photo of a giant hurricane churning in Saturn's northern hemisphere April 29. This false-color image indicates low clouds in red and high ones in green. The eye of the storm measures some 1,250 miles (2,000 kilometers) across — 20 times larger than the average hurricane eye on Earth — with wind speeds reaching 330 mph (530 km/h) near the vortex's edge. Astronomers are unsure how long the storm has been active, as the Cassini spacecraft was only recently able to start capturing data from Saturn's north pole. — K. F.


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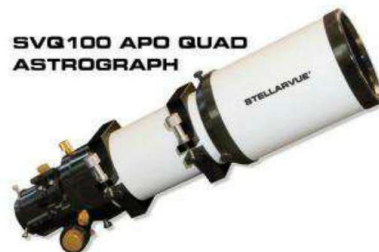
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The most colorful stars

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An astroimage that has white stars is fine, but we all know that stars come in many colors. If we can create the same picture with a background of beautifully colored stars, it becomes magical — and it takes our imaging to a whole new level of technical excellence.

The problem with stars is that some of them are much brighter than the deep-sky target we want to record. So, when we stretch our image for the object, the stars blow out and become pure white. What we need to do is to stretch the stars in a way that preserves their color. Here's how I do it.

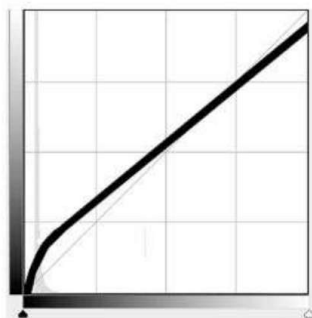


Image 1. To stretch the image data, the author creates a color curve that curves within the shadowed areas but remains flat in the ranges of midtones and highlights. ALL IMAGES: TONY HALLAS

1. I begin with the unstretched 16-bit RGB TIFF file. I need to stretch this data in a way that the shadows come up but the high-lights remain compressed, so I create a color curve line like you see in Image 1. To do this, open “Curves.” What you will see is a flat line. The image is “resting,” but you are going to disturb it. Any time you raise the curve, it lightens the image, and where

you raise the line dictates what part of the image you are brightening. In this case, we are trying to brighten the shadows (the area in the lower left on the curve) and leave the midtones and high-lights untouched. To leave them resting, keep their parts of the curve a straight line.

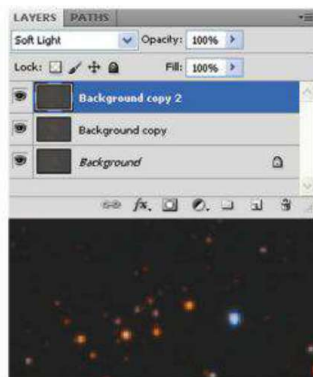


Image 2. Combining layers in Photoshop's “Soft Light” mode lets you push the colors of stars while at the same time darkening the background.

2. I repeat the previous step as many times as I think it is necessary, using “Levels” every now and then to reset the black point. I also increase the saturation 20 points as often as the image can absorb it without the stars pixelating. In the end, I am looking for an image where the stars have colorful bodies and I can see the background.



+



=



Image 3. Pasting the colorful stars (middle) atop the washed-out ones (left) does two things. It preserves the brightness of your original non-stellar target, and it enhances the colors of the surrounding stars.

FROM OUR INBOX

Strings, and a correction

The article “What string theory tells us about the universe” by Sten Odenwald in the April 2013 issue was well done, but it left me — as an armchair astronomer — wondering whether we're perhaps in the same intellectual muddle the scholastics of the Middle Ages experienced before Nicolaus Copernicus and Galileo Galilei debunked all their complicated theories for explaining why and how celestial bodies move across the celestial vault.

— **William Zuna**, Tallahassee, Florida

German-born British astronomer Caroline Herschel compiled her list of objects in 1829, not a century later as mistakenly written in the April 2013 article “The reluctant astronomer” on p. 47. We apologize for any confusion. — **Astronomy Editors**

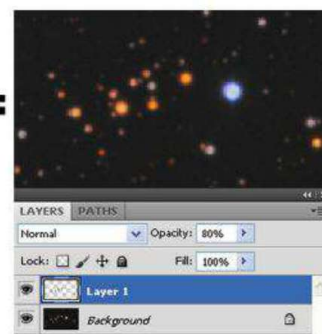
3. It's all right to leave your image a little on the light side; our next step will be to make the stars even more colorful and to darken the background. That will make it easier to transfer the star color to the blown-out stars in our normally stretched deep-sky image. Push F7 to open your “Layers” palette, and make a duplicate layer. Combine in the “Soft Light” mode (Image 2). Immediately, your background should have darkened and the stars should have become more colorful. Do this one more time by duplicating the duplicate layer, and the background should be almost black with colorful stars. Then flatten the layers.

4. We now want to spill some of the colorful edge of the star into the lighter, less colorful nucleus. For the smaller stars, go to “Blur,” then “Surface Blur,” and put in a radius of 1 or 2 and a threshold around 125. Click the “Preview” button on and off to see how this is smoothing out the stars and mixing the colors into their centers. For larger stars, select an area around the stars and use a radius of 5 to 10.

Now we have some colorful stars to add to the washed-out stars in the normally stretched image. Because these stars all came from the same master file, registration is not an issue.

5. The final step (Image 3) is to combine the colorful stars into the washed out image. Open both images and use “Select,” then “Color Range” at a strength of 30 to 40 to select all the colorful stars in the second image. Do this by clicking on the “+” eyedropper after your first selection. Then hit Control-C to copy these, close the image (leaving the first image open), and hit Control-V.

The colorful stars will now paste on top of the washed-out stars as a layer. Align them. You now can adjust the density, saturation, and transparency of the layer to fit. You also can slightly blur the stars to make a smoother transition between them. For a slightly different effect, try changing the “Combine” mode from “Normal” to “Color.” Sometimes this creates a better look. Either way, you now will have the best of both worlds — a deep-sky image with colorful stars. ☺



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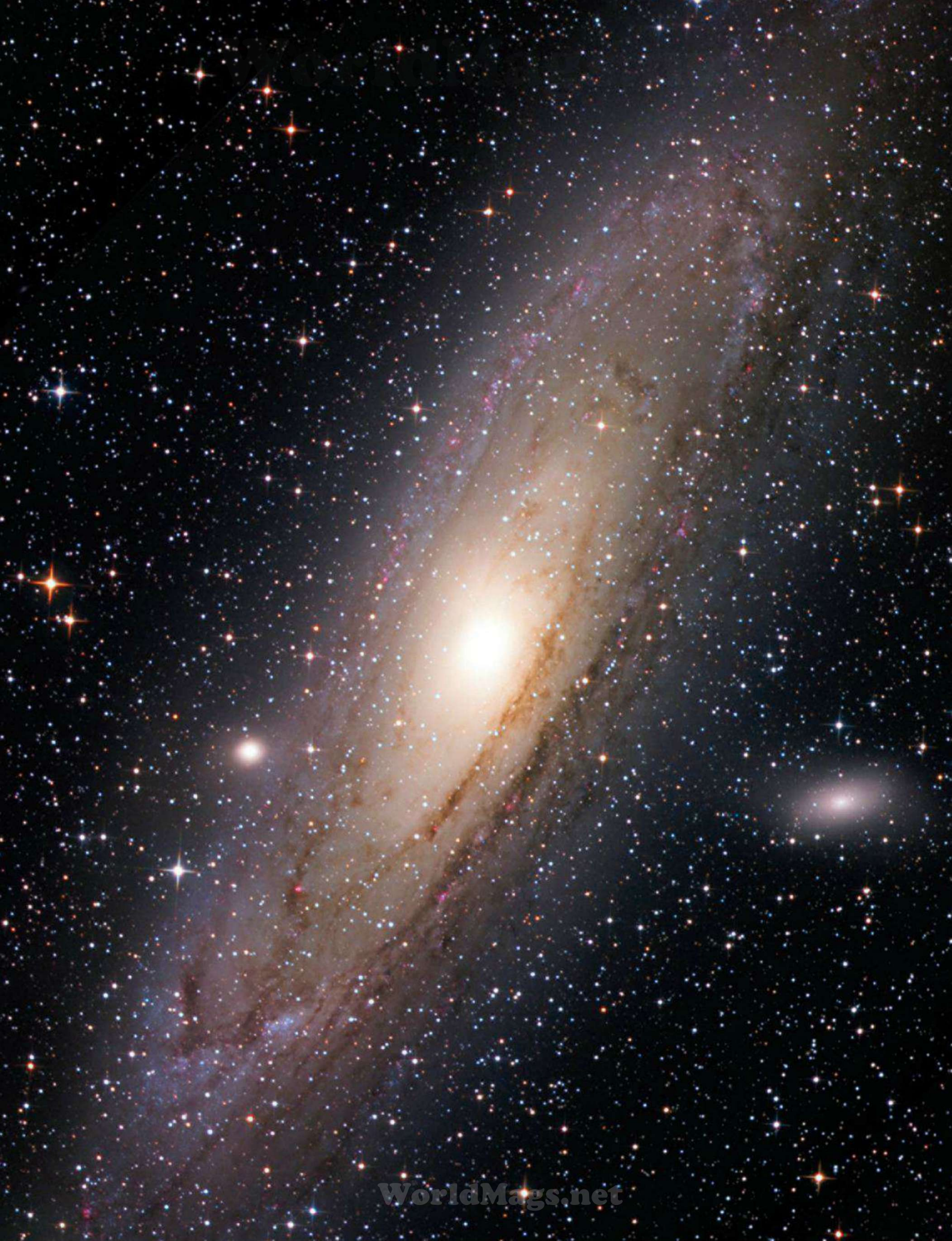
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From Jupiter's mysterious moons to dark matter and energy, astronomers' biggest breakthroughs have lifted the veil on our complex universe.

by Richard Talcott

Ninety years ago, Edwin Hubble established that this "spiral nebula" in the constellation Andromeda is a galaxy distinct from the Milky Way. See entry 28 for more on this monumental discovery. BOB FERA

40 GREATEST ASTRONOMICAL DISCOVERIES

What's the greatest discovery in the history of astronomy? Ask a dozen scientists, and you'll probably get as many answers. A planetary scientist is bound to have a different perspective from a stellar astrophysicist, and neither likely would choose the same breakthrough as a cosmologist. Observers and theorists would disagree as wholeheartedly as emeritus professors and newly minted graduates.

That's one reason why this list doesn't rank these 40 discoveries in order of importance. Instead, it progresses from near to far. You'll find solar system discoveries first and cosmological breakthroughs last, with stars and galaxies in between. You'll see theories mixed with observations and current research side by side with the classics.

Not surprisingly, many of these fundamental discoveries hit close to home. The history of astronomical research teaches that it's easier to observe nearby objects and also to study them in greater detail.

So sit back and take some time to digest the list. Think about what you'd add to it or which you'd drop in a heartbeat. Amateur astronomers like to say that the sky belongs to all of us — I'd like to think that the universe does, too.

Astronomy senior editor **Richard Talcott** has been a witness to more of these amazing discoveries than he would care to admit.

1 Most people skip our home world when thinking about astronomy, but Earth is a planet, too. One of its fundamental properties — a trait it shares with other planets — is its spherical shape. In the fourth century B.C., Greek philosopher Aristotle showed this by noting that our planet's shadow always appears round during lunar eclipses, which can happen only if Earth is a sphere.

2 In 1543, Polish astronomer Nicolaus Copernicus published his revolutionary model of the solar system, which placed the Sun in its correct position at the center, with Earth and the other planets orbiting it. Although this heliocentric model faced fierce resistance, particularly from the Catholic Church, it ultimately won the day.

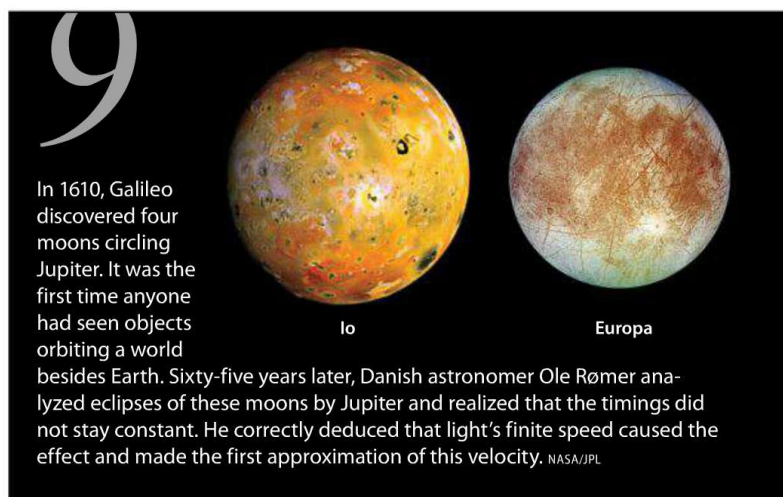
3 In the early 1600s, German theorist Johannes Kepler devised his three laws of planetary motion. He concluded that the planets orbit the Sun on elliptical paths, each planet's orbit sweeps out equal areas in equal times, and that the square of a planet's period is proportional to the cube of its distance from the Sun.



In 1610, Italian scientist Galileo Galilei observed Venus through his newly improved telescope and saw it go through phases just like the Moon does. According to the geocentric model (in which Earth lies at the solar system's center), Venus should always appear as a crescent. The gibbous phases Galileo witnessed convinced him that Copernicus' heliocentric model is correct. NASA

7 In 1796, French astronomer and mathematician Pierre-Simon Laplace developed the still accepted hypothesis that the solar system's planets condensed out of a dust-rich nebula surrounding the embryonic Sun. Laplace also established the basic stability of our planetary system.

8 On the first night of the 19th century, Italian astronomer Giuseppe Piazzi discovered Ceres — a rocky object that circles the Sun between the orbits of Mars and Jupiter. At the time, many scientists thought Ceres was a planet filling the wide gap between its neighbors, but several comparable objects — now called “asteroids” — soon turned up in similar orbits.

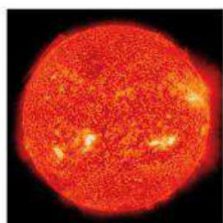


In 1610, Galileo discovered four moons circling Jupiter. It was the first time anyone had seen objects orbiting a world besides Earth. Sixty-five years later, Danish astronomer Ole Rømer analyzed eclipses of these moons by Jupiter and realized that the timings did not stay constant. He correctly deduced that light's finite speed caused the effect and made the first approximation of this velocity. NASA/JPL

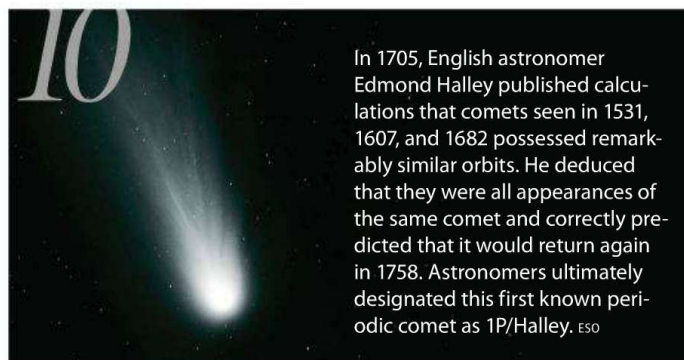
Io

Europa

5 Scientists think life requires liquid water, but Earth was the only planet known to have water until spacecraft observations of Mars in the 1970s and later proved that at least one other world once possessed this liquid gold. Images of ancient river deltas (such as this one in Eberswalde Crater) taken from orbit and analysis of rocks from rovers on the surface settled the case for water on the Red Planet. NASA/JPL/MSSS



In 1938, German-American physicist Hans Bethe figured out that stars generate energy by continuously converting hydrogen into helium in their cores. Before Bethe deciphered this nuclear fusion process, no one could understand how our star (at left) could maintain its luminosity for billions of years. NASA/SDO/AIA



In 1705, English astronomer Edmond Halley published calculations that comets seen in 1531, 1607, and 1682 possessed remarkably similar orbits. He deduced that they were all appearances of the same comet and correctly predicted that it would return again in 1758. Astronomers ultimately designated this first known periodic comet as 1P/Halley. ESO

11 In 1687, Englishman Isaac Newton published his masterwork, *Principia*, which laid out the laws of motion and of universal gravitation. It gave convincing proof that the planets orbited the Sun and, when researchers analyzed binary star systems in detail during the 19th century, that physical laws hold throughout the cosmos.

LEARN MORE

Many of the discoveries here were subjects of full-length articles in previous *Astronomy* issues. To purchase a PDF package of them, visit www.Astronomy.com/extracontent.

12 In 1781, William Herschel spied Uranus, the first planet discovered since antiquity. Although Uranus is barely bright enough to see with naked eyes, no one had recognized its movement against the background stars — a telltale sign it belongs to the solar system — until Herschel tracked it with his telescope.

13 In 1846, German observers Johann Galle and Heinrich d'Arrest discovered the eighth planet from the Sun, Neptune. They knew where to look because French mathematician Urbain Le Verrier had calculated the object's position based on how its gravity perturbed Uranus' motion. The 8th-magnitude world turned up at the predicted position.



Ganymede

Callisto

14 In 1930, following an exhaustive search through millions of star images, American astronomer Clyde Tombaugh spotted Pluto on a pair of photographic plates. At the time, the discovery was hailed as the solar system's ninth planet. But it turned out to be something perhaps even more important — the first known Kuiper Belt object. Astronomers wouldn't discover the second until 1992.

15 In 1838, German astronomer Friedrich Bessel measured the apparent shift of the star 61 Cygni relative to more distant stars as Earth orbited the Sun. The star's "parallax" yielded the first accurate determination of the distance to an object beyond the solar system. For 61 Cygni, it lies about 11 light-years from Earth.

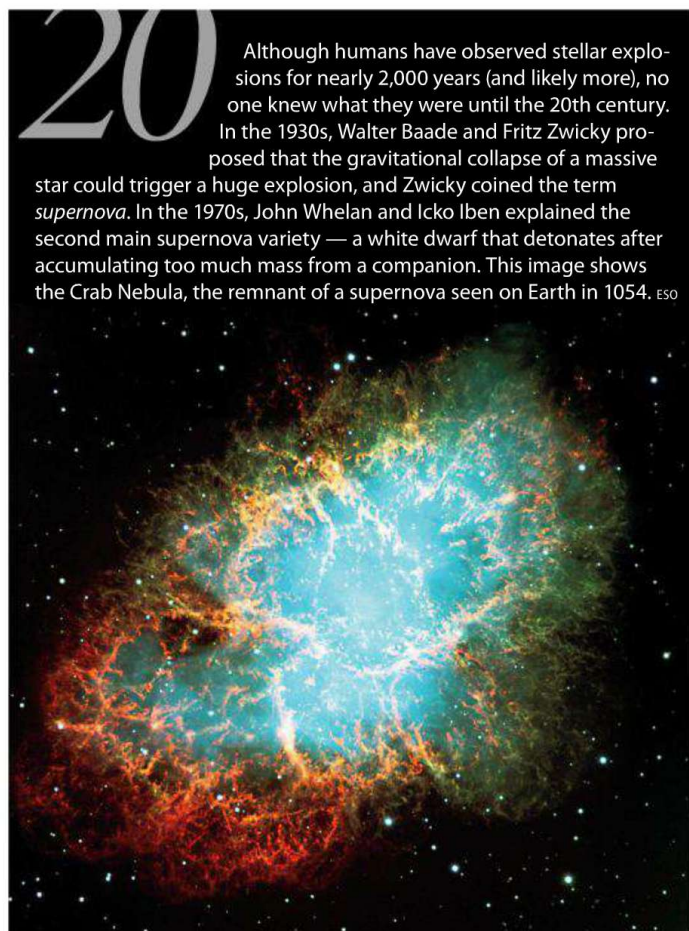


16 In 1862, American astronomer and telescope maker Alvan Clark discovered Sirius B (circled), a dim companion to the night sky's brightest star. The luminary's escort turned out to be the first known white dwarf, a type of star with the approximate mass of the Sun compressed into a sphere the size of Earth. It took until the 20th century, however, for scientists to understand that these objects represent the end stage of evolution for Sun-like stars. NASA/ESA/H. BOND (STScI)/M. BARSTOW (UNIVERSITY OF LEICESTER)

17 In the 1860s, English astronomer William Huggins attached the newly invented spectroscope to his telescope and turned it to the sky. He studied the stars Aldebaran and Betelgeuse and found that they contain calcium, iron, magnesium, sodium, and more — the first proof that stars are made of similar materials as the Sun. He also observed several nebulae and discovered that they are made of luminous gas.

18 In the 1910s, Danish astronomer Ejnar Hertzsprung and American Henry Norris Russell independently plotted the luminosities (or intrinsic brightnesses) of stars against their temperatures (or colors). They found that most stars lie along a narrow strip that runs from hot and luminous to cool and dim — the so-called main sequence, where stars spend most of their lives fusing hydrogen into helium.

19 The study of how stars evolve didn't take off until the 1950s and '60s, when computers became sophisticated enough to carry out lengthy and complex calculations. The first detailed solar models showed how stars evolve from the main sequence into red giants after exhausting the hydrogen in their cores. By the 1960s, the models revealed how stars of different masses fuse helium into carbon, oxygen, and even heavier elements.



20 Although humans have observed stellar explosions for nearly 2,000 years (and likely more), no one knew what they were until the 20th century. In the 1930s, Walter Baade and Fritz Zwicky proposed that the gravitational collapse of a massive star could trigger a huge explosion, and Zwicky coined the term *supernova*. In the 1970s, John Whelan and Icko Iben explained the second main supernova variety — a white dwarf that detonates after accumulating too much mass from a companion. This image shows the Crab Nebula, the remnant of a supernova seen on Earth in 1054. ESO

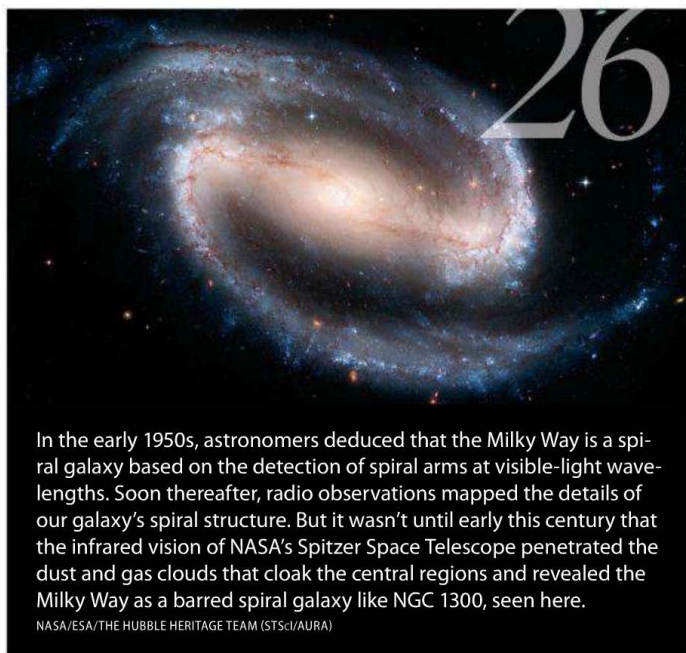
21 In 1967, Cambridge University graduate student Jocelyn Bell discovered several peculiar objects that emit powerful radio bursts several times every second. Within a year, Thomas Gold deduced that these so-called pulsars are rapidly rotating neutron stars — the remnants of massive stars that explode as supernovae.

22 In 1991, American radio astronomers Aleksander Wolszczan and Dale Frail discovered the first planets beyond our solar system. Against all expectations, the three planets orbit a pulsar cataloged as PSR B1257+12. Four years later, Swiss astronomers Michel Mayor and Didier Queloz discovered the first planet around a Sun-like star, 51 Pegasi. As of May 20, 2013, researchers have confirmed nearly 900 exoplanets.

23 By the early 1970s, NASA satellites had discovered several X-ray-emitting binary stars in which a visible star orbited a massive yet unseen companion. Many astronomers suspected that some of these invisible objects must be black holes. The best case: Cygnus X-1, which appeared to harbor a body with a mass of roughly 10 Suns that emitted no light. Subsequent observations confirmed this object to be the first known star-sized black hole — an object so dense that even light can't escape its gravitational pull.

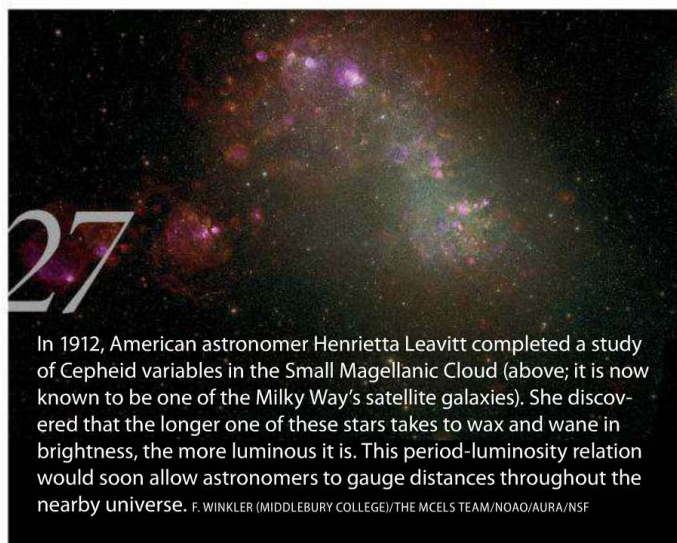
24 In 1931, American astronomer Karl Jansky detected radio emission coming from the Milky Way's center. Although he had built his radio antenna to study interference from terrestrial sources, the finding launched the field of radio astronomy.

25 In the 1910s, American astronomer Harlow Shapley studied the positions and distances of the 93 known globular star clusters in our galaxy. He found that these star cities — each of which holds tens, if not hundreds of thousands of stars — formed a spherical distribution centered on a spot in Sagittarius between 25,000 and 30,000 light-years from Earth. He correctly deduced that this spot marks the center of the Milky Way.



In the early 1950s, astronomers deduced that the Milky Way is a spiral galaxy based on the detection of spiral arms at visible-light wavelengths. Soon thereafter, radio observations mapped the details of our galaxy's spiral structure. But it wasn't until early this century that the infrared vision of NASA's Spitzer Space Telescope penetrated the dust and gas clouds that cloak the central regions and revealed the Milky Way as a barred spiral galaxy like NGC 1300, seen here.

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



In 1912, American astronomer Henrietta Leavitt completed a study of Cepheid variables in the Small Magellanic Cloud (above; it is now known to be one of the Milky Way's satellite galaxies). She discovered that the longer one of these stars takes to wax and wane in brightness, the more luminous it is. This period-luminosity relation would soon allow astronomers to gauge distances throughout the nearby universe. F. WINKLER (MIDDLEBURY COLLEGE)/THE MCELS TEAM/NOAO/AURA/NSF

28 In 1923, American astronomer Edwin Hubble discovered a Cepheid variable star in M31 and, using the period-luminosity relation found by Henrietta Leavitt a decade earlier, showed that M31 lies well beyond the confines of the Milky Way. Scientists named it the Andromeda Galaxy, and it became the first galaxy known besides the Milky Way.

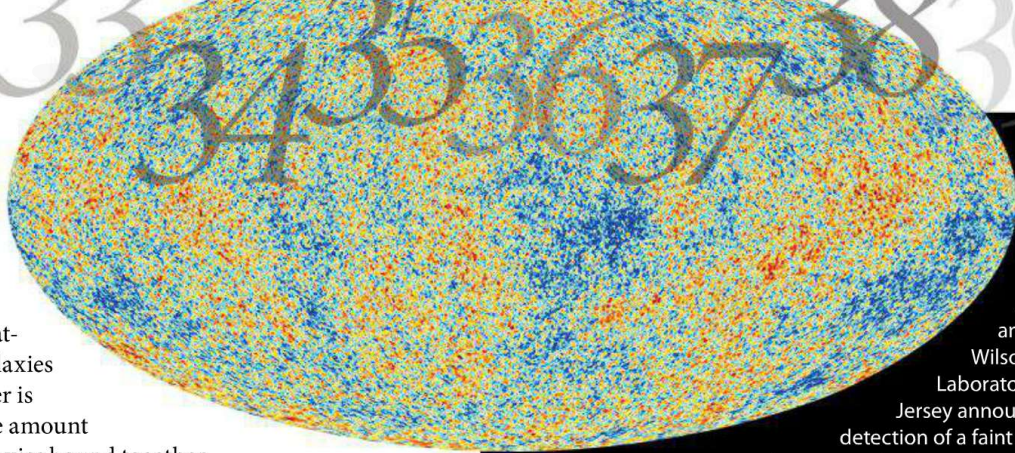
29 In 1997, astronomers confirmed that a supermassive black hole lurks at the center of the giant elliptical galaxy M84 in the Virgo cluster. They used the Hubble Space Telescope to measure the velocity of gas swirling around an unseen object at the galaxy's center and deduced that it weighs at least 300 million Suns. In the 16 years since, researchers have found a giant black hole in the core of nearly every large galaxy, including the Milky Way.

30 In the 1990s, astronomers began to realize that large galaxies get built up when they collide with and devour smaller ones. Galactic cannibalism explains why young galaxies in the distant universe appear small and misshapen — they have not yet merged with enough other youngsters to form big systems. It also describes the process by which galaxies such as the Milky Way and Andromeda disrupt and swallow dwarf galaxies that pass too close.

31 In 1963, Dutch-born astronomer Maarten Schmidt explained the bizarre spectra of a handful of radio-emitting objects that visually look like stars (and were dubbed quasars, short for quasi-stellar radio sources). He found the objects' emission lines were simply those of normal elements shifted far to the red by cosmic expansion, which made quasars among the universe's most distant and luminous objects. Astronomers now recognize them as galaxies that produce prodigious energy as matter swirls into a supermassive black hole. (The sky's brightest quasar, 3C 273, lies at the center of the image.) NOAO/AURA/NSF

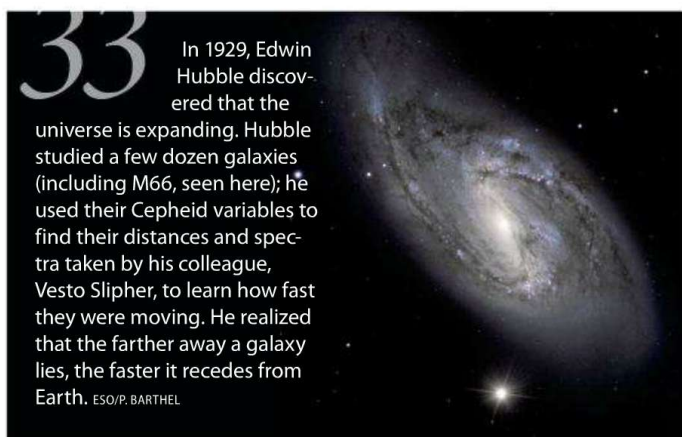


32 In 1933, Swiss astronomer Fritz Zwicky discovered that the visible matter contained in the galaxies of the vast Coma cluster is barely 10 percent of the amount needed to keep the galaxies bound together. This was the first indication that the universe has vast quantities of dark matter, which gives off no light but possesses gravity. Recent observations by the European Space Agency's Planck satellite show this still mysterious stuff makes up 27 percent of the mass-energy content of the universe, more than five times what normal matter contributes.



In 1965, Arno Penzias and Robert Wilson of Bell Laboratories in New Jersey announced their detection of a faint microwave glow emanating from the entire sky.

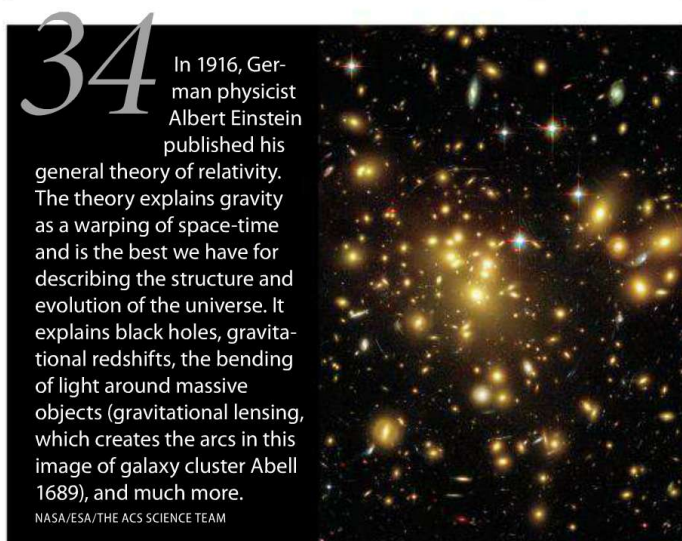
This radiation turned out to be the fading echo of the Big Bang that gave birth to our universe, cooled to a minuscule 2.7 kelvins (4.9° Fahrenheit above absolute zero). The Planck satellite captured this view of the radiation. ESA/THE PLANCK COLLABORATION



33 In 1929, Edwin Hubble discovered that the universe is expanding. Hubble studied a few dozen galaxies (including M66, seen here); he used their Cepheid variables to find their distances and spectra taken by his colleague, Vesto Slipher, to learn how fast they were moving. He realized that the farther away a galaxy lies, the faster it recedes from Earth. ESO/P. BARTHEL

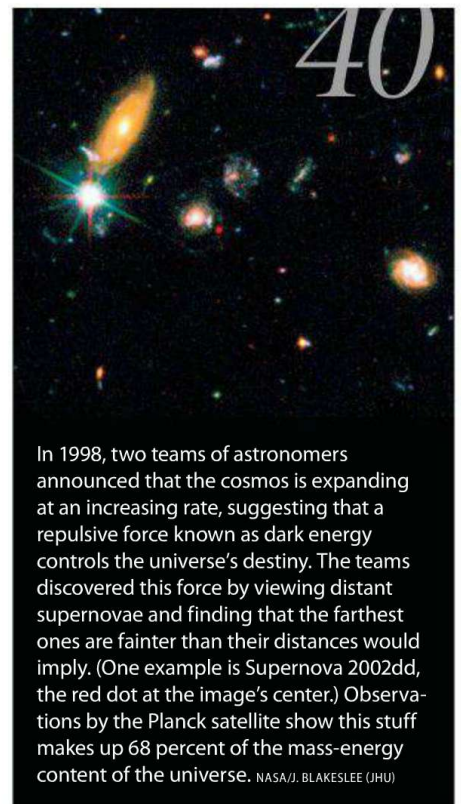
37 In 1981, American physicist Alan Guth proposed that the universe experienced a brief period of exponential growth shortly after the Big Bang. "Inflation" solved several problems in standard Big Bang cosmology, including why the universe appears so uniform and its geometry is nearly flat. Observations made with the Wilkinson Microwave Anisotropy Probe and Planck satellites confirm that some form of inflation did occur.

38 Starting in the 1980s, astronomers came to realize that the contents of the universe are not spread smoothly throughout space. Clusters of galaxies bunch together along filaments separated by huge voids where few galaxies exist. The overall structure, dubbed the "cosmic web," likely arose in the early universe when gravity amplified tiny irregularities in the distribution of matter.



34 In 1916, German physicist Albert Einstein published his general theory of relativity. The theory explains gravity as a warping of space-time and is the best we have for describing the structure and evolution of the universe. It explains black holes, gravitational redshifts, the bending of light around massive objects (gravitational lensing, which creates the arcs in this image of galaxy cluster Abell 1689), and much more. NASA/ESA/THE ACS SCIENCE TEAM

39 In 1997, a host of ground-based and space telescopes confirmed that gamma-ray bursts — fleeting blasts of high-energy radiation — are nature's biggest explosions. The Italian-Dutch satellite BeppoSAX pinpointed the February 28 burst, and Earth-based optical instruments were then able to spot its faint host galaxy several billion light-years from our planet. A typical gamma-ray burst radiates more energy in a few seconds than the Sun will in its entire 10-billion-year lifetime.



In 1998, two teams of astronomers announced that the cosmos is expanding at an increasing rate, suggesting that a repulsive force known as dark energy controls the universe's destiny. The teams discovered this force by viewing distant supernovae and finding that the farthest ones are fainter than their distances would imply. (One example is Supernova 2002dd, the red dot at the image's center.) Observations by the Planck satellite show this stuff makes up 68 percent of the mass-energy content of the universe. NASA/J. BLAKESLEE (JHU)

35 In 1957, Margaret and Geoffrey Burbidge, William Fowler, and Fred Hoyle described how nearly all the elements in the universe were produced either by fusion in the cores of stars or during the supernova explosions of massive stars. Their work on stellar nucleosynthesis accurately predicted the abundances of nearly all the elements except for primordial hydrogen and the helium and lithium produced in the first minutes after the Big Bang.



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40 greatest mysteries of the universe

Astronomers know more about the universe than ever but still have much to learn. **by Sarah Scoles**

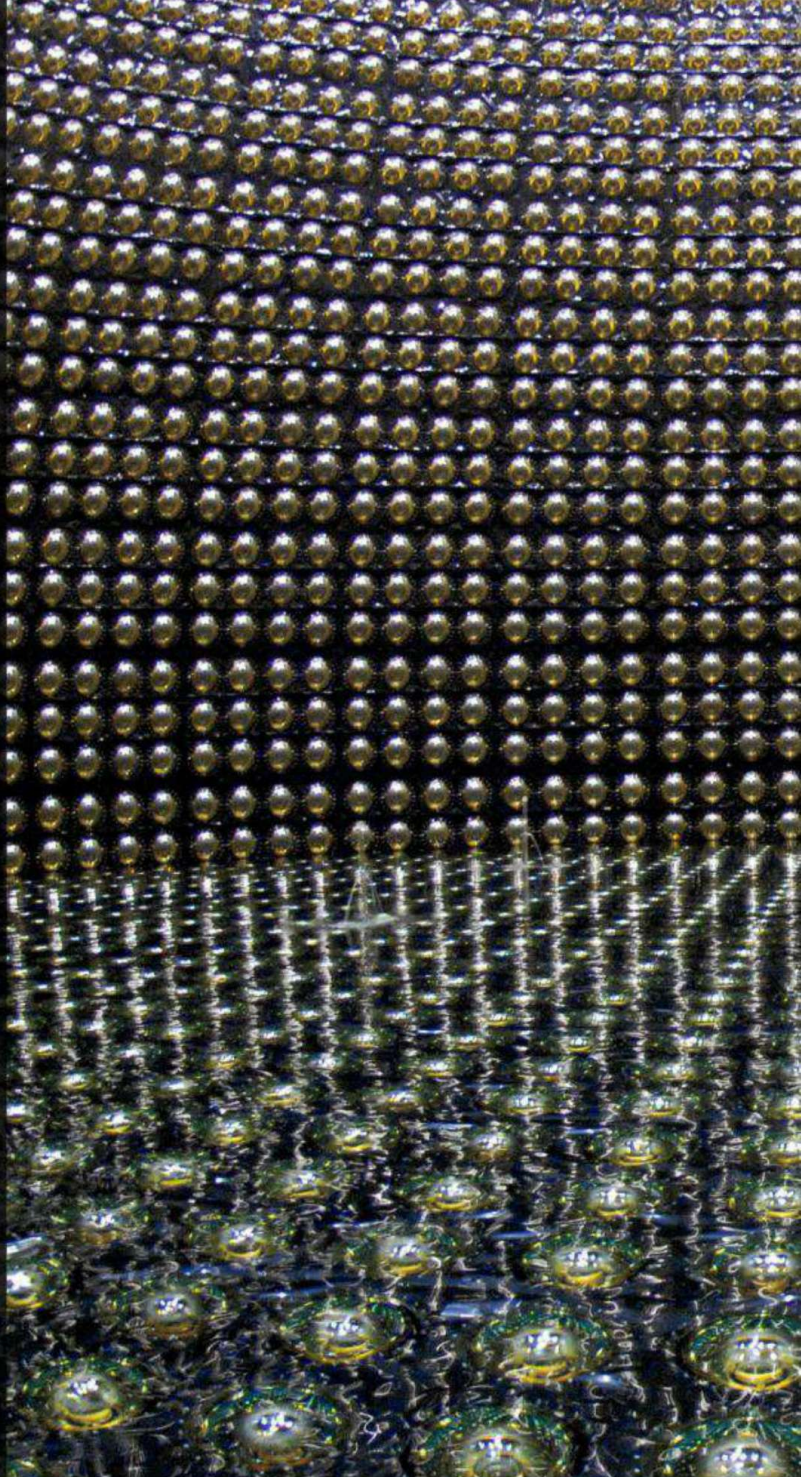
The first mysteries of the universe were questions such as: What is the Sun? What are the dimmer lights that appear in the evening? What is Earth, exactly? Since then, scientists have found that the Sun is a star similar to the thousands of others that we see in the night sky and the sextillions that exist in the universe. Earth is not the center of anything but, instead, is a planet similar to the many other planets that exist around most stars. Astronomical discoveries systematically have shot down attempts to proclaim our special place in the universe.

In the past 40 years, though, astronomers have found that while we are in a common place in the universe, the universe itself is not

commonplace. Shortly after the Big Bang, it may have expanded faster than the speed of light. Now, it is not only expanding but also doing so faster all the time. The overwhelming majority — 95.1 percent — of the universe is made of dark matter and dark energy. Bursts of high-energy radiation and particles stream through space all the time. The more scientists discover, the more questions they realize need to be asked.

In 40 more years, many of the 40 questions that follow may have answers. Those answers, though, will surely lead to more mysteries, to things we currently do not know we do not know. But this article is about things we know we do not know. The 40 mysteries represent problems whose answers scientists are actively seeking, and they range from the beginning of the universe to its end, from right next door to beyond the observable horizon.

Sarah Scoles is an associate editor of *Astronomy* magazine.





The Super-Kamiokande Neutrino Detector, also known as "Super-K," in Japan is a tank containing 50,000 tons of water and 13,000 photomultipliers that detect interactions with neutrinos coming from the Sun, the atmosphere, the decay of protons, and supernova remnants and explosions. By understanding neutrinos, scientists can learn more about why the universe is full of matter.

KAMIOKA OBSERVATORY/ICRR (INSTITUTE FOR COSMIC RAY RESEARCH)/THE UNIVERSITY OF TOKYO

1. How big is the universe?

Telescopes can see galaxies whose light has been traveling almost 13.8 billion years and thus look as they did just after the Big Bang. Because the universe is expanding at an accelerating rate, those galaxies are now some 46 billion light-years away. The observable universe thus has a diameter of 93 billion light-years, yet plenty is beyond that horizon. But how much?

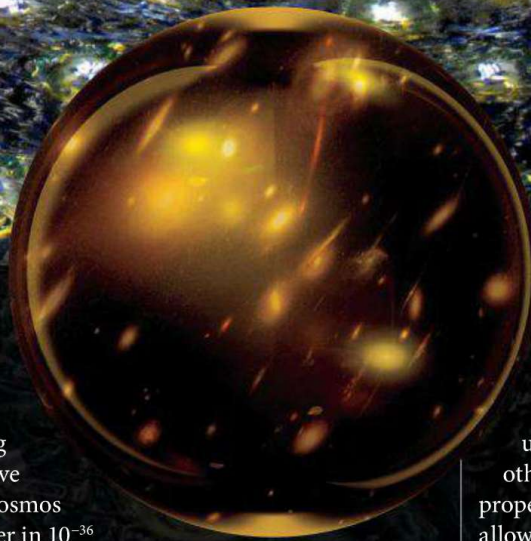
2. Did inflation happen?

The universe has been expanding since the Big Bang, but there may have been a time when the cosmos became 10^{78} times bigger in 10^{-36} second. If the inflationary epoch happened, it would make the current universe much bigger than it would otherwise be.

If cosmic inflation occurred, the universe grew to 10^{78} times its size in 10^{-36} seconds. At the end of inflation, it would have been as big as the circular image above. The rapid expansion of the early universe could explain its large-scale structure and why that structure appears homogeneous. ASTRONOMY: ROEN KELLY

3. Do we live in a multiverse?

Ours could be the only universe, or there could be others with different physical properties. Inflation theory allows others; string theory posits that they float in a higher-dimensional "brane" and bump into each other. While these are interesting ideas to ponder, they are not easy to test with the technology currently available.



4. What is dark energy?

Dark energy is the mysterious force that causes the universe to expand at increasing rates despite gravity's attraction. But scientists do not know what it is — only that it is 68.3 percent of the universe's energy density.

5. What is dark matter?

The difficulty with dark matter is its darkness. Scientists can detect its gravitational influence, but they have not seen it, even though it is 84 percent of the universe's matter and 26.8 percent of its energy density, according to the latest result from the European Space Agency's Planck space mission. In addition to figuring out what it is, scientists want to know its temperature and its connection to regular matter.

6. Why is there so much matter?

Soon after the Big Bang, matter and antimatter mostly annihilated each other. But you may

have noticed quite a few protons, electrons, and neutrons were left behind. What is strange is not how many of them there are, but that there are any at all.

7. Is string theory real?

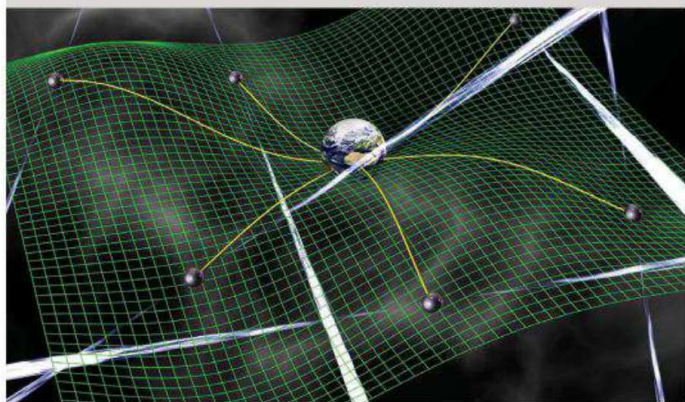
String theory, the idea that fundamental particles are made of one-dimensional strings, could unify the physics of the small (quantum mechanics) and the physics of the large (general relativity) in a "theory of everything." Although it may be real, it does not produce many ideas that currently are testable and could prove as much.

8. What is the true nature of gravity?

Gravity is the only fundamental force that does not yet have a discovered "carrier," or mediating particle, in quantum field theory. The hypothetical "graviton" particle would unite large-scale gravity with its underlying quantum causes.

9 Do gravitational waves exist?

Interactions between massive objects should send ripples called gravitational waves through space-time. The more massive the objects are, the stronger the undulations are, according to general relativity. The only trouble? No one has seen them. Researchers using laser-mirror combinations or pulsars are racing to find the waves and open a new window on the universe.



Every gravitational interaction should cause undulations to flow across space-time as "gravitational waves." Those from massive objects' close encounters are strongest. Scientists are using pulsars, which are stable clocks, to detect them. DAVID CHAMPION/NANO GRAV

LEARN MORE

To read about how scientists currently are working toward solving some of these cosmic mysteries, visit www.Astronomy.com/extracontent.

10. How and when did the universe's first galaxies form?

While there could be older ones, the oldest known galaxy is 13.35 billion years old. Scientists discovered it because of radiation coming from its active supermassive black hole — a quasar. It has so few heavy elements that its stars must have just been born, meaning the black hole formed first, at least in this case. But it is unclear how such black holes form and how they affect subsequent star formation.

11. What reionized the universe?

Immediately after the Big Bang, the universe was too hot to form atoms, so all matter was a charged plasma. But after it cooled, protons and electrons combined to form neutral hydrogen. Millions of years later, something produced enough energy to strip these atoms of electrons, reionizing them. But what did it? Individual stars or galaxies?

12. What role does magnetism play in star formation and galaxy evolution?

Magnetic fields affect charged particles, and the universe is full of both charge and magnetism. The fields around and within galaxies and star-forming regions guide the behavior of gas and plasma, affecting structures' shapes and interactions. Scientists do not yet have a firm grasp, though, on how much influence magnetic fields have had in the past and will continue to have as the universe continues to change.

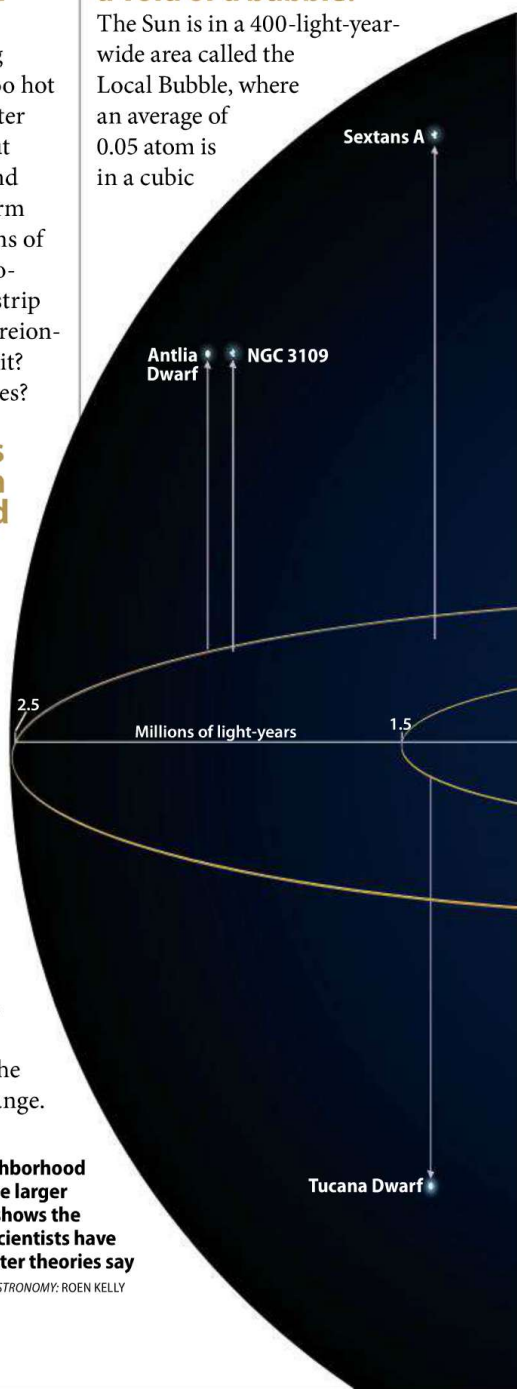
► The Local Group is our neighborhood of galaxies, which is part of the larger Virgo Supercluster. This map shows the galaxies, big and small, that scientists have found in our cluster. Dark matter theories say there should be many more. ASTRONOMY: ROEN KELLY

14. Where are all the little galaxies?

According to dark matter models, galaxy clusters should have a few large galaxies, more small ones, and many tiny ones. So far, scientists have found far fewer than expected in the Local Group and other assemblages. The discrepancy is called the "missing satellites problem." New simulations suggest dwarf galaxies' high velocities may strip away their gas, preventing them from forming stars and leaving them dark.

15. Is the Local Bubble a void or a bubble?

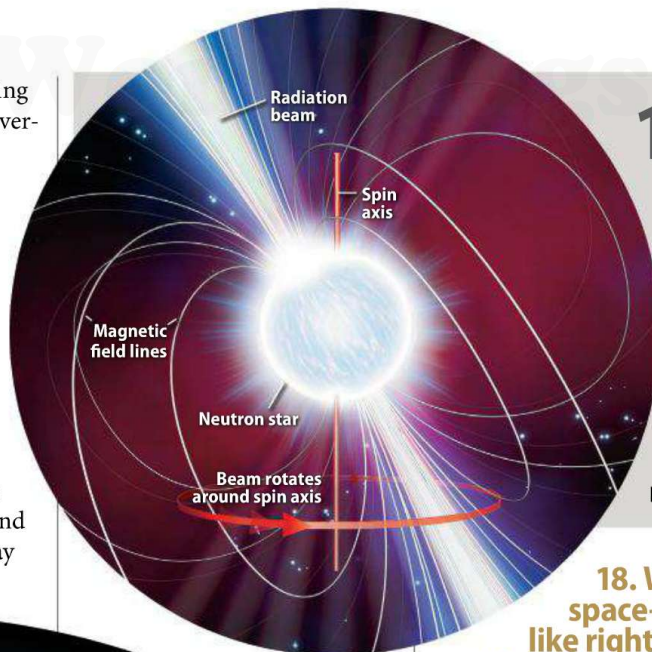
The Sun is in a 400-light-year-wide area called the Local Bubble, where an average of 0.05 atom is in a cubic



centimeter of space — making it 10 times less dense than average for the Milky Way. A supernova may have blown material away, or the space may be “naturally” empty.

16. How do stars explode?

Most massive stars end their lives as supernovae. Despite the cosmic regularity of this event, though, scientists have not been able to simulate stellar collapse and subsequent explosion the way they happen in nature.



17 What controls the properties of compact stellar remnants?

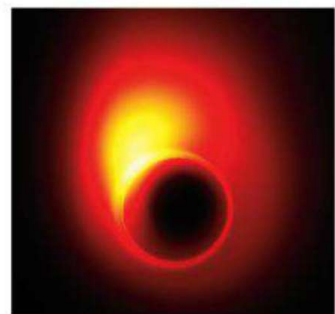
Massive stars eventually collapse into black holes or neutron stars. But at what point does a star become a black hole and not a neutron star, and is that point always the same? The mechanisms governing size and spin are also mysteries whose solutions constrain what exotic matter is inside these objects.

Pulsars are the remnants of massive stars. Every time a pulsar spins, a pulse of radiation shines in Earth's direction, as if this compact body were a lighthouse. ASTRONOMY: ROEN KELLY

18. What is space-time like right outside black holes?

Some of Einstein's predictions are hard to verify — how space acts right outside the densest objects in the universe, for instance. Now, a gigantic collaboration called the

Event Horizon Telescope is attempting to take a picture of the event horizon around our galaxy's central



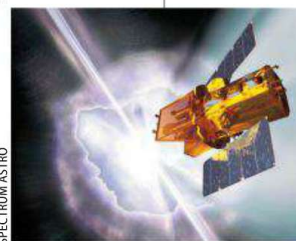
AVERY BRODERICK/ABRAHAM LOEB/RAMESH NARAYAN

A black hole's event horizon describes the sphere from which even light cannot escape. A ring of photons orbits just outside, as this simulation shows. Researchers are creating a telescope that will be able to take a picture of it.

black hole, Sagittarius A*, to see if it matches what Einstein led us to expect.

19. What causes black hole jets?

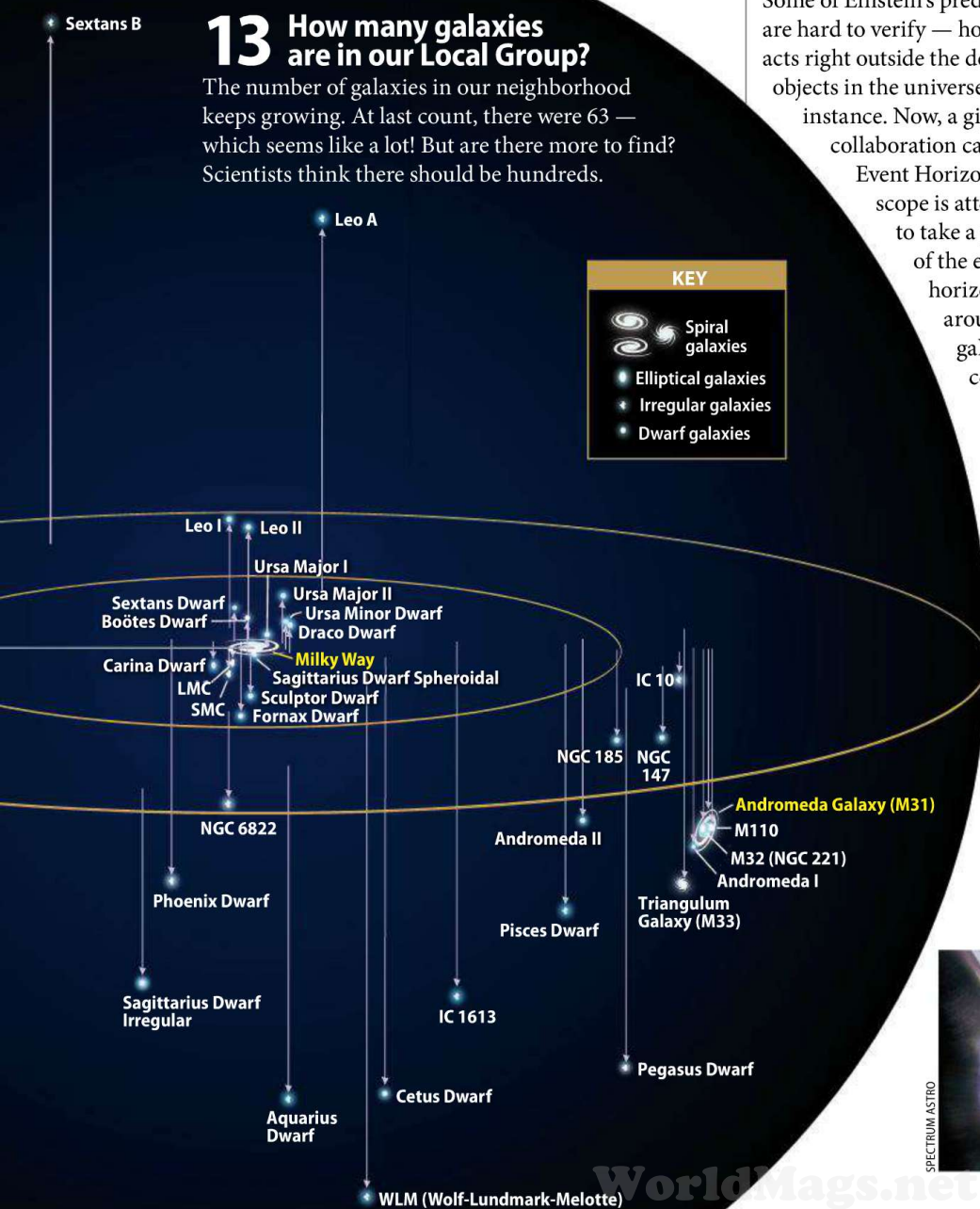
When material falls toward a black hole, it forms an inwardly spiraling disk. Some of the disk is accelerated away in jets at near light-speed. Scientists are not sure what causes the jets, though recent results from NASA's Swift and Fermi gamma-ray telescopes suggest those from stellar-mass black holes form the same way as those emitted by the supermassive. Whatever way that is.



Swift is one of NASA's two gamma-ray space telescopes. By observing the highest-energy photons, they capture information about cataclysmic events and violent phenomena.

13 How many galaxies are in our Local Group?

The number of galaxies in our neighborhood keeps growing. At last count, there were 63 — which seems like a lot! But are there more to find? Scientists think there should be hundreds.



KEY	
	Spiral galaxies
	Elliptical galaxies
	Irregular galaxies
	Dwarf galaxies

20. Does the Milky Way have orphan black holes?

When our galaxy was young, it likely swallowed smaller galaxies, just as planets swallow debris in their orbits. However, gravity may have given these galaxies' black holes a kick away from their stars. If so, these lone-wolf black holes are still around, roaming throughout the Milky Way.

21. Where are the missing supernova remnants?

Scientists expect some 60 supernovae to have exploded in the Milky Way in the past 2,000 years. But they have found only 20 remnants. The 40 "missing" ones either await our discovery or do not exist, implying that ours is an anomalous part of the universe, though astronomers expect us to be average.

22. Where are the missing baryons?

As much regular matter — baryons — as there is, some is missing. Big Bang nucleosynthesis and the cosmic microwave background predict and measure, respectively, how much of each of the "light" elements — hydrogen, helium, and lithium — should be in the universe. Scientists see those abundances in general, but not in our neighborhood.

23. How do stars form?

Scientists know what happens after a gas cloud collapses to form a star, but not why the gas collapses in the first place. Magnetic field lines may condense with the molecular cloud, pushing ionized gas and electrons together, or the interstellar wind could induce the density that puts the gas on the path to becoming a protostar.

24 How many brown dwarfs exist?

Brown dwarfs are failed stars — gaseous spheres that never acquired enough mass to begin fusion. They do not emit much light, making detection difficult, but are important to understanding how a star becomes a star. The Wide-Field Infrared Survey Explorer found just one brown dwarf for every six regular stars, while scientists expected the numbers to be equal.



The National Astronomical Observatory of Japan's Subaru Telescope is located on Mauna Kea, Hawaii. The instrument did the most sensitive survey of the brown dwarf population — a faint type of object that is not quite gas giant and not quite star. SUBARU/NAOJ

25 How did our solar system begin?

Our solar system began as gas that collapsed and formed a disk, which coalesced into the Sun and planets — or so the canon says. But the model cannot explain orbital tilt or what caused the initial collapse — perhaps a nearby supernova sending shock waves through a molecular cloud. Perhaps not.



This illustration shows a protostellar disk, the stage between the initial collapse of the molecular cloud and the coalescing of the remaining material into planets. With radio and infrared telescopes, astronomers can see through the gas and dust blocking the visible light in these regions and see how systems like ours form. NASA/JPL

26. Why is the Sun's corona so hot?

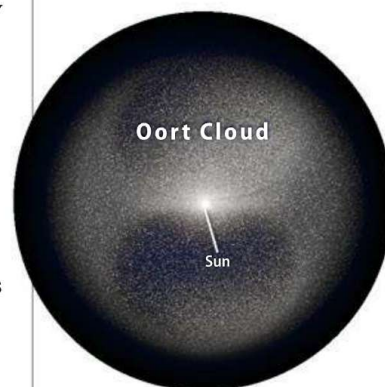
The outer part of the Sun is millions of degrees hotter than its surface. This heat has to come from somewhere, but if the surface is cooler, heat should flow there from the corona. Waves in the Sun's plasma or its magnetic energy may roast this mysterious part of our star. Recent results from the High-Resolution Coronal Imager suggest that the energy released when once-tangled magnetic fields straighten out and relax is enough to heat this part of the Sun.

27. Where is the solar system's edge?

Voyager 1, the 36-year-old probe, has traveled three times as far from the Sun as Pluto. But it is not out of the solar system yet, despite reports to the contrary. When the interstellar wind balances the solar wind, the solar system ends. Voyager will tell us where that is when it gets there, assuming it is still functioning.

28. When will we see the Oort Cloud?

The Oort Cloud is a 0.8-light-year-distant group of icy and rocky bodies that scientists have never seen. The worlds do not emit their own light and are so small and distant that their reflected light is minuscule; however, scientists believe this is where long-period comets originate. The objects total some five times Earth's mass.



The Oort Cloud, which scientists have never seen, extends beyond the orbits of other solar system objects. It contains trillions of icy planetesimals and surrounds the planets' orbits at a distance of nearly a light-year from the Sun. ASTRONOMY: ROEN KELLY

29 How are comets and asteroids related?

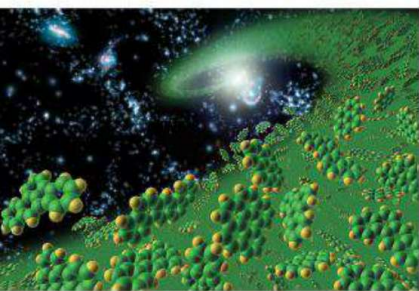
Asteroids are rocky and appear dark. Comets are icy, dirty, and light up as they approach the Sun and their components sublimate and reflect sunlight. Right? Actually, scientists have found objects that have characteristics of both. Some asteroids are "comets" whose volatile elements have burned off. Some comets are "asteroids" that have a halo of ice and dust.

30. How many stars have rocky planets?

The latest data from High Accuracy Radial velocity Planet Searcher and Kepler say 40 percent of red dwarf stars have super-Earths in their habitable zones and 17 percent of Sun-like stars have Earth-sized planets. More precise estimates are on the way and will show how our solar neighborhood compares to the rest of the galaxy.

31. What were the primordial sources of organic matter?

Scientists have discovered that stars can synthesize organic molecules and then eject them into space. Additionally, meteorites from our solar system contain organic matter, suggesting that our presolar nebula also produced these complex compounds. More research will show under what conditions stars and nebulae both accomplish this feat.



Microbes produce methane, and intelligent extraterrestrials may create synthetics, like chlorofluorocarbons, that scientists could detect. ASTRONOMY: ROEN KELLY

32 Is biology universal?

Before animals and plants, single-celled organisms emerged from amino acids and nucleotides. The building blocks of these DNA building blocks exist in space, as do other organic molecules. Their prevalence suggests the universe skews organic on its own. If carbon-bearing compounds are commonplace, they might regularly stick together into the sugars that form DNA's nucleotides.



Telescopes like the Atacama Large Millimeter Array can find molecules that may be precursors to life. ALMA/ESO/NRAO/NAOJ

33 What percentage of stars have planets?

Sensitive telescopes like Kepler and the High Accuracy Radial velocity Planet Searcher have found Earth-mass planets thousands of light-years away, and the latest data suggest there are 100–200 billion planets in the Milky Way. Optimistic scientists estimate that nearly 100 percent of stars have planets, but all agree the number of planets at least equals the number of stars in the Milky Way.



The High Accuracy Radial velocity Planet Searcher is attached to the 3.6-meter telescope at La Silla, Chile. It is able to detect stars' movements, which, if periodic, reveal the gravitation of a planet. ESO/LA SILLA

34. Are we alone?

There could be life around a nearby star or lurking somewhere inside our solar system (or its past). So far, scientists haven't found evidence of living organisms here or elsewhere, but they continue searching.

35. How would we recognize the presence of extraterrestrial life?

We often think of alien searches as broadcast-based. But other emissions could identify life both civilized and not. Metabolizing cells make methane, and

intelligent, industrial life might produce synthetic chemicals (like chlorofluorocarbons), both of which scientists could detect in exoplanetary atmospheres. Possibilities abound!

36. What does the dynamic sky look like?

The sky is not a picture but a movie. Telescopes are able to see objects that change on different short (in astronomical terms) timescales — microsecond to microsecond or year to year. The Large Synoptic Survey Telescope, in particular, will revolutionize knowledge of variable stars, gamma-ray bursts, pulsars, quasars, supernovae, potential alien signals, and other varying objects as yet unknown by imaging the whole sky every night.

37. What causes highly energetic cosmic rays?

Cosmic rays are charged particles (like the protons shot out of supernovae) traveling at high speeds. But ultra-high-energy cosmic rays approach the limits of how energetic particles can

be. Active galaxies, galactic interactions, gamma-ray bursts, hypernovae, and dark matter transformation could produce them. Facilities like the Pierre Auger Observatory in Argentina will find answers and new questions as they continue research.

38. What are the properties of neutrinos?

Billions of neutrinos pass through us every minute, but they have hardly any mass, have no charge, and barely interact with matter and electromagnetic fields. They come from, among other things, the Sun, supernovae, and colliding black holes. But how have they influenced the universe's evolution? Knowing more may explain why everything is made of matter and not antimatter.

39. How balanced is the universe?

The universe's "equation of state" describes the forces that act on the universe and how it will behave in the future. The equation depends on how matter, radiation, dark energy, and the cosmological constant (which describes the expansion of the universe and may be dark energy) compare in strength. Once scientists determine how these quantities stand up to each other, they can figure out what to expect after they are long dead.

40. How disorderly is the universe?

Entropy — disorder — increases with time, according to the second law of thermodynamics. When it maxes out, the temperature will be the same everywhere across the universe. This will happen when stars and galactic cores stop producing energy and are so far apart that they do not interact. The current entropy of the universe could tell us how far it is from this "heat death."



Where will astronomy be in 40 years?

The future of astronomy involves larger collaborations, greater computing power, and bigger telescopes. **by Debra Meloy Elmegreen and Bruce G. Elmegreen**



Forty years is the length of a career. What astronomy will look like in 2053 depends on what today's young astronomers and astronomy enthusiasts will do. But it is not entirely in their hands. Astronomy, like other fields of science, is progressing at the pace of general technology, swept up in the exponential growth of sensors, computers, and manufacturing innovations. It is growing faster still by the rapid adoption of social networking tools and electronic publication. For example, the average number of authors on an astronomy paper increased from two to 10 in the past 40 years, and the citizen-science website Zooniverse (which hosts Galaxy Zoo and 14 other projects) has had more than 830,000 contributors since it began six years ago. The picture of astronomy has changed from lone astronomers working on mountaintops to teams working at home and in their offices.

Astronomy will evolve tremendously in the next four decades, just as the past four have brought unexpected discoveries and new ways of doing science.

The transformation began at the dawn of the Information Age and has led to an explosion of knowledge about our place in the universe. In the 1970s, we barely recognized the nearest supercluster of galaxies, but now we can map superclusters and galaxies out to 95 percent of the visible limit of the cosmos. The perceptible limit of the universe is shrinking before our eyes, even as the cosmos expands into space and time. Today, computers dominate nearly all aspects of observations and analysis. What will drive the next revolution in astronomy?

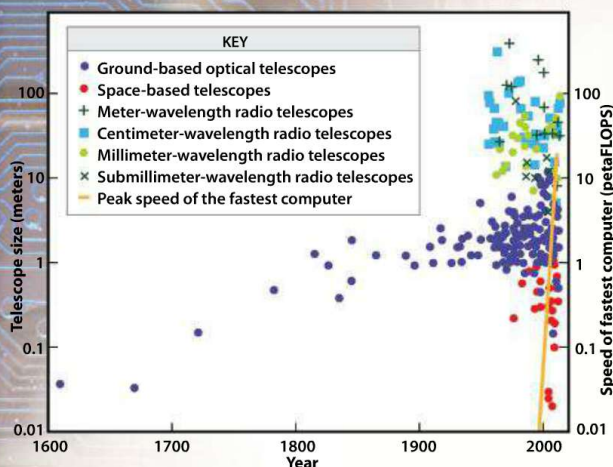
Reflection leads to action

To fully understand the change that computers and modern technology have brought about, we can reflect on the status of astronomy 40 years ago when we (the authors) met at Princeton University. Astronomers had just begun using photographic plates to study wavelengths slightly longer than (and thus redder than) visible, and photomultiplier tubes gave unprecedented sensitivity. Calculation on a slide rule was common, and hand-held four-function calculators were brand new. University campuses hosted giant computers controlled by foot-long decks of punched cards — scientists punched holes into cards that the computers could read. Attendants then fed these cards into the computer and handed them back to the researchers, along with printed output, after a half-day wait.

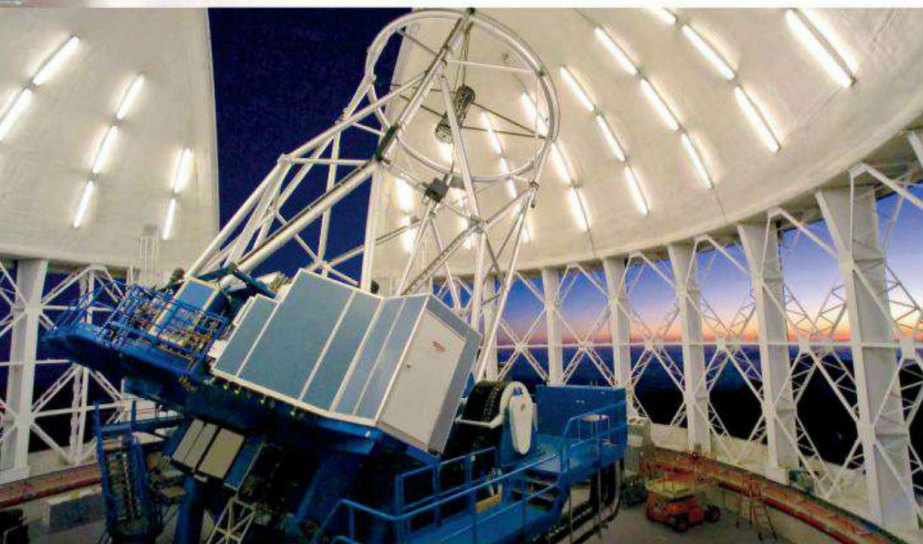
Forty years ago, NASA was 15 years old and held the world spellbound with the last of the six manned Apollo Moon landings. The first American space station, Skylab, had just launched.

The largest optical telescope in the world was Palomar Observatory's 25-year-old 200-inch Hale Telescope in California, while the biggest for radio waves was Arecibo Observatory's 1,000-foot-wide dish in Puerto Rico. Kitt Peak National Observatory in Arizona, at age 15, was the center of public astronomy research in the United States. It proudly offered the brand new 4-meter Mayall Telescope and the giant McMath-Pierce Solar Telescope, while the National Radio Astronomy Observatory had a 36-foot-wide dish on the same mountain to detect millimeter

Evolution of instruments



The sizes of the world's largest optical and radio telescopes have grown exponentially during the past four centuries, but that growth has been slow compared to the recent pace of computer technology development. ASTRONOMY: ROEN KELLY, AFTER DEBRA MELOY ELMEGREEN AND BRUCE G. ELMEGREEN



The Gemini Observatory runs two 8.1-meter telescopes; one is in Hawaii (pictured here) and the other in Chile. They are two of the world's largest optical scopes. GEMINI OBSERVATORY/AURA

Debra Meloy Elmegreen, a professor of astronomy, holds the Maria Mitchell Chair at Vassar College and is past president of the American Astronomical Society; she served on the committee for Astro2010: The Astronomy and Astrophysics Decadal Survey. **Bruce G. Elmegreen** is an astronomer and staff scientist at the IBM T. J. Watson Research Center and a member of the National Science Foundation's Mathematical and Physical Sciences Advisory Committee. Both are Fellows of the American Association for the Advancement of Science.

wavelengths. A complementary 4-meter optical telescope (now named for Victor M. Blanco) would arrive the next year at the Cerro Tololo Inter-American Observatory in Chile.

What had these and other instruments revealed to astronomers? They were used to measure the expansion rate (and therefore the age) of the universe, but could only get it right within a factor of two. From galaxy spin and the motions of galaxies in clusters, astronomers suspected that an invisible dark matter is present, but dark energy (now known to accelerate cosmic expansion) was still Albert Einstein's "biggest blunder." Observations supporting its existence didn't come until the 1990s.

Black holes were in the news because alternate explanations for Cygnus X-1, an X-ray source discovered nine years earlier via rocket flight, were proving untenable. Astronomers also suspected that super-massive black holes power extremely bright point sources called quasars, but their present understanding that black holes are central inhabitants of most galaxies was a long way off.

Scientists had observed the Big Bang's relic cosmic microwave background radiation, but it appeared to be perfectly smooth and so gave no indication of the beginnings of cosmic structure that they now study. They had produced catalogs of the sky's emission at centimeter wavelengths showing radio galaxies and hydrogen gas, but the most

sensitive radio interferometer in the world, the Very Large Array in New Mexico, would not be completed for another seven years.

While astronomers had already discovered pulsars — dense spinning cores of once massive stars — it would be another year before they observed the first binary pulsar. This system would give definitive evidence that gravitational radiation exists, which Einstein had hypothesized decades prior.

Millimeter-wavelength radio astronomy was in its infancy, with the discovery just three years earlier of carbon monoxide emission from interstellar space — this molecule is still the best tracer for dense star-forming clouds. Infrared astronomy also was showing its potential with the surprising find six years earlier of a newborn star in the Orion Nebula that dust conceals at optical wavelengths. Forty years ago was an incredibly exciting time for astronomy. Since then, the Royal Swedish Academy of Sciences has awarded seven Nobel prizes in physics for astronomy topics.

The current state

Today, there are 13 optical telescopes with diameters larger than 8 meters (such as the Keck observatories in Hawaii and the Gran Telescopio Canarias of the Canary Islands) and CCD detectors with more than 1 billion pixels (for example, the camera on the Panoramic Survey Telescope and Rapid Response System [Pan-STARRS] in Hawaii). We use technology called adaptive optics to correct for the blurring effect of Earth's atmosphere and provide angular resolution better than 0.1 arcsecond in optical light (like GeMS on the Gemini South Telescope in Chile). We have instruments called spectrographs to capture the spectra, or component colors, of up to 4,000 sources at once using optical fibers (such as the Large Sky Area Multi-Object Fiber Spectroscopic Telescope in China).

We've launched telescopes to study the entire range of light: gamma rays (the Fermi Gamma-ray Space Telescope); X-rays (the Chandra X-ray Observatory and the Nuclear Spectroscopic Telescope Array); ultraviolet (the Galaxy Evolution Explorer); optical (the Hubble Space Telescope and Kepler); infrared (the Spitzer Space Telescope and the Herschel Space Observatory); and submillimeter to millimeter (Planck).

Five active unmanned spacecraft explore Mars, and other probes transmit data while approaching or orbiting the Sun, Mercury, Jupiter, Saturn, Pluto, the Moon, comets, asteroids, and interstellar space beyond Pluto. Humans have continuously occupied the orbiting International Space Station for more than 12 years.

Today's astronomers have a steerable radio telescope bigger than a football field (the Green Bank Telescope in West Virginia) and huge radio interferometers (such as the Very Long Baseline Array in North America and the recently upgraded Karl G. Jansky Very Large Array in New Mexico). Scientists also recently dedicated the Atacama Large Millimeter/submillimeter Array of 66 antennas in Chile and started operating the software-driven LOW Frequency ARray (LOFAR) based in the Netherlands. LOFAR illustrates how modern computers can keep pace with live radio signals from multiple sites spread out over a continent — as many future instruments will require. Modern computers also can simulate stellar and interstellar dynamics with billions of resolution elements to give unprecedented realism.

What comes next?

The Decadal Survey is a crucial study to determine the astronomical priorities in the United States. The National Academy of Sciences appoints committees to prepare three surveys related to our field: One covers astronomy and astrophysics, another planetary sciences, and the third solar physics. These surveys reflect community consensus on the most urgent science questions and important future instruments and programs. They help inform Congress and the federal funding agencies, such as the National Science Foundation, NASA, and the Department of Energy, about scientific priorities.

The most recent surveys emphasize discovering and characterizing planets around other stars; understanding dark matter and dark energy; observing the first stars and galaxies in the universe; measuring the physical constants that characterize the cosmos; exploring Mars for signs of past habitability and one day returning martian rocks to Earth; venturing to frozen water worlds such as Jupiter's moon Europa; probing our outermost and innermost planets and comets; and detailing magnetic properties and variations of the Sun and its effects on Earth.

Soon to begin construction in Haleakala, Hawaii, the Advanced Technology Solar Telescope will measure the Sun's activity and determine how it impacts weather and communications on Earth. The Large Synoptic Survey Telescope (LSST) in Chile should see first light within a decade. LSST will scan the entire accessible sky every few days, building up an extraordinarily deep map by stacking all of the images while searching for transient objects such as near-Earth asteroids. It will study billions of Milky Way stars, trace dark matter using billions of galaxies, and measure numerous distant supernovae to map out the universe's acceleration.

We anticipate that the James Webb Space Telescope will launch in 2018. With its infrared sensitivity, this spacecraft will probe the end of the universe's "Dark Ages" to find the era long ago when the first stars and galaxies formed. Webb also will observe a wide variety of objects closer to home — such as new stars, protoplanets, and young planetary systems — that could shed light on how our solar system formed.

Also in the planning stages are three monster ground-based optical telescopes: the European Extremely Large Telescope, a 39.3-meter behemoth, plus the 25-meter and 30-meter observatories both led by private groups and universities in the U.S. with international partners.

All of the telescopes and instruments under construction and planned for the future will be highly complementary, meaning they'll observe different parts of the electromagnetic spectrum of the same sources or combine survey capabilities with deep views. For example, the proposed Chilean-based 25-meter submillimeter CCAT will survey



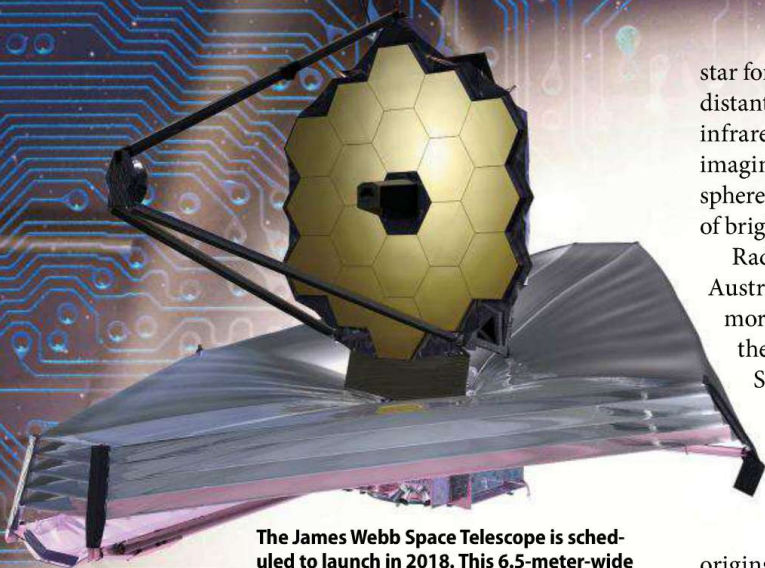
The Gran Telescopio Canarias is the largest optical telescope in the world; its primary mirror is made up of 36 hexagonal segments and spans 10.4 meters. The instrument began scientific operations in March 2009. INSTITUTO DE ASTROFÍSICA DE CANARIAS (IAC)/PABLO BONET



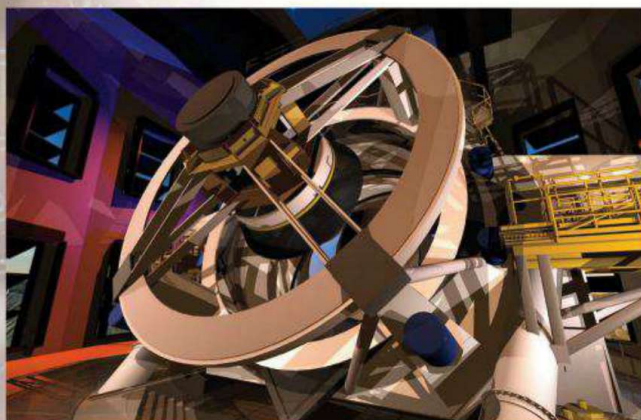
An adaptive-optics system lets optical telescopes see resolutions of 0.1 arcsecond. It does so by creating a bright "star" in the field of view via laser and then corrects for the blurring effect of Earth's atmosphere. ESO/YURI BELETISKY



The Atacama Large Millimeter/submillimeter Array (ALMA) is the newest radio telescope. Commissioned March 13, ALMA is observing the sky from the Chajnantor Plateau in the Chilean Andes. ESO/C. MALIN



The James Webb Space Telescope is scheduled to launch in 2018. This 6.5-meter-wide reflector will study the distant universe in infrared radiation. NASA



Astronomers expect the Large Synoptic Survey Telescope to begin observations within a decade. This instrument will scan 20,000 square degrees of sky 1,000 times over 10 years to create a deep survey in six optical wavelength bands. TODD MASON, MASON PRODUCTIONS INC./LSST CORPORATION



The Square Kilometre Array is scheduled for full operation in the mid-2020s. This next-generation radio telescope will use three different types of radio detectors, illustrated here: Some 3,000 dishes (top), each 15 meters wide, will compose most of the telescope with low-frequency antennas (middle), and mid-frequency arrays. SKA ORGANISATION/TDF/DRAO/SWINBURNE ASTRONOMY PRODUCTIONS

star formation, protoplanets, our solar system's Kuiper Belt, and distant galaxies and clusters. Its data will complement space-based infrared observations from Webb. Astronomers will combine LSST's imaging survey with spectra of faint objects, such as exoplanet atmospheres, taken on 30-meter telescopes and with spectroscopic surveys of brighter objects on 4-meter telescopes.

Radio telescopes with survey capabilities, like the multi-beam Australian Square Kilometre Array Pathfinder, will complement the more-sensitive MeerKAT radio array in South Africa. In 10 years, the Square Kilometre Array (SKA) — situated in Australia and South Africa — will revolutionize radio astronomy at meter and centimeter wavelengths with a sensitivity some 50 times greater than anything today. The SKA will map radio emission and the end of the universe's Dark Ages, study accretion disks and jets around black holes and protoplanetary disks, measure gravitational waves as they flow past pulsars, probe the origins of cosmic magnetism, and look for transient signals from nearby stars that might indicate life.

Amateur astronomers also have increasingly complex facilities at their disposal. Today's advanced devotees routinely use sophisticated telescopes to take deep CCD images. This trend will no doubt continue. The astronomical community always will need small telescopes to provide long-term monitoring of variable objects. As research instruments like Pan-STARRS and LSST detect transient sources, networks of small telescopes become crucial for monitoring the most interesting objects.

Looking to great discoveries

One area of astronomy that looms on the horizon is the study of gravitational waves rippling across space-time from merging black holes or pulsars. The North American Nanohertz Observatory for Gravitational Waves project currently studies radio waves from pulsars, looking for hints of this curvature in space-time. The Laser Interferometer Gravitational-wave Observatory in Louisiana and Washington may detect these waves in the next decade, while space-based gravitational wave missions may be feasible in the next two. These instruments should help us understand gravity both where the waves are made and farther out in the extremely weak fields of the waves themselves.

In the particle astrophysics realm, new ground-based telescope arrays will detect optical cascades — called Čerenkov radiation — from the high-energy particles produced by cosmic rays and gamma rays when they hit Earth's atmosphere. Such radiation comes from the highest-energy objects and events in the universe, such as black holes and supernovae. Laboratories thousands of feet below Earth's surface, like the Sanford Underground Research Facility in South Dakota, and particle accelerators, like the European Organization for Nuclear Research, will continue looking for the mysterious particles that make up dark matter. Theoretical physicists also may begin to understand dark energy, although at the moment it seems totally unworldly. Sophisticated computers will be able to model astronomical processes in ever-increasing detail, showing how galaxies and galaxy clusters build up by accreting material and forming stars in an expanding cosmic web of dark matter, normal matter, and dark energy.

Space-based missions such as Euclid and the Wide-Field Infrared Survey Telescope (WFIRST) and ground-based instruments like the South Pole Telescope in Antarctica and the Dark Energy Survey in Chile will study dark matter and dark energy by probing their effects on vast scales. Euclid, a project by the European Space Agency in collaboration with NASA, will study both optical and infrared wavelengths. The project, planned for a 2020 launch, will target a wide area of the sky to measure shapes and distributions of galaxies and galaxy clusters out to distances where the universe appears less than half of its current age.

Meanwhile, WFIRST is a proposed NASA mission in the early planning stages. Its spectroscopic and imaging capabilities for surveying galaxies and monitoring supernovae will complement Euclid's. WFIRST also will search for exoplanets using a technique called microlensing, in which a foreground planet slightly distorts light from a background star.

The next large space telescope for NASA and its international partners after the 2.4-meter Hubble and the 6.5-meter Webb might be an 8- to 16-meter reflector for ultraviolet, optical, and infrared wavelengths — called the Advanced Technology Large-Aperture Space Telescope. (The Space Telescope Science Institute in Baltimore studied this concept.) Such a telescope would have an angular resolution five to 10 times better than Webb and a sensitivity up to 2,000 times better than Hubble. It would be able to image large features on Earth-sized exoplanets closer than 150 light-years from us and begin to resolve the oldest globular clusters of hundreds of thousands of stars at great distances, where they can appear at the time of their formation.

The technologies that have led to the discovery of nearly 3,000 confirmed and candidate exoplanets are now on the brink of detecting other Earths. Some of these Earths are likely to be within their stars' habitable zones (where the temperature allows liquid water to exist on their surfaces) and may even have life-sustaining atmospheres.

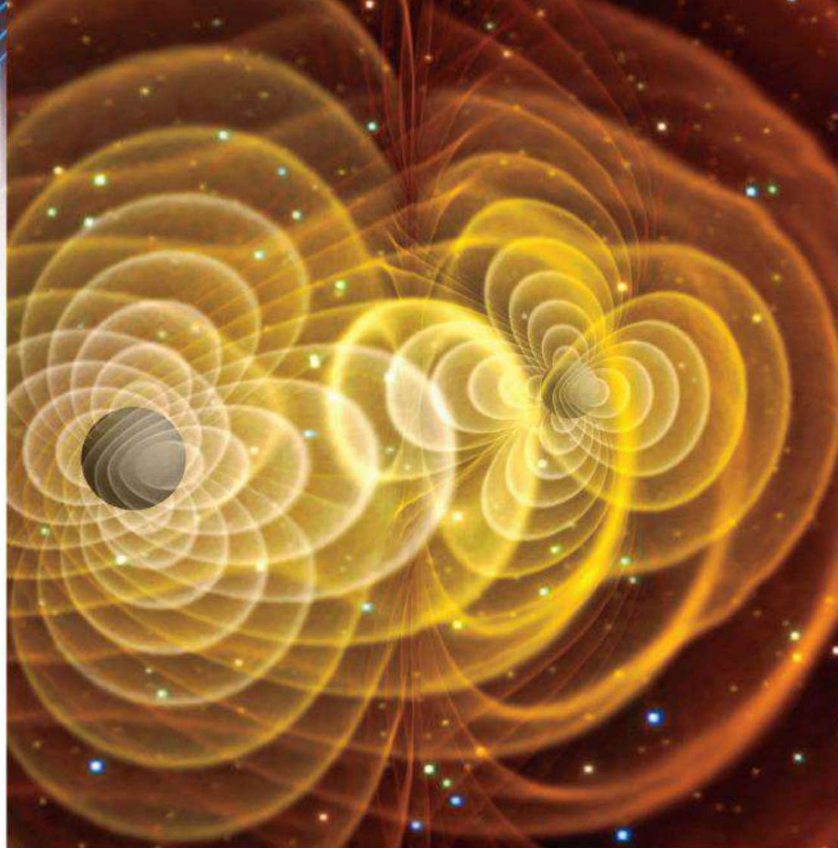
Scientists don't really know what sustains life, but hopefully continued exploration of our solar system will make this clearer. Satellites that probe planet interiors, icy moons, and primitive asteroids could reveal a variety of conditions that once supported life. A proposed new NASA mission would ferry an asteroid to lunar orbit so that visiting astronauts could examine it up close. With all of these missions, we may come to understand whether Earth is common or not.

Moving forward

Next-generation instruments push every conceivable boundary in technology, including the ability to record, store, and analyze enormous amounts of data. We will need large computers and more intelligent software to use the half petabyte of data (a petabyte is about 1 million gigabytes) that will come each month from LSST and the exabyte of data (some 1 billion gigabytes) that the SKA will store each year.

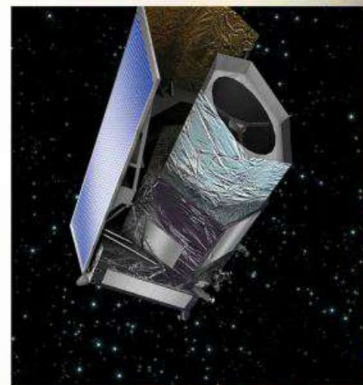
The International Virtual Observatory Alliance (a consortium that started about a decade ago and now has 20 member countries) should help with the organization, distribution, and analysis of these data. Its goals are to develop software tools to easily analyze large amounts of archival information and to facilitate collaborations among scientists who want to use that material. Scientists will need exaFLOP computers (1 billion billion Floating-point Operations per second) just to process the SKA data into maps and an additional exaFLOP of processing power around the world for subsequent analysis of the radio sky.

The universe has always proved full of surprises, and that will likely continue. Most new instruments have led to fascinating discoveries of unexpected phenomena and objects. That's what makes science exciting and drives astronomers to keep expanding their reach. If the past is any indication of the future, the members of the next generation are certain to look back and marvel at how far they have come in the course of their own careers. 🌌



Gravitational waves, curvatures in space-time that sometimes result from merging black holes, will be a major area of future research.

To study the effects of the mysterious dark matter and dark energy, the European Space Agency, in collaboration with NASA, will launch Euclid in the next decade. (The telescope is shown in this artist's concept.) ESA/C. CARREAU



A NASA mission concept is the Advanced Technology Large-Aperture Space Telescope. This would observe ultraviolet, optical, and infrared light like the Hubble Space Telescope, but would be much larger. Current designs range between 8 (top) and 16 meters, whereas Hubble is 2.4 meters. MSFC ADVANCED CONCEPTS OFFICE (TOP); NORTHROP GRUMMAN AEROSPACE SYSTEMS/NASA/STScI (BOTTOM)



August 2013: Neptune's summer surge



Venus posed with the Moon on the evening of September 11, 2010. The two brightest objects in the night sky have a return engagement set for August 9. STEFANO DE ROSA

The brightest planet and the prettiest planet vie for attention as darkness falls in August. Once they set in late evening, the sky is bereft of bright planets until the wee hours, when Jupiter leads a parade that also features Mars and, early in the month, Mercury.

The only planetary denizens of the midnight hour are the distant ice giants, Uranus and Neptune. The latter of these worlds will be a prime target late this month when it reaches opposition and peak visibility. But August's top attraction likely will be the year's best

meteor shower, the Perseids, which peaks under Moon-free skies before dawn August 12.

We'll begin our tour of the night sky while twilight still brightens the western horizon. Despite this glow, **Venus** sticks out like a sore thumb because it shines brilliantly at magnitude -3.9. No other celestial point of light rivals it. The planet remains visible throughout August at essentially the same altitude. If you view from mid-northern latitudes a half-hour after sunset, it hovers about 10° high all month.

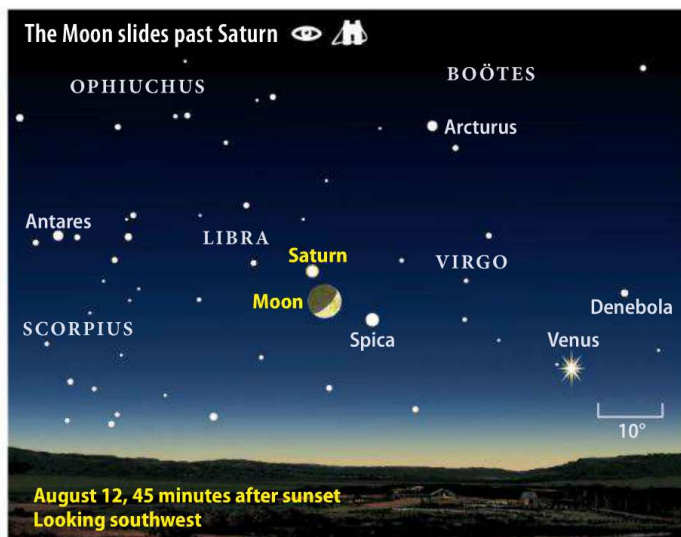
On August 9, a thin crescent Moon passes 5° south (to the lower left) of Venus. Set against the colorful twilight glow, the pair will look spectacular with naked eyes or binoculars and will make a fine photographic subject. Add elegance to your images by placing a distinctive

foreground feature in silhouette. The three-day-old Moon appears 10 percent lit that evening; through a telescope, Venus shows an 80-percent-lit phase on a 13"-diameter disk.

On August 10, the Moon crosses from Leo the Lion into Virgo the Maiden. Venus makes the same leap the following night, by which time the Moon (now 25 percent lit) lies near Virgo's brightest star, 1st-magnitude Spica.

Venus continues its trek across Virgo for the remainder of August. By the 31st, the planet lies 6° northwest of Spica, the only star in Virgo visible with naked eyes during twilight because the constellation holds no other brighter than 3rd magnitude. Point a telescope at Venus on the month's final night, and you'll see a disk that spans 15" and appears three-quarters lit.

Virgo harbors one other planet these August evenings, and it's a beauty. **Saturn** resides at the large constellation's eastern end, which places it significantly higher than Venus in the evening sky. On the 1st, it stands 20° above the southwestern horizon at the end of twilight. By the 31st, it appears half that high.



A waxing crescent Moon stands between two 1st-magnitude objects — the planet Saturn and the star Spica — the evening of August 12. ASTRONOMY: ROEN KELLY

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.

RISINGMOON

High walls and lava flows

The waxing Moon slinks low across the southern sky on summer evenings. Our celestial companion takes on shades of pale yellow through orange because its light takes a longer path through Earth's atmosphere. To observers south of the equator, however, Luna rides high and shines white during August.

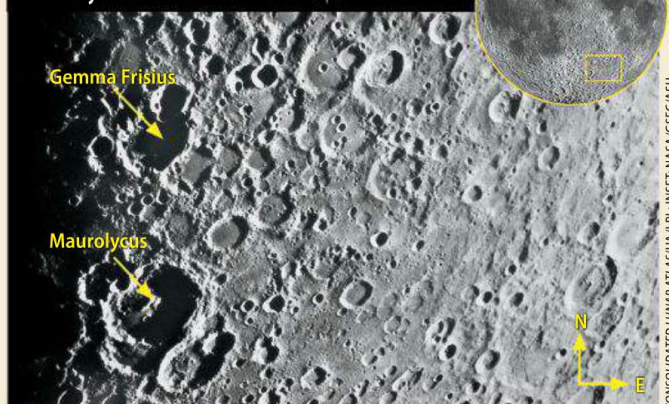
After sunset August 12, the waxing crescent appears in the southwest below Saturn. Turn your telescope on the Moon's disk, and soak in the breathtaking series of maria in the north before scanning southward across the craters arrayed along the terminator that separates lunar day from night.

Maurolycus, a crater named after a 16th-century Italian

mathematician who disagreed with Copernicus' Sun-centered solar system, sits in the southern third of the disk. The impact that carved out this 70-mile-wide beauty occurred on a relatively thin part of the lunar crust. The blow fractured the crust, creating pathways for lava to seep up and smoothly pave the floor around a complex of central peaks. The impact wiped out half of a crater that lies immediately south of Maurolycus and another one to the northwest.

As the lunar bombardment continued, newer impacts broke up and softened older features. The small craterlets on Maurolycus' floor are the freshest, but can you figure out the sequence of impacts that created the

Maurolycus and Gemma Frisius



The Moon's southeastern quadrant features a pair of large craters that come into sharp relief shortly before First Quarter phase.

group on the crater's northwestern edge? Although the picture above helps, your own observations on the 12th and following evenings are the best way to get the time line straight. A similar story plays out on the crater

group anchored by Gemma Frisius a short hop to the north.

As Full Moon approaches, you should see a ray from the distant crater Tycho crossing Maurolycus. Use high magnification to spot this subtle stripe.

When the waxing crescent Moon passes through Virgo before midmonth, it helps create an attractive scene August 12. That evening, the 35-percent-lit Moon forms a triangle with Saturn and Spica. Our satellite appears 5° below the ringed planet and 8° to Spica's upper left. At magnitude 0.7, Saturn shines almost imperceptibly brighter than Spica.

Although Saturn looks pleasant enough with naked eyes and binoculars, it doesn't truly shine until you view it through a telescope. That's the only way you can see the gorgeous rings, which span 38" in early August and tilt 17° to our line of sight.

Even the smallest scope will show the rings. With a bit of care, you should see Saturn's shadow obscuring a small section of the rings behind and just east of the planet's disk. Although the

— Continued on page 50

METEORWATCH

Summer's grand meteor show

The Perseid meteor shower will be at its best before dawn August 12. Not only does this year's top shower produce lots of meteors — up to 100 per hour under optimal conditions — but it also reaches its peak with the Moon out of the sky. From mid-northern latitudes, the waxing crescent sets shortly after 10 P.M. local daylight time the previous evening.

If predictions hold, the highest rates should be on display from eastern Europe and northern Asia. Although observers in North America might see "only" 80 meteors per hour under a dark sky on the 12th, rates on the following morning could be nearly as high. Wherever you view from, the hour or so before dawn should deliver the best views.

Perseid meteors

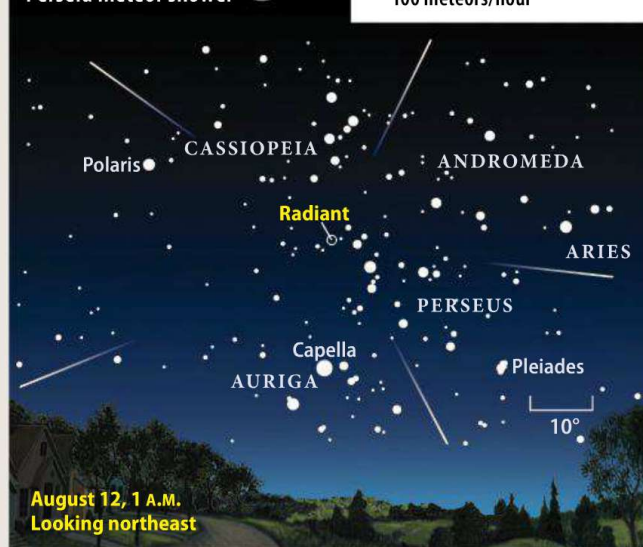
Active Dates: July 17–Aug. 24

Peak: August 12

Moon at peak: Waxing crescent

Maximum rate at peak:
100 meteors/hour

Perseid meteor shower



The waxing crescent Moon sets well before the prime viewing hours begin at the peak of 2013's finest meteor shower. ASTRONOMY: ROEN KELLY

OBSERVING HIGHLIGHT

Neptune reaches its 2013 peak the night of August 26/27, when it glows at magnitude 7.8 and appears 2.4" across through a telescope.



WorldMags.net

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:

11 P.M. August 1
10 P.M. August 15
9 P.M. August 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

AUGUST 2013

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.

Calendar of events

- 3** The Moon is at apogee (252,173 miles from Earth), 4:53 A.M. EDT
- 4** The Moon passes 5° south of Mars, 7 A.M. EDT
- 5** The Moon passes 4° south of Mercury, 5 A.M. EDT
- 6** New Moon occurs at 5:51 P.M. EDT
- 9** The Moon passes 5° south of Venus, 10 P.M. EDT
- 12** The Moon passes 0.6° north of Spica, 5 A.M. EDT
- 13** The Moon passes 3° south of Saturn, 4 A.M. EDT
- 14** First Quarter Moon occurs at 6:56 A.M. EDT
- 16** Asteroid Iris is at opposition, 1 P.M. EDT
- 17** Asteroid Ceres is in conjunction with the Sun, 9 P.M. EDT
- 18** The Moon is at perigee (225,100 miles from Earth), 9:26 P.M. EDT
- 19** Mars passes 6° south of Pollux, 8 A.M. EDT
- 20** Full Moon occurs at 9:45 P.M. EDT
- 21** The Moon passes 6° north of Neptune, 11 A.M. EDT
- 24** The Moon passes 3° north of Uranus, 3 A.M. EDT
- 26** Neptune is at opposition, 10 P.M. EDT
- 28** Last Quarter Moon occurs at 5:35 A.M. EDT
- 30** The Moon is at apogee (251,581 miles from Earth), 7:46 P.M. EDT
- 31** The Moon passes 4° south of Jupiter, 1 P.M. EDT

SPECIAL OBSERVING DATE

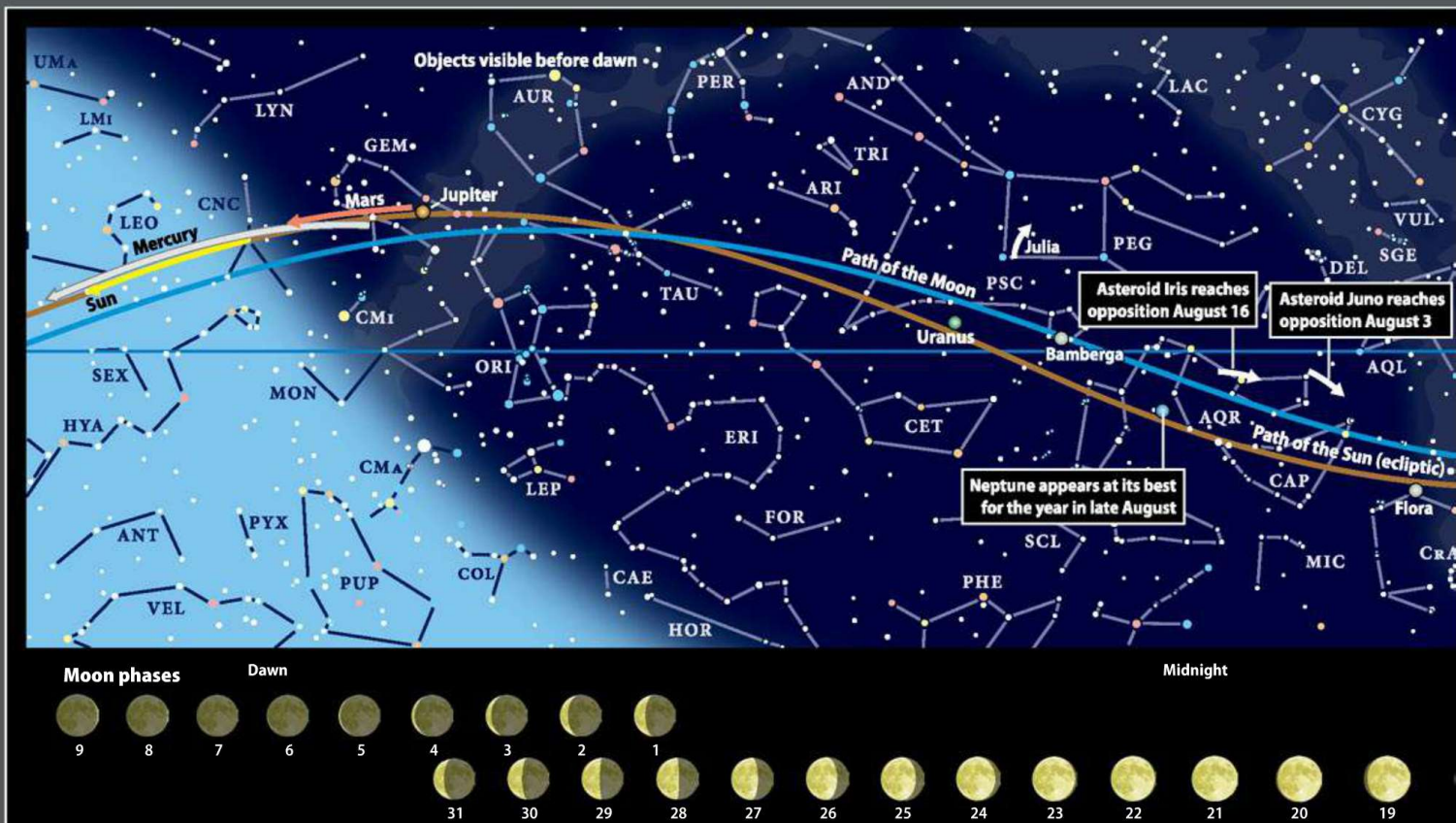
- 12** The Perseid meteor shower appears best under Moon-free skies before dawn today and tomorrow.

See tonight's sky in Astronomy.com's

STARDOME

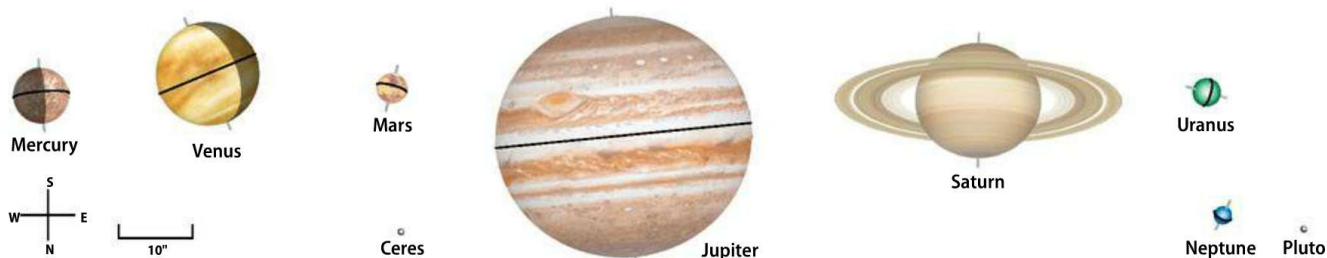


BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT www.Astronomy.com/starchart.



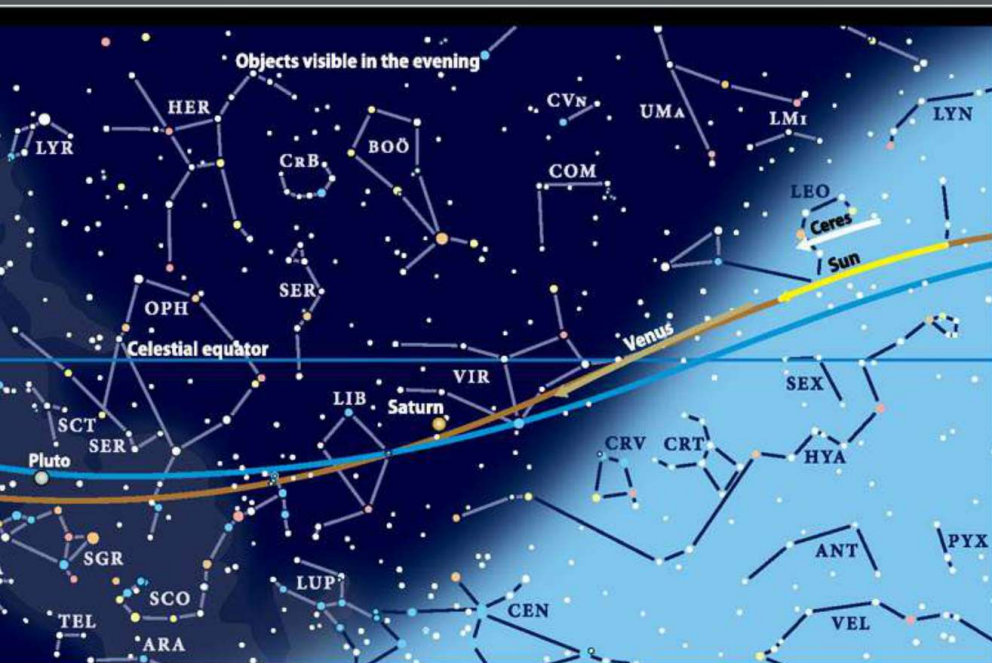
The planets in the sky

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



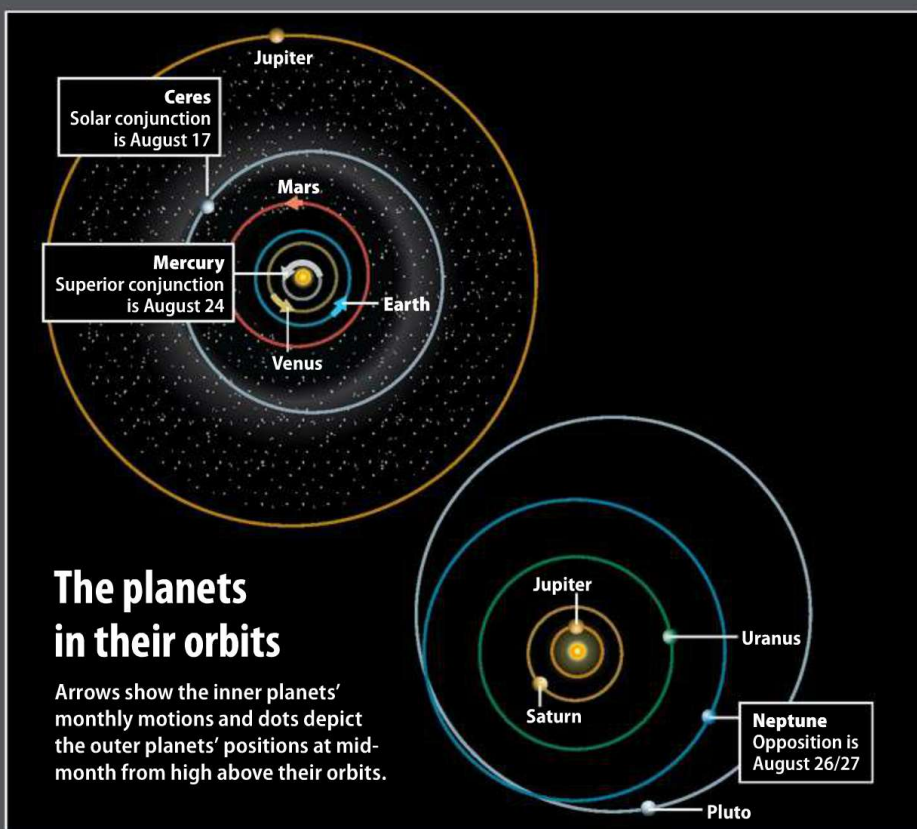
Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Aug. 1	Aug. 15	Aug. 15	Aug. 15	Aug. 15	Aug. 15	Aug. 15	Aug. 15	Aug. 15
Magnitude	-0.1	-3.9	1.6	8.4	-2.0	0.7	5.8	7.8	14.1
Angular size	7.3"	13.4"	4.0"	0.4"	33.7"	16.5"	3.6"	2.4"	0.1"
Illumination	44%	79%	97%	100%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.917	1.241	2.357	3.561	5.856	10.086	19.376	28.992	31.744
Distance (AU) from Sun	0.341	0.724	1.575	2.559	5.141	9.849	20.044	29.984	32.490
Right ascension (2000.0)	7h22.6m	11h53.4m	7h32.9m	9h53.6m	6h46.3m	14h17.0m	0h45.3m	22h24.9m	18h38.8m
Declination (2000.0)	20°32'	1°36'	22°34'	20°04'	22°52'	-11°16'	4°05'	-10°39'	-20°00'

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.



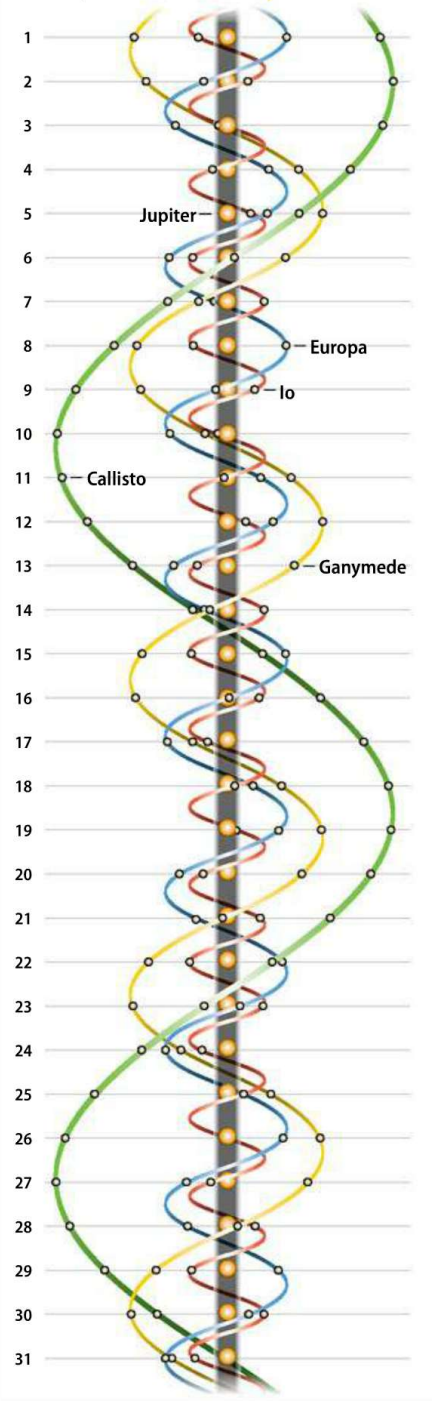
Early evening

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.



Jupiter's moons

Dots display positions of Galilean satellites at 5 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

WHEN TO VIEW THE PLANETS

EVENING SKY

Venus (west)
Saturn (southwest)
Neptune (east)

MIDNIGHT

Uranus (east)
Neptune (southeast)

MORNING SKY

Mercury (east)
Mars (east)
Jupiter (east)
Uranus (southwest)
Neptune (southwest)

shadow extended farthest from the planet and concealed the biggest part of the rings in late July, the view in early August is nearly as good. It gives the ringed world a striking 3-D appearance.

Saturn also boasts several moons visible through small telescopes. Eighth-magnitude Titan shows up even in late twilight. It stands north of the planet August 2 and 18 and south of the gas giant August 10 and 26.

Tethys, Dione, and Rhea all glow at 10th magnitude and lie closer to Saturn than Titan. A similarly bright moon, Iapetus, appears well west of the planet. It reaches greatest western elongation August 17, when it shows up clearly through small scopes because its brighter hemisphere then faces Earth.

Neptune lies opposite the Sun in our sky the night of August 26/27. Opposition marks the peak of an outer



Neptune's distinctive blue-gray hue appears most conspicuous in late August, when the planet reaches opposition in Aquarius. *ASTRONOMY: ROEN KELLY*

planet's observing season because it then shines brightest (magnitude 7.8), appears largest through a telescope (2.4" across), and remains on view all night. For a distant world like Neptune, however,

the view doesn't deteriorate much even a couple of months on either side of opposition.

Neptune lies in the sparsely populated constellation Aquarius. On August 1, the ice giant resides 1.1° due

COMETSEARCH

Hone your comet-viewing skills on M64

Comet ISON (C/2012 S1) has the potential to be one of the best — if not the best — comets during our lives. Even experienced amateur astronomers will be challenged to see every nuance ISON offers. An exceptionally bright comet typically has subtle features near its core and a gas tail that contains strands and kinks caused by the interaction between ionized molecules in the tail and the charged particles of the solar wind.

If you are new to the hobby, now is the time to train yourself to detect these features. Practice also should be the mantra for knowledgeable observers. Even the most experienced ones have trouble discerning delicate details after three months of cloudy skies or when their busy lives get in the way.

With ISON currently glowing at around 12th magnitude in morning twilight, however, the

comet isn't the best object for honing your skills. An ideal practice target lies in the early evening sky. The Blackeye Galaxy (M64) is a spiral with subtlety to spare. A newbie will need an 8- to 10-inch telescope to clearly see the dark patch that gives the galaxy its name; experienced observers should view with a 4- to 6-inch instrument to reawaken dormant skills.

Is the dark patch round? The eyepiece view should show you that it isn't. If ISON mimics comets Hyakutake (C/1996 B2) and Hale-Bopp (C/1995 O1), it will show a similar-looking shadow cast by the nucleus onto the surrounding ball of gas and dust called the coma.

Also, which edge of M64's dark patch looks more diffuse, and which one is sharper? Use a range of magnifications, up to the maximum that seeing conditions allow, to make these

Spiral galaxy M64 stands in for ISON

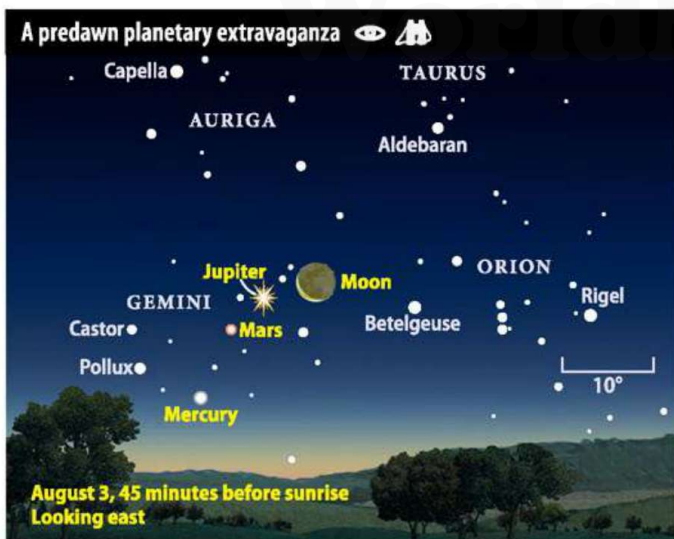


The Blackeye Galaxy (M64) in Coma Berenices is no comet, but it will help train your eye for viewing Comet ISON later this year.

small features easier to spot. Sketching the scene also helps train your eye to see detail.

For viewing features in Comet ISON's tail, observe the Veil Nebula in Cygnus. Although the bands of light in this supernova remnant appear brighter at low power, you will need higher magnifications and time at the eyepiece to pick out structure within the swaths of nebulosity.

To gauge how far Comet ISON's tail extends, practice on the emission nebula NGC 7822 in Cepheus. You'll need low power to trace the extent of this long, low-contrast stretch of interstellar gas. You'll get a better view by covering your head with a dark cloth to keep out any stray light. Keep at these techniques, and you'll be ready for ISON this autumn.



A waning crescent Moon passes Jupiter, Mars, and Mercury in early August amid the glittering stars we typically associate with winter. ASTRONOMY: ROEN KELLY

west of magnitude 4.8 Sigma (σ) Aquarii. The planet's westward motion relative to the starry background carries it 1.8° from the star by the 31st. You can see Neptune through binoculars if you hold them steady (or use a tripod); you'll need a telescope and moderate magnification to discern its blue-gray disk. The best time to look is when it's high in the south from around midnight to 4 A.M. local daylight time.

Neptune's sister planet, **Uranus**, trails about two hours behind its neighbor. Uranus shines at magnitude 5.8 and makes an easy target through binoculars among the dim background stars of southern Pisces. The planet lies 3.6° south of magnitude 4.4 Delta (δ) Piscium. A telescope reveals Uranus' $3.6''$ -diameter disk and blue-green color. For more details about observing Uranus, Neptune, and their moons from August through October, see "Prime time for Neptune and Uranus" on p. 80.

The remaining planets put on a show in the eastern sky before dawn. August 1 finds a waning crescent Moon among the background stars of the Hyades star cluster in Taurus. Trace a line from there to the lower left, and you'll see

Jupiter, Mars, and Mercury before reaching the horizon.

On August 3, the Moon lies 7° to Jupiter's right. The following morning, our satellite appears 5° to the lower right of Mars, and it passes 5° to Mercury's lower right the day after that (August 5). The Moon returns to Jupiter's vicinity August 31.

The brightest of the morning planets is **Jupiter**, which shines at magnitude -2.0 in mid-August. The giant world lies among the background stars of Gemini and climbs higher with each passing day. By the 31st, it rises around 2 A.M. local daylight time. The observing season for Jupiter is getting underway, and views of the planet through a telescope should be exquisite. In moments of steady seeing, subtle atmospheric features come into view on the world's $34''$ -diameter disk.

Mars appears only 5° from Jupiter in early August, but the gap grows to nearly 20° by month's end. The magnitude 1.6 Red Planet crosses from Gemini into Cancer during August's final week and ends the month 5° west of the Beehive star cluster (M44). A telescope shows little, if any,

LOCATING ASTEROIDS

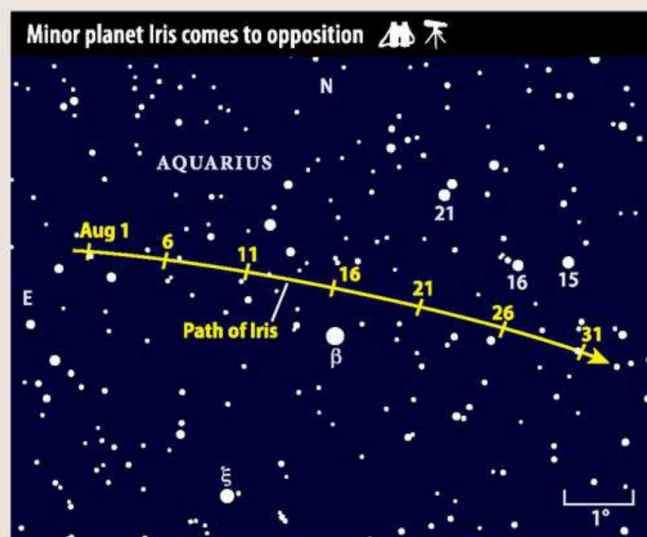
Seek the rainbow rock in watery Aquarius

The brightest asteroid to reach opposition in 2013 is not, as it usually is, one of the "Big Four" discovered in the 19th century's first decade. Instead, 7 Iris is this year's winner — it glows at magnitude 7.9 when it lies opposite the Sun in our sky August 16. Englishman John Hind discovered this asteroid in 1847 and named it after the Greek goddess of the rainbow.

Iris spends the month in western Aquarius, southwest of the prominent Great Square of Pegasus. This region lies one-third of the way from the southeastern horizon to the zenith in mid-evening and reaches its peak halfway up in the southern sky around 1 A.M. local daylight time.

Your best guide to finding Iris is the 3rd-magnitude star Beta (β) Aquarii. On August 16 and 17, Iris lies just $40''$ — a bit more than the Full Moon's diameter — north of Beta. There won't be anything else at that position rivaling the minor planet's 8th-magnitude glow.

The Full Moon passes through this area August 19 and 20, so try to catch Iris before then. The easiest way to find it is to match the stars in your telescope's field of view with those on the chart below. If a similarly bright background star makes it hard to identify the asteroid, make a quick sketch of the field and come back a night or two later. The dot that moved is Iris.



Asteroid 7 Iris reaches its peak in mid-August, when it glows at magnitude 7.9 near the much brighter star Beta (β) Aquarii. ASTRONOMY: ROEN KELLY

detail on Mars' disk, which measures just $4''$ across.

For northern observers, the period from late July to early August is one of the best to view **Mercury** this year. On August 1, the innermost planet stands 10° high in the east-northeast 30 minutes before the Sun rises. It shines at magnitude -0.1 and grows brighter

with each new morning. By the 9th, it reaches magnitude -1.0 and should be just as easy to spot despite appearing a couple of degrees lower in the twilight. When viewed through a telescope during this period, Mercury's disk shrinks from $7''$ to $6''$ while its phase waxes from 44 percent to nearly 75 percent lit. ☿



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

40 years of AMATEUR ASTRONOMY

We live in our hobby's golden age — just look at what's happened in the past four decades.

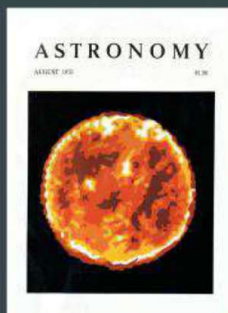
by Michael E. Bakich

Being an amateur astronomer is a lot of fun. We observe startlingly beautiful celestial objects, record once-in-a-lifetime events, and make lasting friendships with like-minded people along the way. But we also have watched technology march merrily along, and the benefits to our hobby from bright people with marketable ideas have been great.

Since *Astronomy* appeared in August 1973, average telescope size has increased, computerization has revolutionized our hobby, social interaction (live, not just online) has increased dramatically, and the Internet has become pervasive. As a trip down memory lane, I present the following list of highlights that have had a bearing on amateur astronomy from the past four decades. Your list may vary. If you think I've omitted something important, email me at mbakich@astronomy.com. If I agree, I'll apologize in a blog. ☺

Michael E. Bakich is a senior editor of *Astronomy* who has enjoyed all the advances in our hobby through more than 40 years.

1973



Astronomy magazine premieres with the August issue.



Doug Berger, president of the Astronomical Association of Northern California, conducts the first Astronomy Day, April 7. ASTRONOMICAL ASSOCIATION OF NORTHERN CALIFORNIA

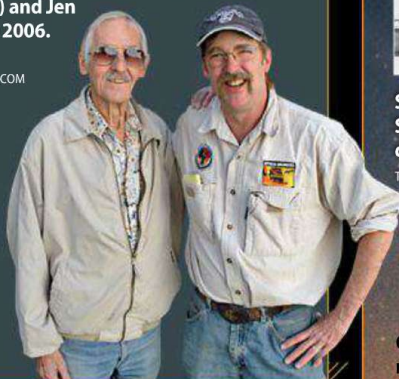
1975



Orion Telescopes & Binoculars begins operation in Watsonville, California. ORION TELESCOPES & BINOCULARS

In February, Del Woods (left) founds Day-Star Filters, the first company to offer high-quality Hydrogen-alpha filters to amateur astronomers. He sells the company to Vic (pictured) and Jen Winter in 2006.

JEN WINTER/
WWW.IJCSTARS.COM



1976



Stellafane, a meeting organized by the Springfield Telescope Makers in Vermont, celebrates its 50th anniversary. SPRINGFIELD TELESCOPE MAKERS, INC.

Comet West (C/1975 V1) reaches perihelion February 25. For a few days, observers can glimpse the magnitude -3 object in the daytime. ESO

1985



The Astronomical Society of Kansas City celebrates its 50th anniversary. ASTRONOMICAL SOCIETY OF KANSAS CITY

The first Winter Star Party occurs February 15–17 at the Mahogany Hammock site in Florida Everglades National Park.

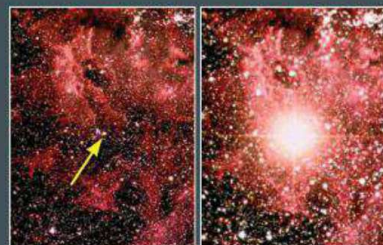
The first ad for a CCD digital camera — by the Eikonix Corporation of Bedford, Massachusetts — appears in the October issue of *Astronomy*. Electronic imaging by amateur astronomers begins.

1986



Halley's Comet reaches perihelion February 9. It won't be at its closest point to the Sun again until February 2061. RICHARD WAINSCOT

1987



Supernova 1987A blazes forth in the Large Magellanic Cloud, a satellite galaxy of the Milky Way that lies 163,000 light-years away. It is the closest supernova since 1604. ANGLO-AUSTRALIAN OBSERVATORY

1988



The International Dark-Sky Association — the only nonprofit organization fighting light pollution — incorporates. INTERNATIONAL DARK-SKY ASSOCIATION

1989



The Astronomical Society of the Pacific celebrates its 100th year of existence.

ASTRONOMICAL SOCIETY OF THE PACIFIC



Dave Kriege begins Obsession Telescopes in Lake Mills, Wisconsin. Since then, the company has sold more than 2,000 large Dobsonian-mounted reflectors. DAVE KRIEGE

1990

Adobe Systems releases *Photoshop 1.0*, an image-editing program. Its subsequent value to astrophotography is immense.



Adobe Photoshop™
Macintosh version 1.0.7

Thomas Knoll, John Knoll, Steve Guttman and Russell Brown

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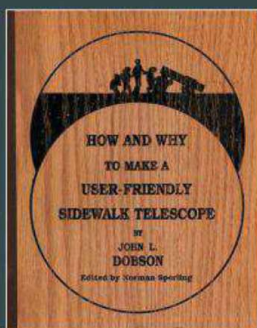
MacApp™ ©1985, 1986, 1987 Apple Computer, Inc.

Adobe Photoshop

OK

ADOBE SYSTEMS, INC.

1991



MICHAEL E. BAKICH LIBRARY

John Dobson publishes *How and Why to Make a User-Friendly Sidewalk Telescope*. The book (with a plywood binding) popularizes the Dobsonian mount.

The first Grand Canyon Star Party (GCSP) occurs at the South Rim. Starting in 1994, the GCSP also holds events at the North Rim.

1992

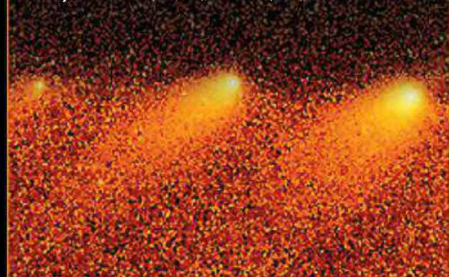
The Rockland Astronomy Club holds the first Northeast Astronomy Forum in Suffern, New York.

Meade Instruments introduces the LX200, the first commercially successful go-to system for amateur telescopes. MEADE INSTRUMENTS



1993

On March 24, astronomers Eugene and Caroline Shoemaker and David Levy discover Comet Shoemaker-Levy 9 (D/1993 F2). H. A. WEAVER (UHU/APL)/T. E. SMITH (STSCL)/NASA



1994

The 21 fragments of Comet Shoemaker-Levy 9 hit Jupiter in July. Crowds swarm astronomy club observing sessions to catch a glimpse of the impact scars.

NASA/ESA/H. WEAVER AND E. SMITH (STScI)

1996

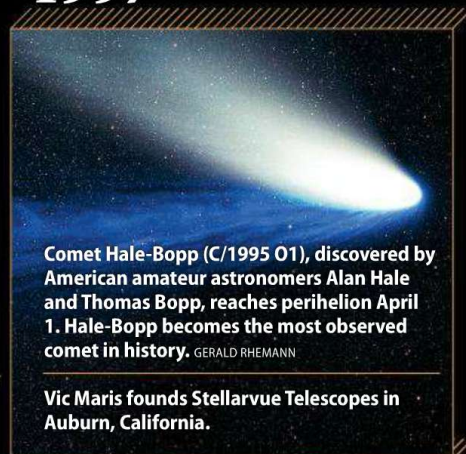
Japanese amateur astronomer Yuji Hyakutake discovers Comet Hyakutake (C/1996 B2) on January 31. It approaches to within 9.3 million miles (15 million kilometers) of Earth on March 25, with its tail stretching 100° across the sky. MICHAEL STECKER



1997

Comet Hale-Bopp (C/1995 O1), discovered by American amateur astronomers Alan Hale and Thomas Bopp, reaches perihelion April 1. Hale-Bopp becomes the most observed comet in history. GERALD RHEMANN

Vic Maris founds Stellarvue Telescopes in Auburn, California.



1995

Rick Singmaster begins Starmaster Portable Telescopes in Arcadia, Kansas.



▲ Sir Patrick Moore develops the Caldwell Catalog. He chooses 109 deep-sky objects — the same number as in the Messier catalog — in order of declination, north to south. ANTHONY AYIOMAMITIS

1998

The 60th anniversary of Orson Welles' *War of the Worlds* radio broadcast occurs October 30. NASA



1999

The Riverside Telescope Makers Conference celebrates its 30th birthday. The conference's current home is at Camp Oakes, a YMCA camp near Big Bear City, California.

2000

Kodak discontinues Technical Pan Film. The era of film astrophotography effectively ends a few years later when the company's film stock runs out.

2001



The Santa Barbara Instrument Group begins operation in Goleta, California.

SANTA BARBARA INSTRUMENT GROUP



Russ Lederman founds Denikmeier Optical to produce binocular products.

RUSS LEDERMAN



During the early morning hours of November 18, the Leonid meteor shower reaches storm levels. For a short period of time, some observers estimate counts of more than 1,000 meteors per hour. STEPHEN PITT

2002

Meade Instruments offers the first ultra-high transmission coatings (UHTC) for commercial telescopes. These coatings increase image brightness by approximately 15 percent.



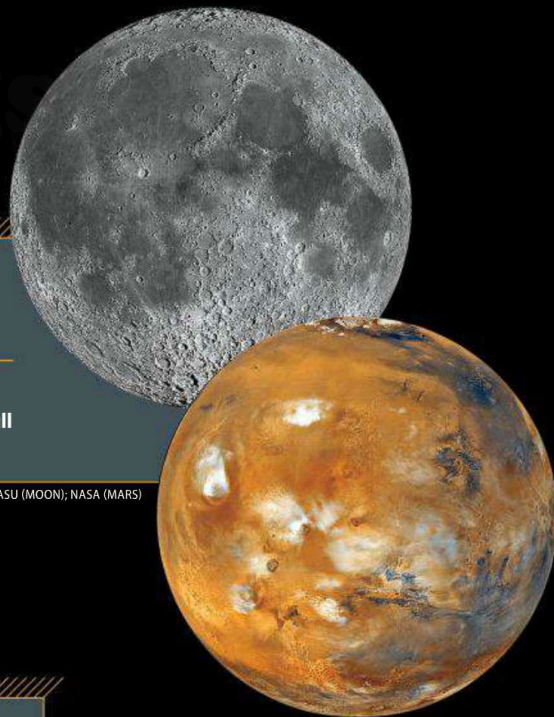
► David J. Eicher becomes editor of *Astronomy*. KALMBACH PUBLISHING CO.

2003

High school student Jennifer Barlow of Midlothian, Virginia, organizes the first National Dark Sky Week, April 1–8.

► According to a false Internet rumor, on August 28, Mars appeared as big as the Full Moon to the naked eye.

NASA/GSFC/ASU (MOON); NASA (MARS)



2004

On January 23, amateur astronomer Jay McNeil images M78 and, while processing it, discovers a reflection nebula now known as McNeil's Nebula.

GEMINI OBSERVATORY



The first meeting of the Advanced Imaging Conference occurs in Santa Clara, California.

Night Sky Network

"Astronomy clubs bringing the wonders of the universe to the public."

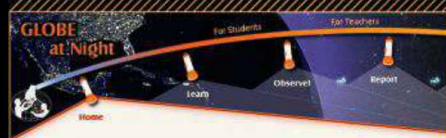


The Astronomical Society of the Pacific and NASA found the Night Sky Network, a nationwide coalition of astronomy clubs bringing the science, technology, and inspiration of NASA's missions to the public.

ASTRONOMICAL SOCIETY OF THE PACIFIC

The first transit of Venus since 1882 occurs June 8.

2005

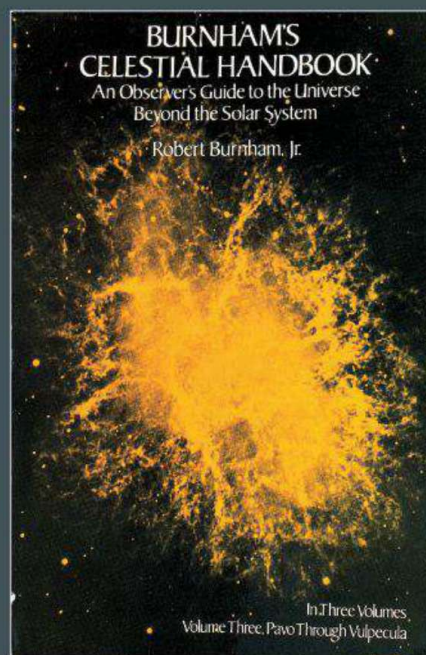
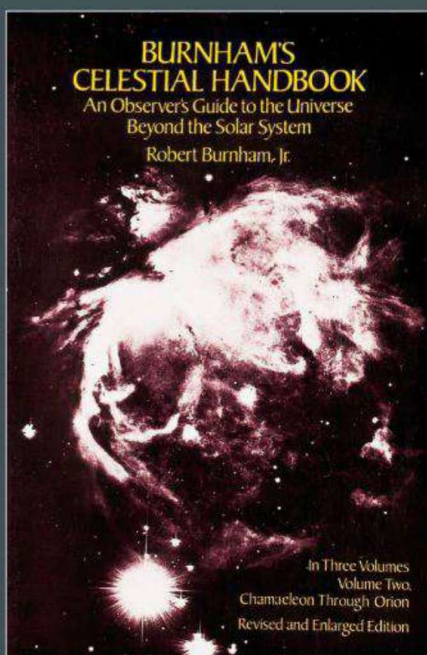
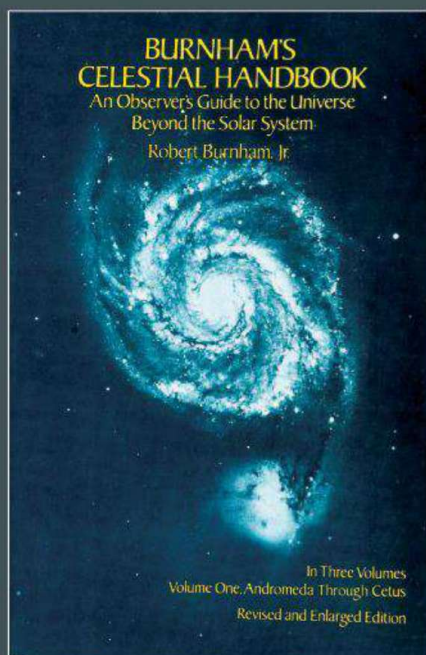


The Globe at Night program, an international citizen-science campaign to raise awareness about light pollution, begins.

GLOBE AT NIGHT

2006

The observing classic *Burnham's Celestial Handbook* by Robert Burnham Jr. celebrates its 40th birthday. MICHAEL E. BAKICH LIBRARY



2007



Tele Vue introduces the 13mm Ethos, an eyepiece with a 100° apparent field of view.

ASTRONOMY: WILLIAM ZUBACK



BBC PHOTO ARCHIVE

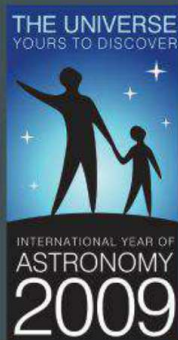
Sir Patrick Moore's *The Sky at Night* television program celebrates its 50th anniversary running on the BBC.

2008

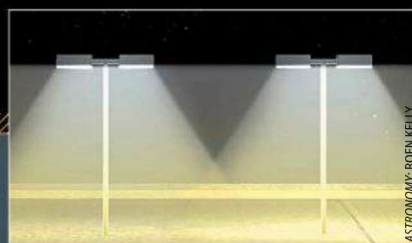


The first Pacific Astronomy & Telescope Show occurs September 13 and 14 in Pasadena, California. PACIFIC ASTRONOMY & TELESCOPE SHOW

2009



▶ The International Year of Astronomy celebrates the 400th anniversary of Italian astronomer Galileo Galilei pointing a telescope skyward. INTERNATIONAL YEAR OF ASTRONOMY 2009



ASTRONOMY: ROEN KELLY

The first full-cutoff light fixture, General Electric's M100, celebrates its 50th birthday. The fixture marked the first time manufacturers seriously addressed light pollution.

▶ The Vixen Co., Ltd., makers of Vixen optical products, celebrates its 60th anniversary.

2010



Celestron celebrates its 50th anniversary.

The first International Observe the Moon Night (InOMN) occurs September 10. In 2012, volunteers conduct 577 InOMN events in 49 countries.

2011

The American Meteor Society celebrates its 100th year of existence.

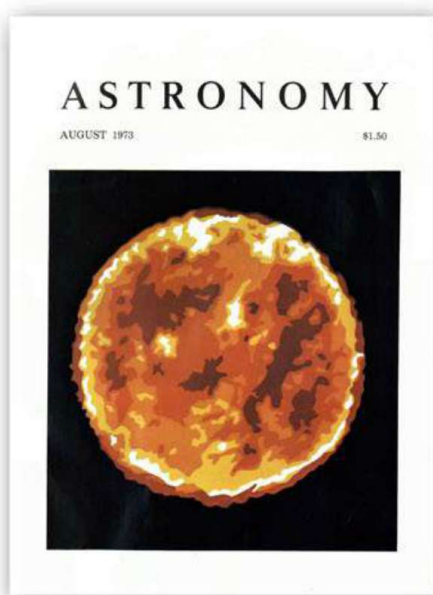
The American Association of Variable Star Observers also celebrates its 100th year of existence. AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS



2012

▶ The last transit of Venus until 2117 occurs June 5. PETE LAWRENCE

The Chicago Astronomical Society — the oldest astronomy club in the Western Hemisphere — celebrates 150 years of organized amateur astronomy.



August 1973: First issue

Astronomy magazine's path to "stardom"

From its modest beginnings, the publication now leads the astronomy hobby as the most popular magazine of its kind in the world.

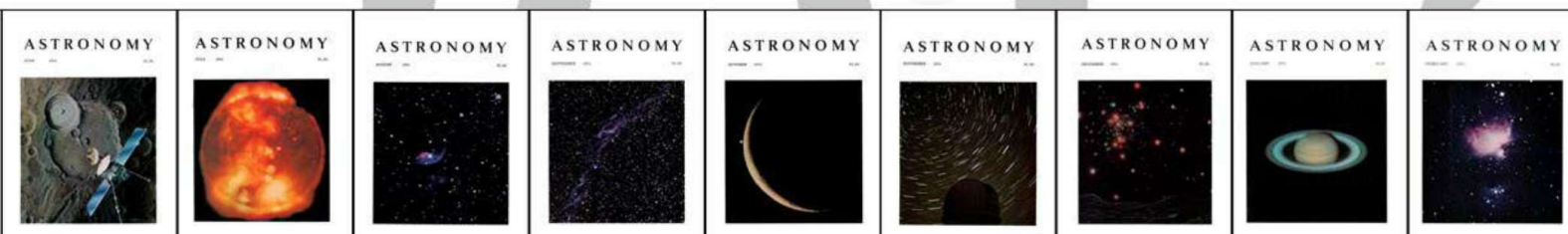
by David J. Eicher

Little did Steve Walther know that his brainchild would turn into the world's greatest magazine about astronomy. At 29, the graduate of the University of Wisconsin-Stevens Point launched a periodical about his first love: the stars. The enterprise took root in Milwaukee, Wisconsin, an unlikely place for a magazine about astronomy.

In 1973, Milwaukee was a city of just more than 700,000, a Germanic locale overshadowed by nearby Chicago and characterized — lampooned, in fact — by the four B's: beer, bikes (Harley-Davidsons, specifically), bratwurst, and bowling. The following year, the city would gain comic fame with the launching of the TV series *Happy Days*, which was followed by *Laverne and Shirley* in 1976. In 1973, though, it was a gritty, economically challenged manufacturing city that French fur traders had settled as early as 1818.

Born in 1944 in Stevens Point, Walther became interested in astronomy as a child and enjoyed photographing constellations with short exposures using a camera and tripod. By the time he was 14, he had an insatiable thirst for observing and astrophotography. Walther read *Sky & Telescope* as a young man and recommended it at star parties. But he dreamed of a magazine for astronomy enthusiasts of a different type, a wider audience who enjoyed gazing at the sky or reading about the latest cosmic discoveries without the tone of a serious scientific journal. The seeds of *Astronomy* magazine were sown.

In college, Walther majored in communications. Enrolling in an independent study course that allowed him to create and articulate a magazine project, he defined what would later become *Astronomy* magazine. The course provided the framework to think what, exactly, the magazine might



contain; Walther laid down a plan to reach lay readers interested in the science, entry-level hobbyists, amateur and arm-chair astronomers, and those who simply believed the night sky was beautiful.

Walther planned a magazine that was substantial in content but also illustrated like a coffee-table book. He wanted an open dialog with the readers so he could “converse” with them in a community. He wanted to emphasize the sheer joy and excitement of astronomy and highlight new wonders of the universe.

Walther’s desire to make the magazine a reality only increased after his college graduation. Although he worked in public relations, Walther and his brother David, a Milwaukee attorney, set up a corporation in 1972 — they called it AstroMedia Corp. — with the intention of publishing a magazine. And what should the magazine’s name be? There was only one obvious choice — *Astronomy*.

1973

By mid-1973, the Walthers were ready to launch their new enterprise. The first issue of *Astronomy* was published on a web press in Pewaukee, Wisconsin, on July 17, 1973. Its cover showed a multiwavelength image of the Sun, and it was 48 pages, containing five feature articles and plentiful information about what to see in that month’s sky. An observational highlight focused on hunting Comet Kohoutek (C/1973), which was then approaching. Alas, it turned out to be much fainter than many predictions.

David J. Eicher is editor of *Astronomy* magazine. He joined the magazine in 1982 as an assistant editor and has held every position on the editorial staff over his 31-year career. He began by founding *Deep Sky Monthly* magazine, which became *Deep Sky*, at age 15.

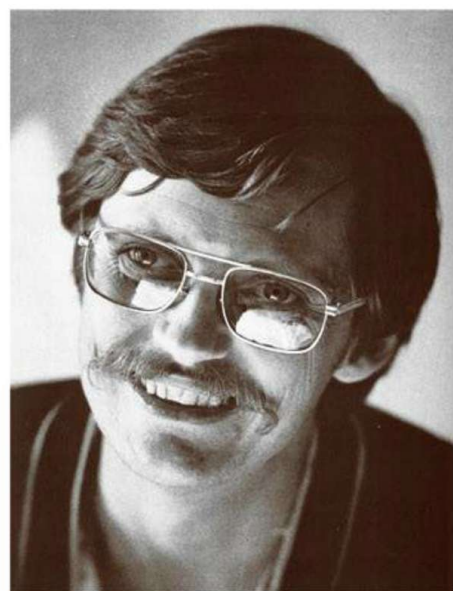
Contributors included Jay Pasachoff on solar eclipses, William Bruce Weaver on the search for “Planet X,” R. Newton Mayall on variable stars, and John Sanford on photographing the heavens. The first issue had a circulation of about 18,000.

In this original incarnation, the staff consisted of Steve Walther as the publisher and editor, Penny Oldenburger in the role of managing editor, Craig McFarland Brown as the art director, and a number of outside contributors. The magazine’s first office was a small suite at 757 North Broadway Street in downtown Milwaukee. The tiny staff would grow and change as the magazine exceeded even what Walther had dreamed of.

1974

Astronomy’s first full year was a time of growth for the magazine and for its publisher a chance to experiment. The issues mostly remained at 64 pages, the content a blend of astronomy, cosmology, planetary science, observing, imaging, and telescopes. By year-end, the magazine’s fledgling circulation reached 30,000 and ad pages grew, giving Walther the freedom to plan bigger things. The highlights included Fred Whipple writing about comets, an interview with black-hole theorist Kip Thorne, Carl Sagan on the martian “canals” and “lost pictures,” Ben Bova on pseudoscience, and Isaac Asimov on Alpha Centauri.

The magazine’s growing popularity allowed a larger staff. It added Canadian science writer Terence Dickinson as editor, with Walther morphing to editorial director. The magazine’s catchy tag line, “The World’s Most Beautiful Astronomy Magazine,” played prominently on the table of contents, betrayed the growing presence of artwork in a day when close-up views of article subjects simply did not yet exist,



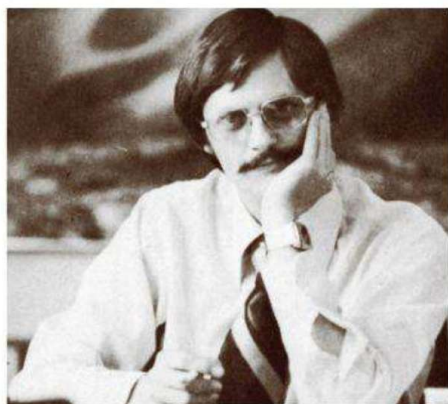
KALMBACH PUBLISHING CO.

A Wisconsin native, Steve Walther founded *Astronomy* magazine in 1973 as an outgrowth of a college journalism project at the University of Wisconsin-Stevens Point. Seven years later, it had become the largest-circulation magazine on the topic in the world and has remained so since.

either from space probes or the Hubble Space Telescope. Vic Costanzo and others regularly contributed artwork, and major names that would transform astronomical art — Don Dixon, Mark Paternostro, Adolf Schaller, and Rick Sternbach — were starting to appear. The fabulous scenes — “man’s dreams of worlds unseen,” as Walther used to say — became a hallmark of the magazine.

1975

In 1975, Walther increased the magazine to 80 pages, and its circulation grew to more than 40,000. Feature stories appeared from a constellation of stars in the world of astronomy. They included George O. Abell



Editor and Publisher Steve Walther in his office in May 1976, when the magazine was on a solid footing and making a big splash in the astronomy world. That year, *Astronomy* moved to a new office to accommodate a growing staff. KALMBACH PUBLISHING CO.

on nearby galaxies, William K. Hartmann on Saturn, Sagan on Saturn's moon Titan, James Oberg on the Apollo-Soyuz mission, Donald Goldsmith on understanding quasars, and Michael Zeilik on the Big Bang and galaxy formation. Frances Weaver became the magazine's managing editor, and Ray Villard briefly joined the staff as an assistant editor — he would go on to be press officer for the Hubble Space Telescope. The magazine now had the space to deliver articles on a wider range of subjects — observing, constellations, deep-sky objects, astrophotography, equipment, planetary viewing, eclipses, comets, etc. *Astronomy* was becoming well-known; in April, Sagan discussed it as he talked astronomy with Johnny Carson on *The Tonight Show*.

1976

America's bicentennial anniversary was a year of change for the magazine. The content was sharpening, the editorial flow moving smoothly. The graphics were coming together, too, with professional-looking artwork gracing the pages along with ever-better photographs of sky objects. The magazine had hit its stride. Issues remained at 80 pages with the exception of a special edition published in July, focusing on the history of American astronomy. This 112-page issue was crammed with stories on everything from Native American sky lore to the history of astrophotography to a multifaceted chronology of American

astronomy written by astronomers Michael Mendillo, David DeVorkin, and Richard Berendzen. An observational event injected new life into the hobby of stargazing, too: the appearance in late 1975 and the spring of 1976 of the brilliant Comet West (C/1975 V1), which dazzled naked-eye viewers.

As a result, paid circulation approached 60,000 and the staff grew, necessitating a move to a suite at 411 East Mason Street in Milwaukee. New staff members included a production manager, David Schwartz, and Editorial Assistant Henry J. Phillips, who would become a prolific writer. Significantly, Richard Berry joined the staff as technical editor; he would play an enormous role in the magazine's future. A native of Stamford, Connecticut, Berry received his master's degree in astronomy from York University in Toronto, where he investigated post-eclipse brightening of Jupiter's moon Io using photoelectric photometry.

Yet the magazine operated under a dark cloud after a terrible incident mid-year. In August 1976, Walther was riding high and celebrating the success of his brainchild. With the magazine catching on rapidly, he threw a party for contributing authors, photographers, and sponsors. Beside a pool, surrounded by drinks and hors d'oeuvres, talking his best game with his closest friends, Walther collapsed. He was diagnosed with a brain tumor and immediately underwent surgery and the long struggle to return to normal. He spent little time at the office ever again, however, mostly working at home on marketing ideas and future plans. At this point, Robert Maas joined the company as president of AstroMedia Corp., and his guidance was crucial in keeping the business on track.

1977

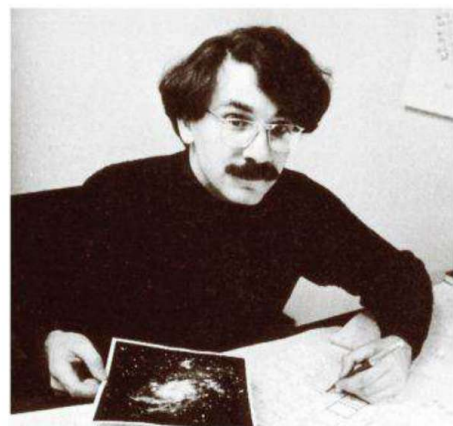
As Berry described in a note in the November 1977 issue, Walther maintained his zany sense of humor throughout his illness. He would often answer his phone, "Sleepy Hollow, Steve speaking; may I help you?" When informed that his tumor contained a type of cell called an astrocytoma, he joked that he had his own *Star Wars* going on inside his head. His condition deteriorated in July 1977. On the morning of the 27th, unable to walk, he insisted on being wheeled into the office. When the remaining staff arrived, they discovered

the following note on the front door: "Hey there, gang — I was here before any of you. Does this mean that I've been the only puff of ectoplasmic 'spook' to haunt the hall-lowed — EMPTY! — halls of *Astronomy* at 5:30 A.M.? Are you sure that the ephemeris doesn't lie? Is Venus really the brightest starlike object in the eastern a.m. sky!? Boooo!" A few weeks later, on September 14, 1977, Walther died at age 33.

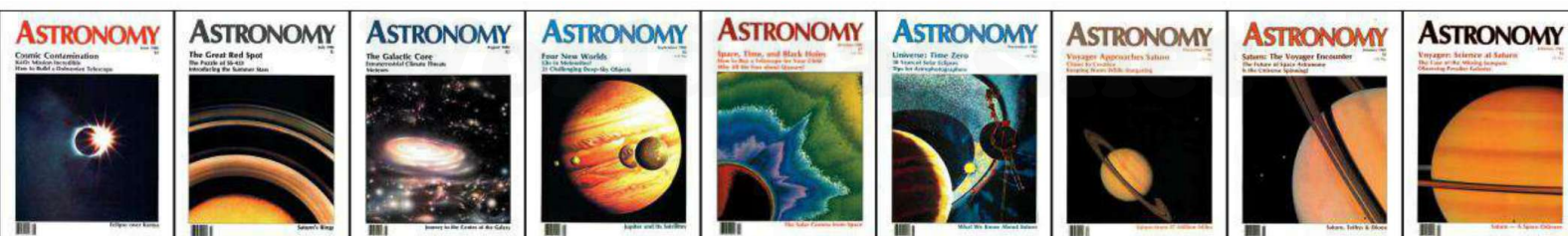
With the founder gone, Maas took control of the magazine's financial aspects, and Berry became editor. Over the next 15 years, Berry's leadership would be paramount in building the title into the largest-circulation magazine of its kind in the world. Oldenburger, the managing editor, gradually moved out of the central focus before leaving in 1979. The magazine rolled on, with major topics in 1977 including Hartmann describing results from the Viking landers, Barry Parker outlining about life evolving in elliptical galaxies, Tom Schroeder describing a hypothetical interstellar cruise to Alpha Centauri, and Oberg writing about the cometary explosion at Tunguska.

1978

By the late 1970s, the hobby of amateur astronomy had reached maturity. Numerous choices were cropping up among ready-to-buy telescope brands. Telescope making, the art of crafting your own scope after usually grinding your own mirror, was taking off as a way to obtain a large telescope



Richard Berry became the magazine's editor following Steve Walther's death and began an important 15-year tenure of overseeing *Astronomy*'s growth into the world's leading title on the subject.



inexpensively. An information avalanche was just beginning about what you could see in the sky — people were discovering that objects traditionally considered beyond the limits of backyard scopes were, in fact, observable. By decade's end, the magazine would have a circulation just shy of 100,000 and feature a full array of stories about the hobby and the science of astronomy, aggressively covering news-related events as well as background features.

The magazine's continued growth, and another tragedy, called for further staff changes. Phillips, the comical (now) associate editor who had done much of the staff writing since the end of 1975, died after a lengthy illness in May 1978, five days short of his 26th birthday. To rebuild the staff, Berry hired two new associate editors, Robert Burnham and Dewey Schwartzburg. Burnham also would play a huge role at the magazine over several eras. He was a librarian before coming to the magazine and an expert photographer, experienced observer, book collector with his own 750-pound printing press, and science enthusiast. Schwartzburg was an Episcopal priest who also had a degree in astrophysics from Harvard and had been a founding member of the Shreveport Astronomical Society in Louisiana.

As if this weren't enough drama in the tumultuous year of 1978, Berry and Maas had big plans to spread the interest of astronomy to younger children and to cultivate the growing interest in home-built telescopes. In the fall of 1978, AstroMedia Corp. began publishing *Telescope Making* magazine, a quarterly printed in black and white with Berry as editor. The first issue sported a mere 16 pages and featured stories about optical designs, telescope mountings, and mirror-making, with simple photos and diagrams. It was an immediate hit with the telescope-making movement, which was rising thanks to the efforts of John Dobson of the San Francisco Sidewalk Astronomers. Dobson and others encouraged people to make their own large telescopes by grinding cheap mirrors and mounting them in simple two-axis "gun mounts" that later came to be known as Dobsonian reflectors.

In January 1979, AstroMedia also began publishing a monthly magazine for young astronomy enthusiasts called *Odyssey*.

Designed for children ages 8 and older, *Odyssey* featured articles about astronomy and space exploration, included a trademark robot character named Ulysses 4-11, and was edited by veteran newspaper journalist Nancy Mack. The operation set up shop adjacent to the *Astronomy* staff, and the whole thing operated like one big family astronomy club.

1979

In 1979, the hobby of amateur astronomy was gaining momentum by leaps and bounds. On the backside of the Apollo program and with the popularity of movies like *Star Wars*, interest in space and astronomy was riding high. That seemed to coincide with the baby boomers' discovery of the universe around them and with the growing interest in making large telescopes. The space shuttle was looming in the near future; astronomical discoveries were coming thick and fast. A total eclipse of the Sun darkened the northwestern part of the United States. The Voyager 1 and 2 probes were set to make their first large steps in a "grand tour" of the solar system.

The magazine sported extensive features about the Voyager mission, some stretching to 22 pages. To keep operations smooth, Katherine King came on as an editorial administrator. Within several years, she would marry the well-known astronomical artist Bruce Bond and, as Katherine Bond, rise to managing editor of the title.

1980

The next decade would be an enormous one for the hobby, the science, and *Astronomy* magazine. The run-up to the appearance of Halley's Comet in 1985–86 would stoke a phenomenal fire in the belly of amateur astronomy, even if better comets had appeared and would also come later. The comet's fame meant instant recognition from the general public and intense curiosity about its appearance this time around. But Halley would not arrive until mid-decade; years of growth for the magazine would come first.

An important personnel change occurred on the cusp of the 1980s when Thomas L. Hunt joined the staff as art director. Hunt was a graphic artist and designer who had graduated from the University of Wisconsin-Milwaukee and had



Robert Burnham was another major influence in the magazine's history. A friend of Richard Berry's who joined the staff as an associate editor in 1978, he would serve as the engine driving much of the magazine's content, as well as editor-in-chief following Berry's tenure.

previous experience with Reiman Associates in Milwaukee. He was also an active amateur astronomer and exhibited enthusiasm for transforming the look of the magazine, giving it a more modernized appeal. The magazine grew slightly to 86 pages (occasionally as many as 114), featured new typography, and included new design ideas for display type, article openers, and departmental layouts.

By this time, *Astronomy* magazine had grown to a circulation of 122,000, surpassing the long-established *Sky & Telescope* to become the largest-circulation magazine of its kind in the world. *Astronomy* has never relinquished this position.

1981

Astronomy's growth required relocating the magazine again to larger office facilities. Maas, Berry, and AstroMedia Corp. chose a 20-year-old stone building at 625 East St. Paul Avenue, near Milwaukee's lakefront, as its new corporate headquarters. The building had previously served as a bar and nightclub that had featured, among



ROBERT BURNHAM

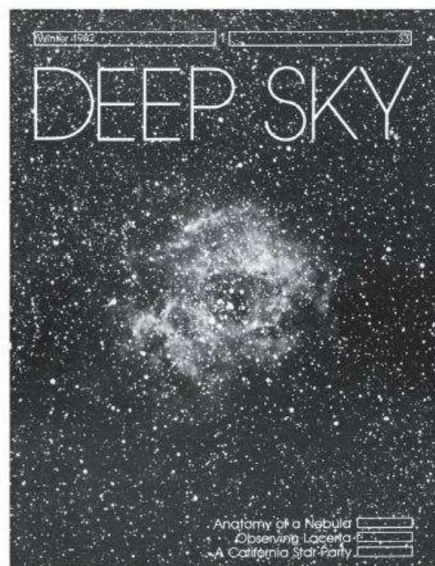
Thomas Hunt joined the magazine's staff in 1980 as art director and supervised the design and illustration for nearly 17 years. He poses here with Katherine Bond, nee King, managing editor, who had married astronomical artist Bruce Bond.

other things, mud-wrestling matches. The 10,000-square-foot facility stood immediately west of the city's famous Summerfest grounds — site of the world's largest annual music festival — such that during the summertime, AstroMedia staff could work away as they heard rehearsals and sound checks for numerous bands. The building's facilities contained, for the first time, plenty of space for the staffs of *Astronomy*, *Odyssey*, and *Telescope Making*.

1982

In 1982, the magazine continued its hefty coverage, ranging from 88 to 112 pages. Editor Berry continued a wide-ranging approach, covering many science and hobby topics. In his "Behind the Scenes" editorial column, he frequently commented on the dwindling funding for planetary science in the NASA budget. In the middle of the year, the magazine's newsstand distribution grew considerably because of an arrangement with a new wholesaler. The now-celebrated "white border" around an astronomical image on each cover, which had been inspired by *Scientific American's* look, helped it stand out.

In September 1982, more staff changes took place, including two new assistant editors. The first was Francis Reddy, who would be a force as a writer and editor during the 1980s and who would leave and then return after a 19-year absence. The



By 1982, *Deep Sky* was six years old.

second was David J. Eicher, who would play a major role in the history of the magazine and become its longest-duration employee.

Eicher was a 21-year-old native of Oxford, Ohio, and had attended Miami University there. He had written for the magazine occasionally and was well-known in the amateur astronomy community for founding *Deep Sky Monthly*, a publication for deep-sky observers and imagers, at age 15 while a high-school student. This amateur journal had a circulation of 1,000 by the time Eicher joined the *Astronomy* staff. With the guidance of Berry, Burnham, and Maas, AstroMedia reformulated the publication into a quarterly, which would be retitled *Deep Sky*, with Eicher continuing as editor. Within several years, *Deep Sky* became the leading voice of observers and imagers and grew to a circulation of 15,000.

1983

The magazine cruised right along through this year, anticipating the big return of Comet Halley and covering a wide range of astronomical topics. In 1983, the magazine's 10th year of publication, issues were generally 88 pages. Big science topics included Reddy on galaxy formation, the cosmic distance scale, and aurorae; Hartmann on the asteroid Vesta; Stephen Edberg on the Halley Watch program; Van R. Kane and Charles E. Kohlhase on Voyager's journey to Uranus; David Darling

on black holes; David Morrison on future solar system exploration; Jesse Eichenlaub on the probes dispatched to study Halley; and Michael Carroll on a proposed mission to Saturn.

1984

The magazine maintained its momentum in 1984. The hobby continued at full speed, with telescope creation taking enormous strides in equipment, design, and technique, all shown frequently at amateur meetings and written about in *Telescope Making*. The information explosion continued at full swing, with *Deep Sky* describing objects no one had thought of going after a few years before. While guidebooks from the 1960s suggested that targets like the Veil Nebula were beyond the capability of amateur astronomers, now observers, better-informed and with larger scopes, were viewing obscure objects like Maffei 1 and the Hercules cluster of galaxies.

1985

By the middle of the decade, Halley mania was beginning to take hold. At the magazine, two significant staff changes took place. Reddy, the productive assistant editor, left, though he would return. Bond also left as managing editor to manage her husband's art business, and Stephen Cole was hired as her replacement.

There was big news from the corporate standpoint, too. Early in the year, Kalmbach Publishing Co., a Milwaukee-based hobby publisher whose stable included *Model Railroader*, *Trains*, and *FineScale Modeler*, bought AstroMedia Corp. It was a psychological shake-up; Berry, in his March 1985 editorial, admitted the move "came as something of a surprise to us." AstroMedia had been something of a loosely run company, very productive and outstanding with deadlines and work ethic, but also psychologically laid back and un-corporate. If, for example, an employee needed to observe late at night for a story and drag himself in at 11 A.M. the next day, it was no big deal. And AstroMedia's little group of employees numbered about 40, giving the whole enterprise a family-style, astronomy-club atmosphere. With a company that produced multiple magazines and had more than 200 employees about to acquire AstroMedia, it felt like being taken over by IBM.



1986

Comet Halley continued to be visible in 1986, reaching its peak brightness in the spring and plunging southward. Feature stories highlighted the fate of the universe by Darling; astronomy and astrology by George Reed; the strange star Epsilon Aurigae by Jeffrey L. Hopkins and Robert Stencil; Voyager's continued mission by Kohlhasse; Uranus and Voyager by Berry; Giotto's encounter with Comet Halley by Berry; scientific observations of Halley by Cole and Richard Talcott; Pluto's enigmatic status by Ken Crowell; space science after the *Challenger* explosion by Donald F. Robertson; Earth satellite imagery by Andrew Maslowski; what scientists learned from Comet Halley by Berry and Talcott; the latest on black holes by Parker; the second-generation Palomar Sky Survey by Tom Wilson; Voyager's course for Neptune by Kohlhasse; the story of Mount Wilson Observatory by Joseph M. Horodyski; and a discussion of how the Sun rotates by James Charles LoPresto.

Staff changes were on the docket for 1986, too. Burnham, now the magazine's first senior editor, was growing restless and loved the American Southwest; he left the magazine in 1986, remained an active contributing editor, and would return by 1988. To right the ship, Maas and Berry hired two more assistant editors, Jeff Kanipe and Talcott. Kanipe was a native of Austin, Texas, a longtime astronomy enthusiast, and a freelance writer. He had contributed



Assistant Editor David J. Eicher is interviewed on television during 1984 at *Astronomy's* offices in Milwaukee. The editors of the magazine remain popular radio and television sources for scientific discoveries and upcoming celestial events to this day. ROBERT BURNHAM

to the McDonald Observatory's news features and also to its *StarDate* radio program. He would play an important role in the magazine's upcoming decade. The second hire, Talcott, was a native of Stamford, Connecticut, who, before coming to the magazine, was an astronomy teacher at Marietta College in Ohio and whose background included mathematics and computer programming. He would be a significant force at the magazine for years into the future, becoming one of its most devoted employees.

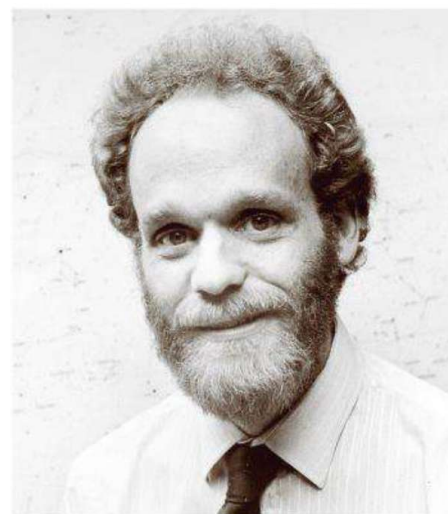
By the spring of 1986, AstroMedia employees had moved to their new home at Kalmbach's corporate headquarters, 1027 North 7th Street in Milwaukee, a relocation spanning all of 1.5 miles. Buoyed by interest in Halley's Comet, the magazine's circulation was now 174,000.

1987

The biggest bolt from the blue in 1987 came from the Southern Hemisphere, where astronomers discovered a supernova in the Large Magellanic Cloud. Designated Supernova 1987A, it was the brightest stellar explosion observed in several hundred years, and it provided an observational bonanza for astrophysics.

1988

The next year brought a continuation of many things — the staff was largely intact,



Richard Talcott joined the staff in 1986 as an assistant editor and has played a significant role in the magazine's history ever since, rising to senior editor and being centrally involved with many important aspects of the title. KALMBACH PUBLISHING CO.

the articles covered a wide spectrum, and the routine was fairly consistent. Kanipe was promoted to be the magazine's fourth associate editor. Burnham returned from the Southwest to be a senior editor. In July 1988, the magazine underwent a redesign, unwrapping a teal-blue color scheme.

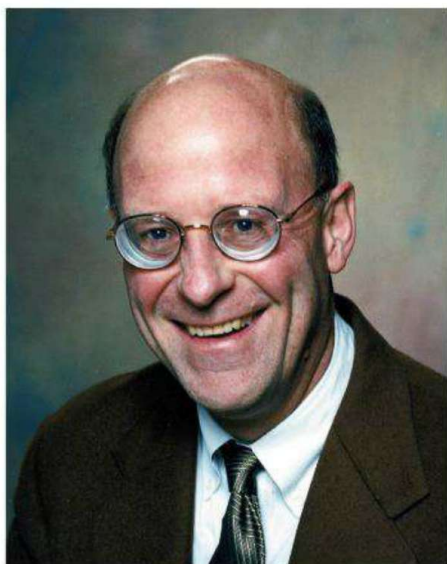
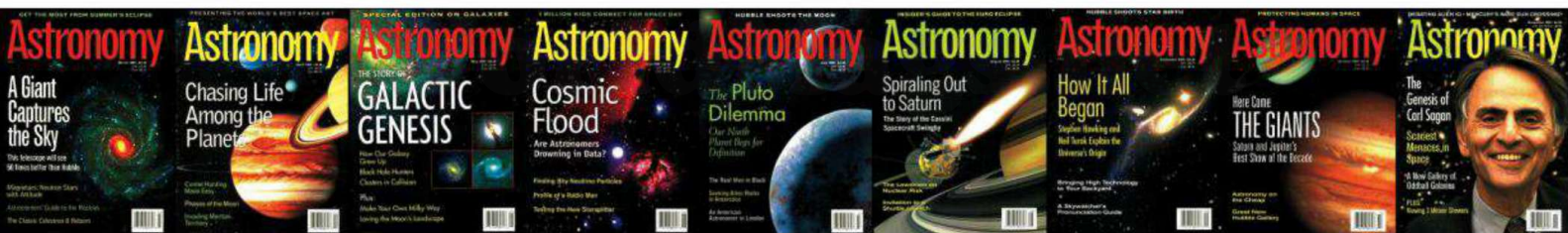
1989

This was the year the shuttle program reignited, three years after the *Challenger* accident. In the summertime, Voyager 2 encountered the planet Neptune. In the middle of the year, *Astronomy* began producing an insert called *Astronomy Educator*, edited by Cole, that addressed classroom issues. The July 1989 issue offered a special package on the 20th anniversary of the Apollo 11 lunar landing.

The largest development of the year was the biggest and last move for the magazine. In July, Kalmbach moved its corporate headquarters from downtown Milwaukee some 14.5 miles west of the city into the bedroom community of Waukesha. The new 81,000-square-foot facility (which would be further expanded) stood in an office park near the intersection of Interstate 94 and Moreland Blvd., at 21027 Crossroads Circle. This location continues as Kalmbach's headquarters today.



Assistant Editor Francis Reddy prepares to view the May 30, 1984, partial eclipse outside the AstroMedia building in downtown Milwaukee, Wisconsin. ROBERT BURNHAM



The magazine's fourth publisher, James Slocum, a veteran officer at Kalmbach Publishing Co., took over the publishing direction for *Astronomy* magazine in 2000. KALMBACH PUBLISHING CO.

1990

The new decade started out with great stability for *Astronomy* magazine. The hobby was pushing forward, with many new people still dabbling in it and becoming freshly made backyard astronomers. Because of this, telescopes were selling and advertising holding its own; circulation was steady at about 160,000. Staff changes did occur, though, as when Cole departed for a career with the American Geophysical Union. Needing a new managing editor, Kalmbach found Rhoda I. Sherwood, a journalist and manager from the Milwaukee area. That spring, Alan Dyer joined the magazine as its fifth associate editor; he would be an important contributor, with telescopes, astrophotography, and astronomy outreach as some of his many strengths, for the next three years. Eicher was promoted to be the magazine's sixth associate editor.

During this period, the International Astronomical Union (IAU) honored three *Astronomy* editors with named minor planets. The IAU designated asteroid 3617 Eicher in honor of David J. Eicher, for the work he did with *Deep Sky*, and for his two books on viewing deep-sky objects. Similarly, the IAU named asteroid 3684 Berry for Richard Berry, for his promotion of amateur astronomy through *Astronomy*,

Telescope Making, and books. Lastly, 4153 Roburnham was named for Robert Burnham, then senior editor of *Astronomy*, for his popularization of the hobby and for his various astronomy-related books.

1991

A total eclipse occurred in Baja Mexico and Hawaii on July 11 and attracted thousands of travelers. Berry, Dyer, Eicher, and Talcott all traveled there to cover it for the magazine. Meanwhile, the Cosmic Background Explorer (COBE) satellite data provided convincing proof of the Big Bang theory of the origin of the universe, and David Bruning arrived as another associate editor.

1992

This year was a pivotal one in the history of *Astronomy*. After 16 years at the magazine, nearly all of which he spent as the magazine's editor-in-chief, Berry departed to pursue freelance and writing projects. "Astronomy was a tiny magazine" when he joined, Berry wrote in his editorial in the February 1992 issue. "The entire editorial staff worked together in a single office remodeled from an old beauty parlor. We typed our stories on terrible manual typewriters and pasted up pages with hot sticky wax. It was a tacky, primitive environment, and I loved it." With the magazine long having been the largest in the world on its subject, Berry moved on to new adventures. He had taken very good care of it, as he had promised the dying Walther he would.

With Berry departing, Kalmbach promoted Senior Editor Burnham, Berry's longtime top lieutenant and good friend, to be the fourth editor-in-chief. Burnham kept the title on an even keel, with a very similar approach to Berry's. But there was also a conundrum: What to do with the quarterlies, *Deep Sky* and *Telescope Making*? They ceased publication.

1993

Burnham continued to lead the magazine throughout 1993, *Astronomy*'s 20th anniversary. A special August issue featured a story by Eicher in which astronomers predicted breakthroughs that would happen in the coming 20 years. The astronomy world witnessed an ambitious space walk that repaired the Hubble Space Telescope's optics, unleashing its power and allowing

its data and images to revolutionize our understanding of the cosmos.

1994

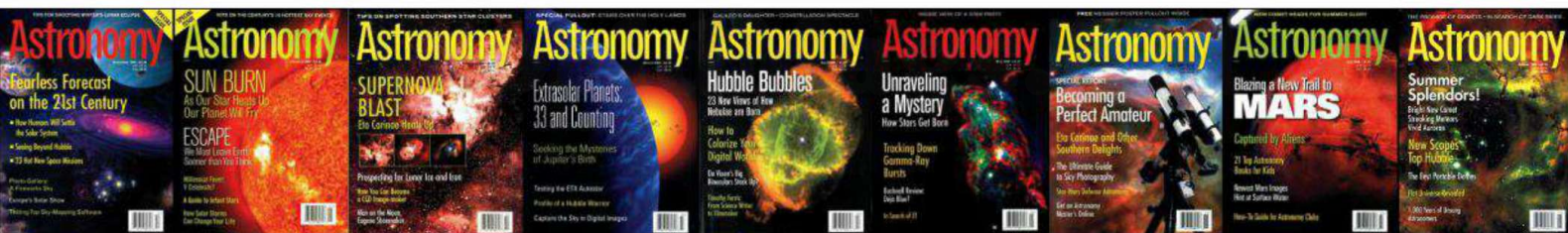
The biggest changes to the *Astronomy* staff in 1994 came when Maas, the man who had righted the financial ship for AstroMedia Corp. and continued on as publisher at Kalmbach, left to pursue other opportunities. The magazine's third publisher, replacing Maas, was Russell G. Larson, the longtime editor and publisher of Kalmbach's flagship title, *Model Railroader*.

Astronomy celebrated the Apollo 11 Moon landing's 25th anniversary with a special July issue, including stories about the Moon voyagers by Andrew Chaikin; Clementine's lunar mapping by Bruning; and the ways Apollo changed our understanding of our satellite's geology by Graham Ryder.

Meanwhile, two big observational events occurred. First, an annular eclipse washed over the United States in May. To see the event, Eicher, Associate Editor John Shibley, and Talcott loaded into a car and drove to Springfield, Illinois, choosing Abraham Lincoln's Tomb as their observation spot (and betraying Eicher's interest in Civil War history). Then, in July, the many fragments of Comet Shoemaker-Levy 9, which had been co-discovered by *Astronomy* contributor David H. Levy, smashed into Jupiter in an event unique in the observed history of the solar system.

1995

The magazine rolled on as always, with great momentum and solid story plans that covered astronomy as well as ever. A big staff change occurred in the middle of the year when Sherwood, who had been managing editor for five years, left to work on other Kalmbach projects. *Astronomy* rehired Kanipe, who had left five years prior to edit *StarDate* magazine, as a replacement. The title also hired another associate editor — Robert Naeye, a young science writer who had worked as a researcher at *Discover* magazine and became *Astronomy*'s ninth associate editor. He would stay on board for five years before leaving to be editor of *Mercury* magazine, published by the Astronomical Society of the Pacific. Later still, he was hired as editor of *Sky & Telescope* magazine, *Astronomy*'s



competitor. And Talcott, who had been with the magazine since 1986, was promoted to associate editor in this year, becoming the 10th person with this title.

1996

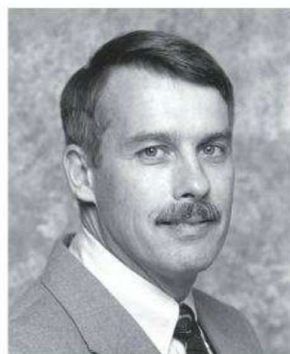
The following year was a huge one for the astronomy world and a pivotal one for *Astronomy* magazine. The discovery of extrasolar planets gained momentum. In March, a recently discovered comet, Comet Hyakutake (C/1996 B2), thrilled observers with a spectacularly bright appearance in the Northern Hemisphere, displaying a magnificent tail that stretched as long as 100° across the sky. Moreover, a second comet, Hale-Bopp, was discovered and would remain visible for some 15 months, brightening late in the year and especially in the spring of 1997.

With Comet Hyakutake dazzling people as it hung over their sky, the magazine's circulation surged to 171,000. And during this period of growth, the magazine experienced a staff shake-up: Burnham left as editor mid-year, ending his aggregate 16 years on the editorial staff. In addition, Art Director Hunt moved on after 17 years, and Kanipe departed as managing editor, ending his total of six years spent in various positions.

Sensing that the hobby was rapidly growing, Kalmbach took a new approach to *Astronomy*, believing it might break into a much wider, more mainstream audience. The company hired Bonnie Bilyeu Gordon, who had worked in New York on a variety of magazines including *Sea Frontiers*, *Self*, *Health*, and *Science*, as the magazine's fifth editor-in-chief. Gordon's first issue as editor was November 1996. Eicher, who had been with the title for 15 years, had a busy year. In the summer, he became the second senior editor in the magazine's history. That title lasted only six weeks, however, as he was quickly promoted to become the magazine's seventh managing editor. Kalmbach hired Carole Kramer (later Carole Ross), a Milwaukee designer whose experience included *Quality Progress* magazine and children's books, as art director and brought Patti Kurtz on as assistant editor.

1997

This year was the first full one of Gordon's editorship, and it brought changes in the magazine's staff, coverage, tone,



Kalmbach Publishing Co. veteran Dick McNally became *Astronomy*'s ninth managing editor in 2004. His previous experience included work at *FineScale Modeler*. KALMBACH PUBLISHING CO.



Editor-in-Chief David J. Eicher has spent more than half his life on the staff of *Astronomy* magazine, after founding and editing the popular magazine *Deep Sky* as a teenager.



Publisher Kevin P. Keefe is both a trains and a music expert, having spent years as editor of *Trains* magazine and as arts and entertainment editor of the *Milwaukee Sentinel*.

and design. The most significant outward changes appeared in the July issue, which was radically redesigned with new features and a completely new appearance. The magazine's recognizable white-bordered cover was now gone, replaced by a so-called full-bleed cover where the picture covers the whole area of the paper. The design became more playful and reminiscent of general media, with decoration sometimes replacing straight astronomical imagery. New types of stories appeared that were geared to more general readers, including travel stories, astronomer profiles, and a question-and-answer column. With the bright comets surging the hobby, circulation now reached 182,000.

1998

Cosmology loomed large in 1998 with the discovery of dark energy — the force that accelerates the expansion of the cosmos. The middle of 1998 marked the magazine's 25th anniversary, and an influx of hobbyists attracted by two bright comets brought circulation to 191,000. A 25th anniversary issue in August 1998 had several special stories, including a look at the next 25 years in astronomy conducted as a round-table discussion in Washington, D.C., featuring commentary by Alan Boss, Martin Harwit, Anne Kinney, John Mather, Bohdan Paczynski, Vera Rubin, Michael Shao, Alex Szalay, and James Trefil. The issue also featured an essay contest; a look back at 25 years of space missions by Hartmann; a story on newly released Hubble images by

Naeye; and a summary of major celestial objects discovered over the past 25 years by Rex Graham.

The magazine's staff continued to evolve. Graham joined the staff as the third senior editor in the magazine's history. His background consisted of science writing for newspapers and magazines for 17 years. At the same time, Andrea Gianopoulos, a writer with a planetarium education background at the Science Museum of Virginia, came on board as an associate editor. Late in the year, Tracy Staedter, who previously had been an editorial assistant and worked on *Earth* magazine, was hired as an associate editor when Kurtz left the magazine.

1999

The final year of the decade arrived, and science developments were both hopeful and disastrous in this year. The Stardust mission to a comet and the Chandra X-ray Observatory were both launched successfully, but the "martian hex" continued. Both the Mars Climate Orbiter and the Mars Polar Lander were lost before they were able to commence science at the Red Planet. On August 11, 1999, a solar eclipse was widely observed across Europe and Asia, and several editors traveled to see it occur and report on the story.

2000

This year saw a few changes at *Astronomy* magazine. Naeye was promoted to become the magazine's fourth senior editor. The biggest staff change came mid-year



with the retirement of Larson, who had been publisher for six years. In his place, James Slocum, a longtime Kalmbach editor and executive who had worked in newspaper journalism, took over as the magazine's fourth publisher. Bob Berman and his "Strange Universe" became part of the publication. In August, *Astronomy* sponsored a large star party in Davis, California, within driving distance of San Francisco; in October, it hosted a similar star party near Denver. The magazine also launched an improved website and assigned Gianopoulos to be the magazine's first Web editor.

2001

The following year — that magical sci-fi year of 2001 — brought several developments to the field and to the magazine. In February, the NEAR-Shoemaker spacecraft landed on the asteroid 433 Eros. In November, a Leonid meteor "storm" thrilled observers around the world. A total eclipse occurred in Africa, and several staff members went to Zimbabwe to see it. And Pluto lost its status as a planet at the American Museum of Natural History in New York.

On the staff, Talcott earned a well-deserved promotion to senior editor, becoming the fifth to hold the title in the magazine's history.

2002

The next year was another big one in the magazine's history, with many changes in the masthead. Editor Gordon left the magazine, and Kalmbach decided it wanted to revert to a more traditional approach to the editorial content; Eicher, who had been with the title for 20 years, was promoted to be the magazine's sixth editor-in-chief.

Eicher assembled a team that included Kalmbach staff member Tom Ford as the new art director, the fourth in the magazine's history, and Patricia Lantier, a veteran journalist, as managing editor. (Prior to Lantier starting, a Kalmbach veteran, Dick McNally, stepped in to help as de facto managing editor for several months.) Maggie McKee joined the magazine as an associate editor, as did Pamela L. Gay. By the beginning of 2003, the new team consisted of Eicher, Lantier, Talcott,

Gay, McKee, and Elesia Janke, who was the magazine's editorial associate.

2003

This year was a big one in the astronomy world in a variety of ways. In February, the second tragedy attached to the Space Shuttle Program occurred when *Columbia* disintegrated during reentry, killing its crew of seven. In August, Mars put on a great show with an opposition that made it quite large and bright in the sky, and *Astronomy* entered its 30th year of publication. A major redesign took place with the March 2003 issue, unveiling new graphics, departments, feature treatments, typography, and other bells and whistles. A long-time contributor, Glenn Chaple, started as a regular magazine columnist.

The magazine's staff underwent further changes. In the springtime, Michael E. Bakich joined the staff as an associate editor. Bakich would play a significant role in developing the magazine's hobby coverage; he was a planetarium educator and author of several books on astronomy. Late in the year, Gay departed, and Burnham was rehired as a senior editor. This marked Burnham's second return to the magazine, his third stint, and he again would play a crucial role in science coverage and in refining *Astronomy's* editorial tone and take on the hobby.

2004

In 2004, Lantier left as managing editor to become editor of another Kalmbach title, *Bead Style*. McNally replaced her as the magazine's ninth managing editor. A retired U.S. Air Force lieutenant colonel, McNally had been managing editor of another Kalmbach title, *FineScale Modeler*, and was editor-at-large for the whole company. McNally's management skills and expertise in the publication world (which included work at *Airman* magazine and *The American Legion Magazine*) would serve the staff well.

And an old friend returned: Reddy, who had been an assistant editor along with Eicher back in the early 1980s. After 20 years of absence, Reddy now rejoined the staff as an associate editor. His museum, writing, and computer expertise added greatly to the title's success during the first decade of the century.

2005

Some staff changes occurred in 2005: Burnham left the magazine late in the year, this time to work on Mars programs at Arizona State University, ending his aggregate 18 years of service on the title. Art Director Ford moved to other Kalmbach titles, and *Astronomy* hired LuAnn Williams (soon to be LuAnn Williams Belter) to be the magazine's fifth art director. A polished and experienced design professional and a Wisconsin native, Belter had experience at Raintree Publishers, McDill Design, and other organizations, and she previously had worked on other Kalmbach titles including *Art Jewelry*, *Trains*, *Classic Trains*, and *Model Railroader*. The magazine also added an assistant editor in the first half of the year when Liz Kruesi, an enthusiastic writer who had studied physics, joined the staff.

Further, near year-end, Slocum retired as publisher. The magazine's new publisher would be Kevin Keefe, who stepped in as vice president, publisher, and, like Slocum, head of the entire editorial department at Kalmbach. Keefe's background included time at the newspaper the *Milwaukee Sentinel*, where he was, among other things, arts and entertainment editor. At Kalmbach, he was editor of *Trains* magazine and then became associate publisher and finally publisher of a group of titles. He became the magazine's first publisher who was also an amateur astronomer.

2006

This year, Bakich was promoted to become the magazine's seventh senior editor. Laura Layton, a Chicago native, physics student, and writer, joined the title as an associate editor. Laura Baird, who joined the staff in 2003, was promoted from copy editor to associate editor, underscoring her much-expanded role with editing for the magazine. Late in the year, Assistant Editor Kruesi left to attend graduate school; she would become yet another staff member to return, in her case two years later.

The field of astronomy witnessed some wild events in 2006. A spectacular total eclipse washed over Europe and the Middle East on March 29, and several *Astronomy* staff members went on journeys to cover the story. The Stardust spacecraft returned particles from Comet 81P/Wild 2. The



Wilkinson Microwave Anisotropy Probe satellite confirmed and expanded on earlier results from COBE, nailing the age of the universe at 13.7 — Planck now says 13.8 — billion years. Astronomers shockingly “demoted” Pluto, placing it in a class of dwarf planets along with Ceres and Eris. The exoplanet count reached 200. Astronomers found more dwarf satellites of the Milky Way. The Mars Reconnaissance Orbiter spacecraft commenced an amazing map of the Red Planet. And Venus Express settled into orbit around our neighbor.

2007

Staff changes were few. By year-end, Reddy was promoted to be the magazine’s eighth senior editor. Daniel Pendick, a talented science writer who had been an editor of *Earth* magazine, joined the staff as an associate editor, and Stephen James O’Meara began writing the “Secret Sky” column.

2008

The year marked the magazine’s 35th anniversary. McNally was promoted from managing to executive editor. McNally thus became the title’s first executive editor

since Dickinson began in 1974. Having worked for the magazine for the second time, this time for four years, Reddy left to pursue other projects at year-end. Yet another former employee returned to fill the gap when Kruesi rejoined, this time as an associate editor, the 25th in the magazine’s history. Matt Quandt, who had been an intern and then assistant editor, was named the magazine’s online editor because of his heavy Web focus. And Baird, who had been copy editor and then associate editor, left to pursue local journalistic opportunities; in her place, the magazine hired Karri Ferron, a sharp-eyed graduate of the University of Missouri’s journalism school, as the title’s eighth copy editor.

2009

This particular year saw minimal staff changes at *Astronomy* magazine. Pendick, though, did leave for other journalistic work. His departure opened up the opportunity for Bill Andrews to join the publication’s staff as an assistant editor. Andrews was a young and energetic graduate of MIT who had earned his master’s degree in science writing from the University of

Wisconsin-Madison. He became *Astronomy* magazine’s 13th assistant editor.

2010

The 38th year of the magazine’s existence witnessed one major staff change — McNally retired. To replace him, the company hired Chris Raymond, another Kalmbach returnee. Andrews was promoted to associate editor, and contributor Tony Hallas came on board as a columnist.

The present staff

That brings us to the present day. Over the past couple of years, Ferron took on Web duties and was promoted to assistant editor. Ronald Kovach, formerly senior editor of *The Writer*, became the managing editor after Raymond’s departure. He is an experienced editor whose history includes exceptional work at big-city newspapers. Andrews departed for our sister magazine, *Discover*, also located in our building. To replace him, Sarah Scoles joined the staff as an associate editor; she graduated from Agnes Scott College, earned a master’s degree from Cornell University, and worked at the National Radio Astronomy Observatory in Green Bank, West Virginia.

Astronomy’s current staff very much enjoys bringing you the world’s leading magazine on the subject. Not only do we present the world of astronomy in print, but also in various digital forms and on our website, www.Astronomy.com. Getting up, coming into work, and spending another day in the office is a joy. Eicher, the editor-in-chief, knows the magazine better than anyone else, having been on the staff for 31 of the magazine’s 40 years. Senior Editor Talcott has been on board for 27 of those years. Art Director Williams Belter enjoys blending the world of astronomy with spectacular, eye-grabbing graphics and typography and oversees the creation of illustrations. One of the company’s illustrators, Elisabeth Roen Kelly, has been churning out fantastic astronomical graphics that help to bring unseen deep-space worlds alive since her arrival in 1996.

Never before has such a history of *Astronomy* magazine been written. Writing this story has brought back numerous memories, and many exciting times certainly still lay ahead in the magazine’s next 40 years. ☛



Today, a staff of 12 brings readers the thorough coverage of the science and hobby they’ve come to expect from *Astronomy* magazine. The group includes, back row (left to right): Editorial Associate Valerie Penton, Illustrator Elisabeth Roen Kelly, Managing Editor Ronald Kovach, Senior Graphic Designer Chuck Braasch, Publisher Kevin Keefe, Associate Editor Sarah Scoles, Assistant Editor Karri Ferron, Associate Editor Liz Kruesi; front row (left to right): Senior Editor Michael E. Bakich, Editor David J. Eicher, Art Director LuAnn Williams Belter, and Senior Editor Richard Talcott. KALMBACH PUBLISHING CO.

REFRACTING LIGHT

Q: WHAT PRODUCES THE "BLUE FLASH" DURING SUNSET?

Tom Hamilton, San Clemente, California

A: The blue flash during sunset is a relatively uncommon phenomenon. It appears just before the last rays of the Sun slip beneath an unobstructed horizon — where both the bending, or refraction, of light and mirage effects (multiple or inverted images) are greatest. As the Sun approaches the horizon, the atmosphere acts as a prism and begins to separate the Sun's image into its component colors. Because blue light is refracted more than red light (due to its shorter wavelength), the top rim of the Sun turns blue. It is this blue bit of sunlight that you might rarely see just above the horizon (a mirage) at the last instant of sunset — a phenomenon we call the blue flash.

Seeing the blue color, however, requires extremely clear and transparent sky conditions. The reason is that the light path of the last ray of sunlight to your eye passes through the densest part of the atmosphere where air molecules, water vapor, and atmospheric contaminants effectively scatter blue and violet

light away from your eyes more than any other color; this is why green flashes are more common than blue ones. Blue flashes are more visible at higher elevations, where the atmosphere is thinner and contaminants fewer.

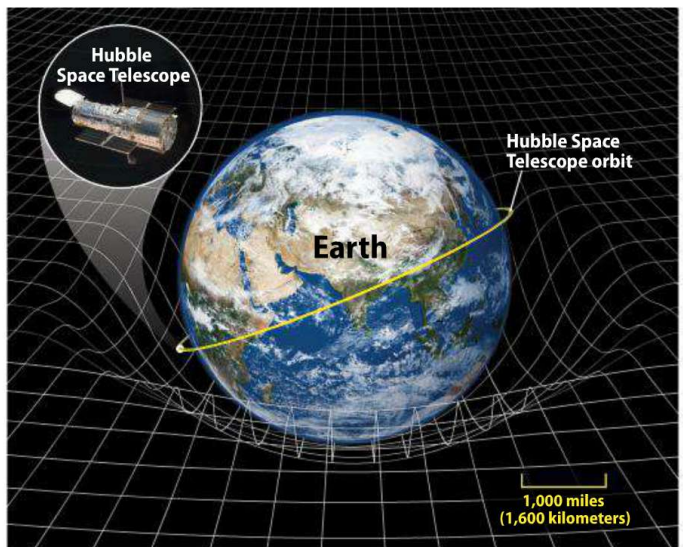
The "flash" terminology is misleading, so you might expect to see an intense flaring of blue light. Generally, however, the opposite is true, and the last bit of sunlight gets progressively smaller. Only on rare occasions, under specific atmospheric conditions, does a true flash appear. The best blue flashes occur under mirage conditions, which can magnify refraction and enhance the view for a couple of seconds before the phenomenon vanishes.

Of course, you must be very careful when looking for the blue flash, keeping your direct gaze away from the Sun until only the last segment of the upper rim is visible. Staring directly at the Sun's entire disk, even when it lies low in the sky, may cause eye damage.

Stephen James O'Meara
Contributing Editor



Earth's atmosphere acts as a prism to bend — or refract — light, with red bending the least and blue/purple the most. When the Sun is close to the horizon, an observer can see blue light for a second or two if the atmosphere is extremely still and the sky clear. HINRICH BASEMANN



Just as you would distort a trampoline you stand on, objects with mass (like Earth) warp space-time. Light, along with anything else (such as the Hubble Space Telescope), traveling through the universe must follow these distortions.

Q: IF PHOTONS HAVE NO MASS, HOW CAN BLACK HOLES GRAVITATIONALLY AFFECT THEM? HOW CAN THE HUGE GRAVITY OF A GALAXY CLUSTER BEND THEIR PATHS?

Richard Phelps
Plano, Texas

A: Objects with mass warp space-time like you warp a trampoline's surface when you step on it. When a photon is zipping through the universe, it has to follow the bends and curves of space-time — space-time is, after all, the only thing to travel through! So when the photon encounters a massive object, its path "dips" and "rises." If you rolled a marble along the stepped-on trampoline, its path, too, would dip and rise. Photons, though they have no mass, exist in the universe, and where the universe is curved, they must follow.

Black holes bend space-time more than anything else in the universe because of their extreme densities. Think of satellites: If scientists want a satellite to stay in orbit, they have to send it up with a certain speed.

If the speed is too low, it will fall back down to Earth. If it's too high, it will keep on going out into space. The speed at which the satellite would continue into space is called the "escape velocity." All of these effects are due to the actual curvature of space-time from Earth's mass.

At a certain distance from a black hole's center, the escape velocity is faster than the speed of light, so photons that come within that distance follow space-time into the black hole and cannot escape.

Sarah Scoles
Associate Editor

Q: ARE THERE EVEN PRELIMINARY IDEAS ABOUT WHAT DARK ENERGY IS?

David Michel
Kettering, Ohio

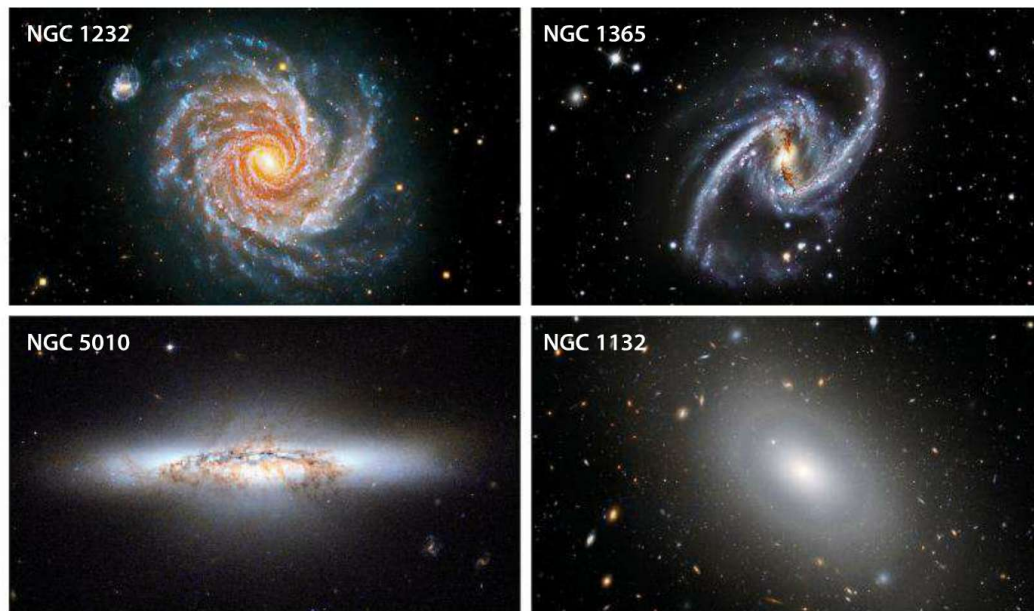
A: The term *dark energy* refers to whatever is causing the universe's expansion to speed up. Two groups of scientists announced this result in 1998, and the team leaders won the Nobel Prize in physics in 2011. We call it "dark" because we can't see it, and we call it "energy"

because we think it fuels the expansion of the universe.

One of the leading ideas to explain dark energy is called the “cosmological constant.” This idea originated with Albert Einstein, who stated that this constant keeps the universe static in size rather than letting it contract due to gravity. Once scientists discovered in the 1920s that the universe is expanding, Einstein retracted the idea and called it his greatest blunder. With the finding that the expansion is accelerating, however, scientists reintroduced this type of modification. An implication of this model, that energy density is constant while the universe expands, is hard to accept because it implies something that repels instead of attracts like gravity, but the model does agree with all the data we currently have.

Another idea is that Einstein’s general theory of relativity, the basis for gravity, needs a modification. Gravity agrees with all the measurements made up until now; any change to the theory has to maintain that agreement. One way to test for modifications to gravity is to study the growth of clusters of galaxies since the Big Bang. Both the expansion of the universe as well as gravity influence the number and size of galaxy clusters; the former is pulling them apart while the latter is pulling them together into the clusters. The precision measurements required to study this are now just barely within our reach.

We have other ideas, too. We don’t even know if dark energy is a thing; it could be a property of space that we don’t yet understand how to think about. In any case, it is one of the great mysteries in science. Over the next decade, new projects such as the Dark Energy Survey, which will start collecting images in September 2013, will take the next



The gravitational force of moving stars and rotation control much of a galaxy’s shape. Shown here are different examples of structure: a grand design spiral (NGC 1232), barred spiral (NGC 1365), lenticular (transition between spiral and elliptical, NGC 5010), and elliptical (NGC 1132). ESO/IDA/DANISH 1.5M/R. GENDLER AND A. HORNSTRUP (NGC 1232); ESO/IDA/DANISH 1.5M/R. GENDLER/J.-E. OVALDSEN/C. THONE/C. FERON (NGC 1365); ESA/HUBBLE & NASA (NGC 5010); NASA/ESA/THE HUBBLE HERITAGE (STSC/AURA)-ESA/HUBBLE COLLABORATION/M. WEST (ESO, CHILE) (NGC 1132)

step in unraveling the nature of dark energy.

Brenna Flaugher

*Fermi National Accelerator Laboratory,
Batavia, Illinois*

Q: HOW DO WE GET SUCH BEAUTIFUL, ORNATE, AND SYMMETRICAL SHAPES OF GALAXIES — PINWHEELS, OVALS, SPIRALS, AND CENTRAL BARS — WHEN THE SAME GRAVITATIONAL FORCES ARE AT WORK AS THOSE THAT AFFECT EARTH AND THE SUN’S OTHER PLANETS?

Ron Herron

Santa Barbara, California

A: This question illustrates fascinating properties of the gravitational force. A single spherical object, such as Earth or a star, has its shape due to gravity. So at first we might expect all objects held together by gravity should have roughly spherical shapes.

A number of factors, however, complicate this situation. One is

circular motions that result from spin or, more technically, angular momentum. For example, the Sun’s planets lie approximately in a plane, and our star’s gravity in combination with the amount of orbital spin determine their movements. Now consider a situation where we fill up space with spinning matter in orbits, and we can form a disklike structure — this is the basic form of a major component of spiral galaxies.

When we have many objects in a system, gravity attracts and encourages them to clump together. Two local examples are the Moon’s long-term companionship with Earth, and the Local Group of galaxies. In galaxy disks of hundreds of billions of stars, the effects of gravitational gregariousness are subtle. One phenomenon is that gravity produces wakes of stars that shear outward in the disk to help form spiral arms. Bars are similar, but more complicated, structures that result from systems of stars that rotate slowly in bulk over time while individual stars

move rapidly on elongated orbits within the bar.

If rotation is less pronounced, it produces flattened balls (called “oblate spheroids”) that we see in some elliptical galaxies and the central bulges of spirals.

A third class of impressive features can occur when galaxies, and especially those with disks, collide. In such cases, gravity can pull material out from galaxies to make “tidal debris”: extended spiral arms, bridges, loops, and even shells of stars.

Jay Gallagher

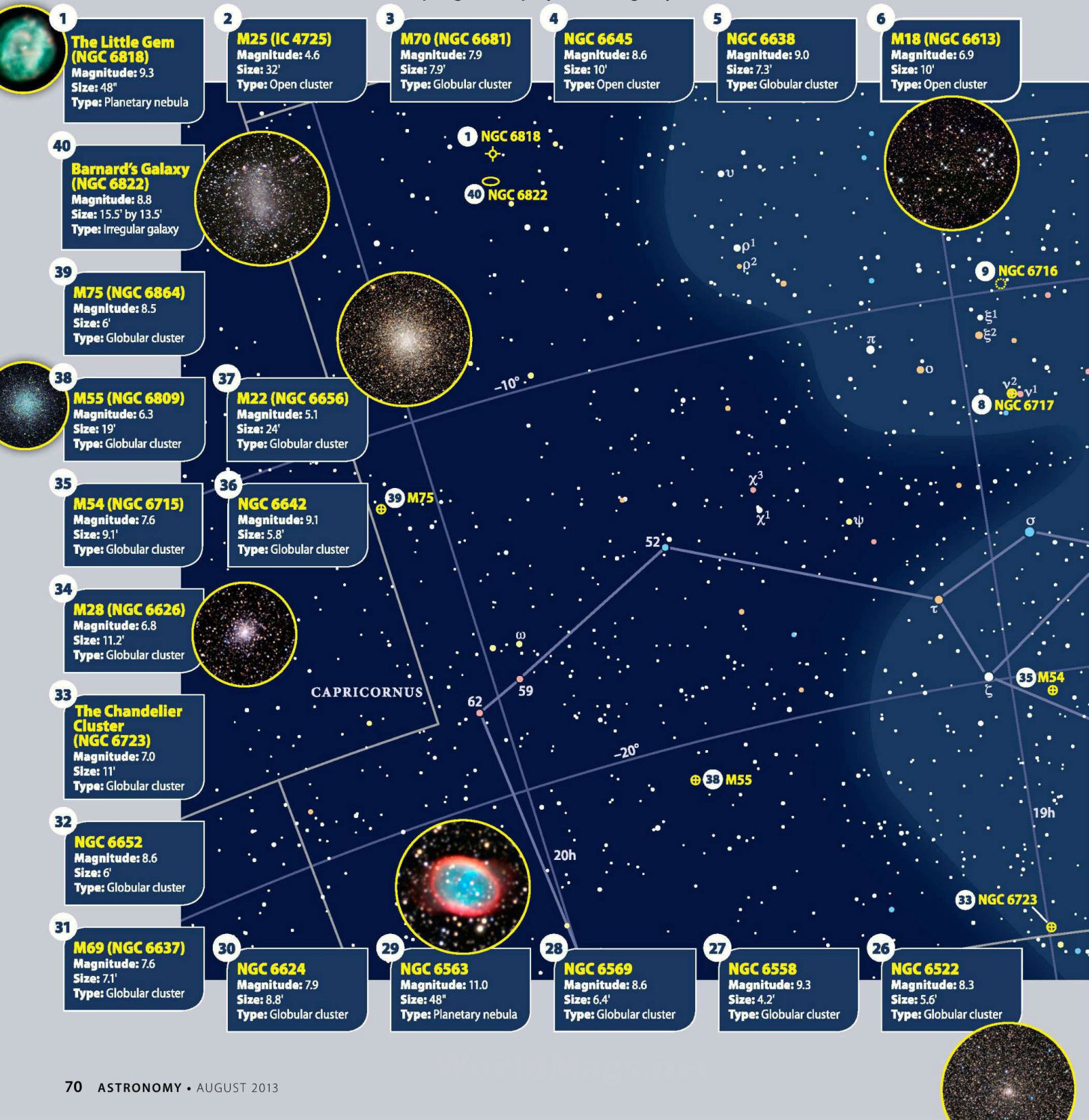
University of Wisconsin-Madison

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.

40 DEEP-SKY TARGETS IN SAGITTARIUS

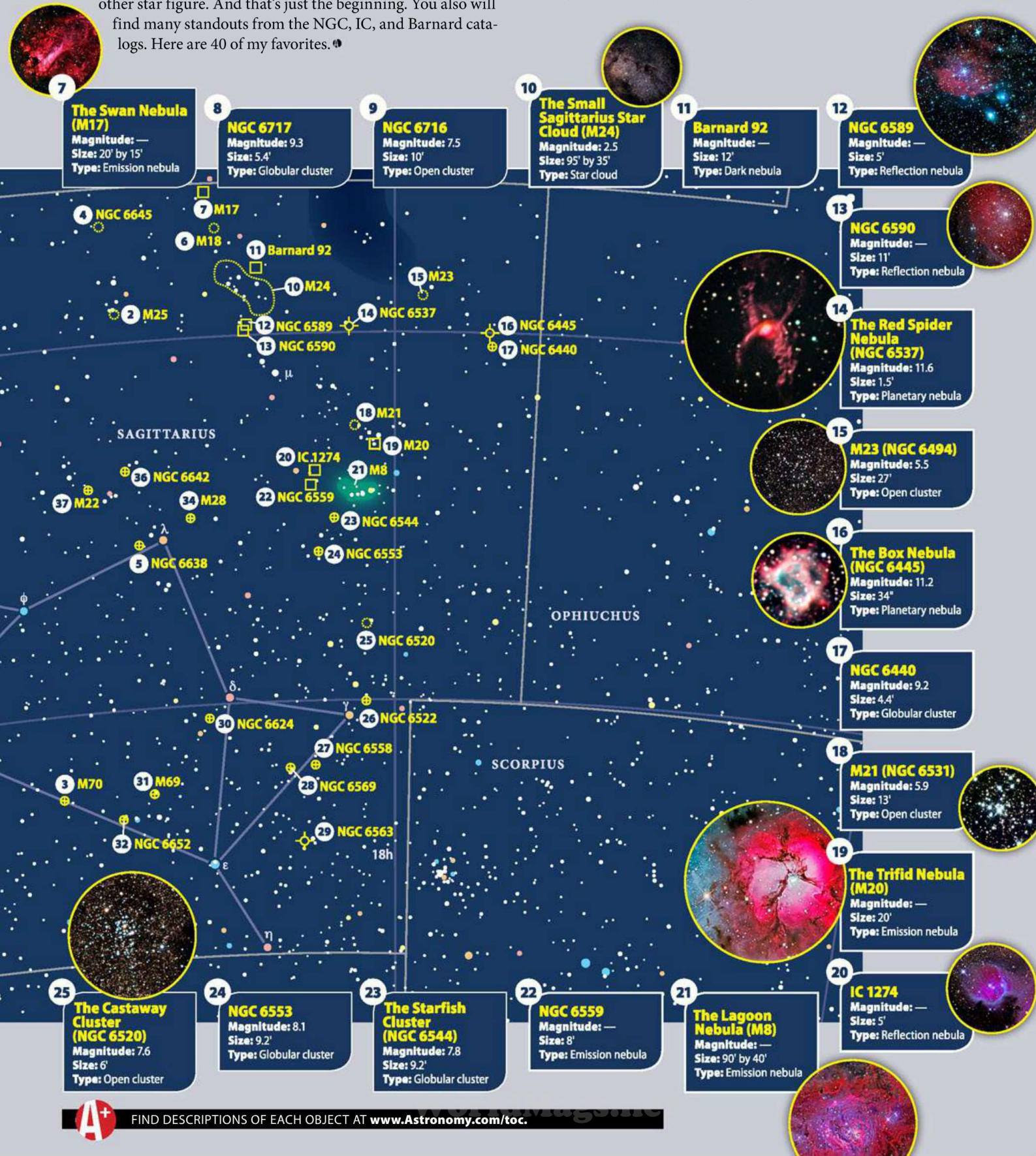
The Archer contains a dizzying variety of dazzling objects. **by Michael E. Bakich**



The constellation Sagittarius the Archer ranks 15th in size and 35th in overall brightness (the number of visible stars per unit area) out of the sky's 88 star patterns. But many observers would rank it at the top of the heap with regard to fascinating deep-sky treats. You'll find no fewer than 15 Messier objects here — four more than in any other star figure. And that's just the beginning. You also will find many standouts from the NGC, IC, and Barnard catalogs. Here are 40 of my favorites. ☛

Michael E. Bakich is a senior editor of *Astronomy* and author of 1,001 *Celestial Wonders to See Before You Die* (Springer, 2010).

MITCH AND MICHAEL DYE/ADAM BLOCK/NOAO/AURA/NSF (NGC 6818); ANTHONY AYIOMAMITIS (M18); BOB FERRA (M17); DEAN SALMAN (M24); MICHAEL SIDONIO (NGC 6589); ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA (NGC 6590); ADAM BLOCK/NOAO/AURA/NSF (NGC 6537); ANTHONY AYIOMAMITIS (M23); LISA DOMBROW/PHIL TERRY/ADAM BLOCK/NOAO/AURA/NSF (NGC 6445); ANTHONY AYIOMAMITIS (M21); DANIEL VERSCHATSE/ANTILHUE OBSERVATORY (M20); ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA (IC 1274); R. JAY GABANY (M8); AL KELLY (NGC 6520); ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA (NGC 6563); HAREL BOREN (M28); BERNHARD HUBB (M22); DANIEL VERSCHATSE (M55); CHUCK KIMBALL (NGC 6822); ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY (FINDER CHART)



FIND DESCRIPTIONS OF EACH OBJECT AT www.Astronomy.com/toc.

Hunt down SUMMER'S BEST DARK NEBULAE

For a totally new observing experience, ignore the bright and instead aim for darkness. **by Michael E. Bakich**

When scanning the Milky Way on a summer night, you'll probably come across various "voids" in the bright star clouds of our galaxy. But these dark shapes aren't areas to skip over in favor of the next brilliant star cluster or emission nebula. Instead, it's time to target these dark nebulae — interstellar clouds that obscure the light coming from the stars or bright nebulae behind them — as their shapes are among the strangest in the sky.

Peering into the darkness

When American astronomer Edward Emerson Barnard first began to photograph dark regions in the Milky Way in

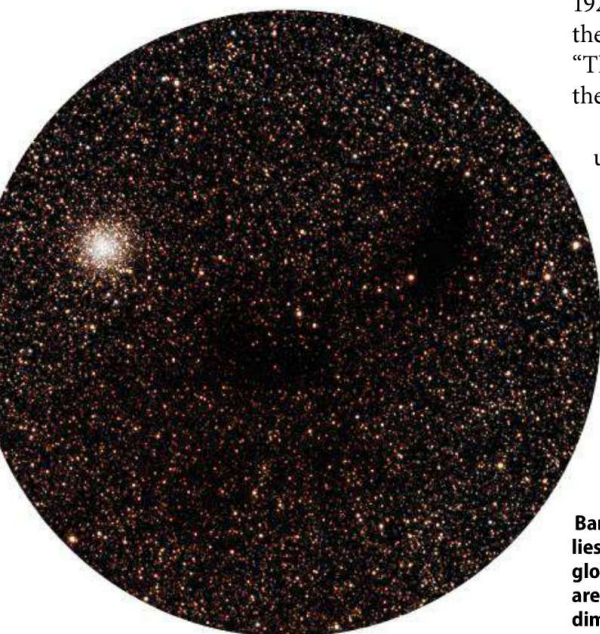
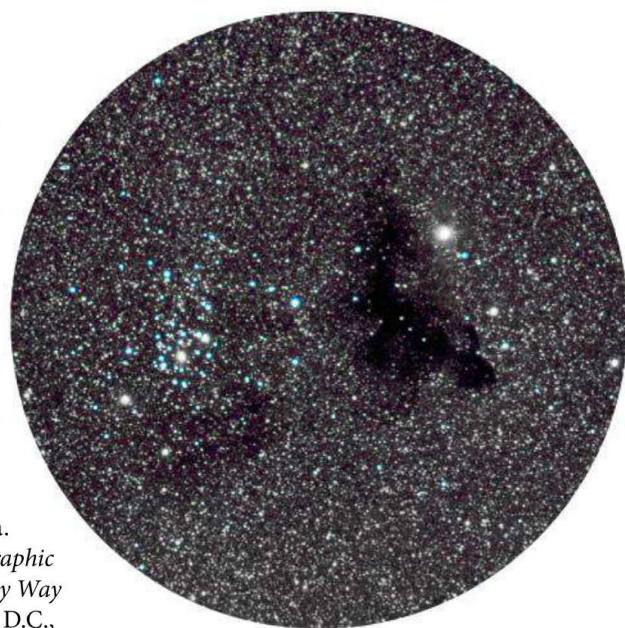
The Ink Spot (Barnard 86) in Sagittarius presents a striking contrast to the bright star cluster NGC 6520. This dark nebula received its common name based on Edward Emerson Barnard's description of it: "It looks like a drop of ink on the luminous sky." JASON WARE

1904, he — along with the majority of astronomers — believed that these areas were starless voids that contained nothing. As he built up a large collection of photographs, however, Barnard began to question this idea.

In the introduction to *A Photographic Atlas of Selected Regions in the Milky Way* (Carnegie Institution, Washington, D.C., 1927), Barnard presented a strong case for the existence of dark nebulae, stating, "There need be no hesitation in accepting the fact that such bodies exist."

Barnard's atlas helped astronomers understand the true nature of dark nebulae. These areas weren't "great cavities or vacancies," as English astronomer William Herschel claimed a century earlier. Rather, these dark regions are vast clouds of relatively dense gas and dust that obscure the light from bright, more distant objects behind them. By doing so, they produce some of the most amazing sights in the sky.

Barnard 64 is a comet-shaped dark nebula that lies just 25' west (right) of the magnitude 7.7 globular cluster M9 in Ophiuchus. The two objects are so close that the interstellar dust cloud likely dims its starry neighbor. BERNHARD HUBL



Working in the dark

The largest of the dark nebulae, which astronomers refer to as molecular clouds, are areas of star formation. The darkness of these objects is due to one of the clouds' main constituents: dust grains. The clouds also contain molecular hydrogen and a few other gases like helium, formaldehyde, and ammonia, but those don't block any light. Dark nebulae also rank as some of the coldest spots in the universe. The internal temperature of these clouds is only about 10 kelvins (−440° Fahrenheit).

The clouds must be super-cold for the gas to condense into stars. If there's too much heat, the particles will be traveling

Michael E. Bakich is an Astronomy senior editor who has a fondness for dark nebulae.

The Rho Ophiuchi region is home to multiple dark nebulae, including Barnard 44, which spans an amazing 6.5°. To target B44, start at the brilliant yellow luminary Antares (Alpha [α] Scorpii) and look for a dark dust lane that travels to the east (left in this image). TONY HALLAS

too fast and bounce off one another, rather than sticking together to form ever-larger objects that eventually become stars. Luckily, when regions within a dark nebula begin to collapse, the dust grains within the clouds radiate the energy away, keeping things cold. At some point, however, gravity overwhelms the opposing forces in a section of the cloud and a star forms.

Darkness all around

The most comprehensive list of dark nebulae comes from American astronomer Beverly T. Lynds. She wrote *Catalogue of Dark Nebulae*, which appeared in *The Astrophysical Journal Supplement Series* in May 1962.

To create the catalog, she used the National Geographic Society Palomar Observatory Sky Survey photographs (both the red and blue prints) to search for dark nebulae. The declinations of the objects in her catalog, therefore, range from 90° to -33°, which was the extent of the survey. A cloud had to be visible on both color photographs in order for her to record it. She also set a minimum size. Each of her dark nebulae has an area greater than 0.05 square degree — about five times the area the Crab Nebula (M1) covers.

Lynds was a thorough researcher. Her list contains an amazing 1,791 nebulae. And while some are quite small, nearly 20 summertime objects rank among the darkest such objects in the sky. You'll find those in the table titled "The darkest of the dark."

Some dark targets

We'll begin our hunt for summer's best dark nebulae in the Rho Ophiuchi region, named for the magnitude 4.6 star Rho (ρ) Ophiuchi it surrounds. To get to the area, first center on Antares (Alpha [α] Scorpii). Stifle your natural urge to observe globular clusters M4 and NGC 6144 — you're here to hunt nebulae.

Start by scanning the area above (north) and left (east) of Antares through binoculars or the lowest-power, widest field of view your telescope will allow. But avoid using any filters, which don't help because they dim the surrounding stars, reducing the contrast between them and



THE DARKEST OF THE DARK

This table lists the darkest summer nebulae in Beverly T. Lynds' *Catalogue of Dark Nebulae*, which appeared in *The Astrophysical Journal Supplement Series* in May 1962. In addition to cataloging them, she estimated their opacity (darkness) based on a comparison with the neighboring star fields. All nebulae listed here have an opacity of 6, the darkest of the six classes she assigned.

LDN #	Constellation	R.A.	Dec.	Area
1757	Ophiuchus	16h32m	-19°36'	0.061
1709	Ophiuchus	16h33m	-23°46'	0.099
43	Ophiuchus	16h35m	-15°50'	0.070
260	Ophiuchus	16h48m	-9°35'	0.074
204	Ophiuchus	16h48m	-12°05'	0.167
158	Ophiuchus	16h48m	-14°05'	0.056
162	Ophiuchus	16h49m	-14°15'	0.124
65	Ophiuchus	17h13m	-21°54'	0.088
100	Ophiuchus	17h16m	-20°53'	0.075
219	Ophiuchus	17h40m	-19°47'	0.084
513	Serpens	18h11m	-1°33'	0.127
429	Serpens	18h17m	-8°19'	0.068
570	Serpens	18h27m	-0°28'	0.066
557	Serpens	18h39m	-1°47'	0.181
530	Scutum	18h50m	-4°47'	0.124
581	Aquila	19h07m	-3°55'	0.072
673	Aquila	19h21m	11°16'	0.199
704	Aquila	19h27m	13°46'	0.097
694	Aquila	19h41m	10°57'	0.109

Key: LDN # = object number in Beverly T. Lynds' *Catalogue of Dark Nebulae*; R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Area is in square degrees



The Snake Nebula (Barnard 72, center), an S shape composed of multiple dark nebulae, slithers across Ophiuchus 1.4° north-northwest of the magnitude 3.3 star Theta (θ) Ophiuchi (bottom in this image). The Snake's average width is between 2' and 3'. JASON WARE

MORE GREAT SUMMER OBJECTS FROM BARNARD'S CATALOG

American astronomer Edward Emerson Barnard prepared the first catalog of dark nebulae in *A Photographic Atlas of Selected Regions in the Milky Way* (Carnegie Institution, Washington, D.C., 1927). Here are six more selections not included in the main text from his list that will jump-start your observing of this wonderful class of objects.

Name	Constellation	R.A.	Dec.	Area
B42	Ophiuchus	16h29m	-25°18'	0.04
Pipe Nebula, stem (B65/6/7)	Ophiuchus	17h21m	-26°48'	5.00
Pipe Nebula, bowl (B78)	Ophiuchus	17h33m	-25°42'	7.78
Parrot's Head Nebula (B87)	Sagittarius	18h04m	-32°42'	0.04
Barnard's E (B142/3)	Aquila	19h41m	11°00'	2.44
The Cygnus Rift (B348/9)	Cygnus	20h37m	42°12'	16.00

Key: Name = object number in Edward Emerson Barnard's *A Photographic Atlas of Selected Regions in the Milky Way*; R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Area is in square degrees

the dark nebula. For this initial hunt, look for the absence of stars caused by dark nebula Barnard 44 (B44). This dark, sharply defined lane, which Barnard called "remarkable," starts at the magnitude 4.8 star 22 Scorpii and runs eastward an incredible 6.5°, ending at the magnitude

5.6 star 24 Ophiuchi. You'll have to scan back and forth with your scope. None has a field of view that large.

To find another Barnard object in Ophiuchus, center on globular cluster M9. Just to its west, you'll spot B64. Use a 4-inch or larger scope and a magnification less than

100x to study the target. Of it, Barnard wrote, "It is somewhat cometary in form and has a very black core or head that sharply abuts against the thick stratum of stars." In fact, the nearness of B64 to the globular probably reduces M9's light by a full magnitude.

Next up in Ophiuchus is the enigmatic Snake Nebula (B72), the 74th entry in Barnard's catalog. It carries the designation B72, however, because he added two "extra" numbers to his list before B72: B44a and B67a. You'll get your best views of the Snake Nebula through a telescope/eyepiece combination that yields a field of view around 0.5°. To find this object, look 1.4° north-northeast of magnitude 3.3 Theta (θ) Ophiuchi.

Continue your hunt by heading southeast to the constellation Sagittarius. To target the Ink Spot (B86), aim for magnitude 7.6 NGC 6520, a nearby open star cluster, and look a little to its west. Together, these objects present a wonderful contrast. Using an 8-inch telescope, you'll see about 30 stellar members of NGC 6520 against a bright background of distant stars.

No such background exists for B86. Its starless, irregular form stands out against myriad faint stars. Look for the orange magnitude 6.7 double star HD 164562 on B86's western edge. It's a nice complement to the scene.

Next, head one constellation north to Scutum, which is home to a whole complex of dark nebulae. Barnard objects 114 through 118 lie 1.8° south-southwest of magnitude 4.8 Eta (η) Scuti. Alternatively, you can find the complex's northern edge 0.5° southeast of the Wild Duck Cluster (M11). From there, the darkness drifts southward some two Full Moon widths. Best results come through telescope/eyepiece combinations that yield approximately 75x.

Let's end our hunt with a funky dark nebula. Look midway between magnitude 4.8 Epsilon (ε) Coronae Australis and magnitude 4.2 Gamma (γ) Coronae Australis to find Bernes 157. This ultra-dark spot sits at the southeastern edge of the region inhabited by nebulae NGC 6726 and NGC 6729. Also, less than 1° to the northwest, you'll find the Chandelier Cluster (NGC 6723).

Starlight absorption in this region is as high as 8 magnitudes, so you'll need a large aperture to capture the few 13th-magnitude stars strewn across Bernes 157. I find it fascinating that dark nebulae blot out starlight because, in say 10 million years, this star-forming region will be alive with new stars.

The best views of Bernes 157 are through either large-aperture binoculars (70 millimeters or greater) that magnify at least 15 times or through telescope/eyepiece combinations that yield magnifications between 30x and 50x. This dark patch isn't small — it covers an area almost as large as two Full Moons.

This object's catalog name is one you may not have heard of. In 1977, Claes Bernes of Stockholm Observatory compiled a new catalog of bright nebulae in dense dust clouds. He found 160 such objects in 80 different dark clouds. Most of these objects are reflection nebulae, and all are star-forming regions Bernes suggested astronomers target for radio and infrared observations.

Enjoy the darkness

Luckily, there's no trick to observing dark nebulae. You simply have to "re-tune" your thinking to search for dusky objects against a bright background. With all other celestial targets, we look for bright regions against a black sky.

And summer in the Northern Hemisphere is by far the best time to search for



ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA

HAVE FUN THIS WINTER: OBSERVE THE HORSEHEAD NEBULA

Once upon a time, the 33rd object in Edward Emerson Barnard's catalog was considered one of the ultimate observing tests. Actually seeing B33 moved amateur astronomers from "good" to "great." Well, times change, mainly because technology improves. Today, the Horsehead Nebula is still a test, but seeing it won't make you a legend. Here are some tips to help you locate this elusive object when it reappears this winter.

1) Use the largest telescope you can beg, borrow, or buy. The Horsehead Nebula has been seen in apertures as small as 5 inches, but not easily.

2) Dark adaption is essential, especially when using medium-sized telescopes. (It's not that important if you're

using a 30-inch telescope.) Some observers place a black cloth over their heads to minimize stray light. Related to this, make certain you position Alnitak (Zeta [ζ] Orionis) out of the field of view.

3) Use a Hydrogen-beta filter if you can. This filter is a superb help for locating the Horsehead. You also can use it on the California Nebula in Perseus and the Cocoon Nebula in Cygnus. That's pretty much it, however, so make your purchase accordingly.

4) A star chart will be handy, but an image of the area can prove much more useful. Identify the stars around the Horsehead Nebula to define its shape. For comparison purposes, pay particular attention to patterns of stars. Volume 2 of *Burnham's Celestial Handbook*

(Dover Publications, New York, 1978) has five photographs of B33. Many observers have suggested that the one taken by David Healy of Sierra Vista, Arizona (on p. 1344), is the best for visual observation.

5) Begin by searching for the emission nebula IC 434. If you can't see this steadily, you won't see the Horsehead, which appears fairly low in contrast against this nebula.

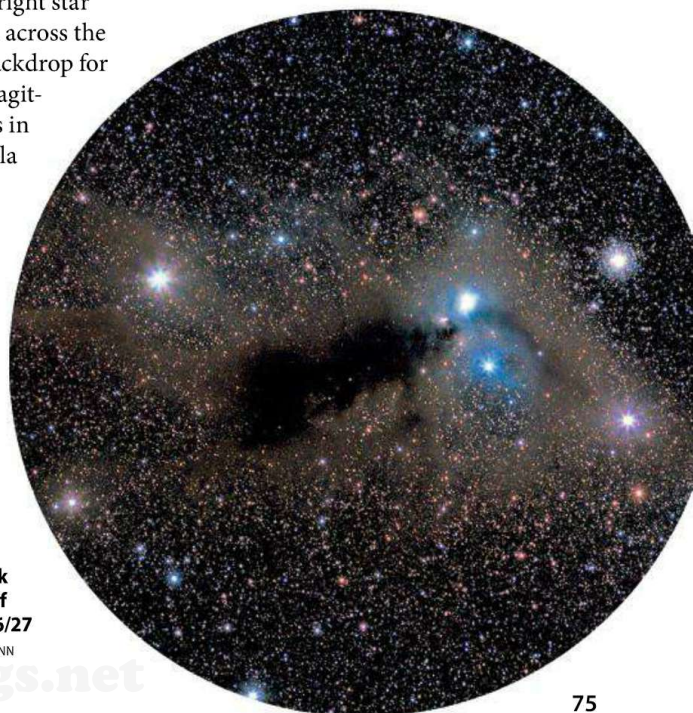
6) The Horsehead Nebula is not a minuscule object. It is larger than you think, especially at magnifications higher than 150x.

7) Your spotting the Horsehead depends on sky conditions. If the transparency (sky brightness) or the seeing (atmospheric steadiness) is bad, try for it on a different night. — M. E. B.

these objects. That's when the bright star clouds of the Milky Way stretch across the heavens, providing a colorful backdrop for these dusty regions. You'll see Sagittarius, Ophiuchus, and Scorpius in the south and Cygnus and Aquila overhead. Later, Cassiopeia and Cepheus — both of which contain dark nebulae you can observe in the fall — rise in the northeast.

So set up your telescope, insert your lowest-power eyepiece, and start hunting dark nebulae. I'm sure the search will enlighten you. ☾

The dark nebula Bernes 157 lies in the heart of the Corona Australis Dark Cloud Complex just southeast (left) of the blue reflection nebulae NGC 6726/27 and the pinkish NGC 6729. GERALD RHEMANN



A backyard imager ADVANCES SCIENCE

An unexpected email opened the door for this astroimager to contribute to our understanding of the universe.

text and images by R. Jay GaBany

I was born too soon. Unlike the generations that will follow, I will never experience the wonder of traveling beyond Earth's atmosphere, walking on the Moon, venturing to another planet, or visiting the remote places that fill my imagery. Astrophotography is my only method of personally exploring the universe, and such an interest has allowed me to discover previously unsuspected talents and forge long-lasting relationships.

In and out of imaging

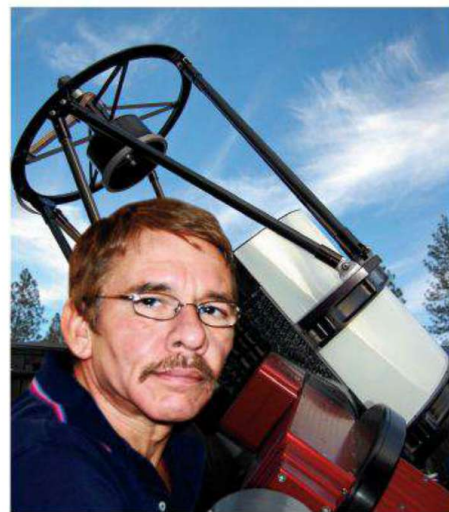
My interest in astronomy began at age 5 when my father held me on his shoulders and pointed to Sputnik moving through the night sky shortly after it launched. Like many others, I grew up during the Space Age, and the race to the Moon propelled my enthusiasm for the hobby.

I dabbled in astrophotography early, starting with a high school science fair project in 1970. For it, I took an image of Comet Bennett along with an 8mm motion picture of the Mercury transit May 9 through my 2.5-inch department store refractor. To my surprise, the exhibit ultimately received a state championship award the following year.

I returned to imaging for the 1986 apparition of Halley's Comet. For the event, I learned the tedious art of long-exposure photography with a single lens reflex film camera attached to a 16-inch reflector on a wobbly equatorial mount. To get the pictures, I chased a guide star through a cross-hair eyepiece with a joy-stick control. But after Halley, frustrations with manual guiding, career objectives, and family obligations combined to distract my interest until I discovered the capabilities of digital cameras around 2004.

Away from the light

While I am fortunate to live in an area in Northern California with seemingly endless clear nights from May to October, I also have to contend with intense light pollution. So I began following the paths first trod by professionals. For more than a century, astronomers have evaded the

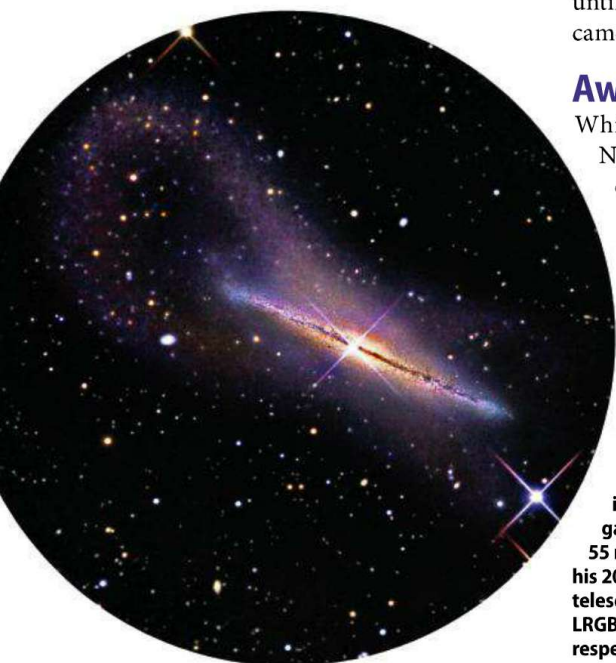


The author images through a 20-inch RC Optical Systems Ritchey-Chrétien telescope located high in the California Sierra Nevada between Yosemite and Kings Canyon national parks.

blinding effects of light pollution by locating their instruments on high mountaintops, far from civilization.

Likewise, after many months of imaging from my somewhat light-polluted backyard with modest success, I began exposing pictures using remote-controlled instruments located under dark skies in New Mexico and near Melbourne, Australia. My target list favored many of the most popular deep-sky objects because they are inherently evocative to me. However, I preferred very long exposures because they could reveal previously unseen or unsuspected structures.

Today, my Blackbird II Observatory, which includes a 20-inch RC Optical Systems Ritchey-Chrétien telescope and an Apogee Alta U16M-HC 16-megapixel CCD camera, lies in the Sierra Nevada between Yosemite and Kings Canyon national



This image of the Diamond Ring Galaxy (NGC 4013) in Ursa Major first revealed an enormous river of old stars cast off during the ancient merger of a dwarf satellite galaxy with this edge-on spiral located about 55 million light-years distant. The author used his 20-inch RC Optical Systems Ritchey-Chrétien telescope, an SBIG STL-11000 CCD camera, and LRGB exposures of 630, 90, 54, and 108 minutes, respectively, for this image.

R. Jay GaBany is a amateur astrophotographer in San Jose, California. During the fall of 2012, the editors of Time magazine included him in "The 25 Most Influential People in Space."



The author's image of spiral galaxy M94 inspired his collaboration with astronomer David Martínez-Delgado. The photo revealed a pattern of spiral arms later confirmed in infrared and ultraviolet images provided by the Spitzer and Galaxy Evolution Explorer space telescopes. To capture such detail, the author used his 20-inch RC Optical Systems Ritchey-Chrétien telescope, an Apogee Alta U16M-HC CCD camera, and LRGB exposures of 550, 90, 54, and 108 minutes, respectively.

parks. I continue to use the Internet to operate everything remotely.

Unfortunately, many professional astronomers five to 10 years ago couldn't do the same. They had to journey to distant observatories when gathering data. And some of these sessions were mundane, accompanied by tedious hours monitoring the progress of a pre-established observing plan. So, how did professional astronomers avoid the tedium of an uneventful observing run? It turns out that some surfed the Internet and reviewed amateur astrophotography galleries, searching for possible hints of new discoveries unsuspected by the imagers.

A lucky happenstance

Such was the circumstance when I received an email message from David Martínez-Delgado of the Max Planck Institute for Astronomy in Germany, after he serendipitously chanced upon my website, www.cosmotography.com, more than seven years ago. Martínez-Delgado leads an international team of professional astronomers searching for evidence of ancient stellar remnants around spiral galaxies in the local universe to support the cold dark matter (CDM) theory of galactic evolution. According to CDM theory, dwarf galaxies were the first star systems



The aptly named Umbrella Galaxy (NGC 4651) lies about 35 million light-years away in the constellation Coma Berenices. The faint fan-shaped and narrow structures extending about 50,000 light-years beyond the galactic disk represent the remnants of a dwarf galaxy that the spiral ripped apart and consumed. This image combines RGB data collected by the author with luminance data from the 8.2-meter Subaru Telescope.

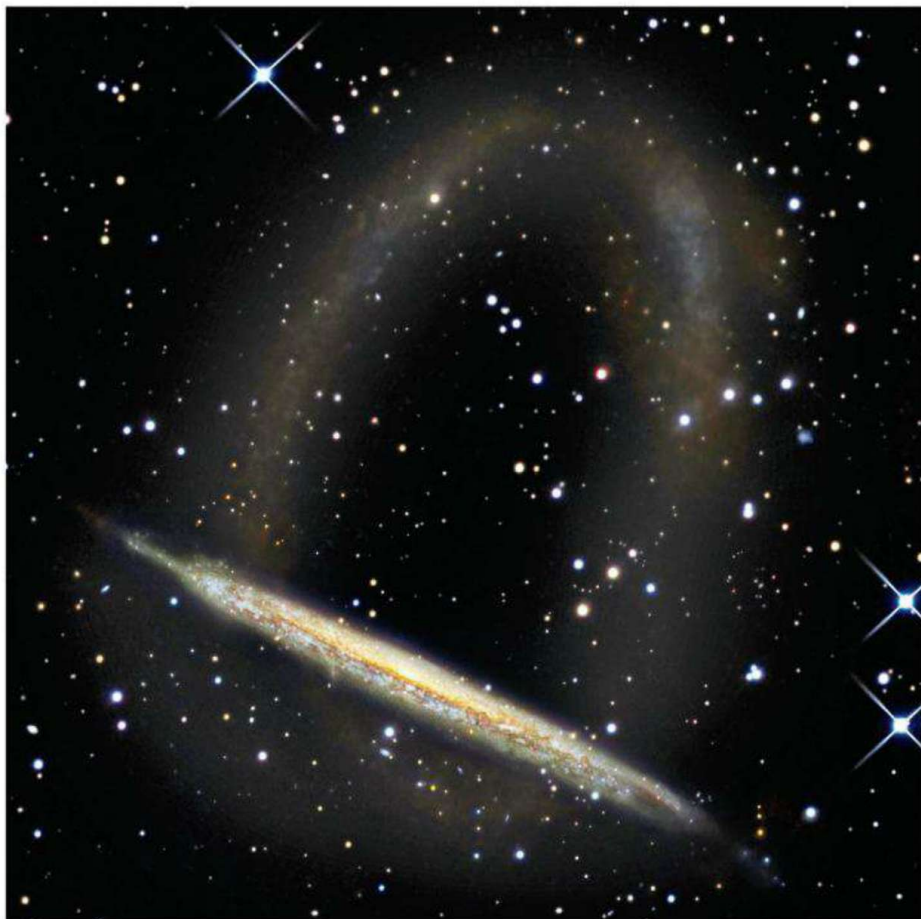
to form after the birth of the universe. Then, over time, they merged to build larger island universes like the Milky Way.

Martínez-Delgado's message indicated that my image of spiral galaxy M94 in Canes Venatici had caught his attention. It

turns out that my more than 13-hour total exposure had revealed a ringlike structure, reminiscent of a stellar stream, extending from the galaxy's bright central region where previous photographs only had displayed an amorphous band of encircling



NGC 3521 is also known as the Bubble Galaxy because it lies within debris shells that have persisted after the assimilation of one or more dwarf satellite galaxies in the distant past. The author used his 20-inch RC Optical Systems Ritchey-Chrétien telescope, an Apogee Alta U16M-HC CCD camera, and LRGB exposures of 570, 240, 240, and 240 minutes, respectively.



This deep image of the Splinter Galaxy (NGC 5907), located 50 million light-years from Earth in the constellation Draco, revealed a vast looping structure as evidence for the ancient accretion of a long-lost satellite galaxy. The author used his 20-inch RC Optical Systems Ritchey-Chrétien telescope, an SBIG STL-11000 CCD camera, and LRGB exposures of 465, 120, 72, and 144 minutes, respectively, for this image.

stars. He asked if I would like to join his team of astronomers in a quest for galactic stellar fossils. I eagerly agreed.

Pro-am collaboration

As the first project, Martínez-Delgado asked me to process infrared and ultraviolet images of M94 produced through NASA's Spitzer and Galaxy Evolution Explorer space telescopes. These pictures confirmed that an extended set of faint spiral arms surrounds M94, as first indicated by my digital photograph. Ultimately, the team's research paper proposed that these dim structures were not caused by the gravitational disruption of a dwarf galaxy but instead an oval distortion propagating outward from M94's core.

Although this initial project failed to uncover evidence for galactic merger activity, it did provide other conclusions. Our pro-am collaboration supported Martínez-Delgado's suspicion that such a partnership could equal or outperform results obtained from professional instruments in the detection of faint, diffuse wide-field features. His belief arose from recent CCD advances both in sensitivity and larger affordable chips combined with the virtually limitless observation time available to privately owned observatories.

Next, Martínez-Delgado asked me to obtain deep images of NGC 4013, an edge-on spiral located about 55 million light-years from Earth toward the constellation Ursa Major. Also known as the Diamond Ring Galaxy because of its coincidental alignment behind a bright Milky Way star, this stellar system had always been regarded as a galaxy in isolation. Based on hints seen in images collected with the Kitt Peak National Observatory 0.9-meter and the Isaac Newton 100-inch telescopes, however, the team suspected it might be surrounded by a river of stars — the relics of a satellite galaxy absorbed by its larger host spiral. The results of my nearly 15-hour exposure revealed, for the first time, a giant looping structure that matched predictions for an edge-on, projected view of a stellar tidal stream from a dwarf satellite moving in a close, nearly circular orbit.

Continued success

Although I had anticipated each project with Martínez-Delgado would be my last, the relationship has continued. Next up was the Splinter Galaxy (NGC 5907) in Draco, long considered a prototypical example of a warped spiral in relative isolation. My more than 13-hour exposure revealed, however,

LONG EXPOSURES

The author often captures long-exposure photographs of well-known targets beyond the galaxies he currently images for his research. He used a 20-inch RC Optical Systems Ritchey-Chrétien telescope and an SBIG STL-11000 CCD camera for each of these LRGB photos.



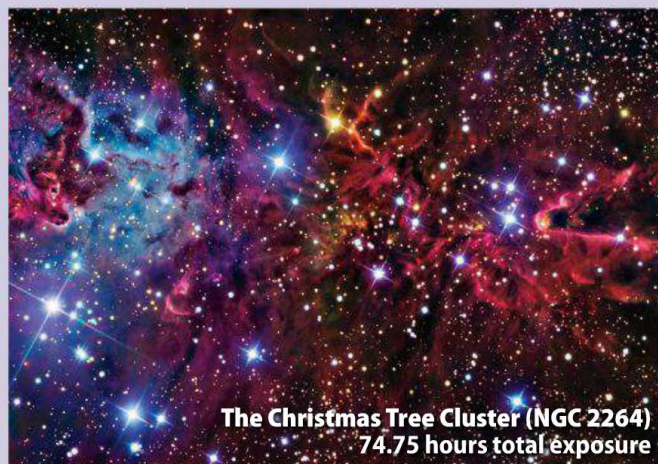
The Omega Nebula (M17)
18.7 hours total exposure



The Crab Nebula (M1)
24.2 hours total exposure



The Iris Nebula (NGC 7023)
20 hours total exposure



The Christmas Tree Cluster (NGC 2264)
74.75 hours total exposure

that spectacular looping stellar contrails surround the galaxy. These structures represent the final orbits of a small satellite galaxy that was subsequently disrupted and absorbed by its larger companion long ago.

For a survey of stellar tidal streams in nearby spiral galaxies, we studied the Umbrella Galaxy (NGC 4651) in Coma Berenices, one of the most remarkable and brightest examples of galactic accretion we've so far detected. The galaxy exhibits a jetlike spear that's strikingly coherent and narrow. Although astronomers previously reported this structure in 1959, no scientist ever interpreted it as a stellar tidal stream. However, my 13-hour image also revealed a spectacular crescent-shaped shell surrounding the east side of the star system that

resembles an umbrella and corresponds to the epicenter of the former dwarf galaxy.

We also studied the Bubble Galaxy (NGC 3521) in Leo, which scientists have classically categorized as a flocculent galaxy due to the enormous amount of material partially obscuring its spiral structure. However, my 21-hour image revealed evidence of one or more previous mergers with dwarf galaxies that left discernible substructures, such as an almost spherical cloud of debris visible on its eastern side and a large, elongated cloud to the west. Both represent debris shells belonging to an umbrella-like structure similar to that seen in my image of NGC 4651. But their looser appearance suggests they were accreted much further in the past. Moreover, the

galaxy is enveloped in a bubble of multiple debris shells that may represent additional evidence of ancient mergers.

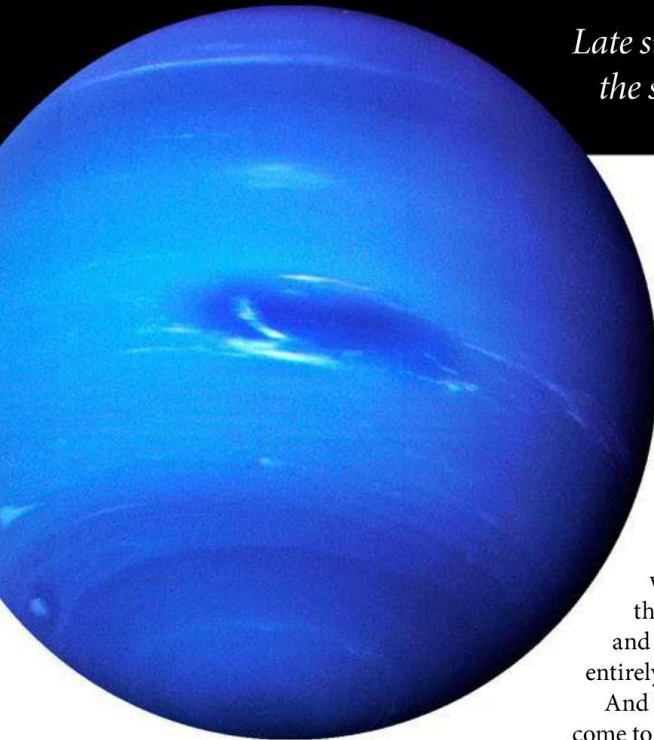
Moving forward

Today, I'm a co-author on 10 peer-reviewed scientific papers, and several others are in various stages of completion. Martínez-Delgado and I also intend to publish a book summarizing the results of our research sometime in the near future. Because of this continued relationship, my imaging target list now includes seldom-pictured galaxies that greatly interest Martínez-Delgado and his team. Who knew one email encounter could open the exciting potential for an amateur astroimager to make contributions to our understanding of the universe. ☛



PRIME TIME for NEPTUNE & URANUS

Late summer and early fall are the best times to track down the solar system's distant planets. **by Richard Talcott**



▲ Neptune's cloud patterns showed up nicely to the cameras aboard the Voyager 2 spacecraft when it flew past in 1989. NASA/JPL

▲ Triton appears as a conspicuous dot to Neptune's upper right in this amateur photo of the most distant major planet. DAMIAN PEACH

When the solar system formed some 4.5 billion years ago, the dust-rich, gaseous nebula that surrounded the emerging Sun produced eight major planets and so many dwarf and minor planets that astronomers have yet to catalog them all. Out of all the bodies that formed, however, the solar nebula apparently gave birth to only one set of twins.

Uranus and Neptune are more alike than any other pair of solar system objects scientists have studied in detail. They have

nearly identical masses and diameters, similar compositions and colors, and faint dusty ring systems that resemble each other more than they do either Jupiter's or Saturn's. Astronomers refer to Uranus and Neptune as "ice giants" to differentiate them from their larger gas-giant cousins. The "ice" refers to the significant amounts of methane, water, and similar compounds in their interiors compared with Jupiter and Saturn, which consist almost entirely of hydrogen and helium.

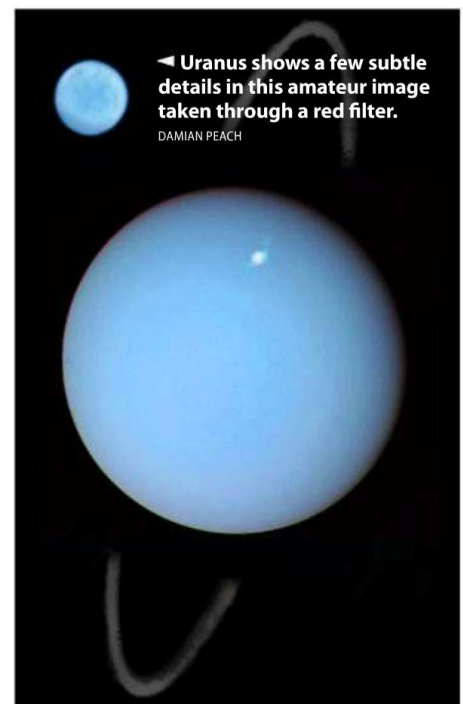
And this year, these two peas in a pod come to opposition and best visibility just over a month apart. Neptune reaches this position August 26 while Uranus follows suit October 3. Whenever a planet lies opposite the Sun in our sky, it rises near sunset, appears highest in the south around local midnight (1 A.M. daylight time), and sets as the Sun comes up. Opposition also marks a planet's closest approach to Earth and the time when it shines brightest. For these distant worlds, however, the differences are subtle: Neither appears more than 0.1 magnitude dimmer than its peak at any time from early August to late October.

The two also occupy the same general area, lying in adjacent constellations among the so-called watery star groups that encompass much of the early autumn sky. Uranus moves slowly against the backdrop of southern Pisces the Fish while Neptune plies the central region of Aquarius the Water-bearer. Their proximity to each other provides backyard observers with a perfect opportunity to track them both down on any clear night during our three-month window.

Flying above the water

With a go-to telescope, you probably could bag both of these planets in five minutes. But what's the fun in that? With a little more effort, you can spy these two worlds with nothing more sophisticated than binoculars. And under a clear, dark sky, you can spot Uranus with naked eyes if you know where to look.

The autumn sky's most prominent star pattern is your gateway to the planets. The Great Square of Pegasus comprises four similarly bright stars: Alpha (α), Beta (β), and Gamma (γ) Pegasi, with Alpha Andromedae forming its northeastern

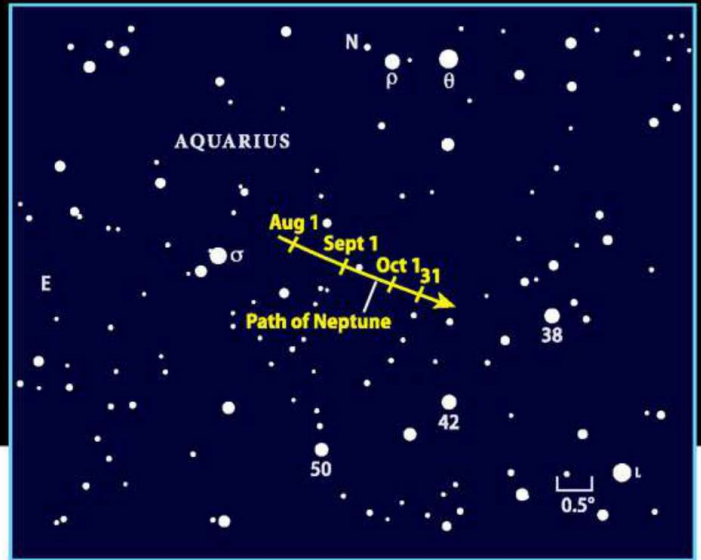


◀ Uranus shows a few subtle details in this amateur image taken through a red filter. DAMIAN PEACH

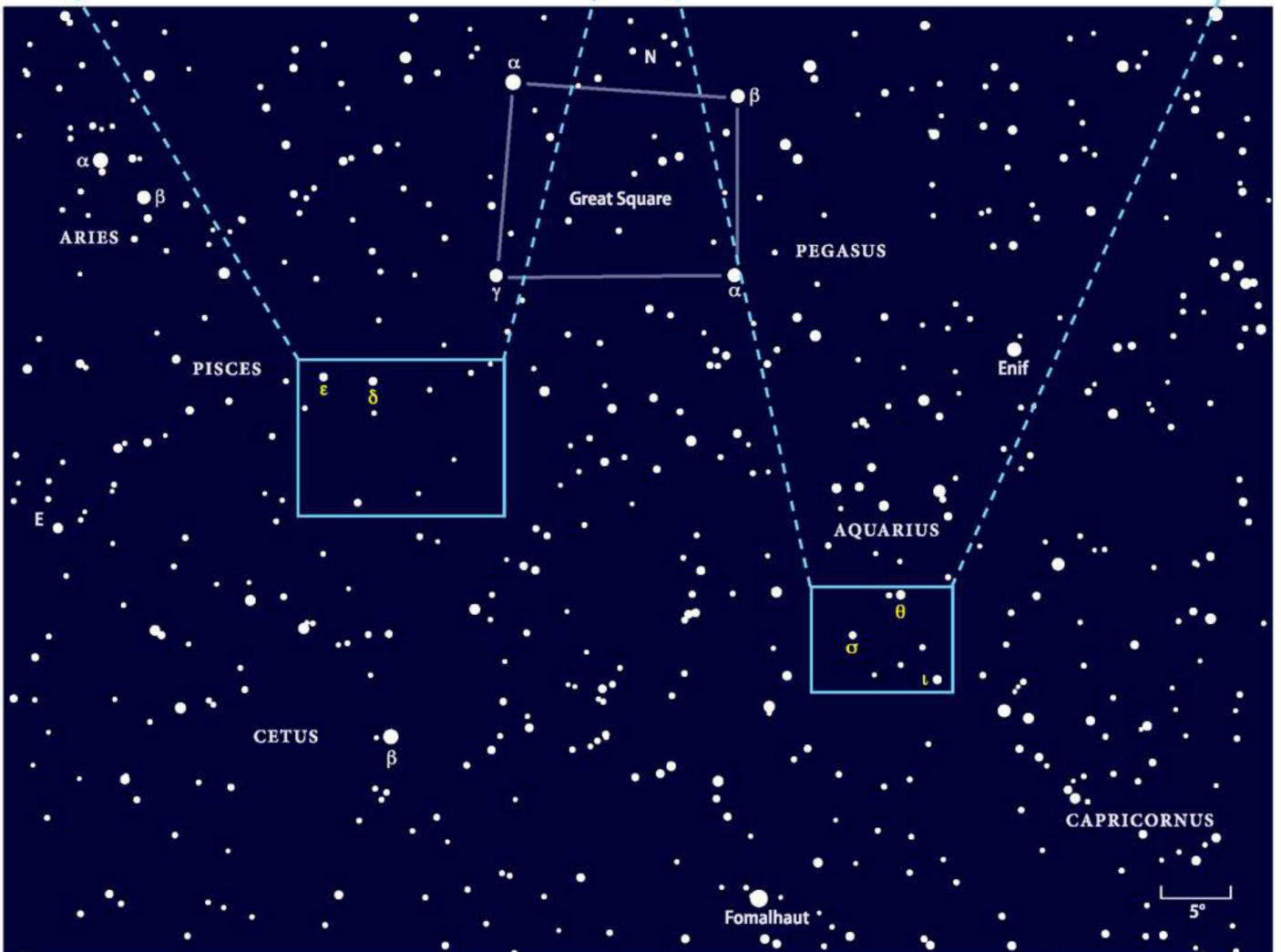
Hubble's sharp eye was able to capture Uranus' faint rings and whitish aurora in 2011. The planet's distinctive color, however, most impresses backyard observers. NASA/JPL



Fourth-magnitude Delta (δ) Piscium, which lies 12° southeast of Gamma (γ) Pegasi (at the southeastern corner of the Great Square), will get you to Uranus' vicinity. Once you find Delta, drop approximately 4° south and a bit west to find the planet. ASTRONOMY: ROEN KELLY



Use the 5th-magnitude stars Sigma (σ) and 38 Aquarii as your guides to Neptune. This stellar pair resides nearly 30° south-southwest of Alpha (α) Pegasi, the Great Square's southwestern corner. The planet remains between these two stars from August to October. ASTRONOMY: ROEN KELLY



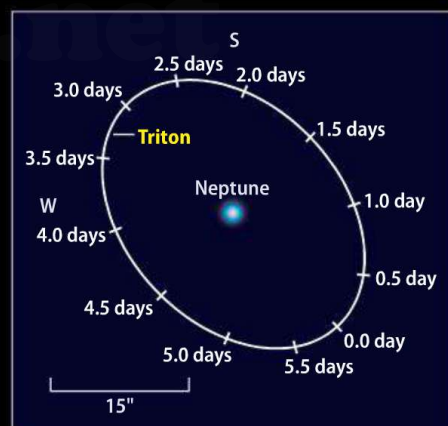
The distant planets Uranus and Neptune reach peak visibility this year in late summer and autumn. You can find their locations in adjacent constellations south of the Great Square of Pegasus, the four bright stars at the top center of this map. ASTRONOMY: ROEN KELLY

TRITON

Date	Greatest eastern elongation	Date	Greatest eastern elongation
Aug. 1	4 P.M. EDT	Sept. 17	5 P.M. EDT
Aug. 7	1 P.M. EDT	Sept. 23	2 P.M. EDT
Aug. 13	10 A.M. EDT	Sept. 29	11 A.M. EDT
Aug. 19	7 A.M. EDT	Oct. 5	8 A.M. EDT
Aug. 25	4 A.M. EDT	Oct. 11	5 A.M. EDT
Aug. 31	1 A.M. EDT	Oct. 17	2 A.M. EDT
Sept. 5	10 P.M. EDT	Oct. 22	11 P.M. EDT
Sept. 11	8 P.M. EDT	Oct. 28	8 P.M. EDT



Neptune's Triton boasts watery geysers and cantaloupe-like terrain, though this distant view from Voyager 2 doesn't reveal these intriguing features. NASA/JPL



Track down Neptune's Triton late this summer or in autumn by calculating how far it has progressed along its orbit since its previous greatest eastern elongation. ASTRONOMY: ROEN KELLY

corner. The Square stands out in an otherwise unremarkable area. It clears the eastern horizon by 10 P.M. local daylight time in early August and reaches its highest position in the south around 4 A.M. Earth's motion around the Sun brings the Square to the same position two hours earlier every month, so by early October, you can find it due south around midnight.

Both Uranus and Neptune lie generally south of the Great Square. Since Neptune reaches opposition before its sibling, let's target it first. Head about 20° (roughly three binocular fields) south-southwest of Alpha Peg, and you'll spy a Y-shaped group of stars known as the Water Jar. Neptune lies 10° due south of this asterism.

The planet spends the summer and fall moving in a west-southwest direction between Sigma (σ) and 38 Aquarii. Use these two 5th-magnitude stars to zero in on Neptune. In early August, the planet resides 1° west of Sigma. This gap grows to 1.7° by opposition, when Neptune glows at magnitude 7.8. Coincidentally, the planet slides just 4' south of a similarly bright star the evening of September 10. By the end of October, Neptune has pulled 3° away from Sigma and within 2° of 38 Aqr.

The close-up finder chart at the top right of p. 81 shows stars a full magnitude (a factor of 2.5 in brightness) fainter than Neptune, so you should be able to tell which object the planet is without a problem. To confirm your identification, target it through your telescope and insert an

eyepiece that provides a magnification of at least 150x. The planet should show a tiny but distinct disk that measures 2.4" across and a noticeable blue-gray hue.

Closer to the Square

Once you've found Neptune, the hunt for Uranus should be a breeze. Not only does Uranus glow some seven times brighter than Neptune, but it also lies significantly closer

**AT OPPOSITION
AUGUST 26, NEPTUNE
SHINES AT MAGNITUDE 7.8
FROM A DISTANCE OF 2.69
BILLION MILES (4.35
BILLION KILOMETERS).**

to the Great Square. Start at the Square's southeastern corner (Gamma Peg) and head 12° southeast to 4th-magnitude Delta (δ) Piscium. This will serve as your Uranus guide star for the next several months.

At the beginning of August, the planet lies 3.5° from Delta, just a tick west of due south. Like Neptune, Uranus follows a west-southwesterly track, but it moves noticeably faster owing to its quicker orbital pace. By the time of its early October opposition, the planet lies in a tight triangle of 6th- to 8th-magnitude stars that spans less

than 1°. The solar system world shines at magnitude 5.7, significantly brighter than any of its stellar neighbors.

Once you've found Uranus through binoculars, set them aside so you can look for the planet with your naked eyes. If you have good eyesight and view from a dark location, you should be able to spot it. If not, look a bit to the side of the planet's position. This technique uses your eyes' more light-sensitive rods, which could be just the boost you need to see it.

The close-up map at the top left of p. 81 depicts stars more than two magnitudes fainter than Uranus, so you should have no trouble identifying the planet from the starry background. A telescope operating at 100x can verify your find by revealing the planet's 3.7"-diameter disk and striking blue-green color.

A trio of faint moons

Merely spotting the ice giants brings a thrill to many novice observers. As the first planets discovered since antiquity, they have a cachet that the more familiar planets can't match. And because you can't just walk outside and spot them right away, the effort delivers a certain amount of satisfaction.

If difficult observations breed happiness, however, Uranus and Neptune could be your tickets to nirvana. Although the planets are relatively easy to find, their moons are exceedingly hard to pick out from the starry background.

Most amateur astronomers realistically can hope to spy two satellites of Uranus — Titania and Oberon — and Neptune's Triton. The first two glow at magnitudes 13.2 and 13.4, respectively, when Uranus

TITANIA

Date	Greatest northern elongation
Aug. 6	10 P.M. EDT
Aug. 15	3 P.M. EDT
Aug. 24	8 A.M. EDT
Sept. 2	1 A.M. EDT
Sept. 10	6 P.M. EDT
Sept. 19	11 A.M. EDT
Sept. 28	4 A.M. EDT
Oct. 6	9 P.M. EDT
Oct. 15	2 P.M. EDT
Oct. 24	7 A.M. EDT

OBERON

Date	Greatest northern elongation
Aug. 12	3 A.M. EDT
Aug. 25	2 P.M. EDT
Sept. 8	1 A.M. EDT
Sept. 21	noon EDT
Oct. 4	11 P.M. EDT
Oct. 18	10 A.M. EDT
Oct. 31	10 P.M. EDT



Uranus' biggest moon, Titania, shows mottled patches and a large canyon in this Voyager 2 view. NASA/JPL



The ice-covered surface of Oberon showed vague patches of light and dark to Voyager 2's cameras in 1986. NASA/JPL

comes to opposition; Triton shines at magnitude 13.0 when Neptune reaches its peak. To see any of them, you'll need a 10-inch or larger telescope.

These moons' faintness is only part of the problem, however: None strays far from its host. Oberon never appears more than 44" from Uranus while Titania maxes out at 33". Triton is the easiest of the three to see even though it always remains within 17" of Neptune. It triumphs because it glows slightly brighter than the others and Neptune produces much less glare than Uranus.

The key to finding any of them is knowing how, when, and where to look. First, you'll need an observing site with a dark transparent sky. You'll also want to choose one where the seeing is steady. Turbulence in Earth's atmosphere will cause planetary images to appear mushy and wash out the faint moons entirely.

Steer clear of sites that look out over parking lots, buildings, or rooftops — anything that absorbs the Sun's energy during the day and reradiates it at night. Observing over a grassy field or a large body of water helps a lot. So does leaving your scope outside for an hour before viewing so it has time to reach the ambient air temperature.

You'll also want to avoid glare from Earth's Moon. Try to observe within a week or so of a New Moon, which occurs August 6, September 5, and October 4.

The orbital diagrams at the top of these pages will help you figure out where the moons reside at any time you observe. For Uranus (above), the adjacent tables list the times of Titania's and Oberon's greatest northern elongations during August, September, and October. The current geometry

of the uranian system places the satellites farthest from Uranus when they are either north or south of the planet.

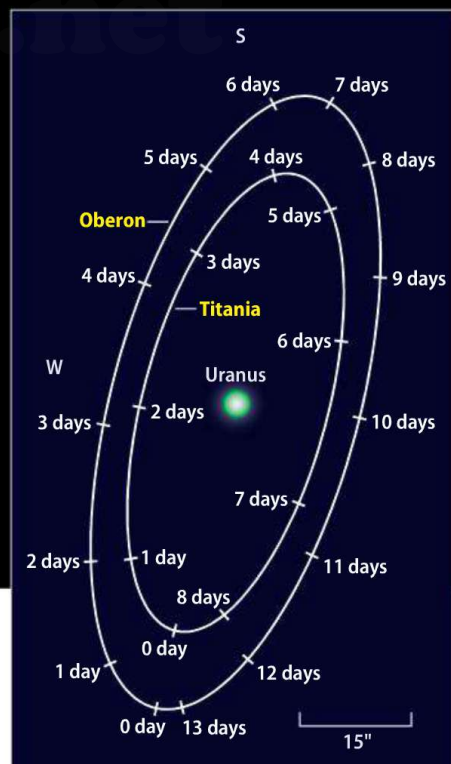
After you decide when you want to look for the moons, calculate for each moon how much time has elapsed since the previous elongation. For example, if you plan to observe at 10 P.M. EDT the night Uranus reaches opposition (October 3), you'll find Titania's previous northern elongation

**AT OPPOSITION
OCTOBER 3, URANUS
SHINES AT MAGNITUDE 5.7
FROM A DISTANCE OF 1.77
BILLION MILES (2.85
BILLION KILOMETERS).**

occurred September 28 at 4 A.M. EDT, so 4 days and 18 hours have elapsed. Similarly, 11 days and 10 hours have passed since Oberon was at its greatest elongation.

Then use the diagram to figure out approximately where on its orbit each moon lies. The farther from Uranus a moon appears, the easier it will be to see. The illustration shows south at top to match the view through most telescopes when the planet lies highest in the south.

The same technique works for Triton (opposite page). For this moon, the table



Uranus' two most conspicuous moons, Titania and Oberon, never stray far from the planet's glare. Plot their positions on this chart based on the time elapsed since they last reached greatest northern elongation.

lists greatest eastern elongations because the moon lies farthest from Neptune at that point and at the opposite side of its orbit. If you observe on the August 26 opposition at 11 P.M. EDT, the moon will be 1 day and 19 hours along its orbit. If you see a faint speck in this position, you've found Triton.

Going even deeper

If these moons don't offer enough of a challenge, Uranus has two harder-to-see moons that will test your observing acumen. With a 16-inch telescope, a high-power eyepiece, and excellent viewing conditions, you just might glimpse the smaller satellites Ariel and Umbriel. Ariel glows at magnitude 13.2 but remains within 14" of Uranus; magnitude 14.0 Umbriel never appears more than 20" from the planet. Use planetarium software to pinpoint their positions before you begin your search.

No matter how deeply you want to test your observing skills, Uranus and Neptune provide a valuable exam. Take 10 or 15 minutes to hunt down a pair of solar system siblings using nothing more than binoculars, or haul out your big scope and scour distant worlds searching for faint moons. Either way, you'll get an observing thrill that's hard to beat. ☾

NEW PRODUCTS

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Pleasanton, California

SBIG's STT-8300M CCD camera features two-stage cooling, twin variable-speed fans, USB 2.0 and Ethernet, and a fast, low-noise readout of the 8.3-megapixel chip. It measures 4.9 by 4.9 by 2.9 inches (12.5 by 12.5 by 7.4 centimeters).

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[t] 925.463.3410

[w] www.sbig.com



Equatorial mount

Celestron, Torrance, California

Celestron's Advanced VX Mount features programmable periodic error correction. New motors offer improved tracking and more power. The mount is usable through a latitude range of 7° to 77°, and the NexStar+ hand control offers programming in five languages.

Price: \$799

[t] 310.328.9560

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GPS receiver

PixSoft, Winnipeg, Canada

PixSoft's GPX-NX02 is a 65-channel GPS receiver that lets you add GPS to your telescope's mount. The unit measures 1.5 by 1.8 by 0.6 inch (39 by 45 by 16 millimeters). The package includes the receiver and a cable for your scope.

Price: \$99

[t] 204.885.4936

[w] www.stargps.ca



12-inch telescope

Officina Stellare

Thiene, Italy

Officina Stellare's RIDK 305 is a 12-inch f/7.9 telescope with Riccardi Dall-Kirkham optics. It features a zero-expansion carbon truss-tube, a split light baffle, three fans, four Losmandy-type dovetails, and manually controlled heated mirrors.

Price: 13,500 euros

[t] 323.927.1020

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Equatorial wedge

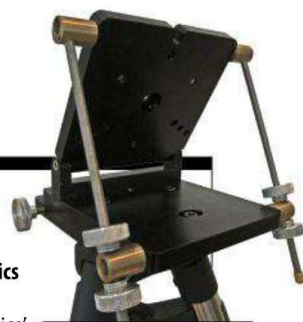
All American Astronomics
Shalimar, Florida

All American Astronomics' Cosmic-Wedgie is an adapter that turns your alt-azimuth mount into an equatorial mount. The unit features stainless-steel pivot bolts and rods, anodized aluminum plates, and brass adjustment pivots.

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[t] 850.543.7052

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Go-to mount

iOptron Corporation, Woburn, Massachusetts

iOptron's iEQ45-AZ German Equatorial-Altazimuth GOTO Mount comes with a rigid portable pier. The mount's payload is 45 pounds (20.4 kilograms) in equatorial mode or 90 pounds (40.8kg) in alt-azimuth.

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Astronomy at 40



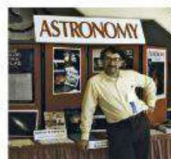
David J. Eicher looks back

This issue marks the 40th anniversary of *Astronomy* magazine, as you'll see celebrated throughout its pages. Since Steve Walther published the first issue in August 1973, the magazine, along with the science and the hobby, has seen its share of triumphs and tribulations.

As David J. Eicher points out in a special anniversary video, *40 years of Astronomy magazine*, the key to the publication's achievements has been the people who work on it. He recalls the magazine's humble beginnings and early successes, the challenges it faced with Walther's sudden passing, the corporate transition the staff dealt with in becoming part of a much larger publishing company, and more. Eicher also chronicles some of the events *Astronomy* covered during the past 40 years, from the Voyager missions and the Dobsonian revolution, to the launch of the Hubble Space



Telescope and the spectacular showing of Comet Hale-Bopp, to the discovery that the universe's expansion is accelerating and the demotion of Pluto. Relive *Astronomy*'s first 40 years with Eicher at www.Astronomy.com/history.



OBSERVING TOOLS

"How to observe meteor showers"

Meteor showers are one of the most popular celestial events because they don't require any observing experience — only comfort and patience. And August brings the biggest shower of 2013, as the Perseids peak under Moon-free conditions. To prepare for these "shooting stars," check out Senior Editor Michael E. Bakich's video "How to observe meteor showers." In it, he explains the basics of what causes these events, where and when to watch, what to bring, and much more. Let Bakich help you get ready for August's Perseids by visiting www.Astronomy.com/intro.



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NEXT ISSUE

The NEW SEARCH for ALIEN INTELLIGENCE

Hunting for ET now involves Dyson spheres, infrared signals, and laser communications. It's definitely not your father's method for locating cosmic intelligence.

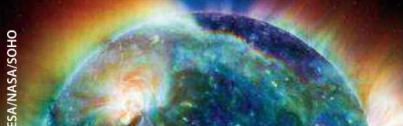
Seth Shostak/SETI Institute



What an active Sun means for Earth

A serious solar storm could cause an electromagnetic mess.

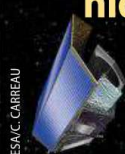
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Astronomy 2013 Summer Sweepstakes OFFICIAL RULES

1. No Purchase Necessary. Official entry forms are bound in the June 2013, July 2013, and August 2013 issues of *Astronomy* magazine. The *Astronomy* 2013 Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and sponsoring companies are not eligible to participate.

2. Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with your name, address, city, state or province, and zip or postal code to: The *Astronomy* 2013 Summer Sweepstakes, P.O. Box 378, Waukesha, WI 53187-1199. Or enter online at www.Astronomy.com/sweepstakes by filling in the Online Entry Form and hitting the SUBMIT ENTRY key. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the 2013 Summer Sweepstakes will be July 19, 2013, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around September 17, 2013, for the following awards: One (1) Grand Prize consisting of a SkyProdigy 6 (retail value \$999.00). One (1) First Prize consisting of an AstroMaster 70AZ (retail value \$149.95). One (1) Second Prize consisting of a SkyMaster 15x70 Binoculars (retail value \$89.95). One (1) Third Prize consisting of a Celestron FirstScope w/accessory kit (retail value \$59.95). Ten (10) Fourth Prizes consisting of a one-year subscription to *Astronomy* magazine (retail value \$42.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 106,841. Sweepstakes void in Quebec and void where prohibited.

4. Validation and Acceptance. Winners in the *Astronomy* 2013 Summer Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Co. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late, or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release, and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected, or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing Co. and will not be returned.

5. Winner's List. For a list of winners, send a stamped, self-addressed envelope to: The *Astronomy* 2013 Summer Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. Residents of FL, VT, and WA may omit stamp. Requests must be received by July 19, 2013. Or check the *Astronomy* website (www.Astronomy.com) after November 16, 2013.

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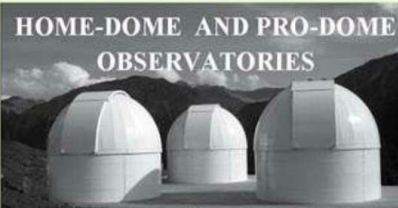


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1. GALACTIC GATHERING

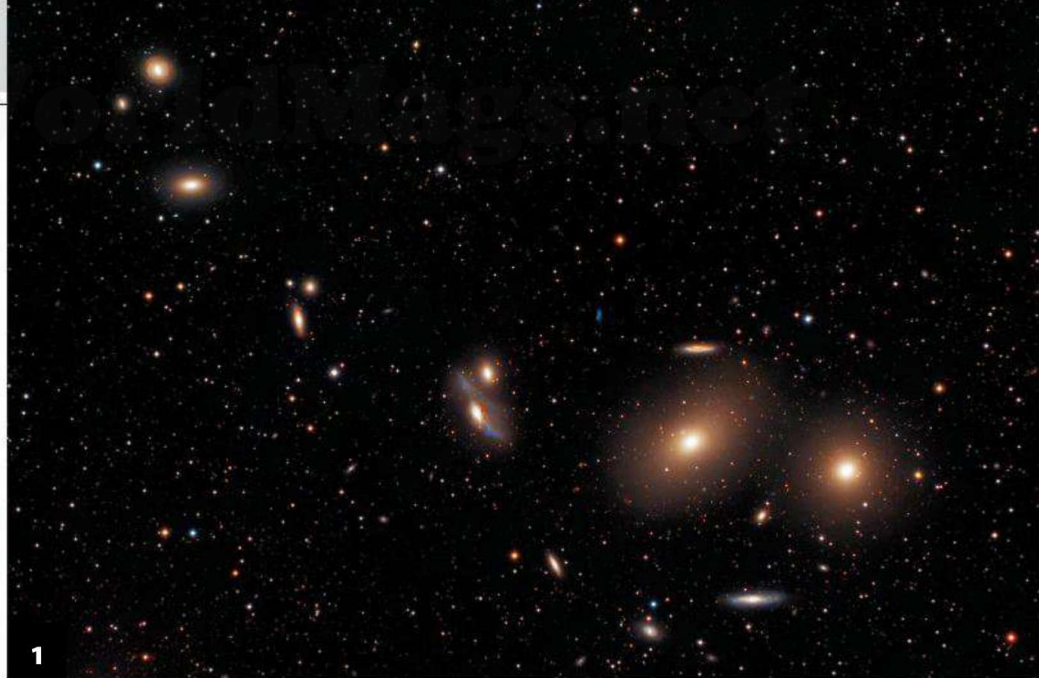
Markarian's Chain stretches through parts of Coma Berenices and Virgo. The large lenticular galaxies M84 (right-most) and M86 form the chain's western boundary. From those two giants, the chain swings to the northeast. Where it stops depends on your perspective, but most observers end it at the bright galaxy to the upper left — NGC 4477. (4-inch Takahashi FSQ-106ED refractor at f/5, SBIG STF-8300 CCD camera, LRGB image with exposures of 430, 161, 193.2, and 230 minutes, respectively)

• *Bob Franke*

2. BOLIDE!

Imagine this photographer's surprise when a brilliant bolide (an exploding meteor) superimposed itself on her image of an aurora. The Pleiades (M45), Taurus, and Jupiter are visible to the left of the meteor. (Nikon D800 DSLR, 24–70mm f/2.8 lens set at 24mm and f/3.2, ISO 800, 8-second exposure taken March 29, 2013, at 11:16 P.M. CST, from Patricia Beach, Manitoba, Canada)

• *Shannon Bileski*



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.



3. ATMOSPHERIC COLORS

Airglow, the gegenschein (counter-glow), and the Milky Way are all visible in this image captured at Las Campanas Observatory in Chile. The green color comes from atomic oxygen emission. Air glow is one of the most overlooked phenomena in astrophotography; instead, it is often considered a side effect. Unlike aurorae, you can see air glow from anywhere on the planet, irrespective of the latitude. (Canon 5D Mark II DSLR, Nikon 14–24mm lens set at f/2.8, three 3-minute exposures, stacked) • *Yuri Beletsky*

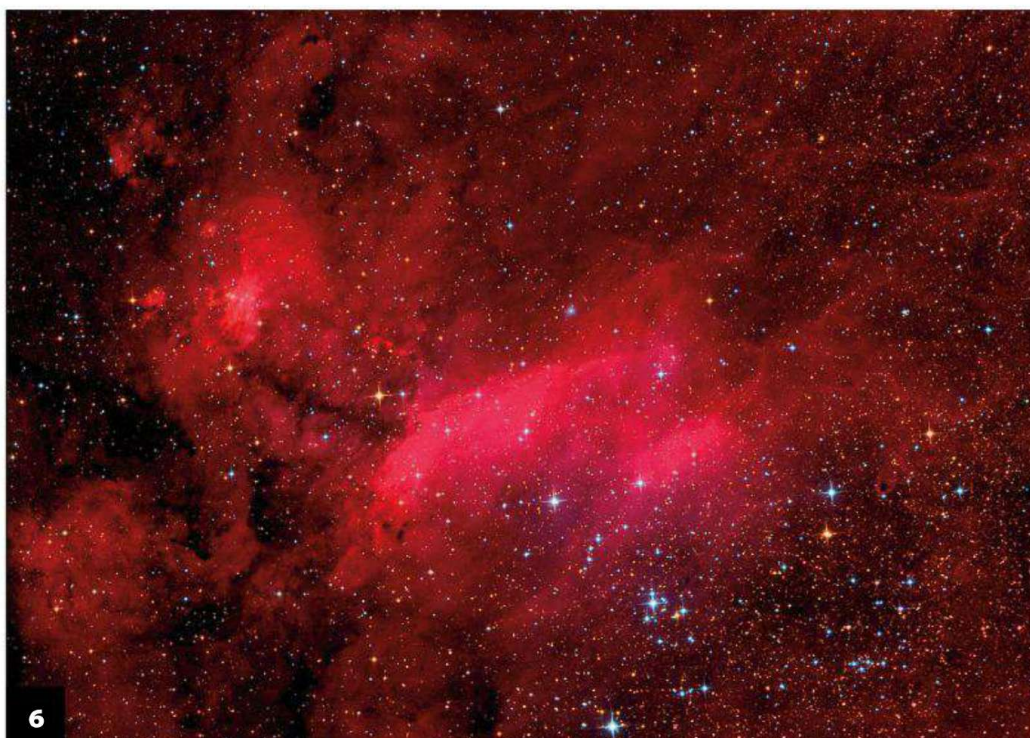


4. SUPERNOVA!

M65 is a magnitude 9.3 spiral galaxy in the constellation Leo the Lion. This image shows it with a guest — Supernova 2013am (arrow). Although the galaxy is relatively close, about 35 million light-years away, the supernova still glowed weakly at 16th magnitude. (17-inch corrected Dall-Kirkham reflector at f/4.5, FLI PL-6303E CCD camera, LRGB image with exposures of 25, 5, 5, and 5 minutes, respectively, taken April 1, 2013, at 3h47m UT) • *Damian Peach*

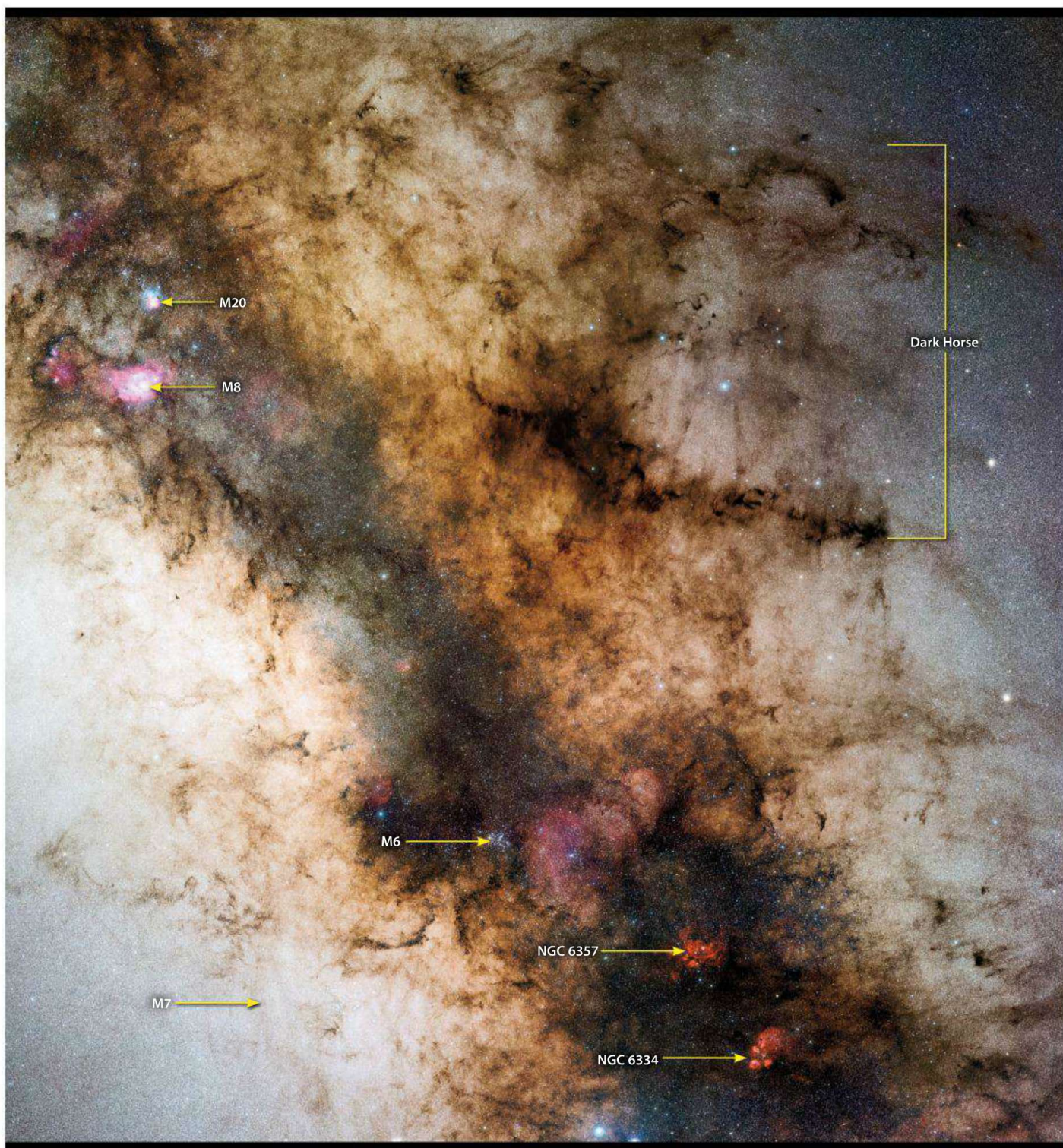
5. GALAXY PAIR

Lenticular galaxy M85 (center) floats through space accompanied by its companion, barred spiral galaxy NGC 4394. The two shine at magnitudes 9.1 and 9.8, respectively, and lie in the constellation Coma Berenices. (8-inch Telescope Engineering Company TEC-200ED refractor at f/9, SBIG STL-11000M CCD camera, LRGB image with exposures of 255, 180, 180, and 180 minutes, respectively) • *Lee Buck*



6. THE PRAWN NEBULA

Emission nebula IC 4628 spans 1.5°, meaning that it covers as much area as eight Full Moons. It lies in an incredibly rich star field in Scorpius and is about 6,000 light-years away. (16-inch Dream Telescopes Astrograph at f/3.75, Apogee Alta U16M CCD camera, H α RGB image with exposures of 25, 6, 6, and 6 minutes, respectively) • *Kfir Simon*



ESO'S GUISARD

Center of the Milky Way like never before

Astronomers at the European Southern Observatory's (ESO) facility in Cerro Paranal, Chile, created this breathtaking mosaic of the center of our galaxy. This 340-million-pixel starscape was made by imager Stéphane

Guisard, an ESO engineer. It shows features of the central Milky Way, from the star clouds in the direction of the galactic center to the bright pink Lagoon (M8) and Trifid (M20) nebulae, to the red emission nebulae

NGC 6334 and NGC 6357. Also visible are dark nebulae, including the "Great Galactic Dark Horse," and many bright star clusters like M6 and M7. This amazing mosaic consists of more than 1,200 images. 

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October 2013: An evening extravaganza

A fine trio of planets gathers in the western evening sky as October begins. Brilliant **Venus** will be the first to capture your attention. Shining at magnitude -4.2 , it shows up clearly nearly halfway to the zenith just half an hour after sunset. During October, Venus wanders a considerable distance eastward, moving from Libra into Scorpius and then into Ophiuchus, where it ends the month on the doorstep of Sagittarius. On the 16th, the planet passes 1.6° north of 1st-magnitude Antares.

Venus becomes a great subject to view through any telescope during October. At the beginning of the month, it appears $18''$ across and 63 percent lit. By month's end, it has grown to $25''$ in diameter and shows a perfect "half-Moon" phase.

Look lower in the western evening sky to spy **Mercury**. The innermost planet reaches greatest elongation October 9, when it lies 25° east of the Sun. As always, spring offers the best evening views of Mercury from the Southern Hemisphere because the ecliptic (the apparent path of the Sun and planets across the sky) then makes a steep angle with the horizon. On the 9th, the inner world shines at magnitude -0.1 and stands out as the sky darkens.

My favorite period for observing the Sun's smallest planet through a telescope occurs after greatest eastern elongation as it draws closer to the Sun. The ideal time this year comes around October

20, when Mercury's disk appears $8''$ across and shows a pleasing 35-percent-lit crescent. Within a week of this date, Mercury becomes lost to the evening twilight.

The third member of the evening trio is magnitude 0.6 **Saturn**. The ringed planet starts October to the upper right of Mercury, but the two worlds achieve the same altitude in the evening sky on the 7th. Coincidentally, the waxing crescent Moon lies nearby the same evening — just above Saturn with Mercury to their left.

By the final week of the month, Saturn suffers the same fate as Mercury and becomes lost in the twilight glow. This means the early part of October will be your last opportunity for several months to observe the ringed planet in the evening sky. Take advantage of the view early this month by aiming your telescope at the lovely planet. On the 1st, the rings span $35''$ and tilt 19° to our line of sight.

If you prefer to do your planet observing at the other end of the night, **Jupiter** fills the bill nicely. The giant planet rises about four hours before the Sun in early October and gains another hour on our star by month's end. It spends the entire month against the backdrop of Gemini the Twins and is clearly visible in the northeastern sky during the morning hours. It makes a fine sight above Gemini's brightest stars, Pollux and Castor, though the

magnitude -2.3 planet easily bests the stars.

Once Jupiter climbs reasonably high in the sky, around the time morning twilight begins, turn your telescope on it for a closer look. A small instrument easily reveals atmospheric detail on the planet's $39''$ -diameter disk. Also note the four bright moons, which appear in a different configuration every night.

The final bright planet emerges low in the east shortly before morning twilight commences. **Mars** lies among the background stars of Leo the Lion, not far from that constellation's brightest star, Regulus. For a few days around October 15, the two appear 1° apart and make a pretty pair through binoculars. At magnitude 1.6, ruddy Mars glows slightly fainter than the blue-white star. A telescope shows a featureless planet only $5''$ across.

The Full Moon on the night of October 18/19 dips into the outer part of Earth's shadow, which creates a **penumbral lunar eclipse**. The eclipse reaches its maximum at 23h50m UT, which favors viewers in Africa. The Moon won't darken much, however, because it never enters our planet's darker umbral shadow.

The starry sky

A constellation that rarely receives much attention lies high in the southern sky on October evenings. Indus the Indian comes by its obscurity

naturally — it possesses only one star as bright as 3rd magnitude. More prominent are the three birds that border it: Grus the Crane, Pavo the Peacock, and Tucana the Toucan.

Indus first appeared on a celestial chart in 1603 in Johann Bayer's classic, *Uranometria*. In this book, Bayer depicted Indus as a naked American Indian standing close to Pavo and holding arrows in both hands. He appears to be aiming one arrow toward the Peacock's body or tail feathers.

The only star in Indus with a proper name is Alpha (α) Indi. Curiously, for reasons that remain unclear, Jesuit missionaries decided to call it "The Persian." At magnitude 3.1, it's the constellation's brightest star.

Indus holds few objects worth viewing through small telescopes. Perhaps the best target is Theta (θ) Indi, a rather attractive double star located 9° southeast of Alpha. Its stars shine at magnitude 4.5 and 7.0 and are separated by $6''$. The dimmer star shows up better when you increase the magnification.

Indus also contains one of the nearest naked-eye stars: Epsilon (ϵ) Indi. This 5th-magnitude object lies 11.8 light-years from Earth. It is perhaps best known in popular culture because it was mentioned several times during the *Star Trek* series. It showed up first in the original television series, near the end of the episode "And the Children Shall Lead." ♀

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

OCTOBER 2013

Calendar of events

- | | |
|--|---|
| 1 The Moon passes 7° south of Mars, 6h UT | 14 Mars passes 1.0° north of Regulus, 22h UT |
| 3 Uranus is at opposition, 14h UT | 15 The Moon passes 6° north of Neptune, 6h UT |
| 5 New Moon occurs at 0h35m UT | 16 Venus passes 1.6° north of Antares, 16h UT |
| 6 The Moon passes 3° north of Mercury, 22h UT | 17 The Moon passes 3° north of Uranus, 21h UT |
| 7 The Moon passes 1.9° south of Saturn, 4h UT | 18 Full Moon occurs at 23h38m UT; penumbral lunar eclipse |
| 8 The Moon passes 5° north of Venus, 12h UT | 21 Orionid meteor shower peaks
Mercury is stationary, 15h UT |
| 9 Mercury is at greatest eastern elongation (25°), 10h UT | 25 The Moon is at apogee (404,557 kilometers from Earth), 14h24m UT
The Moon passes 5° south of Jupiter, 22h UT |
| 10 Mercury passes 5° south of Saturn, 19h UT
The Moon is at perigee (369,814 kilometers from Earth), 23h14m UT | 26 Last Quarter Moon occurs at 23h40m UT |
| 11 First Quarter Moon occurs at 23h02m UT | 30 The Moon passes 6° south of Mars, 1h UT |
| 13 The Moon passes 0.9° south of asteroid Juno, 2h UT | |



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