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March 2016 VOL. 131, NO. 3

On the cover: The Great Red Spot has noticeably shrunk and changed color since Voyager 1 took this image in 1979.

PHOTO: NASA, PROCESSED BY BJÖRN JÖNSSON

FEATURES

GEMINI OBSERVATORY

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OBSERVING MARCH

S&T TEST REPORT

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Charlie has been taking so many awesome pictures with the Star Adventurer it was difficult to choose one for this ad.
Thanks, Charlie!
Milky Way image
Photographer: Charlie Warren
Camera: Canon 60Da
6 panel panorama with 4 minute exposures
8mm fisheye lens at f/3.5
ISO 1600
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Escape to the Stars

SOMETIMES IT CAN SEEM that the world is going to hell in a handbasket. The other night I watched President Obama's live address from the Oval Office about the fight against terrorism, and each of the place-names he mentioned brought to mind its own agonizing memories: San Bernardino. Fort Hood. Chattanooga. Boston. Paris.

We all need ways to try to make sense of such unthinkable deeds, which recently have seemed to reach new depths of depravity. In the wake of each new atrocity, perhaps you talk things over with family and friends. Read or hear commentary from experts. Take a walk and reflect. Listen to our president.

But making sense of what appears senseless can seem an impossible task, and sometimes we just want to get away from it all. Where can we turn for relief, an escape from the madness, if even for a moment?

One obvious answer, and I hardly need to tell you this, is to look up. Gaze at the heavens. Take yourself off our planet altogether. If you're in a light-polluted location, even a meditation on the Moon will do it. Contemplating the universe and our place in it can bring immediate peace of mind, I find. I feel enormously grateful to have this refuge.


S&T: SEAN WALKER

The night sky offers a perfect counterpoint to acts of terrorism down below on our world. Here, disorder; there, order. Here, the unpredictable; there, the predictable. Here, noise; there, silence. All manner of violent happenings do take place in space — supernovae, gamma-ray bursts. Yet from our distant vantage on Earth the heavens appear purely peaceful.

I also find relief somehow in the thought that all that human brutality transpires in an incredibly thin sheath of breathable air that hugs the surface of our planet. Go up a short distance, and it's space that goes on forever. Go down a short distance, and it's solid (or molten) rock all the way to the center of the Earth. Does anything occurring in that narrow envelope make any difference to all that surrounds it above and below? Not a bit. It doesn't matter one iota.

Of course, the escape brought by stargazing and musing on our true place in the cosmos is temporary. We can't hide our heads in the stars. We have to face reality, because what happens in our thin sheath *does* matter.

But it's comforting to think that we can return to the celestial sphere whenever we want. The consolation we can draw from it is available to anyone anytime. It's like the love of your parents or children — it will always be there, ready to calm your fears. ✦

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March 2016 Digital Extra

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- **More Than Spirals**
  Does our spring spirals story have you itching for more? Check out more deep-sky guides.
- **Mars's Disappearing Atmosphere**
  Read more about the MAVEN spacecraft's findings on Mars.

TOUR THE SKY – ASTRONOMY PODCASTS

Photo Gallery

Image by Mike Borman

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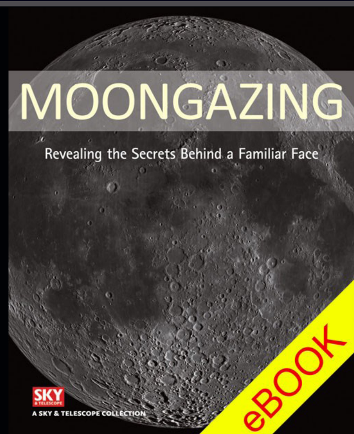

DIGITAL BACK ISSUES:

December, January, and February

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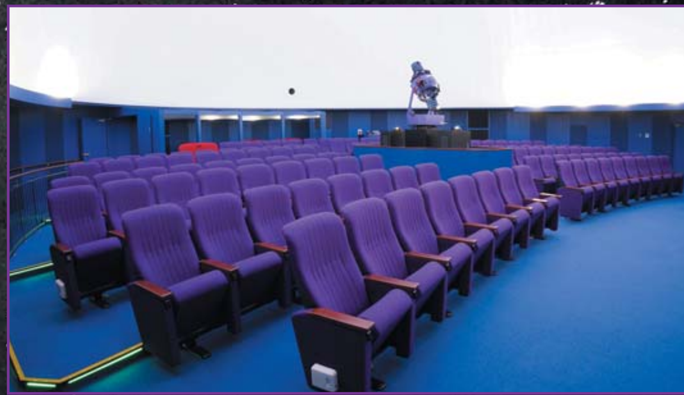
ONLINE PHOTO GALLERY

In this image, Chad Quandt captured the classic Pleiades star cluster during a 6-hour exposure.

Things Are Looking Up for Children of Kariya City Japan

On May 2, 2015 the Kariya City Hands-On Science Museum re-opened after a major renovation. Part of that renovation was to the 15m diameter planetarium. That dome formerly used a GOTO GMII analog opto-mechanical projector for 34 years of successful operations. But in the renovation, staff wanted not only to continue programming as before, but to also take children on exciting and educational voyages into space!

So they chose another GOTO machine - this time a GOTO CHRONOS II was made the centerpiece of the GOTO HYBRID Planetarium®. The CHRONOS II not only replaced dozens of light bulbs with high-efficiency, long-life LEDs, it also brought unprecedented accuracy of motion to the stars, sun, moon, and planets. While older analog projectors suffered from the inherent backlash of gears moving against gears, the new CHRONOS II uses digital computer signals to move these objects to the precise proper locations. And it does this time after time, with no need for re-setting or adjustments. It just plain works beautifully!



Of course the CHRONOS II also brings some 9,500 stars, down to magnitude 6.5. These LED-illuminated stars are smaller, brighter, and more color correct than ever before. Fast and accurate, as well as subtle and beautiful - these are the hallmarks of the GOTO CHRONOS II.

At Kariya, the CHRONOS II is joined by a VIRTUARIUM II fulldome video system. This system is synchronized with the CHRONOS II's motions via the GOTO HYBRID control system, which also features an ergonomically-designed manual control console for easy and fun, live programming with children. The VIRTUARIUM II system projects through GOTO's bespoke lenses to fill the sky with more than 5 million pixels of immersive video animation.
A beautiful interior design with seats which match the city's purple Kakitsubata flowers and a new 10-speaker audio system round out the theater renovation. Other renovations around the rest of the Hands-On Museum encourage a whole new generation of visitors to explore, learn, and have fun with science. You should visit too!

GOTO INC

4-16 Yazakicho, Fuchu-shi, Tokyo 183-8530 Japan
Tel：+81-42-362-5312 Fax :+81-42-361-9671
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URL: www.goto.co.jp/english/index.html

GOTO USA LIAISON

8060 Clearwater Drive, Indianapolis, IN 46256
Tel：+1-317-537-2806
E-Mail: gotousa@earthlink.net
Contact : Ken Miller

Write to Letters to the Editor, *Sky & Telescope*,
90 Sherman St., Cambridge, MA 02140-3264,
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Please limit your comments to 250 words.

First-Time Eyepiece Views

We can relate to Peter Tyson's story (*S&T*: Sept. 2015, p. 4) about showing his daughter Saturn with a telescope for the very first time. Through #popscope (**popscope.org**), our urban-astronomy initiative, we've had the pleasure of bringing many friends, neighbors, and passersby to the eyepiece for their first time. We witness their screams of delight and cries of disbelief as they see the Moon's craters, Saturn's rings, or Jupiter's moons.

What our guests say after viewing makes us laugh and think; sometimes their comments spark wide-ranging conversations that touch on astronomy, cosmology, philosophy, culture, and history. We enjoy these reactions so much, in fact, that we began recording them anonymously. Here are some of our favorites involving the Moon:

"You're telling me we sent men to the Moon and brought them back?"

"I want to go to the Moon, but I have to wait until I'm 15. I don't know how I'm going to afford the rocket."

"All those craters — how can there not be a civilization up there?"

And here are a few involving Saturn:

"On a vu Saturn! On a vu les planètes!" ("We saw Saturn! We saw the planets!")

"It's like a pig's nose!"

"Saturn looks like my ex-husband."

Our guests' memorable utterances remind us that, no matter what our background, we are all the same under the stars — equally humbled, awed, and inspired.

Michael O'Shea
Chicago, Illinois
Viva Dadwal
Montréal, Québec

Quite a few years ago, I was doing a local star party with an 8-inch Dobsonian that I'd built from scratch and decorated with things to attract kids. A boy of about 9 or 10 walked by and asked me what I had in my scope. I told him it was pointed at the crescent Moon. So he looked into the eyepiece and got very excited. Then he pointed to Vega and asked if he could look at that. I told him the name of the star and showed him how to point the scope. It took him several minutes to find it, but he did. Then he announced to everyone with a very loud voice, "I have the star Vega in this telescope! Who would like to see it?" A crowd gathered and looked, and then slowly drifted away.

Then he asked, "What else can I find?" I told him about the big globular cluster M13 and explained that, while he couldn't see it, he could point the finder where it should be and find it himself.

About then a worried father showed up, concerned that his son might break the telescope. I pointed out that I'd made it myself and that it cost only $350, most of that for the main mirror safely mounted at the bottom of the tube. Breakage would not be an issue.

I spent the rest of the evening sitting in my lawn chair, watching this child find various objects in the sky and showing them to anyone who would look. The excitement he had at finding, seeing, and sharing the show with others kept him going for 2 hours. He left exhausted, and I never saw him again. But I'm willing to bet he never forgot that night — and probably got his dad to buy him his own telescope within a few months.

John Duchek
St. Louis, Missouri

VIVASWAT DADWAL

A group called #popscope brings the joys of sidewalk astronomy to underserved communities in several major cities.

Not So Solitary After All

I read with great interest "Supernovae: Lonely Explosions Between Galaxies" (*S&T*: Nov. 2015, p. 12), which details how three solitary white dwarfs unaffiliated with any galaxy produced Type Ia supernovae. But a white dwarf becomes a supernova only after it has accumulated enough gas from a companion star to exceed the *Chandrasekhar limit* of 1.4 solar masses. So by "solitary" do you merely mean "outside a galaxy"? Or did these white dwarfs somehow accumulate the required mass during their lonely travels through intergalactic space?

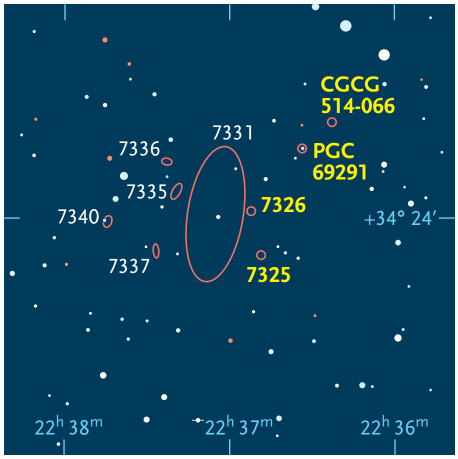
Jim Baughman
West Hollywood, California

Monica Young replies: *You're correct that Type Ia supernovae require a companion — either because the white dwarf siphons off gas and explodes, or because the white dwarf and its companion merge with the same result. So "solitary" refers to the supernova's environment — that is, whether it's part of a galaxy or not.*

Catalog Quirks

I've been getting *Sky & Telescope* since 1969 and have worked my way up to observing with a 16-inch Newtonian reflector for the last 5 years. Since most of my recent observing is devoted to external galaxies, Ted Forte's "favorite things" article (*S&T:* Oct. 2015, p. 32) was an excellent extension of an area I've observed before. However, after I cross-referenced those targets with Steve Gottlieb's NGC and IC observations, it appears that NGC 7325 and 7326 are actually faint double star duos.

Tom Prescher
Tolland, Connecticut



Some faint objects (in yellow) near the galaxy NGC 7331 in Pegasus are not easily identified.

Ted Forte replies: *The historical record concerning NGC 7325 and NGC 7326 suggests that a misidentification of these objects exists in many contemporary catalogs. The objects described in the article and identified in the image on page 38 as NGC 7325 and NGC 7326 are, perhaps, more correctly identified as PGC 69291 and Z514-066 (CGCG 514-066).*

As shown in the revised plot at left, the "real" NGC 7325 is an object southwest of the core of NGC 7331, while NGC 7326 is a double star to the galaxy's immediate west.

For the Record

✸ *Mercury's perihelion precession, due to all causes, is about 574 arcseconds per century. The value of 43 arcseconds per century (S&T: Dec. 2015, p. 4) refers only to the residual, anomalous shift due to relativistic effects. Also, the label in the illustration on that page should state that Mercury's perihelion precesses 0.2° (not 2°) per century.*

✸ *The predicted peak of the Geminid meteor shower (S&T: Dec. 2015, p. 44) was about 18^h Universal Time on December (not August) 14, 2015.*

✸ *The listed date and time of lunar perigee (S&T: Dec. 2015, p. 49) should be December 21st at 9^h UT.*

✸ *The long trail in a star-field image ascribed to a Perseid meteor (S&T: Dec. 2015, p. 70) instead resulted from a pass overhead by the International Space Station.*

75, 50 & 25 Years Ago

Roger W. Sinnott

March-April 1941

Skyrocket Prominence "The coronagraph has seldom been thought of as a visual instrument, [but on] February 6, Mr. Walter Roberts, in charge of the observational work at Climax, was examining an interesting prominence with a small pocket spectroscope. He had just noticed a peculiar doubling of all of the spectral lines . . . evidently a Doppler effect, arising from rapid motion of the gas either toward or away from the observer. . . .

"And then, suddenly, well to the left of the stationary prominence, he saw a small bright patch form, rapidly growing in size and intensity. As he watched, he could see it starting upward. . . . The left-hand prominence shot up like a skyrocket, curving sharply to the right. . . . The entire outburst was over in about five minutes. . . ."

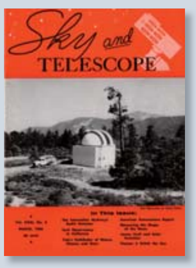
The coronagraph was invented in France in 1931, and Harvard's Colorado station had one of the first three. As told here by Donald H. Menzel, this instrument permitted real-time, white-light views of action off the Sun's limb. A solar eclipse offers similar views — but only for a few fleeting moments.

March 1966

Soft Landing "Two important milestones in lunar exploration were reached in early February, as Luna 9 made the first successful soft landing and sent back the first pictures of the moon's surface texture as viewed from a few feet. . . . The Moscow news agency Tass gives the time of landing as 18:45:30 [Universal Time on February 3rd]. . . .

"The soft landing took place near the edge of Oceanus Procellarum. . . . The camera recorded foreground objects as small as one or two millimeters. . . ."

This Soviet triumph also calmed the fears of those planning NASA's Apollo landings. Instead of plunging into a thick bed of Moon dust, Luna 9 gently bounced when it hit.



March 1991

Quasar Mystery "Astronomers have long puzzled over two stars whose spectra are dominated by emission lines from ionized iron. . . . Now the mystery deepens with the recognition of a new class of 'super strong' iron emitters among the quasars. . . . Sebastian Lipari (Space Telescope Science Institute) and his colleagues report the discovery of the third such quasar, IRAS 18508 – 7815 in Octans. Its extremely strong iron lines defy explanation.

"One of the other two 'iron quasars,' IRAS 07598 + 6508 in Camelopardalis, has similar optical and far-infrared characteristics and redshift. It also lies roughly on the opposite side of the sky. Lipari and co-workers speculate that the two images might be of the same quasar. This seeming impossibility is predicted by Chinese astrophysicist Fang Lizhi's model of a 'multiply connected' universe."

The idea that we could see the same object by looking in opposite directions on the sky is a recurrent theme in cosmology, ever since Albert Einstein first described space-time curvature 100 years ago (S&T: Dec. 2015, p. 18). But a convincing example has yet to emerge.

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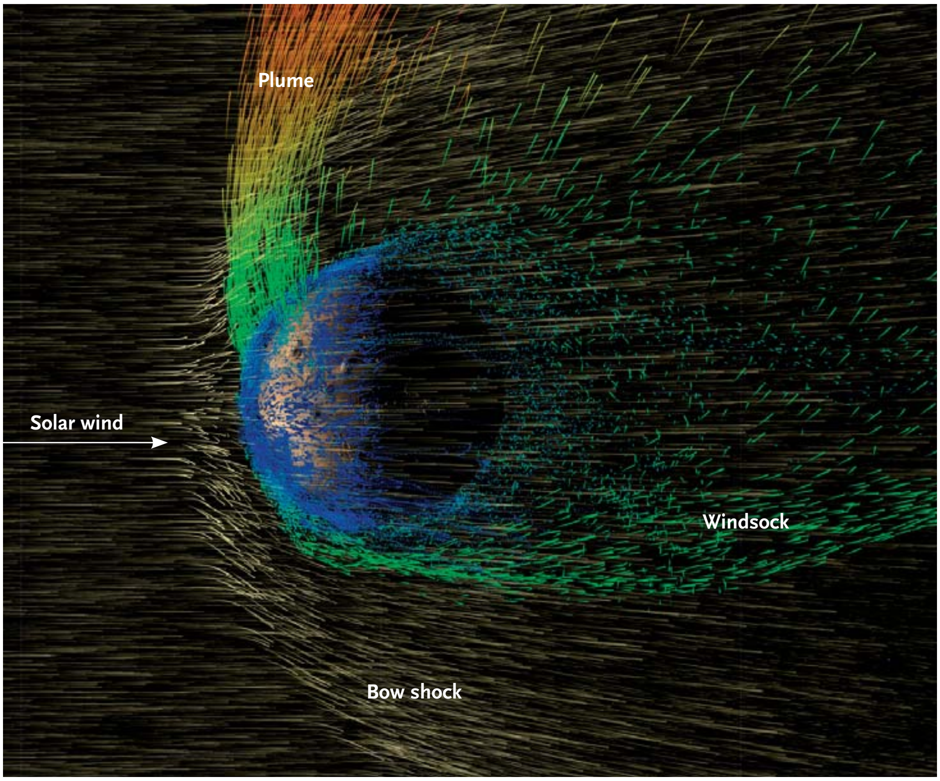
MARS | Red Planet Losing Gas to Solar Wind's Onslaught



NASA / GREG SHIRAH

Measurements by NASA's MAVEN orbiter have detected atmospheric ions leaving Mars at a high rate, driven off by the planet's interaction with the solar wind. Colors indicate the ions' speeds, with red the fastest. Although the atoms leaving through the polar plume move faster, most of the atmosphere (about 75%) escapes through the windsock-shaped tail.

NASA's MAVEN orbiter has painted a detailed picture of how the solar wind robs Mars of its atmosphere.

Today's Mars is surrounded by only a whiff of gas, but scientists think its ancient atmosphere was thicker. A primary theory for where that gas went is that the solar wind blew it away. The solar wind is a river of charged particles that flows out from the Sun, carrying with it the solar magnetic field. All the planets plow through this flow as they orbit our star. Because Mars lost its global magnetic field more than 4 billion years ago, the solar wind smacks directly into its upper atmosphere at several hundred kilometers per second.

NASA sent the MAVEN spacecraft to the Red Planet to monitor this interaction (*S&T:* Sept. 2014, p. 20). After analyzing the first seven months of mission data, principal investigator Bruce Jakosky (University of Colorado, Boulder) and his team have built a cohesive picture of where gas in the upper atmosphere is going. They found that it leaves the planet three ways: in a polar plume, as a downwind tail, and from an extended cloud of gas surrounding the entire planet.

The Mohawk-esque plume is a stream of ions driven from the planet's dayside. These ions are caught up in an electric field that's created by the solar magnetic field as it blows into Mars's upper atmosphere. Because linked magnetic and electric fields are perpendicular to each other, the plume is directed upward from the pole, instead of following the solar wind's flow around the planet (see the simulation at left). About 25% of the atmosphere lost leaves via this route.

The second, and predominant, exit ramp is the windsock-shaped tail streaming behind Mars's nightside. The tail forms as the solar wind hits the upper atmosphere and is deflected around the planet, just like air bends into a bow shock around a supersonic jet. About 75% of the atmosphere lost leaves this way.

A smattering of gas also escapes from the top of the atmosphere as neutral atoms, creating a tenuous corona far from the planet's dayside. Once these atoms become ionized, the solar wind drives them back toward Mars and into the interplanetary depths beyond.

Adding up all these losses, the scientists find that, globally, Mars is losing at least a few trillion trillion (10^{24}) atoms per second. That translates into about 100 grams, or a quarter pound. "I can't help but imagine hamburgers flying out of Mars, once per second," jokes mission co-investigator David Brain (University of Colorado, Boulder).

But Mars can lose its gas a lot faster. When a coronal mass ejection slammed into the planet in March 2015, for example, MAVEN found that escape rates spiked by a factor of 10 to 20. That's important, because scientists think that the young Sun was far more active than the middle-aged star we live with now. A lot of things can influence how well the solar wind strips the planet's atmosphere away, however, and the team hasn't yet figured out what escape rates would have been in the distant past. Mars potentially lost as much atmosphere as Earth has now, so the rate might have been 100 to 1,000 times greater in that early period, Jakosky speculates. The team details these and other results in several papers in the November 6th *Science* and a special issue of *Geophysical Research Letters*.

■ **CAMILLE M. CARLISLE**

Read more about MAVEN's results and watch a video of the solar wind stripping Mars's atmosphere away at http://is.gd/mavenions.

SOLAR SYSTEM | Most Distant Object Found

During November's meeting of the American Astronomical Society's Division for Planetary Sciences, Scott Sheppard (Carnegie Institution for Science) announced that he, Chad Trujillo (Gemini Observatory), and David Tholen (University of Hawai'i) have spotted something farther from the Sun than any other known object in the solar system. This body, designated V774104 for now, lies 103 astronomical units (15.4 billion km) away in the direction of west-central Pisces.

The object turned up in a pair of images taken October 13, 2015, with Japan's 8.2-meter Subaru Telescope, as part of the largest, deepest survey to date for distant denizens of the Kuiper Belt. "We detect the motion of solar system objects by parallax and not by the actual movement of the object," Sheppard explains. An object around 100 a.u. away will shift about 1.3 arcseconds per hour due to Earth's motion, he says, so it's easily detected in a few hours.

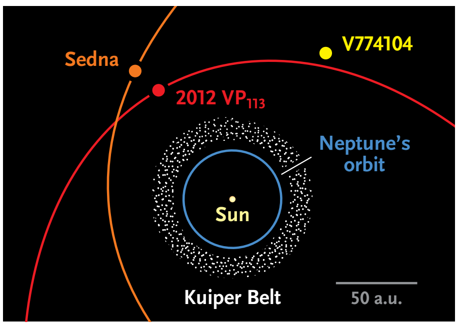
V774104 is so far away that it will take another year of study to determine its orbit. "All we really know is the distance," Sheppard admits. Given its 24th-magnitude brightness and assuming that its surface is 15% reflective, the object might be 500 km (300 miles) across, or about a sixth the Moon's size.

Dynamicists will be eager to learn what kind of orbit V774104 occupies. A highly eccentric track would mean that it periodically swings much closer to the Sun. That's the case with Eris, which likely got flung into its nearly 600-year-long orbit after a gravitational encounter with Neptune eons ago.

But if the orbit is more circular, or if V774104 is near perihelion in an eccentric path, then it's completely unaffected by the massive planets — and that will cause dynamicists to question how it got out there. Two other distant objects, 90377 Sedna and 2012 VP_{113}, are also in orbital limbo. Possible causes run the gamut from gravitational stirring of the distant Oort Cloud by a close-passing star to the presence of an undiscovered, massive planet far beyond the orbit of Neptune. Or they might be the first-found members of the inner Oort Cloud.

■ J. KELLY BEATTY

S&T: GREGG DINDERMAN, SOURCE: SCOTT S. SHEPPARD / CARNEGIE INSTITUTION FOR SCIENCE



Beyond its distance and brightness, astronomers know little about the distant object V774104. Within a year, they hope to determine the characteristics of its orbit.

MARS | Phobos: Future Ring Around the Red Planet?

The little moon Phobos is doomed. It whips around Mars in just 7.7 hours, compared with the 24.7 hours that Mars takes to rotate, and thanks to a teensy tidal interaction that its gravity creates in the Martian interior, the moon is slowly moving closer to the planet. This arrangement can't last: dynamicists predict that Phobos should drop into the Martian atmosphere in perhaps 20 to 40 million years.

Exactly what will take place and when depends on the moon's interior structure, but in December's *Nature Geoscience* researchers Benjamin Black and Tushar Mittal (University of California, Berkeley) conclude that Phobos won't simply plunge intact into Mars. Instead, it's more likely that the moon's dusty, outer layer will be stripped away first, creating a temporary ring that might linger around Mars for 1 to 100 million years. Meanwhile, the solid chunks of Phobos will meet a quicker end, striking the planet's surface and creating a series of oblique craters around its equator.

■ J. KELLY BEATTY

IN BRIEF

Dwarf Galaxies Discovered. Using the 570-megapixel Dark Energy Camera at Cerro Tololo Inter-American Observatory in Chile, Roberto Muñoz (Pontifical Catholic University of Chile) and colleagues have detected 158 dwarf galaxies swarming in the center of the Fornax galaxy cluster. These objects have incredibly low surface brightnesses, up to 100 times fainter even than the dim, nearby dwarf galaxy Leo I. Surveys such as this one are uncovering the expected small, dim dwarfs that simulations predicted but that have long been "missing" in observations. The team reports the finds in the November 1st *Astrophysical Journal Letters*.

■ MONICA YOUNG

Extragalactic Gamma Rays. NASA's Fermi Gamma-ray Space Telescope has discovered that most of the highest energy photons in the Large Magellanic Cloud come from two pulsars. Astronomers already knew about the pulsars, J0540–6919 and J0537–6910, but this is the first time they've been able to pinpoint them as gamma-ray sources and the first time they've detected pulsars outside the Milky Way at these wavelengths. J0540 is the most luminous gamma-ray pulsar ever observed — more than 20 times brighter than the pulsar powering the Crab Nebula, which had been the champion. But J0537's gamma rays don't show a pulse. Why these three young pulsars look so different remains unclear, Pierrick Martin (Institute for Research in Astrophysics and Planetology, France) and others report in the November 13th *Science*. It's also strange that the two pulsars produce 85% of the dwarf galaxy's gamma rays, given that astronomers thought these photons would come from relativistic charged particles swarming the burgeoning star-forming region in which the pulsars sit. Watch a video exploring the team's result at http://is.gd/lmcpulsars.

■ CAMILLE M. CARLISLE

GALAXIES | Astronomers Take M87's Pulse

NASA / ESA / HUBBLE HERITAGE TEAM

The elliptical galaxy M87 dominates the center of the Virgo galaxy cluster. Astronomers have now detected the "heartbeats" of old, red supergiant stars within M87.

Astronomers have measured the shimmer in a galaxy's light as individual, old stars in the galaxy brighten and fade.

To detect the shimmer, Charlie Conroy (Harvard University) and colleagues took a careful look at the giant elliptical galaxy M87, which is filled with old stars. First, the team compiled information about the masses, luminosities, and such for stars of different ages, focusing especially on *asymptotic giant branch* (AGB) stars. These are worn-out, red supergiant stars. They have unstable interiors and brighten and fade over the course of several hundred days.

Second, the researchers combined those data with how different stars' brightnesses would vary. Third, given the population of stars expected to exist in M87, and given how those stars' pulsations would add together in the light we see, they predicted how the brightness of individual pixels in an image of the galaxy would change over time.

The astronomers then looked at a series of more than 50 images of M87 from the Hubble Space Telescope and sought out these variations. In a quarter of the pixels, the team found that the brightness wavered with an average "beat" of 270 days. Although the detected fluctuations are small — a mere 0.1% to 1% of a pixel's brightness — they do seem to be real, the team reports in the November 26th *Nature*.

"This paper is really very interesting," says Claudia Maraston (University of Portsmouth, UK), who specializes in AGB stars and uses them to understand galaxies. She adds that she would like to see this technique applied to other, younger galaxies with larger populations of these variables.

For even though M87's stars are old, they're really *too* old to shimmer strongly. The AGB phase is a short one, only lasting a million years. The stars pulse more brightly the more massive they are, and since bigger ones evolve more quickly, old AGB stars (say, 10 billion years old, like those in M87) are going to be much fainter than young (roughly 1 billion-year-old) ones, Maraston explains. So the pulsations should show up better in younger, star-forming galaxies. They should also be stronger in certain zones of a galaxy, such that we would see spiral disks shimmering more than galactic bulges or halos, which mostly have old stars.

■ **CAMILLE M. CARLISLE**

MILKY WAY | Young Stars in an Old Bulge

A disk of young stars in the Milky Way Galaxy's central regions confirms our galaxy's nonviolent past.

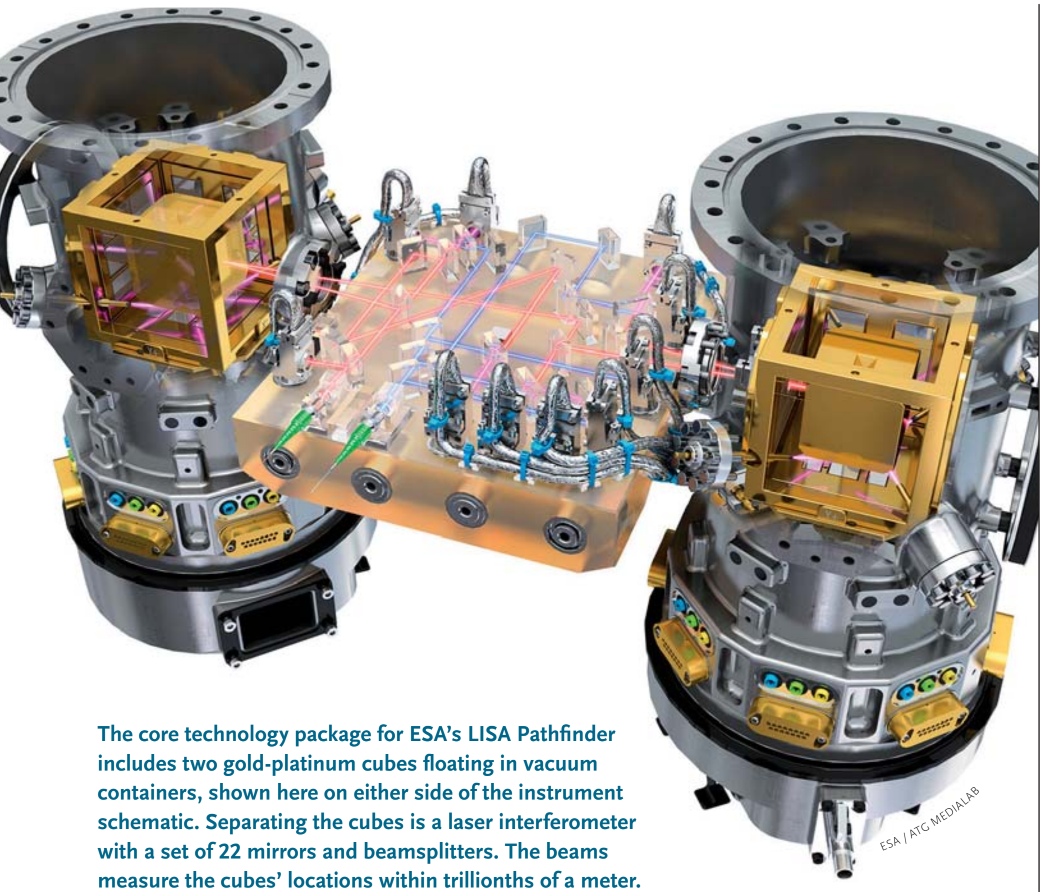
At the center of our galaxy's spiral disk sits a Twinkie-shaped bulge of old stars. And like a Twinkie, it turns out, the bulge contains a "cream filling": a thin plane of very young stars that cuts right through the bulge and lines up with the galaxy's disk. István Dékány (Pontifical Catholic University of Chile) and colleagues found the plane when they discovered 35 Cepheid variable stars, each no older than 100 million years, as part of the VISTA Variables in Vía Láctea project.

"We think that this is essentially a smooth inner continuation of the thin disk that has been known to surround the inner galaxy," Dékány says. The team will report the discovery in *Astrophysical Journal Letters*.

The research shows that, deep within the aging bulge, some process is forming new stars. That's unsurprising, says Melissa Ness (Max Planck Institute for Astronomy, Germany), if the bulge isn't as separate a component as was once thought. Simulations suggest that our galaxy started out as a smooth disk, then formed its bulge as instabilities wracked it and threw stars onto skewed orbits. If that's the case, the bulge got its feedstock from the disk. "That the stars in the bulge are mostly old just reflects that [they] are stars of the disk that formed a long time ago," says Ness. "But this certainly does not prohibit new star formation."

Paola Di Matteo (Paris Observatory) adds that the discovery adds to evidence that mergers played little role in shaping the Milky Way's bulge: "This is another strong indication of the fact that our bulge has been mainly, if not entirely, formed via disk evolution and instabilities."

■ **MONICA YOUNG**



The core technology package for ESA's LISA Pathfinder includes two gold-platinum cubes floating in vacuum containers, shown here on either side of the instrument schematic. Separating the cubes is a laser interferometer with a set of 22 mirrors and beamsplitters. The beams measure the cubes' locations within trillionths of a meter.

MISSIONS | LISA Pathfinder Heads to Space

A trailblazing mission took to the skies on December 3rd as a Vega rocket carrying the LISA Pathfinder spacecraft lit up the night over Kourou, French Guiana.

LISA Pathfinder will test key technologies for the upcoming Evolved Laser Interferometer Space Antenna (eLISA) project, slated for launch in 2034. eLISA will use three free-flying spacecraft to create a laser interferometer a million kilometers on a side in order to search for ripples in spacetime called gravitational waves (*S&T:* Dec. 2015, p. 26). The spacecraft's lasers will measure the position of masses suspended in freefall at the end of each "arm," enabling researchers to look for any jiggling in the cubes' positions induced by gravitational waves passing through the solar system.

LISA Pathfinder serves as a testbed for the new technologies required for the upcoming European Space Agency mission, by mimicking one arm of the future interferometer. The craft carries two 46-mm-wide gold-platinum cubes, each suspended in a vacuum compartment. The compartments are separated by 38 cm, where sits a miniature laser interferometer (see above). Researchers aim to detect any relative motion between the two masses to within a few picometers (a trillionth of a meter or 10^{-12} m).

The LISA Pathfinder mission will also check propulsion, laser ranging, and gravitational sensors built for the full-up eLISA mission, as well as demonstrate the first use of a micronewton propulsion system.

The craft will start its six-month scientific mission in early March, circling around the stable L_1 Lagrangian point between Earth and the Sun.

■ **DAVID DICKINSON**

Watch the recorded LISA Pathfinder launch at http://is.gd/lisapathlaunch.

EXOPLANETS | Watching Young Worlds Grow

Results from the American Astronomical Society's third Extreme Solar Systems meeting in Hawai'i highlight that we're now moving from counting planets to characterizing their formation.

Paul Kalas (University of California, Berkeley), Abhijith Rajan (Arizona State University), and colleagues explored the super-Jupiter orbiting 650 astronomical units from the star HD 106906 — more than 10 times Pluto's farthest point from the Sun. Using images of the system from the Hubble Space Telescope and the Gemini Planet Imager (GPI), the team found that a disturbed ring encircles the star and that the faraway planet's orbit is tilted 21° out of line with this disk. These facts confirm the planet probably formed closer to the star and was later "exiled" by some sort of gravitational encounter.

Another GPI study by Thayne Currie (Subaru Telescope) and others detected spiral arms in the disk surrounding the 10 million-year-old star HD 100546. At least one growing planet sits at an arm's end. The planet's color doesn't match any atmospheric models; instead, the team thinks the emission GPI detects is from gas that's feeding the planet.

■ **MONICA YOUNG**

STELLAR | Massive Star Forms from Disk

Observations from the ALMA and Atacama Pathfinder Experiment instruments in Chile have enabled astronomers to peer through a cocoon and see a stable disk of gas feeding the forming *O*-star at its center. Katharine Johnston (University of Leeds, UK) and colleagues published the results in the November 1st *Astrophysical Journal*. The observations reveal gas swirling in a disk shape around the protostar, dubbed AFGL 4176. The disk spans somewhere between 760 and 980 astronomical units. Outflows also shoot out from both sides of the structure. The result adds to growing evidence that the universe's most massive stars form the same way as its smaller ones (*S&T:* Oct. 2015, p. 24). ✦

■ **MONICA YOUNG**

Could It Be?

We need to learn how to talk about possible signs of E.T. intelligence.

IN MY MOST RECENT column (*S&T:* Jan. 2016, p. 20), I discussed the lack of evidence for technically advanced extraterrestrials. Curiously enough, in the time between writing that and its publication, some possible evidence materialized.

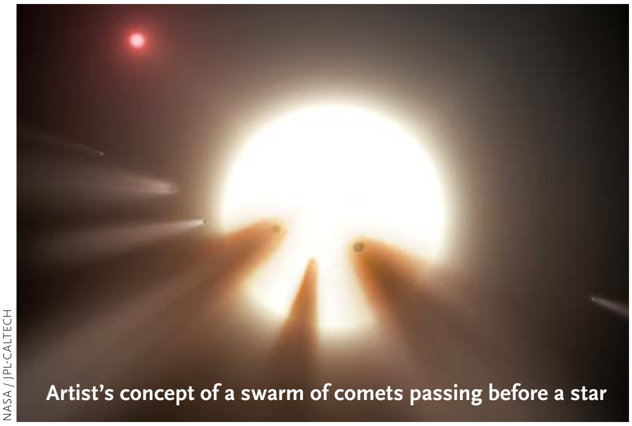
I'm sure you've heard plenty about the star KIC 8462852 (*S&T:* Feb. 2016, p. 14). The Kepler spacecraft found that its light is quivering in a complex way, like a lantern harassed by a large moth. It doesn't match anything predicted or observed around any other star. Something huge — perhaps half the star's diameter — is in orbit there or passing in its vicinity, at times blocking up to 20 percent of the starlight. That's no planet. The dips in the light have come in an irregular pattern, ruling out a simple orbit and hinting at multiple objects. In the absence of a well-understood, straightforward explanation, it's reasonable to entertain exotic hypotheses.

It has long been proposed that technically advanced civilizations should be detectable by their works of "astroengineering." The quirky character of KIC 8462852 resembles descriptions of "alien megastructures" that one can trace to science fiction going back at least to Olaf Stapledon in the 1930s. In 1960 Freeman Dyson described how advanced societies might surround their stars with enormous solar collectors. Stars hosting such "Dyson spheres" would appear dim in visible light but bright with the infrared glow due to waste heat.

Whatever the cause of the odd dips in the light from KIC 8462852, it's clearly not such a Dyson sphere surrounding the whole star. But until scientists have convincingly explained what's going on, is there anything wrong with entertaining the provocative thought that it could be some kind of huge alien construction?

Some scientists and pundits want to condemn that idea as ridiculous and unworthy of mention. But it would have been wrong *not* to consider this enticing possibility for such a strange observation. The correct posture, at this point, is to regard an artificial explanation as extremely unlikely — but not illogical or impossible.

Perhaps this provides a test case, because we have to learn how to talk about these things. In the decades ahead we will be observing more and more exoplanets with better and better instrumentation (*S&T:* Oct. 2015, p. 16). We'll see some novel things, and when we don't understand them, then biosignatures and even technosignatures are possible explanations, and we should consider them without going overboard with either skepticism or credulity. We have to be cautious — but if we refuse to consider outlandish and wonderful possibilities, we might miss something truly important.



NASA / JPL-CALTECH

Artist's concept of a swarm of comets passing before a star

The alien hypothesis has increased the interest with which scientists are scrutinizing this star. Out of this will come new knowledge, most likely not about aliens. Promising plans include making new visible, infrared, and ultraviolet observations. The next time the light of KIC 8462852 flickers we can inspect the material properties of the obscuring stuff: Is it dust? A swarm of comets? Or something seemingly artificial? Quite possibly it's something nobody has thought of yet.

Perhaps someone will have explained the peculiarities of KIC 8462852's light curve by the time this column appears in print. On the other hand, the mystery might endure for years, allowing numerous predictions to be made and tested. Imagine all the fiction, fantasy, nonsense, religion, and good science that a possible alien civilization might inspire if generations go by without a definitive answer. It would serve as a fluttering beacon reminding us that we have a lot to learn. ✦

David Grinspoon *is an astrobiologist, author, and senior scientist at the Planetary Science Institute. Follow him on Twitter at @DrFunkySpoon.*

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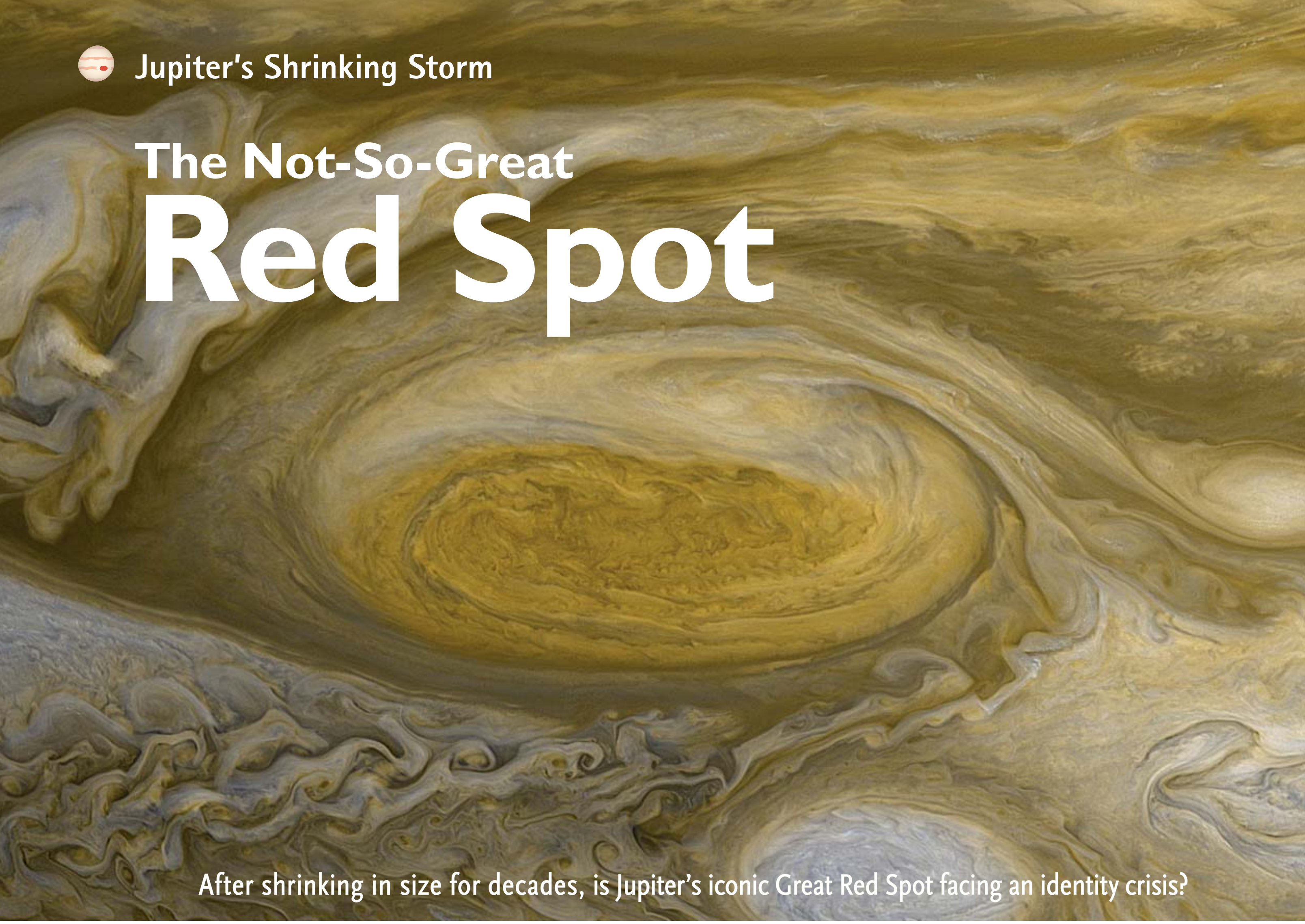
The Not-So-Great Red Spot



After shrinking in size for decades, is Jupiter's iconic Great Red Spot facing an identity crisis?

NASA / JPL / BJÖRN JÓNSSON

Amy A. Simon

Generations of amateur and professional astronomers have viewed and studied Jupiter's Great Red Spot (GRS), one of the giant planet's most easily recognized features. It joins Saturn's rings and the Martian polar caps as "must-see" features for solar system enthusiasts. But the GRS is an inconstant icon. In fact, in recent years observers have become increasingly alarmed about how small (relatively speaking) the spot has become. Visually it's far less impressive than it was two or three decades ago.

So planetary scientists have begun to ask whether this huge cloud system is really shrinking and, if so, might it someday disappear completely? The answer to the first question is unequivocally "yes," but the second one remains a mystery. Given that Jupiter has other small, enduring, red-hued ovals, perhaps the real question should be whether the GRS no longer qualifies as a "great" red spot.

Let's examine the history of this iconic storm and what we do — and don't — know about its evolution.

GIGANTIC STORM Arguably no planetary feature in the solar system is better known than Jupiter's Great Red Spot, or GRS, seen here in a contrast-enhanced composite of Voyager images from 1979. Note the vast regions of disturbed cloud flow to its north and south, along with the Earth-size white oval (designated BC) gliding nearby.

The Past

Historical records reveal that observers regularly measured the GRS from the 1870s onward. It became a popular target for study starting about 1878, in part because it was extremely red and prominent at the time. The earliest accurate size measurements employed transit timings of its red edges, often with finely scored micrometers in the eyepiece. These consistently showed that the GRS had an east-west length of about 34° in longitude. On Earth, this longitudinal extent would be something not quite the size of Australia. But on far larger Jupiter, this expanse corresponds to about 40,000 km (25,000 miles), three times Earth's diameter.

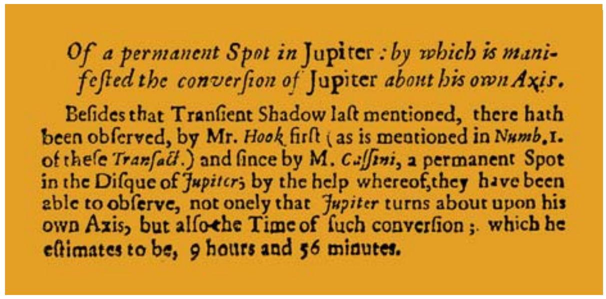
As early as the 1900s, observers clearly saw that the GRS was shrinking. Their measurements often varied, sometimes due to how much the spot blended into the cloudy background around it, but overall a consistent trend emerged. Many years of measurements showed that the spot's length was decreasing in longitude by about 0.14° per year. More recently, high-resolution measurements have refined this rate to an even more rapid 0.19° per year. Thus, the GRS has been steadily shrinking for more than a century. It currently spans about 14° in longitude, less than half its size a century ago.

This begs the question: could the GRS have been observed even earlier by telescopic observers — and, if so, was it even larger then? Some of the earliest telescopic observations by Gian Domenico Cassini and Robert Hooke in the mid-1660s note a "permanent Spot" on Jupiter, which many have since interpreted as being the GRS. It's not clear from the original papers themselves if this is the case, however, because the descriptions are somewhat vague as to size, color, and location. Also, observers provided only intermittent reports of such a feature during the two centuries that followed.

Moreover, the spot was of interest not so much for its color and size but because astronomers could use it to determine the rotation rate of Jupiter to a remarkably accurate 9 hours 56 minutes. Beyond that, it apparently warranted little mention other than as a "small spot in the biggest of Jupiter's three belts" spanning about 12°, as shown in sketches over those years.

Notably, if the recent trend in size were to hold true farther back in time, the GRS would have been 30° to 40° larger in 1665 than in 1878 and thus occupied most of a hemisphere! This clearly would not be a small distinct spot seen rotating across the planet's disk — with that enormous size, it could have certainly stood out and even been seen through the low-resolution telescopes of that era.

Conceivably, the spot reported by Cassini and Hooke might have dissipated and been replaced by the current GRS over the intervening years. Another possibility is that



Of a permanent Spot in Jupiter *: by which is manifested the conversion of* Jupiter *about his own Axis.*

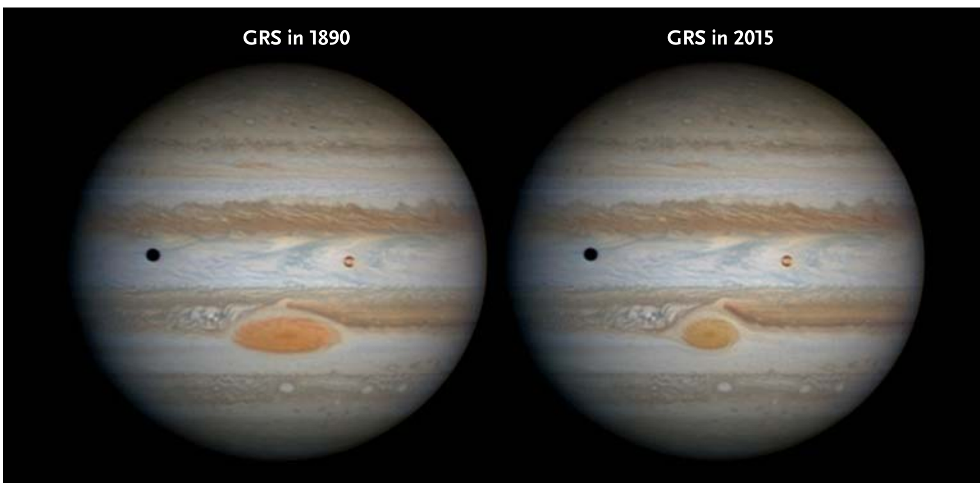
Besides that Transient Shadow last mentioned, there hath been observed, by Mr. *Hook* first (as is mentioned in *Numb.* 1. of these *Transact.*) and since by M. *Cassini*, a permanent Spot in the Disque of *Jupiter*; by the help whereof, they have been able to observe, not onely that *Jupiter* turns about upon his own Axis, but also the Time of such conversion; which he estimates to be, 9 hours and 56 minutes.

HISTORICAL HINTS Early reports of a spot on Jupiter from Robert Hooke and Gian Domenico Cassini appear in the Royal Society's *Philosophical Transactions* (1665–66). Historians generally (but not universally) believe these observers saw something other than the Great Red Spot.

the storm experiences episodes of growth, after which it becomes smaller. For example, despite evidence that the spot clearly was shrinking from the 1870s onward, occasional reports (for example, during 1915–25) gave a larger size — though only by a few degrees of longitude.

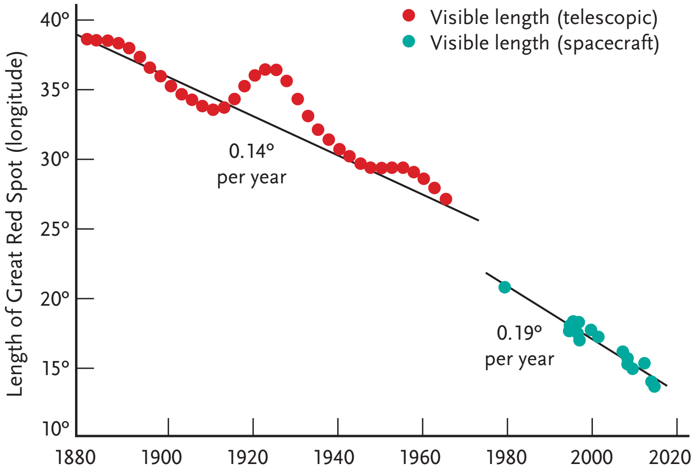
It's also hard to tell whether the larger measurements corresponded to growth of the actual oval of the GRS or to an extended region around it. As many *Sky & Telescope* readers know, the storm itself is sometimes very hard to distinguish from the surrounding clouds. These reports sometimes described the edges as pointy, rather than round, which gives us a clue. Hurricane-like vortices typically have rounded edges, even when very oblong, while the region around the GRS, shaped and bounded by regional winds, can have more angular shapes. Sketches of Jupiter, when compared with modern, high-resolution images, show that, indeed, sometimes the pointed features are not actually part of the storm itself.

This discrepancy shows one downside of using color to delineate storm size. The Great Red Spot's internal structure consists of a high-velocity collar surrounding a somewhat stagnant core. A cloud in this collar can complete a full circuit around the spot's perimeter in about 3 days. Some have suggested that using the location of



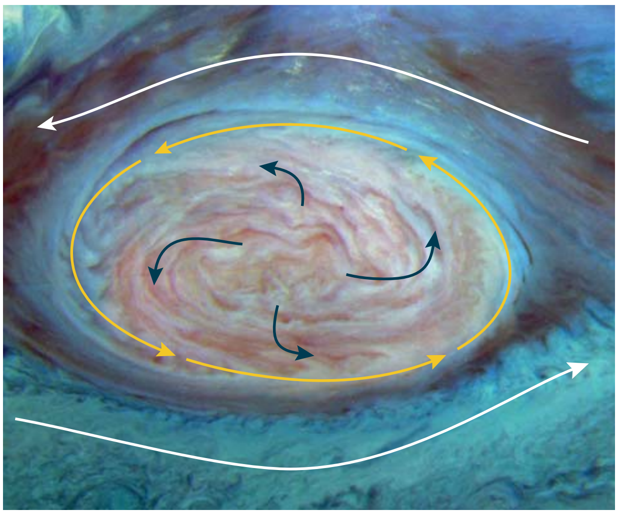
SHRINKING WITH TIME At left is a representation of how the Great Red Spot might have appeared in 1890, albeit at higher telescopic resolution than was available then, as compared with an actual image from 2015.

DAMIAN PEACH



S&T: L. TISCIONE; SOURCE: A. SIMON ET AL. / ASTROPHYSICAL JOURNAL

LESS AND LESS The GRS's length has been shrinking for at least a century, but the rate has accelerated during the past three decades.



S&T: GREGG DINDERMAN, SOURCE: NASA / JPL

TRACKING THE WINDS By using NASA's Galileo orbiter to record the GRS at near-infrared wavelengths, researchers concluded that the upwelling gas in the spot's interior is some 30 km higher than the peripheral collar. As the gas moves from areas of high pressure outward (black arrows), the *Coriolis force* causes it to spin counterclockwise rapidly along its perimeter (orange arrows). Some of that rotational energy probably transfers to the latitudinally confined wind jets flowing past to the storm's north and south (white arrows).

the high-velocity collar is a better measure of the GRS's size. Although this radius is smaller than the colored region, it too is shrinking over time.

The Present

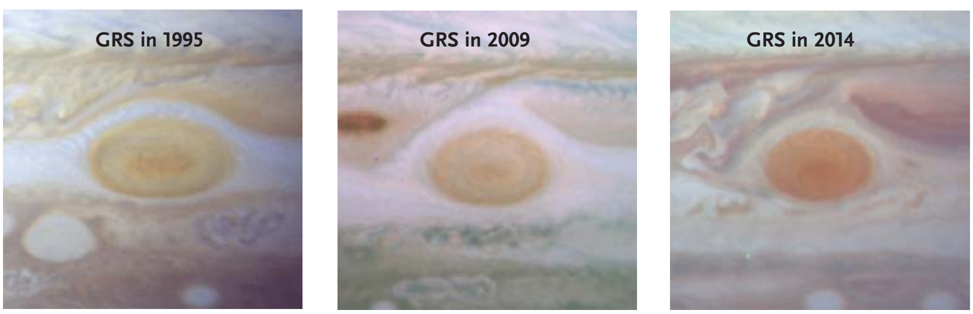
We have more than 20 years of Hubble Space Telescope observations of the GRS. Throughout HST's mission, the storm has gotten noticeably smaller and rounder. Composite images also reveal that the spot does actually change color quite dramatically. This is one key to understanding why the storm is changing.

Jupiter's cloudtops are dominated by bands of alternating winds that flow roughly along the boundaries between dark *belts* and bright *zones*. Storms typically "roll" between these counterflowing jets like ball bearings in their races. In fact, we suspect that large vortices such as the GRS help to maintain the adjacent wind jets by adding convective energy. Conversely, vortices might draw some energy from the wind jets by ingesting small eddies.

This is an active area of study, as we try to understand how waves and vortices are related to Jupiter's very stable wind pattern. The GRS is nestled between a westward-moving jet on the northern edge of the South Tropical Zone (STrZ) and an eastward jet on its southern edge. Since the GRS slightly overfills the STrZ region, those wind jets are deflected around the big oval, which causes turbulence and cloud mixing as the flows return to their normal latitudes after going by.

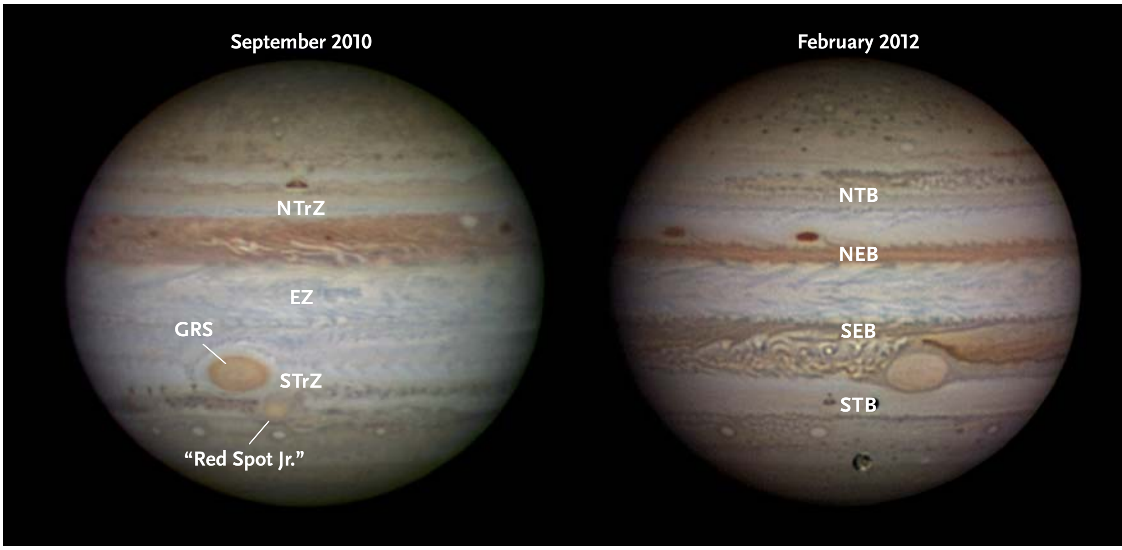
Small eddies on either of those deflected wind jets can be drawn into the flow of the GRS as they pass by and subsequently dragged into its interior. While it's unclear if these additions help sustain the storm, they *do* affect its color. As eddies are ingested and sheared apart, fresh, whiter material often appears within the GRS. Ingesting multiple eddies can turn the storm a very pale color, as occurred in 2012. Conversely, when no eddies accompany the jets, the spot's color can become quite intense — as it did during a widely observed fadeout of the South Equatorial Belt (SEB) in 2010.

In 2014, after a rapid decrease in the spot's length, observers noticed that its color had intensified, even though there were still eddies on the jets nearby. Perhaps these eddies could no longer enter the flow of the GRS for some reason. Why might this be?



NASA / ESA / ZOLT LEVAY

PERIODIC SCRUTINY Hubble Space Telescope enhanced-color views from 1995, 2009, and 2014 show both the GRS's shrinking size and the varying intensity of its hue over two decades.



ALTERED BY UPHEAVAL Compare how Jupiter looked in 2010 *(left)* — with its dark South Equatorial Belt "missing" and its GRS intensely colored — with the view two years later, after the high-altitude clouds obscuring the SEB had dissipated and the GRS had become paler.

DAMIAN PEACH

First, the storm has gotten smaller not just in its longitudinal width but also in its north-south extent. In addition, it occasionally moves slightly northward or southward, affecting which wind jet it deflects more. HST's 2014 measurements show the spot located near its normal central latitude (22° south), but both its north and south edges contracted centerward as the entire system shrunk.

The westward jet still experiences significant deflection around the GRS's northern edge, though perhaps slightly less than previously. However, the eastward jet is now barely deflected southward by the GRS. This means that any entrained eddies in this region are not interacting closely enough to be caught in the spot's flow. We now strongly suspect that these jet interactions are affecting not only the color but also possibly the size of the Great Red Spot. In time, our computer modeling of the GRS's interaction with the nearby wind jets should help us understand the energy exchange between them.

The Future

So what does the future hold for the most famous storm in the solar system? That's difficult to predict, as sudden outbreaks could always alter the energy balance and wind flow near and within the GRS and change our view completely. Atmospheric specialists describe the shape of Jupiter's anticyclonic storms (high-pressure systems like the GRS) by the ratio of their length to width, and it's not unusual for this key aspect ratio to decrease in such storms, particularly right after they form.

For example, the white ovals just south of the GRS first appeared in the late 1930s not as discrete spots but rather as high-altitude clouds and haze that suddenly inundated their latitude band, probably related to a large convective event. The brightened zone then coalesced into three distinct, oblong white storms, which observers designated BC, DE, and FA. By the Voyager flybys in 1979, each had an aspect ratio of about 2. They continued to shrink until merging into a single oval in 2000, with the new, combined oval BA having an aspect ratio of 1.25. In 2005, it turned red — earning the moniker "Red Spot Jr." — and by 2015 its aspect ratio was 1.3. Meanwhile, the GRS's aspect ratio has changed from about 3 during the Voyager flybys in 1979 to the 1.4 it has now.

Computer models suggest that Jupiter's anticyclonic vortices should exhibit preferred aspect ratios, but those depend somewhat on interactions with adjacent wind jets, especially for a large storm that can deflect the jets. So the GRS might eventually reach a shape that is "just right," allowing it to stabilize.

Studies of its internal dynamics will help us to model its fate, so we continue to make yearly Hubble observations. And amateurs' observations are critical for monitoring the GRS. Their regular reports help us to fill in the gaps between studies with HST and professional telescopes. They can also alert us to new happenings that require rapid follow-up.

All things considered, we expect that the Great Red Spot will continue to shrink for some time to come. We don't expect it to disappear completely — but for now what happens in the years ahead is anyone's guess. ✦

***Amy Simon**, an atmospheric dynamicist at NASA's Goddard Space Flight Center, leads the observing team for HST's Outer Planet Atmospheres Legacy monitoring program.*

GET TO KNOW JUPITER

For more information about the study of Jupiter's cloud features and the Great Red Spot in particular, see *The Giant Planet Jupiter* (Cambridge University Press, 1995), authored by John Rogers of the British Astronomical Association. Also see page 48 for a general guide to observing Jupiter and page 50 for a list of times when the GRS is positioned best for telecopic viewing.

Telescope Operators

Katherine Kornei

These men and women are the experts that make discoveries at big professional observatories possible.

CONTROL ROOM COLLABORATORS Astronomer Diana Da Cunha (left) and telescope operator Francisco Cacenes work together at the European Southern Observatory's 3.6-meter instrument at La Silla in Chile. The 3.6 meter's instruments include the exoplanet-hunting HARPS spectrograph. ESO / S. BRUNIER FOR SKYPIX

Part scientist, part engineer, and part therapist — that's the job of telescope operators. Many large research telescopes — from the W. M. Keck Observatory in Hawai'i to the Boeing-borne Stratospheric Observatory for Infrared Astronomy (SOFIA) — employ these jacks- and jills-of-all-trades. TOs, as they're commonly called, are tasked with ensuring the perfect performance of a telescope and its cadre of instruments. They spend their nights working on remote mountaintops and airborne observatories as the liaisons between data-hungry astronomers and complex telescopes worth millions of dollars.

TOs are an integral part of a big-scope observing run because professional astronomers, for all their scientific expertise, often use a particular telescope and instrument combination no more than a few nights each year. These guest observers accordingly lack the day-in, day-out practice of working with a specific telescope — they might know the instrument's strengths, but not its quirks. Focusing and locking on an astronomical target are manageable tasks with your own backyard setup, but navigating the complex software that research observatories use to accomplish these tasks is another matter. Furthermore, safely moving domes than can be 30 meters across or larger, and knowing local weather well enough to decide when to close down, takes a familiarity guest observers don't have. And then there's the setup and maintenance required to accommodate different observing programs, from switching out equipment to refilling cryogenic instruments with liquid nitrogen or liquid helium. These needs are similar at most observatories, and having full-time staff on hand to address them — as opposed to sleep-deprived astronomers unfamiliar with a telescope and its instruments — is critical.

"We're really the expert users of the telescope," says Jesse Ball, a TO at the Gemini North telescope in Hawai'i. "We're expected to learn how all of the instruments and telescope subsystems work together to be able to quickly and effectively troubleshoot any issues at night." Coupled with the vision and curiosity of the observers, TOs' skills help make astronomical discoveries possible.

Hands-on at the Telescope

Observing sessions can depend upon a TO's quick thinking and arsenal of skills. Not surprisingly, many TOs hold undergraduate degrees in physics, astronomy, or engineering, and have often completed additional coursework in computer science. TOs are accordingly well prepared to tackle a range of engineering and software problems.

Their astronomy knowledge also enables TOs to better understand the telescopic data and work collaboratively and diplomatically with astronomers. Given the scarcity of observing time available at large observatories, astronomers treat their nights on a telescope as a precious resource, something that can make or break a graduate student's thesis or pave the way to a successful career.

JESSE BALL

TOP OF THE WORLD Jesse Ball *(top)* shepherds telescopes at Gemini North in Hawai'i *(bottom, at sunset)*. Here he stands on the observing deck; in the background, left to right, are the Subaru Telescope, the twin Keck scopes, and the Infrared Telescope Facility.

GEMINI OBSERVATORY


GARY PUNAWAI / KECK OBSERVATORY

BIG SCOPES Joel Aycock stands with Keck I. The primary mirror is behind him and the attached 1.8 meter f/15 secondary is to his left and reflected in the primary.

"We sometimes work with a few astronomers who are high strung and occasionally need some calming to make the night go more smoothly and productively," says Joel Aycock, a veteran TO at the W. M. Keck Observatory on Mauna Kea. Then there are graduate students working feverishly on their dissertations, who have "an awful lot" riding on the few hours of large telescope time available to them. "You could consider me a therapist in helping them through these crises."

With their academic backgrounds, many TOs could pursue graduate studies in astronomy en route to working as a professional astronomer. However, TOs often find that working with astronomers to make new discoveries satisfies their scientific curiosity.

"The competitive publish-or-perish attitude in academia really dissuaded me," says Ball, who finished his bachelor's degree in physics. "But I really love to learn about the physical processes in our universe, and I'm very hands-on at the telescope."

After completing his undergraduate degree, Ball accepted a job running a college observatory, which entailed managing public outreach, running lab courses, and overseeing student projects. His experience with the college observatory prepared him for TO work first in Albuquerque, New Mexico, and then in Hawai'i, where he has been for the last 8 years.

Aycock echoes Ball's sentiment of being passionate about astronomy and yet not wanting to be a professional astronomer. "I love discovering how things work, solving problems, and helping the real experts develop new techniques and equipment to do the job," Aycock says.

Becoming a TO wasn't Aycock's original plan; he had a computer job lined up in New Zealand after he finished his bachelor's degree in physics at Reed College in Portland, Oregon. "I arrived in Honolulu in the summer of 1974 with a visa and job offer in Christchurch, $1,300 in the bank, two pairs of jeans and three shirts," Aycock explains. He had planned to lay over in Hawai'i for a while to enjoy the sun, but he ran through his savings in just weeks. Since he was stuck in Honolulu, Aycock enrolled in graduate astronomy courses at the University of Hawai'i, Manoa, and discovered the telescopes on Mauna Kea.


ESO / MAX ALEXANDER

ESO / M. MARCHESI

ROLLING OUT THE ANTENNAS *Left:* When astronomers want to change the configuration of the 66 antennas that make up the Atacama Large Millimeter/submillimeter Array (ALMA), they don't do it by hitting a button: transporter operators move the antennas for them. Here, Patricio Saavedra drives the 28-wheel transporter "Otto" across the ALMA site — while wearing an oxygen tube to keep his mind sharp at an elevation of 5,000 meters. *Right:* Here, Otto carries the array's final 12-meter antenna, delivered to ALMA in 2013. The driver's cab is the box in front. The antenna weighs about 100 tons.

ESO / G. HÜDEPOHL (ATACAMAPHOTO.COM)

ESO / MAX ALEXANDER

NIGHT CLASSES ***Left:*** **One of the 8.2-meter telescopes of the four-scope Very Large Telescope at Paranal, Chile.** ***Right:*** **Telescope instrument operator Claudia Cid (left) gives data-handling administrator Cecilia Cerón a crash course on how TOs prepare for the night's observations, while sitting in the Very Large Telescope's control room. Cerón and her colleagues oversee the observatory's data flow, beginning when the instrument takes an image in Chile and ending when it's delivered to ESO staff in Germany.**

Hawai'i would become Aycock's home as he built his career as a TO: first on Maui to work for NASA's Lunar Laser Ranging Experiment, and later on the Big Island with the United Kingdom Infrared Telescope and Keck Observatory. In the 1990s, Aycock helped astronomers collect the first science data from the new Keck I telescope, and he also participated in the construction and commissioning of Keck II. He has now worked as a TO on Mauna Kea for over 30 years. "Once I found a place with the Hawai'i astronomical observatories, I was hooked," he says. "There was no turning back."

Call the Operator

One night while holed up in the control room during an observing session at Gemini North, Ball heard a thunderous *bang!* from the dome floor overhead. The lights flickered. He hustled up the three flights of stairs into the dome — where the temperature was approximately –10°C — and encountered a mini catastrophe: the 2-inch-thick, solid piece of steel that transmitted power to the dome had snapped in half. Gemini's massive dome moves azimuthally on a track containing high-voltage power lines, which supply the power to all the vent gates, dome, shutter, and lights. The connection to one of those lines had failed, creating a massive arc of electricity that snapped the steel.

"I was frantically trying to dismantle the assembly so we could get the dome closed," says Ball. While he was working, the fog rolled in and a light dusting of snow and ice started to fall on the dome floor. "I'm standing there in the dark and fog with a flashlight, frozen-stiff fingers, numb face, and maneuvering my way around damaged pieces of this dome track, all the while working against the clock!"

Luckily, Ball was able to close the mirror cover to preserve the optics during the bad weather. After engineers guided him by phone in re-arming the power breaker and resetting the telescope's interlocks, he restored power to the dome so he could properly close down the telescope. "The day crew was able to check the system the next day," he says, "so we were back to normal operating conditions as soon as we re-opened the next night."

Such incidents are thankfully rare. Some observing sessions are relatively easy, such as when there are only a few, long-exposure targets. But TOs are the first line of defense when something goes wrong at a telescope.

"We always must be aware and on the alert for any small problem that might stop operations altogether," Aycock says. "No lives will be lost, but an astronomer's life career could be jeopardized."

In 2009, Ball helped astronomers observe NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) smash into the Moon. The impact, in which LCROSS and its Centaur rocket intentionally crashed into Cabeus Crater at the Moon's south pole, was designed to eject material that astronomers could study spectroscopically for signs of water and hydrocarbons.

Preparing for the crash took lots of planning. The TOs coordinated with astronomers and engineers to figure out where to point the telescope and which filters to use so that observers caught the expected flash without saturating the detector. "The fact that it was only going to happen once and we didn't get any second chances really made it exciting and challenging — and we pulled it off!"

Sometimes, TOs have to make choices about whether to proceed with observing or not — regardless of how unpopular it will make them with the astronomers. But holding out can have its rewards, too. One night at

S&T: KELLY BEATTY

GABRELLE SAURAGE

FASTEN YOUR SEAT BELTS ***Left:*** **Telescope operators aboard SOFIA have to not only watch the telescope controls but also pay attention to turbulence and airspace restrictions.** ***Right:*** **Telescope operator Gabrelle Saurage stands on the gangway to SOFIA's 747.**

Gemini North, Ball and some astronomers were observing in extremely windy conditions, probably 20 meters per second (45 mph). All telescopes have different "closing limits," and Gemini North's is 22.5 meters per second. "As you can imagine, an 8-meter piece of glass can really catch the wind," Ball says. "We could barely hold onto a guide star and were just about to give up and close the dome."

But right then Ball and his team received word of a gamma-ray burst, a short-lived event for which follow-up at other wavelengths really matters. They decided to go ahead and attempt to observe the burst. "We didn't see anything in the visible filters, but we decided to try our near-infrared imager just in case," remembers Ball. "Sure enough, we got it!"

Thanks to these observations, as well as data from several other observatories, astronomers determined that the gamma-ray burst was one of the most distant sources ever imaged, with a redshift of 8.2. That means the star that died to produce the gamma-ray burst blew up less than 650 million years after the Big Bang.

In Thin Air

TOs like Ball and Aycock, who work on mountaintop observatories, must be prepared to do their jobs in thin air. Mauna Kea, home of the Keck and Gemini North telescopes, among others, is 13,796 feet (4,205 meters) high; there's 40% less oxygen at the summit than at sea level. But TOs don't live at the summit; they have to constantly push their bodies to acclimatize to changes in altitude. Visiting astronomers, on the other hand, only work at mountaintop summits for a few nights each year. Some observatories, such as Keck, even limit astronomers to observing from lower-elevation, remote-observing rooms.

Because TOs generally work a few days at a time and then have a few days off, they're always changing elevation. Ball and Aycock commute regularly from their homes, first to Hale Pohaku — the mid-level facility on Mauna Kea at 9,200 feet where they eat and sleep during their shifts — and then to the summit for each night's observing run. "I calculated my 'average' elevation once — the number of hours I spend at sea level, at Hale Pohaku, and on the summit — and it worked out to something like 9,000 feet," says Aycock. That's well into the high elevation range that can trigger mild altitude sickness if people don't take time to acclimate.

A typical work schedule for Aycock involves driving to Hale Pohaku from his home — a 90-minute commute — at the beginning of his 5-night shift. He eats an evening meal in the Hale Pohaku common room with other TOs and astronomers and then departs for the summit at roughly 5 p.m., depending on the season. The drive to the Keck telescopes takes 20–30 minutes, mostly by dirt road. Aycock makes sure to arrive at the summit at least 30 minutes before sunset to ensure that the telescope, dome, and instruments being used that night are ready to go.

Since TO work often involves acclimatizing to significant changes in elevation — not to mention disruption of circadian rhythm — the job isn't for everyone. But some TOs couldn't think of a better job and savor the freedom that the work affords.

Not Your Average Observatory

All observatories function slightly differently, and many TOs work at several telescopes over the course of their careers. Gabrelle Saurage, who holds an undergraduate physics degree with an emphasis on astrophysics, has been a TO for four different observatories over the course of 14 years: McDonald Observatory in Texas, W. M. Keck Observatory in Hawai'i, Apache Point Observatory in New Mexico, and now the SOFIA telescope aboard a Boeing 747SP jumbo jetliner (*S&T:* April 2015, p. 60).

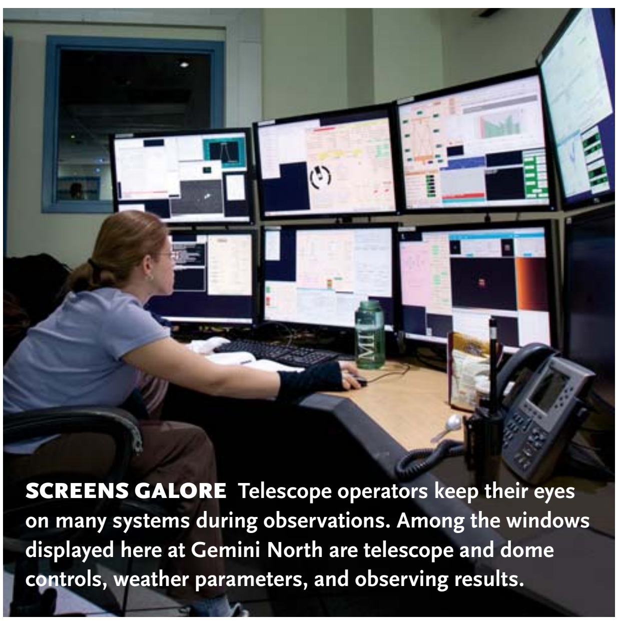
"Working on a 747 is nothing short of awesome," says Saurage. "We wear flight suits, talk on headsets, and see exotic lands."

NASA

OVERSIZED CARRY-ON SOFIA is a modified Boeing 747 that flies high above the atmospheric water vapor that interferes with ground-based telescopes. Its 2.5-meter reflecting telescope peeks out from the rear fuselage.

SOFIA is a modified jetliner with a 2.5-meter telescope installed in its rear fuselage. It flies above most of Earth's atmospheric water vapor, collecting infrared photons that would otherwise be absorbed by water. The aircraft is based in Palmdale, California, but its flights, which last about 10 hours, often take its crew far over the continental United States, the Pacific, Canada, or beyond; two summers ago, they deployed to New Zealand. Working on an airplane, instead of in a windowless control room, has allowed Saurage to see spectacular astronomical sights, such as the aurora at both poles.

Unlike on the ground, where TOs usually operate solo, TOs onboard SOFIA work in pairs during an observing session. One TO is responsible for locating the target in the sky and keeping the target centered in the telescope's field of view, a challenge when SOFIA encounters air turbulence. The other TO communicates with scientists about the goals of the observing session, checks the quality of incoming data, and makes sure that the telescope and instruments are functioning properly.



JOY POLLARD / GEMINI OBSERVATORY / AURA

SCREENS GALORE Telescope operators keep their eyes on many systems during observations. Among the windows displayed here at Gemini North are telescope and dome controls, weather parameters, and observing results.

SOFIA has certain advantages of both a ground-based telescope and a space-based telescope, which affect how Saurage functions as a TO. "We get up to the edge of the stratosphere and thereby above most weather and in a region best suited for far-infrared observations, but then again we can come home every day for repairs, upgrades, and, importantly, switching instruments," she explains. "We are never limited by hardware or weather."

But Saurage finds that her work is more demanding than at other observatories she's worked at, simply because the telescope and its instruments are aboard a flying airplane. "There are the familiar set of commands most telescope operators use to manipulate the telescope — slewing, tracking, and guiding to set up on the desired field," she says. But since they're on a plane, she adds, they have to coordinate with a host of aviation concerns. While a ground-based observing session is affected by weather, TOs onboard SOFIA have to take into account movements of the plane through air turbulence, FAA regulations, airspace restrictions, and pre-determined flight plans. "Setups for observations are significantly more complicated if the observatory is in motion," Saurage concludes.

Saurage, like all TOs, relishes a night of successful observing. And unlike guest observers, TOs have the chance to enjoy these nights regularly — more like amateurs, although TOs' nightly adventures are largely planned by someone else. After some much-needed rest away from their mountaintop or airborne posts, TOs return to take on the roles of scientists, engineers, and therapists for another night. ✦

Katherine Kornei *is a science writer in Portland, Oregon. She has a PhD in astronomy and is grateful to the many telescope operators who helped her collect her thesis data.*

The Spiral Arms of Spring

Embrace the wonders of these grand design galaxies.

UWE GLAHN

Alan Whitman

A 16-inch telescope can reveal tens of thousands of galaxies, but only a handful of them show memorable details at the eyepiece. The finest showpieces are either edge-on galaxies or those that display spiral arms. The Whirlpool Galaxy, M51, is the most famous grand design spiral, but the arms of M83 and M101 are a little easier to see with the 8-inch scopes owned by many amateurs. If you have a medium-to-large-aperture scope and access to good, dark skies, consider adding a few of these spirals to your spring observing lists.

I made most of the observations for this article with my backyard observatory's 16-inch f/4.5 equatorially mounted Newtonian and my 8-inch f/6 Dobsonian. All nights that produced usable observations had excellent transparency — I never attempt serious deep-sky observing on lesser nights. On most nights, the seeing was good or very good, but not always, since strong winds aloft commonly blow here at latitude 49° north in spring, and I live in the lee of two mountain ranges. The descriptions given are often compila-

KNOT HARD TO FIND Patient scrutiny may reveal an elongated knot north of an imagined line connecting the star east of the core of M81 and a Y-shaped group of stars outside the eastern arm (sketch made at 180× with a 16-inch f/4.5 Newtonian reflector).

ARMS EXPOSED Deep-sky images reveal galactic structure not available to visual observers. Note the double stars Σ1387 and Σ1386 southwest of M81.

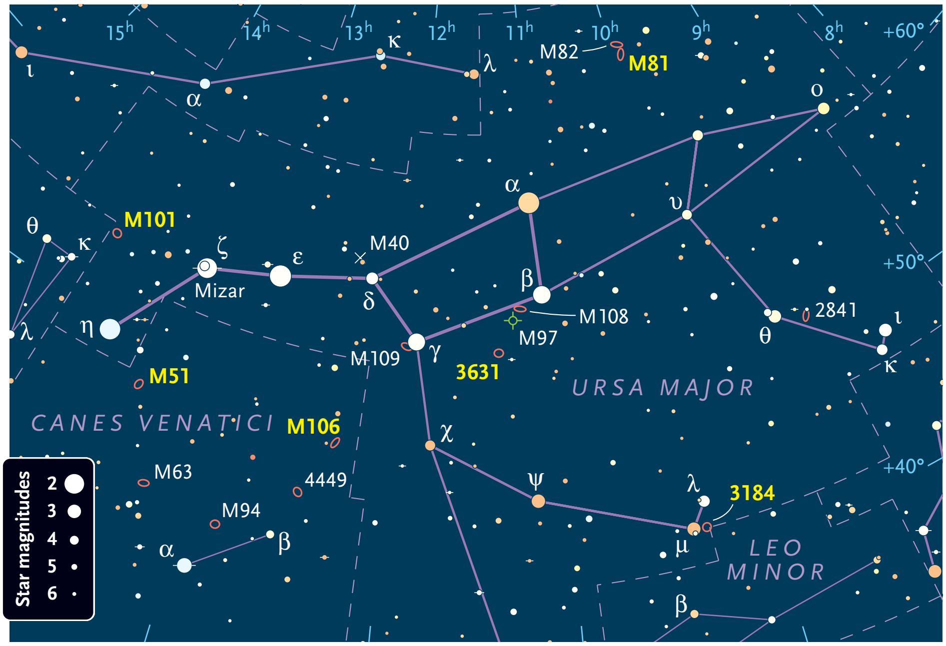
KEN CRAWFORD / IMAGINGDEEPSKY.COM

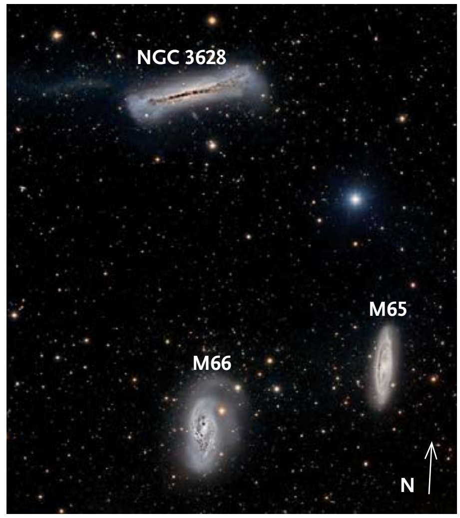
tions that combine the details seen on several nights, so you may not see everything on your first try — I seldom did.

In my 16-inch at 203× Ursa Major's **M81** (also known as one of Bode's Galaxies) shows a very bright 3′ × 2′ oval core holding a very small central region about 10″ in diameter. Within that region shines, to my eye, a stellar nucleus, although some authors disagree with me on this point. A knot hangs on the south end of the core, immediately northwest of the inner of two 11th-magnitude stars.

M81 is one of the closest and brightest spiral galaxies, but its arms are difficult to see — I star-hopped using the underexposed image in *The Night Sky Observer's Guide* (*NSOG*). The arms curl well outside the core, beyond the darker area, and they appeared narrower on the photo under the light from a very faint flashlight than they did in the eyepiece, which surprised me.

A knotty arc, about 3.5′ long, lies south of the core. A 4′ section of the same arm runs east of the central region, ending in an elongated knot. Look for this knot slightly north of a line from a star on the eastern edge of the core to the closest star in the Y-shaped group centered 6′ farther northeast. The section of this eastern arm not visible through amateur instruments appears gravitationally distorted in deep-sky images.





JEFFREY WEISS

IN THE CORNER M66 holds down one corner of the well-known galaxy group, the Leo Triplet. While you're in the neighborhood, look west for the intermediate spiral M65.

North of the galactic center, beyond a dark band, I detected a vague 1.5′ section of arm. This short arc of arm was the most difficult segment to spot, while the eastern arm appeared widest.

Double stars are always the best objects to use to obtain a sharp focus when looking at fuzzy objects like galaxies, and a couple of good candidates shine close to M81. The second-brightest star in the field, located south-southwest of the galactic center, is the binary Σ1387 (Struve 1387), a pair of 10.9-magnitude sparks with a 9″ separation. Immediately to the south shines the 2.1″ double Σ1386, which consists of matched 9.5-magnitude suns.

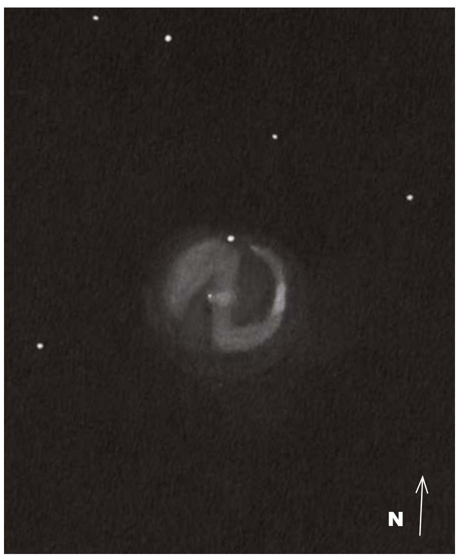
NGC 3184 is conveniently located near Mu (μ) and Lambda (λ) Ursa Majoris, the middle of three naked-eye pairs of stars poetically known as "the Three Leaps of the Gazelle." Bill Ferris, with his 18-inch at high altitude near Flagstaff, Arizona, detected three of NGC 3184's spiral arms. My 16-inch, at 229× in only fair to good seeing, showed a relatively large, bright center with a nucleus and a 14th-magnitude star 1′ northeast. The galaxy appeared darker beyond the core, but I detected an outer ring, shining brightest in the south and southeast, that resembled a view of M51 in an 8-inch scope. An 11th-magnitude star lies on the northern edge of the galaxy. Nice, but I would like a look with bigger glass.

M66, the dominant member of the Trio in Leo, sports a prominent bar, and at 140×, I detected the bright, elongated core lying diagonally across the elongated galaxy. I pulled out two spiral arms with the 16-inch at 261×. The longer arm extends well to the south, almost as far as the main body of the galaxy is long. I also spotted the bright root of the second arm, known colloquially as the Crab's Claw.

Back in Ursa Major, **NGC 3631** at 203× in the 16-inch shows a large, amorphous halo with some mottling. There's a very faint star upon this face-on spiral. The brightest star in the adjacent scalene triangle is a double, Σ1520 (magnitudes 6.6 and 7.9 at 12.7″). The primary appears yellowish. Sissy Haas describes the secondary as "a little white star," but *NSOG* offers "yellowish and pale blue."

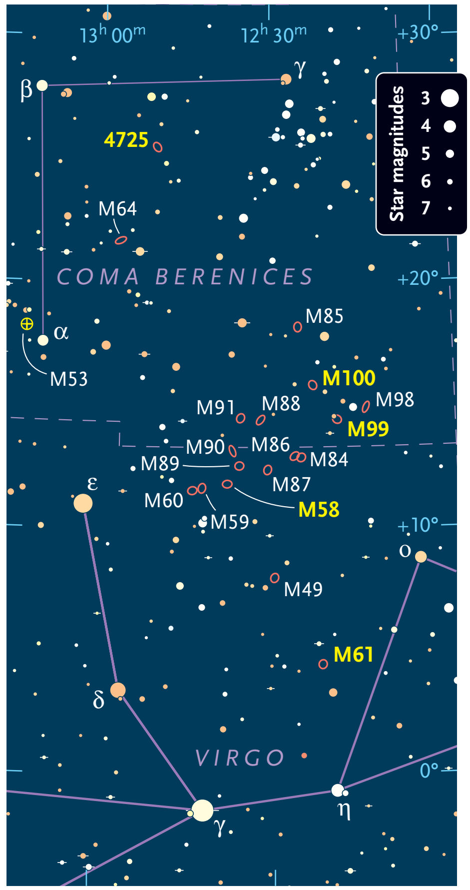
On my third attempt to discern NGC 3631's arms with this scope, I enjoyed a night of superb transparency and very good seeing. After cooling my mirror for

MICHELE BRUSA



UWE GLAHN

BLUE HEAT *Left:* Visually, you won't see any color in NGC 3184, but deep-sky images show the blue of the young, hot stars populating its spiral arms. *Right:* Uwe Glahn picked up the galactic nucleus with its neighboring 14th-magnitude star with his 16-inch reflector at 257×. Look for the 11th-magnitude star at the edge of the northern arm.



three hours, I used a 7-mm orthoscopic eyepiece for its superior light transmission. It yields 261× but gives only a 10′ field of view. I recorded a small, bright core with a nucleus surrounded by a darker ring, then a brighter ring at the outer edge of the halo. With great difficulty, I detected the southwestern arm leading out to the brightest sector of the ring. This may be the toughest spiral arm that I've ever discerned.

At 93× the 8-inch on Ursa Major's **M101** showed a fairly faint nucleus in the small core, two barely discernible spiral arms, and several knots. A 12.5-magnitude star lies on the face of the galaxy 1.3′ north of the nucleus. At 116× the scope revealed three of the cataloged H II regions: NGC 5461 and NGC 5462 are both tiny fuzzies, but intermittently detectable NGC 5455 just looks stellar. NGC 5461 is the easiest to spot of these three targets.

On a night of very good seeing, my 16-inch revealed two of M101's arms at only 76×. At 152× I detected sections of two fainter arms and saw all ten associations or H II regions described by Steve Gottlieb (*S&T:* June 2004, p. 89). Seven knots were quite obvious. In addition to the three mentioned above, NGC 5450, NGC 5471, NGC 5458, and NGC 5447 were easily viewable. The last, NGC 5447, has two components, detectable both visually and through imaging. With the 16-inch, I could see that both NGC 5461 and NGC 5462 are elongated.

The final three knots could be considered mere smudges, only occasionally seen: NGC 5453 and NGC 5449 both yielded at 152×, while NGC 5451 required 229×.

It amazes me that spiral arms can be seen in galaxies that reside in the distant Coma–Virgo Cluster, but they can! New Mexico's Chaco Observatory has a public observing program that I was privileged to direct in 2002–2003. Chaco's 25-inch Dobsonian at 275× in good seeing gave me my finest view of **M61**. A long north-to-south bar holds a bright nucleus. Toward the southern end of the bar sparks a faint, star-like H II region. A short arm extends from the southern end of the bar, curling around until it fades away just inside a 14th-magnitude star to the west. Two arms rise from the bar's northern end. The first, long and impressive, curves along the eastern side of the galaxy until it peters out near the southern end of the bar. Look for a knot due east of the nucleus. The second arm is short but bright; it points to the northeast. I recorded these features on my fourth consecutive night of observing, after which I quit early, at only 1:30 a.m., for fear of falling asleep and tumbling off the very high ladder.

But I've had luck observing Coma spirals with my own scope as well. On a rare night with excellent seeing, my 16-inch at 261× revealed a tiny nucleus and three arms in **M99**. The longest arm, which begins on the southern side of the galaxy, wasn't too difficult; it runs westward and then northwestward. I glimpsed the fainter northern and northeastern arms only with the aid of Ronald Buta's sketch made with a 30-inch reflector at McDonald Observatory (*S&T:* May 2000, p. 126).

M100 in my 16-inch at 174× looks like a large, round glow with a light arc along the northwestern edge (a section of a spi-

Spring Spirals

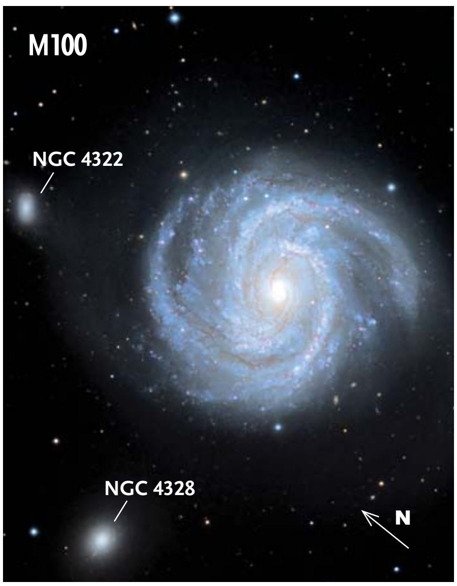
Object	Con	Surface Brightness	Mag(v)	Size/Sep	RA	Dec.
M81	UMa	13.2	6.9	26.9′ × 14.1′	$09^h\ 55.7^m$	+69° 04′
NGC 3184	UMa	13.9	9.8	7.4′ × 6.9′	$10^h\ 18.3^m$	+41° 25′
M66	Leo	12.7	8.9	9.1′ × 4.2′	$11^h\ 20.3^m$	+12° 59′
NGC 3631	UMa	13.4	10.4	5.0′ × 3.7′	$11^h\ 21.1^m$	+53° 10′
M101	UMa	14.9	7.9	28.8′ × 26.9′	$14^h\ 03.2^m$	+54° 21′
M61	Vir	13.4	9.7	6.5′ × 5.8′	$12^h\ 21.9^m$	+04° 28′
M99	Com	13.2	9.9	5.4′ × 4.7′	$12^h\ 18.8^m$	+14° 25′
M100	Com	13.4	9.4	7.4′ × 6.3′	$12^h\ 22.9^m$	+15° 49′
M58	Vir	13.1	9.7	5.9′ × 4.7′	$12^h\ 37.7^m$	+11° 49′
NGC 4725	Com	14.0	9.4	10.7′ × 7.6′	$12^h\ 50.5^m$	+25° 30′
M106	CVn	13.6	8.4	18.6′ × 7.2′	$12^h\ 19.0^m$	+47° 18′
M51	CVn	12.9	8.4	11.2′ × 6.9′	$13^h\ 29.9^m$	+47° 11′
M83	Hya	12.8	7.5	12.9′ × 11.5′	$13^h\ 37.0^m$	–29° 52′

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

BERTRAND LAVILLE (2)

COMPARE AND CONTRAST Bertrand Laville sketched M99 as seen with two scopes: a 25-inch Dobsonian at 130–140× *(left)* and a 10-inch Dobsonian at 127× *(right)*. Don't be afraid to go after the arms with different tools; you may be surprised when a smaller scope reveals something new.

ral arm), and a small, bright core, but no nucleus. Using a photograph as a guide, I perceived several condensations on that northern arm, adjacent to the close pair of stars beside the arm. With some difficulty I could also detect a number of H II regions within the southern arm, southeast of the galactic core. The southern spiral arm remained hidden; I could detect just its brightest condensations in the eyepiece. The most obvious knot lies



JOSEPH D. SCHULMAN

NEVER LONELY Discovered by Pierre Méchain on March 15, 1781, M100 is flanked by two satellite galaxies. Photographs reveal more than your eye can see, but deep-sky images can help guide your visual observations.

halfway between the core and a 14th-magnitude star beyond the southeastern flank of the halo.

At 203× **M58** was so amorphous in the 16-inch that I couldn't tell whether it was large or not! Its small, bright core with a stellar nucleus was apparent, as was a knot closely following. At 152× the galaxy's amorphous halo became a little more apparent, and I suspected a dark lane following the core, with perhaps a spiral arm beyond the dark lane. The halo and spiral arm were shown best at 114×. With this telescope, it's almost unheard of for 114× to show galactic detail better than 203× does, but it sometimes happens!

When I turned my 16-inch on the ring galaxy **NGC 4725** in Coma, upping the magnification to 203×, a long bar aligned northeast-southwest came into view. The bar holds a bright little 10″ diameter core with a nucleus. I saw arcs of the arms that form a ring at both ends of the bar. My study was easier at the southwestern end, since two 14.5-magnitude field stars interfere with the northeastern arm. In any case, the arm segments are subtle — they're not something I'd notice without knowing they were there and specifically looking for them. Indeed, they were invisible at both 114× and 261×.

M106 in Canes Venatici, viewed at 203× in my 16-inch, showed a mottled halo, about 10′ long and elongated 3:1. The small, bright elongated core holds a famously violent nucleus. Of the galaxy's two arms, the one that runs to the northwest, curling a little, is the more prominent. I spotted two elongated condensations along it. The opposite arm extends to the southeast; it's quite subtle. A great galaxy!

One of the more famous — but sometimes more challenging — spirals is **M51**, also known as the Whirlpool Galaxy in Canes Venatici (*S&T:* July 2011, p. 26). A textbook example of a grand design spiral, M51 is interacting with an irregular dwarf galaxy, NGC 5195. My 8-inch reflector at 174× sometimes shows segments of M51's spiral arms, bright nuclei for both galaxies, a foreground star projected on M51, and a hint of the arm leading towards NGC 5195. More rarely, I have recorded a broken-ring structure. My 16-inch at 203× shows eight knots along M51's arms, five of them in the arm not leading to the companion galaxy.

If you keep looking over the decades, one exceptional night may provide the memory of a lifetime. Mine occurred in April 1994, when my 8-inch's mirrors and eyepiece were freshly cleaned. This was during a period when I was making regular visual supernova searches in the region with the Prince George Astronomical Observatory's 24-inch Cassegrain — it's always easier to see detail with smaller aperture if you've seen it previously with a large scope. With excellent seeing and M51 near the zenith, instead of just seeing the broken-ring effect, I could clearly trace both of the main arms at 116×. I also saw the long condensation on the eastern part of the inner eastern arm, and a knot equidistant between the two galactic nuclei. A line, drawn from the 13.5-magnitude foreground star through M51's nucleus and extended 1.5 times this distance, ends at this knot.

I showed M51 to members of the general public with Chaco Observatory's 25-inch at 113×. With this big glass, the novice observers could see well the spiral arms after instruction in averted vision!

Because it lies in Hydra, **M83** is often considered a southern target (indeed, it's also called "the Southern Pinwheel Galaxy"). I enjoyed a fine view of the spiral at 135× through my 8-inch in Arizona, observing the galaxy's bar with a bright nucleus, and a segment of the brightest (eastern) arm. Two years later, during a Messier Marathon with the same scope at latitude 49° north, I lingered over some of the southern objects instead of moving on promptly as one should during marathons. At 93× M83 showed the same details that I had seen in Arizona — remarkable given that it culminates at only 11° altitude at that latitude.

By way of contrast, consider my logbook entry made when viewing M83 at 65° altitude in Australia with Tony Buckley's 14.5-inch Newtonian at 136×: "Wow! Just like the photos! Prominent northeast to southwest bar with a bright core holding a stellar nucleus. Two obvious spiral arms, and the third (shorter) arm was just detected (confirmed by the position of the brightest foreground star on photos). The very long arm which circles the galaxy is only visible for the first half of its length, on the northwestern side of M83." I look forward to viewing M83 with a 30-inch in Australia this April.

These splendid spiral galaxies are worthy of many careful views. It takes time and experience to tease out their low contrast details, so make plans to visit them every spring — your return visits won't disappoint. ✦

Alan Whitman anticipates seeing Howard Banich's sketch of M81 made with big glass in an upcoming issue.

KEN CRAWFORD / IMAGINGDEEPSKY.COM

ORIGINAL MODEL Sketched famously by Lord Rosse in 1845, M51 was the first galaxy to be revealed as spiral. Its interacting neighbor, NGC 5195, likely passed through M51's main disk some 50 to 100 million years ago.

Lowell's Great Refractor Made NEW

Klaus Brasch & Ralph Nye

E. WEBB

At age 119, Lowell Observatory's legendary "Mars telescope" is reborn.

The 24-inch refractor that stands atop Mars Hill in Flagstaff, Arizona, holds a special place in the annals of astronomy. It was built by the renowned firm of Alvan Clark & Sons for Percival Lowell, the Mars enthusiast and wealthy black sheep of a patrician Boston family. The telescope was commissioned in 1897 and has been in active use nearly ever since.

Lowell Observatory and its colorful patron seized the world's attention at the turn of the 20th century when Lowell described and mapped the supposed canals on Mars; he proposed that they were the works of an advanced civilization, designed to carry water from the polar ice caps to the rest of a dying planet. The "canals on Mars" brought fame and later shame to the institution, as it gradually became clear that they were illusory — effects of contrast, atmospheric seeing, and the tendency of the eye to connect dots and regularize randomness when working at the limits of human vision. Or at least Lowell's vision and that of his dutiful assistants.

Despite this controversial beginning, the Lowell refractor soon made substantial contributions to science in the capable hands of three pioneering Lowell astronomers: the brothers Vesto Melvin ("VM") Slipher and Earl C. Slipher and Carl Otto Lampland. Among many other achievements, VM used a modified Brashear spectrograph on the Clark to obtain the first spectra of spiral

FINISHED The 24-inch f/16 refractor, ready for another century of service. The 12-inch "finderscope" is mounted above it; the 4-inch finderscope is out of sight. Access stairs lead to the classical German equatorial mount. The observatory and telescope were declared a National Historic Landmark in 1965.

"nebulae" and discover that most show high velocities of recession. This achievement led to Edwin Hubble's finding that the universe is expanding. VM Slipher also discovered spectroscopically that the Merope Nebula in the Pleiades was not glowing gas but interstellar dust reflecting starlight; it was the first known reflection nebula. In 1905 Lampland used the Clark refractor to obtain some of the earliest good photographs of Mars. For the next half century E. C. Slipher used specially built enlarging cameras and a technique called integration printing to secure some of the finest photographs of the planets from that era (*S&T:* March 2014, p. 68).

With the arrival of the space age in the late 1950s and 1960s, the Clark telescope once again became a centerpiece of lunar and planetary research. NASA funded a Planetary Research Center at the observatory, which carried out two major projects: high-resolution mapping of the Moon in preparation for the Apollo missions (resulting in the U.S. Air Force/NASA Lunar Charts in 1963), and running the worldwide International Planetary Patrol Program, headed by William A. Baum, which generated a database of 1.2 million photographs of the major planets (as told in the January issue, page 52). These provided invaluable information on Martian meteorology and dust storms, the dynamics of Jupiter's atmosphere, the retrograde rotation of Venus's cloud deck, and some of the physical properties of Saturn's ring system, all in preparation for planetary exploration by space probes.

Since then, the great refractor has served as the core attraction in the observatory's Public Program, which welcomes some 80,000 visitors a year. The telescope has also been used by many amateur astronomers for special observing and imaging sessions.

But after performing for over a century, this classic telescope, mounting and dome were in dire need of some tender loving care. Enter master instrument specialist Ralph Nye and his team of skilled co-workers: Jeff Gehring, Glenn Hill, Peter Rosenthal, and Dave Shuck.

From the Ground Up

A major problem was deterioration of the massive bearing wheel at the bottom of the polar axis. Eighteen inches in diameter and 3 inches wide, supporting three tons of moving parts, it was made of relatively soft cast iron; large steel bearings weren't available in 1895. After some 116 years of use, the support wheel had flattened and widened at damaged areas. Consequently, as the telescope moved in right ascension, the polar axle shifted out of its housing by ⅛ inch or so, and when the three-ton assembly fell back to its original position, a loud bang shook the entire telescope!

Replacing it would require taking the entire telescope apart. On the positive side, this would give us a chance to do many other repairs and restorations.

Lowell Observatory started a "Save the Clark Tele-

DISASSEMBLY A crane lifts the 900-pound declination shaft out of its housing for inspection and cleaning. The mount was bolted to a temporary pier at a 35° angle, so the polar axis (behind the big right-ascension circle) would be horizontal for easier removal of parts.

CAREFUL! A crane lowers the refurbished, 11,000-pound equatorial mount through the dome slit.

LOWELL OBSERVATORY (2)

scope" fundraising campaign to finance a thorough job. The institution's many members and friends raised close to $300,000 in three months, enough to totally restore not just the telescope and mount, but also the iconic, 40-foot-high cylindrical wooden dome.

Lowell Observatory has a long tradition of designing and fabricating instruments and telescope modifications, and it has always retained a cadre of specialists and facilities to that end. This saved money and provided the in-house expertise to do the best possible restoration job without cutting corners. For example, coauthor Ralph Nye, Director of Technical Services, has worked at Lowell since 1976. He's in charge of mechanical engineering and maintains the Clark and eight other telescopes, including instrumentation for the observatory's new 4.3-meter Discovery Channel Telescope.

No documentation exists for how the telescope was originally put in place. So Nye's restoration plan centered on taking the instrument apart safely (photographing all parts and their locations), designing and fabricating custom arrangements to process some seven tons of parts, and restoring the wooden dome without damaging it.

The undertaking involved several key steps. First, we locked down the telescope's 32-foot tube parallel to the ground using two special fixtures that bolted to existing holes on the cast iron center section of the tube, then attached these to the mount pedestal using specially designed turnbuckles reminiscent of a truck driveshaft. A similar brace was used to support the five 417-pound right-ascension counterweights.

We carefully removed several trees near the dome to allow room for a 160-foot crane to remove large components through the dome's shutters. To facilitate this, we stripped the telescope of all small parts, along with its 4- and 12-inch Alvan Clark and Sons finder telescopes.

The priceless 24-inch Clark lens assembly was next in line for removal, but this posed a problem. Since the telescope was now locked in place horizontally, the dome could not be rotated freely to allow access to the lens through the dome shutter. We cut a hole in the dome ceiling and lowered a 40-foot strap to lift off the 230-pound lens cell! Before that, however, we had to remove two of the counterweights to balance out the expected weight loss due to removal of the lens assembly and, later, the upper and lower tube sections.

Prior to removing the 860-pound front tube section, we braced a massive wooden beam between the floor and the back section of the tube for added safety and to minimize stress on the temporary support rods.

Since the mount's polar axis is aimed 35° above horizontal (Flagstaff's latitude), and the 960-pound polar shaft would be extremely difficult to remove at such an angle, Nye designed an I-beam support structure set at –35°, to tilt the whole mounting at an unnatural angle. This allowed removal and reinstallation of the polar shaft with a horizontal pull or push.

The telescope had last been serviced several decades before, and at that time many of its parts were treated with lead-based paint to minimize corrosion. To address the lead-paint toxicity problem, we built a wooden fixture allowing the two telescope tube sections to be rolled and treated with a lead-paint stripper and neutralizer. We refinished the tube and many other large parts with a silver-grey powder coating. All other parts and accessories were cleaned and restored to the point where we could do nothing more to make them work or look any better.

DON'T SCRATCH ***Left:*** **The 24-inch objective lens after removal of the lens cap and the adjustable-aperture iris diaphragm that early observers sometimes used. Despite a coating of dust and pollen, the lens was otherwise in good shape.** ***Right:*** **Ralph Nye (left) and Peter Rosenthal carefully clean the rear, flint-glass element of the disassembled 24-inch objective.**

LOWELL OBSERVATORY (2)

By far the most delicate and precious components of this classic telescope were the irreplaceable 12- and 24-inch Clark objective lenses. The fronts of both objectives were covered with years of dust, pine pollen, and contaminants, but were otherwise unharmed. We took both cell assemblies apart with great care, marking the positions of all components carefully on the lens edges and cells as we found them. Original "V" marks remained on the edges of both the crown- and flint-glass elements and lens cells, to show the intended rotation of the elements with respect to each other, but we reinstalled all components exactly as they were when we took them apart — due to the unknown source of the "V" markings (was a better matching of the lens elements done later?) and because the objective performed perfectly as it was.

We cautiously cleaned the lens elements with Alconox mixture, alcohol, distilled water, and Kimwipes. We used a spherometer to document the radius of curvature of all lens surfaces. We also recorded the thickness and diameter of each element and the spacing between them, since no original Clark drawings or specifications exist. All of the lens elements were uncoated, and we left them that way for historical authenticity.

One unexpected finding was a soft, silver-colored metal lining, most likely zinc, machined into both lens cells at their contact areas with the glass. Another surprise inside the 24-inch tube was a special color-correcting assembly that had been installed to minimize chromatic aberration when the telescope was used during the International Planetary Patrol Program in the 1960s.

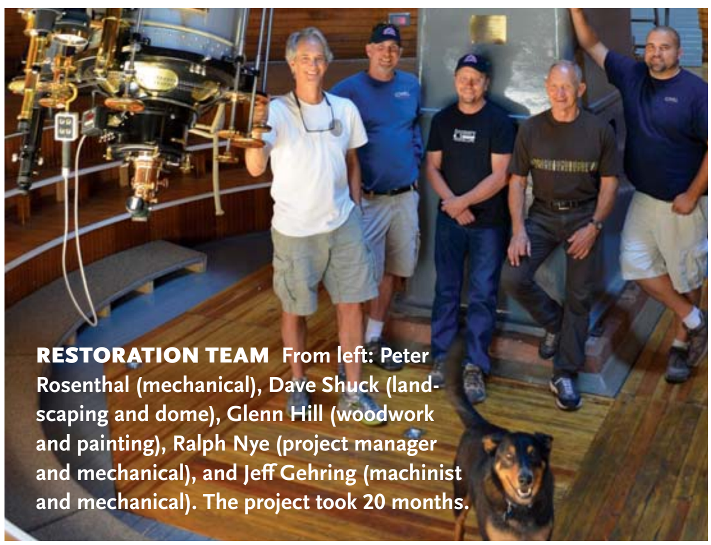
Reassembling the mount and telescopes inside the dome was far easier than their disassembly had been. We polished and clear-coated all of the brass pieces and most of the gearing, shafting, and other metal components, thereby highlighting for all to see the wonderful 1896 engineering and machine work that went into construction of this historic masterpiece. In addition, we fully restored to working condition one of the original mechanical clock drives used to turn the telescope. This beautiful, historic mechanism functions now as if it had just been manufactured.

Lastly, we refurbished the observatory dome with new, smoother-operating top shutters, extensive internal and external wooden slat repair, and weatherproofing and repainting.

The five people involved with the restoration feel great accomplishment and deep appreciation for the donors who made this project possible. This storied astronomical facility now looks as if was built yesterday. It should serve Lowell Observatory's public outreach program for another 100 years. ✦

Retired scientist Klaus Brasch is a docent at Lowell Observatory. Ralph Nye is Director of Technical Services.

BEFORE AND AFTER The team performed fine-scale restoration work throughout. Here, the hollow declination shaft (coming down from top) ends inside the endcap at bottom; the counterweight shaft extends on below. Inside the declination shaft are two coaxial rods that control the right-ascension slow motion and its clutch. They end at the two flat gears seen above in the endcap, here stripped of its outer parts. Other gears engage those to turn the right-ascension sector arm (the large V-shaped part at top) for slow-motion control, and to lock and unlock it.



RESTORATION TEAM From left: Peter Rosenthal (mechanical), Dave Shuck (landscaping and dome), Glenn Hill (woodwork and painting), Ralph Nye (project manager and mechanical), and Jeff Gehring (machinist and mechanical). The project took 20 months.

LOWELL OBSERVATORY (3)

▼ **OPTIMUS EYEPIECES** Stellarvue introduces a line of ultra-wide-field eyepieces. The Stellarvue Optimus series eyepieces (starting at $419 each) feature an immersive 100° or 110° apparent field of view with 15 mm of eye relief. Each eyepiece utilizes eight or more fully multi-coated elements with a black baffled interior to produce views free from reflections and ghosting. The outer lenses are sealed to prevent fogging under normal viewing conditions. Each eyepiece includes rubber grips and eyecups. Available in focal lengths of 3.6, 4.7, and 9 mm in 1¼-inch format with an included 1¼-to-2-inch adapter, and a 20-mm, 2-inch design.

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▲ **COOLED VIDEO** ZW Optical introduces a new series of low-noise cooled cameras. The ASI 224MC-Cool ($649) features the highly sensitive IMX224 color CMOS detector with a 1,304-by-976 array of 3.75-micron pixels. This USB-3.0 camera is capable of recording up to 150 frames per second at full resolution, and it can be cooled to 40°C below ambient. Additionally, the camera can operate in 12-bit format and function as an autoguider for your deep-sky imaging needs with its built-in ST-4 autoguider port. The camera comes complete with a USB-3.0 cable, AC power supply, 1¼-inch nosepiece adapter, and CD with camera drivers and control software.

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OBSERVATORY GUIDE Author John Stephen Hicks has updated his seminal book *Building a Roll-Off Roof or Dome Observatory; A Complete Guide for Design and Construction, Second Edition* (paperback: $34.99; eBook: $19.99). Hicks discusses each aspect of backyard observatory design and construction to help you decide which type suits your needs best. Important considerations including structural variations, placement, and zoning and bylaw requirements common to most states and municipalities are discussed at length. Step-by-step directions and detailed diagrams are included for each phase of construction. 248 pages, ISBN 978-1-4939-3010-4.

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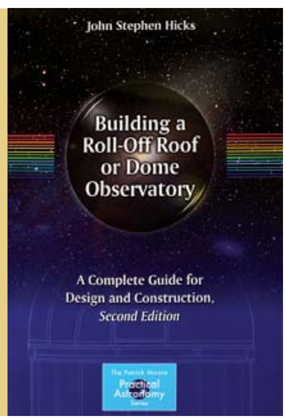
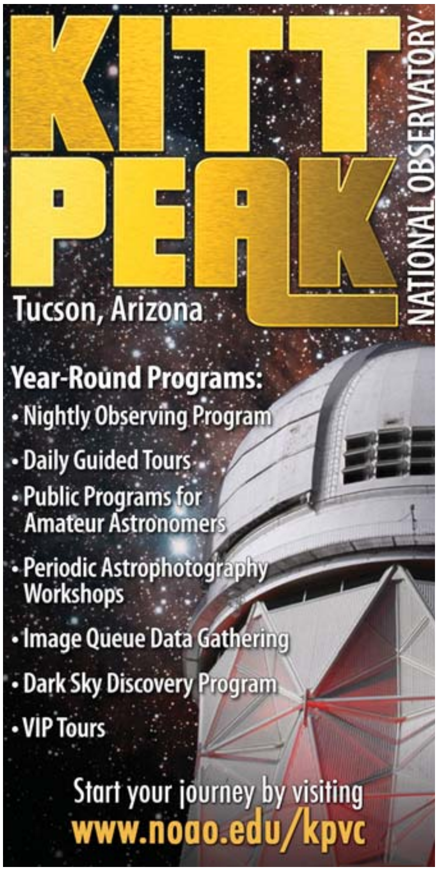


New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information contact the manufacturer or distributor. Announcements should be sent to nps@SkyandTelescope.com. Not all announcements can be listed.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In This Section

Spiral galaxy M81, discovered in 1774 by Johann Elert Bode, is one of the brightest galaxies visible from Earth (page 28).

PHOTOGRAPH: NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA)

Additional Observing Article:

Sky at a Glance

MARCH 2016

1 **MORNING:** The last-quarter Moon hangs between Mars and Saturn, left of Beta (β) Scorpii.

2 **MORNING:** Look for the Moon just 4° or so left of Saturn as they rise in tandem around 1 or 2 a.m.

7 **BEFORE DAWN:** The waning crescent Moon rises left of Venus less than an hour before sunrise. **EVENING:** A double-shadow transit occurs on Jupiter from 7:29 to 8:59 p.m. EST; see page 50.

9 **MORNING:** A total solar eclipse crosses parts of Indonesia and the Pacific; see page 50.

13 **DAYLIGHT-SAVING TIME STARTS** at 2 a.m. for most of the United States and Canada.

14–15 **NIGHT:** A double-shadow transit occurs on Jupiter from 10:22 p.m. to 12:34 a.m. EST.

19–20 **SPRING BEGINS** in the Northern Hemisphere at the equinox March 20, 12:30 a.m. EDT (March 19, 9:30 p.m. PDT).

21 **NIGHT:** A double-shadow transit occurs on Jupiter, from 9:23 to 11:31 p.m. PDT.

21–22 **ALL NIGHT:** The waxing gibbous Moon forms a triangle with Jupiter and Sigma (σ) Leonis.

23 **MORNING:** A penumbral lunar eclipse is visible for parts of North America and Asia; see page 50.

24–25 **ALL NIGHT:** The Moon, just past full, beams 4° above or upper left of Spica.

29 **MORNING:** The waning gibbous Moon, Saturn, Mars, and Spica form an uneven quadrangle.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	Hidden in the Sun's glare all month		
Venus			E
Mars		SE	S
Jupiter	E	S	W
Saturn		SE	S

Moon Phases

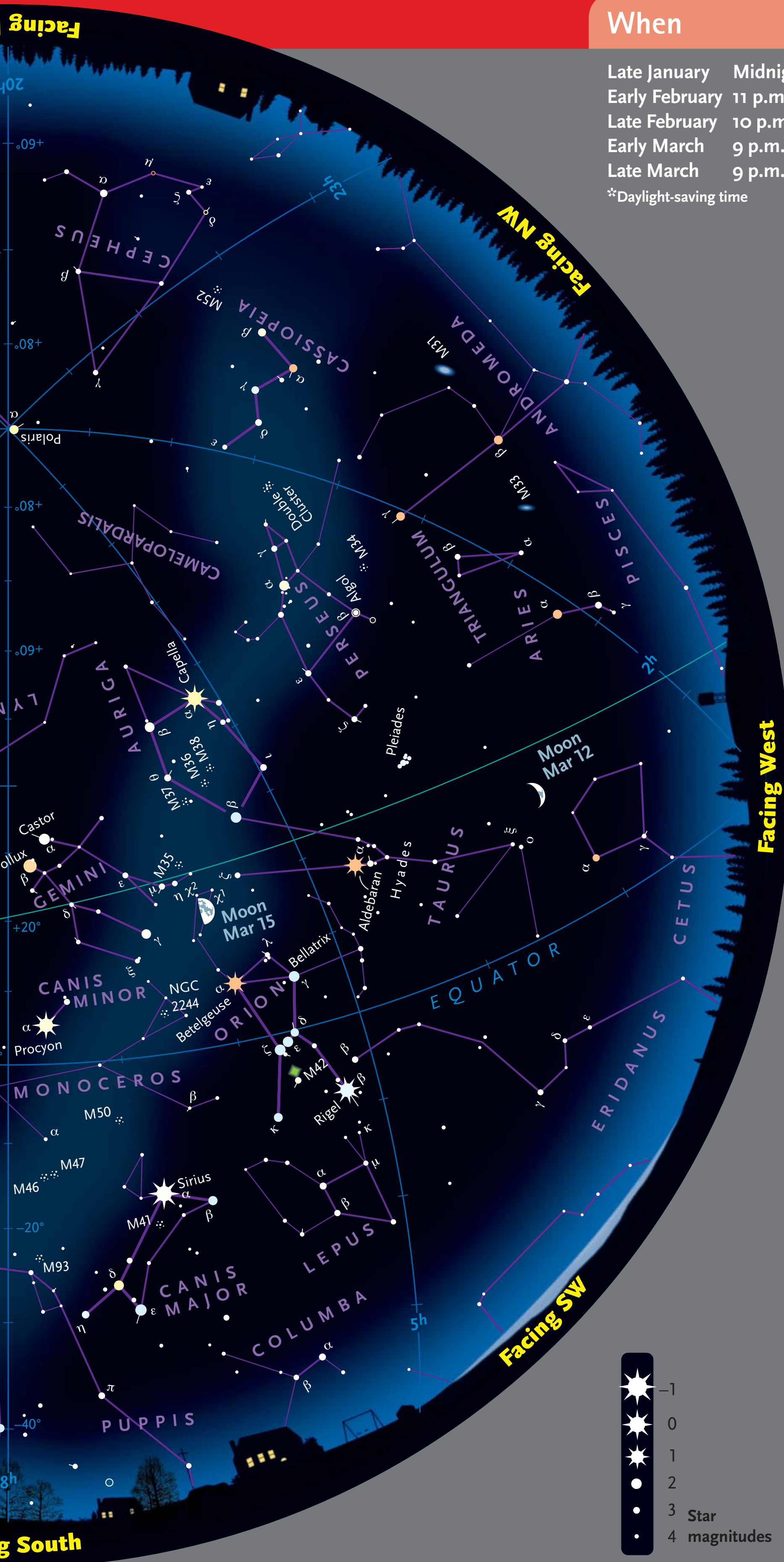
Last Qtr	March 1	6:11 p.m. EST	
New	March 9	8:54 p.m. EST	
First Qtr	March 14	1:03 p.m. EDT	
Full	March 23	8:01 p.m. EDT	
Last Qtr	March 31	11:17 a.m. EDT	

SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Using the Map

Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. Above it are the constellations in front of you. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.

EXACT FOR LATITUDE 40° NORTH.



When

Late January	Midnight
Early February	11 p.m.
Late February	10 p.m.
Early March	9 p.m.
Late March	9 p.m.*

*Daylight-saving time

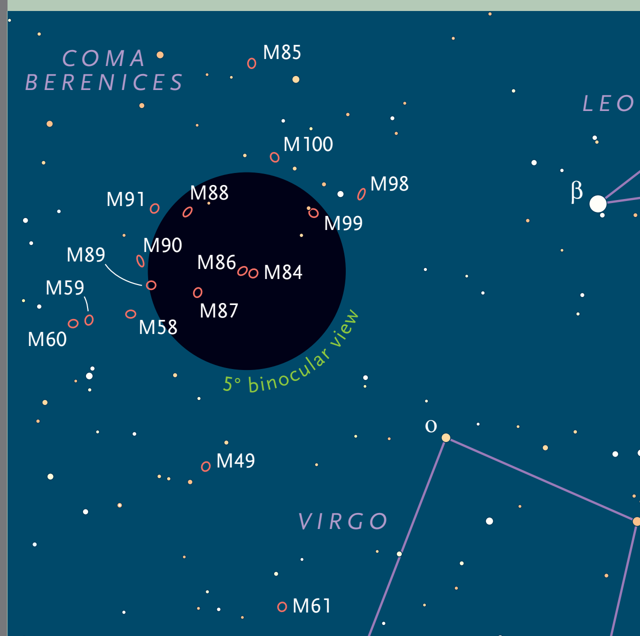
A Marathon Bino Session

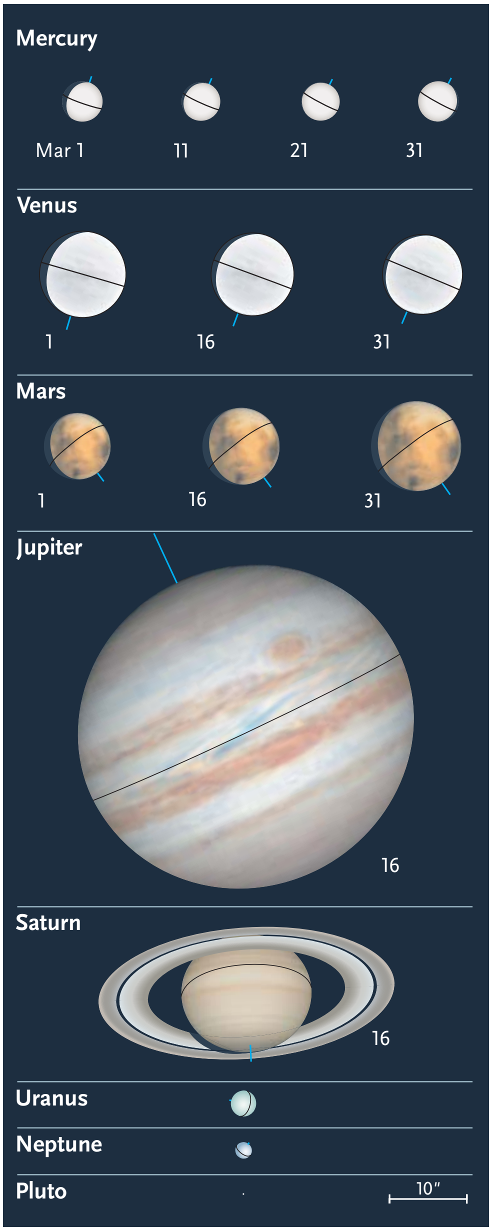
Few approach binocular astronomy as a competitive sport, but it's unquestionably rewarding to challenge yourself from time to time. Running a Messier marathon is a great way to sharpen your observing and planning skills — with particular emphasis on the latter. What's a Messier marathon? Simply an attempt to see as many Messier objects as you can in a single, dusk-to-dawn session. It's only in spring that you have a chance (theoretically, at least) to observe the entire catalog. This year, the prime marathon windows occur on March 12–13 and April 2–3.

What are the secrets to success? First, as I mention above, planning is very important. Have your charts ready and print an observing list that includes a logical sequence. Use Larry McNish's Messier Marathon Planner (**http://is.gd/mmarathon**) or a similar tool to generate one tailored to your location and date. Second, find an observing site with dark skies and good horizons, especially in the east and west. Third, bring a friend or join a group. Long observing sessions are always more fun when the experience is shared. Plus, you can keep each other awake during lulls in the action.

As for equipment, use whatever binoculars you have — obviously, the bigger the better you're going to do. But regardless of model, make sure your binos can be mounted in some fashion. You'll spend a lot of time consulting your charts, and a mount means you don't have to re-find your target every time you do.

Most importantly, have fun. In truth, you're only competing against yourself. There's no prize for achieving a high score — the reward is in the attempt, and a night spent in the company of the stars. ✦



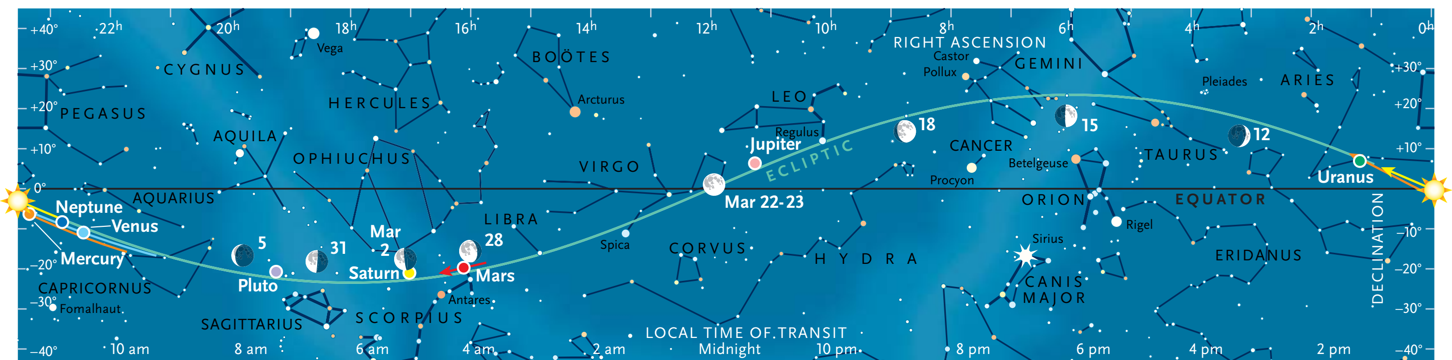


Sun and Planets, March 2016

	March	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$22^h\ 48.4^m$	–7° 35′	—	–26.8	32′ 17″	—	0.991
	31	$0^h\ 38.6^m$	+4° 09′	—	–26.8	32′ 01″	—	0.999
Mercury	1	$21^h\ 42.6^m$	–15° 50′	18° Mo	–0.3	5.2″	87%	1.280
	11	$22^h\ 46.7^m$	–10° 07′	12° Mo	–0.7	5.0″	94%	1.345
	21	$23^h\ 54.5^m$	–2° 21′	3° Mo	–1.7	4.9″	99%	1.358
	31	$1^h\ 06.5^m$	+6° 52′	7° Ev	–1.6	5.2″	96%	1.280
Venus	1	$21^h\ 13.2^m$	–16° 47′	25° Mo	–3.9	11.2″	91%	1.493
	11	$22^h\ 02.2^m$	–13° 08′	23° Mo	–3.8	10.9″	93%	1.536
	21	$22^h\ 49.5^m$	–8° 52′	20° Mo	–3.8	10.6″	94%	1.576
	31	$23^h\ 35.6^m$	–4° 13′	18° Mo	–3.8	10.3″	95%	1.612
Mars	1	$15^h\ 43.5^m$	–18° 23′	103° Mo	+0.3	8.7″	90%	1.078
	16	$16^h\ 05.3^m$	–19° 39′	112° Mo	–0.1	10.0″	91%	0.933
	31	$16^h\ 21.0^m$	–20° 35′	124° Mo	–0.5	11.7″	93%	0.798
Jupiter	1	$11^h\ 22.0^m$	+5° 41′	171° Mo	–2.5	44.4″	100%	4.445
	31	$11^h\ 08.2^m$	+7° 09′	155° Ev	–2.4	43.7″	100%	4.511
Saturn	1	$16^h\ 58.6^m$	–20° 58′	85° Mo	+0.5	16.5″	100%	10.057
	31	$17^h\ 00.6^m$	–20° 58′	114° Mo	+0.4	17.4″	100%	9.569
Uranus	16	$1^h\ 10.4^m$	+6° 50′	23° Ev	+5.9	3.4″	100%	20.879
Neptune	16	$22^h\ 46.9^m$	–8° 36′	16° Mo	+8.0	2.2″	100%	30.914
Pluto	16	$19^h\ 12.8^m$	–20° 52′	69° Mo	+14.2	0.1″	100%	33.410

The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of a planet's disk illuminated by the Sun and the distance from Earth in astronomical units. (Based on the mean Earth–Sun distance, 1 a.u. is 149,597,871 kilometers, or 92,955,807 international miles.) For other dates, see SkyandTelescope.com/almanac.

Planet disks at left have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.



The Sun and planets are positioned for mid-March; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

Fred Schaaf welcomes your comments at fschaaf@aol.com.

Fred Schaaf

The Power of Two

Stellar pairings offer a beauty of their own.

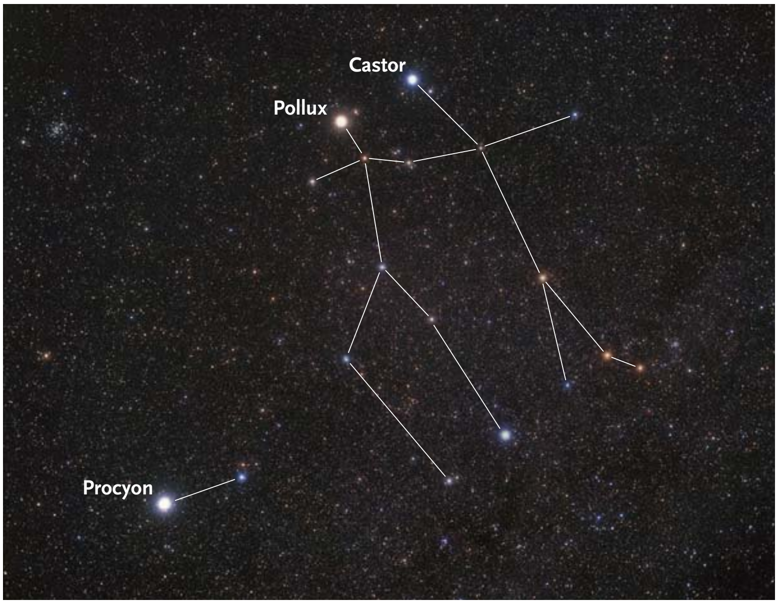
What can planets do that stars can't? One thing is to move into conjunction with another celestial object. Much of the beauty — and all of the drama — of conjunctions is that they're temporary and evolving events. But some of the beauty is also just in the vision of two luminaries posing close to each other in the sky. The stars can offer us this. And let's not forget that "close" is relative — how close together, for instance, do two 1st-magnitude stars have to be to constitute a marvel?

From planet-pairs to star-pairings. Last year was the one I called "the Year of the Conjunctions." Several times, pairings featured bright planets less than ½° degree apart when they were high in a fully dark sky. One more such really close and readily observable conjunction — that of Venus and Saturn — occurred in January.

An ultra-close conjunction of Venus and Jupiter takes place this coming August, but quite low in the dusk. And Mars and Saturn, though reaching opposition a mere 12 days apart in late May–early June, won't get closer than 7° apart in the spring. Not until August will Mars finally have a true conjunction with Saturn, and when it does, the two are, briefly, 4° apart. Compare that to the exactly 4° 30′ separation of a 1st-magnitude and bright 2nd-magnitude star that happen to be close in the sky for more than a single day — in fact, for thousands of years. I'm talking about the twin stars named for history's most famous (albeit mythical) twins, Pollux and Castor.

The twins and the arch of spring. Mars and Saturn are certainly brighter than Pollux and Castor this spring and August. But that's not always so. Mars is often dimmer than magnitude-1.58 Castor, let alone magnitude-1.16 Pollux. And Pollux and Castor's pairing is so noticeable it has determined the identity of one of the most prominent constellations of the zodiac.

Are Pollux and Castor really all that attention-grabbing in a region of sky which features the brightest constellation (Orion), the brightest star (Sirius), and the two brightest naked-eye star clusters (the Hyades and Pleiades)? The stellar duo is actually most eye-catching in spring when those other sights have sunk below the west horizon. As spring progresses, we see in the west after nightfall what *Sky & Telescope*'s Alan MacRobert has called "the Arch of Spring." It's what's left after Sirius, Orion, and Taurus have set: Procyon low in the due west, Capella low in the northwest, and between



AKIRA FUJII

them, highest, at the top of the arch, Pollux and Castor.

Tighter pairings of very bright stars. Pollux and Castor aren't bright enough to simulate perfectly a truly dazzling conjunction of planets. But bright planetary conjunctions are all too liable to occur near the Sun (for one thing, two of the five classic bright planets, Venus and Mercury, are incapable of preceding or following the Sun by more than a few hours at most in our sky). Pollux and Castor, on the other hand, pass high in the sky for observers at mid-northern latitudes. And if you want much brighter star-pairings, all you need do is head (or already be) south.

By an amazing coincidence the three tightest pairings of very bright stars are almost equally so. At present, Alpha (α) and Beta (β) Centauri (magnitudes –0.28 and 0.58) are 4° 25′ apart. Alpha and Beta Crucis (magnitudes 0.77 and 1.25) are 4° 15′ apart. In next month's column we'll discuss how the rankings of the tightest bright pairs are changing — amazingly soon. But we'll end this column with the fact that we can simulate a bright planetary conjunction by looking at a bright double star through the telescope — and none better than Alpha Centauri. The brighter two of its three components are magnitudes –0.01 and 1.35. Their separation changes rapidly and is usually wide — but in 2016 is rather close. ✦

Jove at Best, with Followers

Brightest Jupiter rises at dusk, Mars and Saturn at midnight.

This month features two eclipses: a total solar eclipse on March 8–9 for parts of Indonesia (it's a deep partial for Hawai'i), and a weak penumbral lunar eclipse on March 23rd for western North America and Hawai'i.

Several planets make especially fascinating appearances this month. Jupiter rises around sunset and dominates the sky at its biggest and brightest through the night. Mars continues to brighten dramatically, but this month's change to daylight-saving time delays its rising to approximately midnight. The interval between the rise of Mars and that of following Saturn shrinks from about 90 to 40 minutes in March, bringing the two much closer together in the vicinity of Antares; all three shine highest in the south around the start of morning twilight. Venus rises during morning twilight, later and later, becoming lost from view in early April.

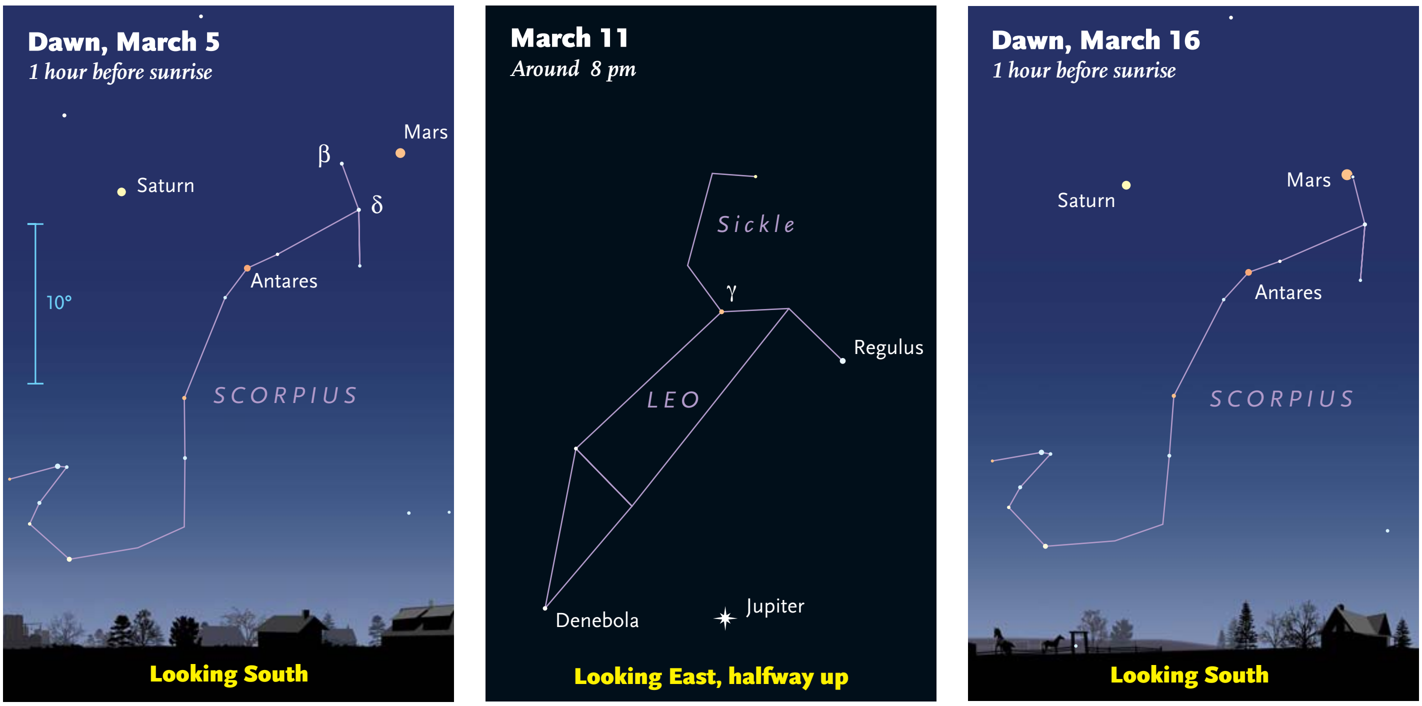
DUSK TO DAWN

Jupiter arrives at opposition on March 8th, beaming at magnitude –2.5 all night long. The kingly planet blazes in or under the hind legs of Leo, the Lion, retrograding slightly west but still trailing almost an entire lion-length behind Regulus. Jupiter is at its closest for the year, but this opposition is the second most distant in Jupiter's 12-year orbital cycle. The orb of Jupiter nonetheless appears 44″ wide now, providing a luxurious wealth of detail in its cloud features in moderate-to-large telescopes. For more about observing Jupiter, see page 50. Charts of the positions of its Galilean satellites appear on page 49.

Uranus is still viewable in the southwest as dusk ends in early March but by mid-month sets too soon after the Sun for observation. See the September 2015 issue, page 48, for a finder chart, or visit **skyandtelescope.com/urnep** to learn more about the ice giant.

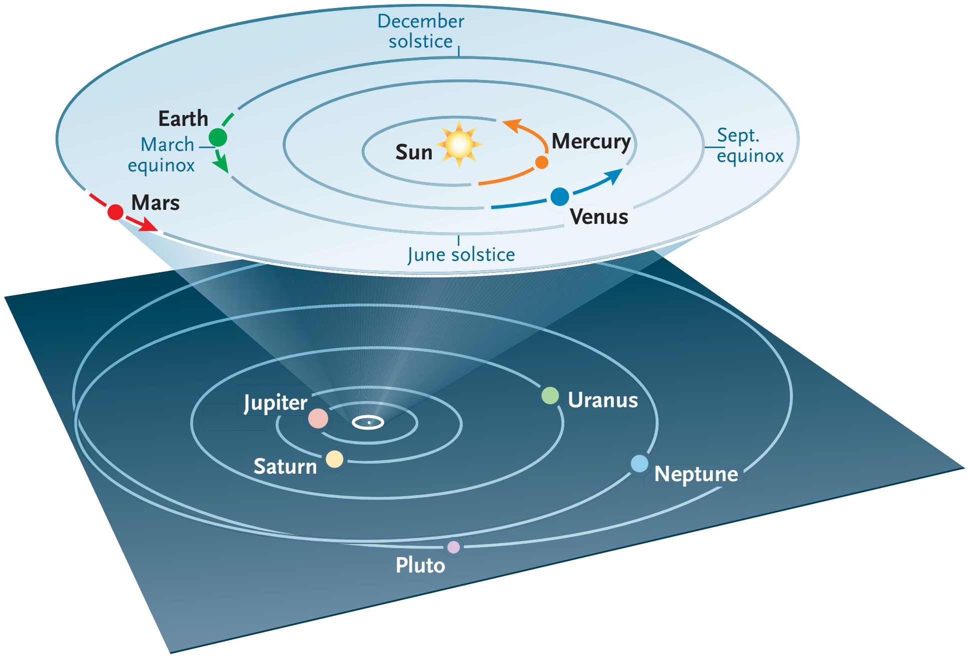
LATE NIGHT TO DAWN

Mars continues to rise around midnight, but its brightness changes rapidly, kindling from magnitude +0.3 as the month begins to –0.5 as it ends. Mars comes within 1 astronomical unit of Earth on March 8th. It will be almost twice as close when passing nearest at the end of May.



These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist at arm's length. For clarity, the Moon is shown three times its actual apparent size.

Fred Schaaf



ORBITS OF THE PLANETS
The curved arrows show each planet's movement during March. The outer planets don't change position enough in a month to notice at this scale.

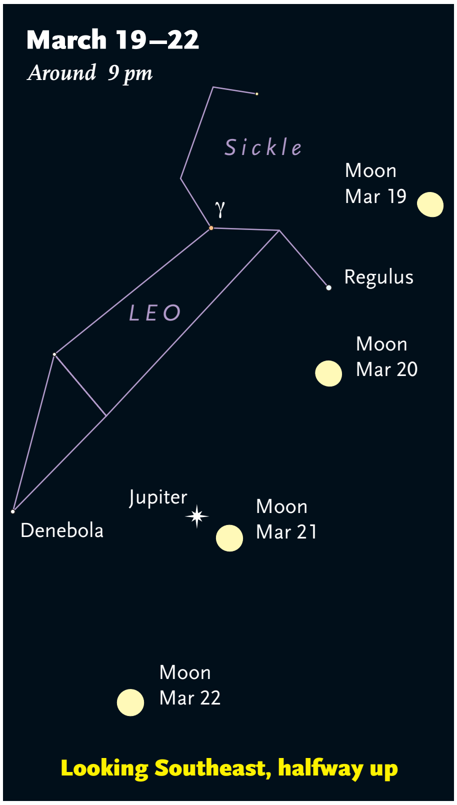
This month, Mars marches out of Libra into Scorpius, passing only 9′ north of the double star Beta (β) Scorpii (Graffias) on the morning of March 16th. The ochre disk enlarges from 8.7″ to 11.8″ wide this month, and a few surface features should be visible through good amateur telescopes (see the March 2014 issue, page 50, for a guide to observing Mars with a telescope).

The Red Planet's finest hour this month is at the beginning of dawn, when it's well up in the south. Watch as it forms an ever-more-compact pattern with Antares and the most telescopically beautiful planet, Saturn.

Saturn, in southern Ophiuchus, spends March watching Mars draw closer and closer. The gap between the two planets shrinks dramatically from 17° to just 9° during the month. Saturn begins retrograde (westward) motion on March 25th. The ringed planet starts the month at magnitude +0.5, just a trace dimmer than Mars — can you perceive the difference when they're at similar altitudes? Try comparing their colors — the orange-yellow of Mars and deep gold of Saturn.

Saturn ends the month at magnitude +0.3 — but that's 0.8 of a magnitude dimmer than rapidly brightening Mars, so you'll certainly be able to tell the difference in brilliance then.

Saturn's equatorial diameter appears about 17″ in the telescope, much larger than that of Mars. The rings, tilted 26° from edge-on, or nearly at their maximum, with a 38″ span.



DAWN

Venus opens March rising in the east-southeast about an hour before the Sun, but comes up only about 25 minutes before the Sun as April approaches. Venus reaches a minimum magnitude for the year of –3.8 on the 5th. This brightness holds steady as Venus slips into the solar glare, to be hidden from our view, in April.

Mercury, which reaches superior conjunction on March 23rd, is poorly placed for observation this month, as are **Neptune** and **Pluto**.

SUN AND MOON

The **Sun** undergoes a total eclipse on March 8–9, mostly for Indonesia (see p. 50. The Sun crosses the equinox on March 20th at 12:30 a.m. EDT, or 9:30 p.m. PDT. This marks the start of spring in the Northern Hemisphere and autumn in the Southern Hemisphere.

The waning gibbous **Moon** hangs between Mars and Saturn on the morning of March 1st and much closer to Saturn the next dawn. The nearly full Moon rises right of Jupiter on the evening of March 21st. On the morning of March 23rd, a penumbral eclipse is visible across the western United States and Hawai'i (see p. 50). The Moon is upper right of Mars at dawn on March 28th and upper right of Saturn on March 29th. ✦

What's to See on Jupiter

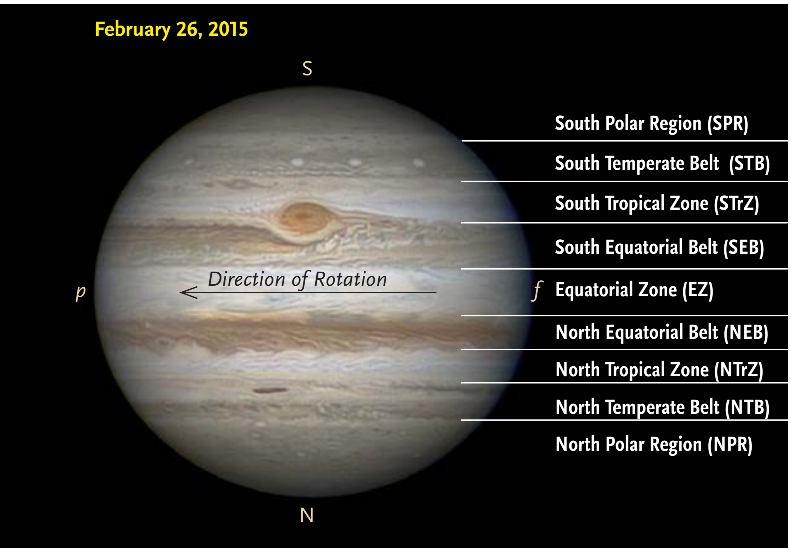
Shining from the legs of Leo, the giant planet is closest in February and March.

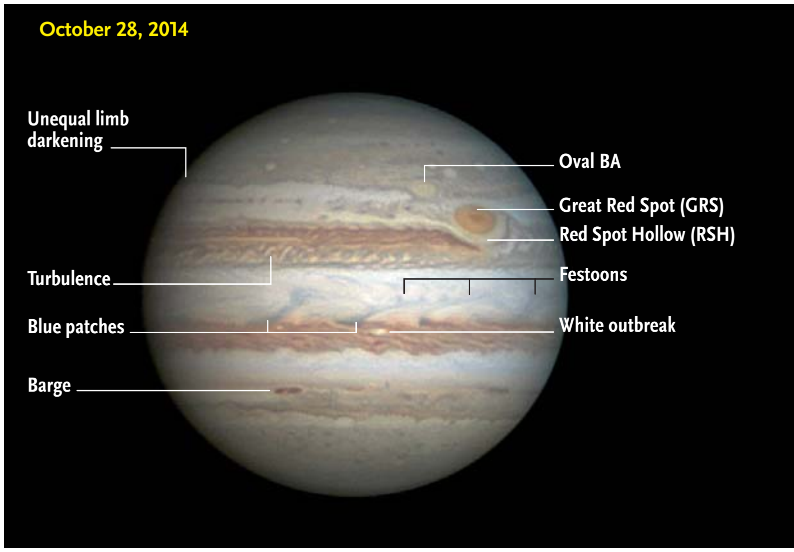
As Jupiter oppositions go, this year's (on March 8th) is nothing special. Jupiter is near the aphelion of its orbit, so throughout February and March it will appear 43 or 44 arcseconds across its equator, compared to the 50″ it displays at its closest oppositions. The next of those doesn't happen until September 2022.

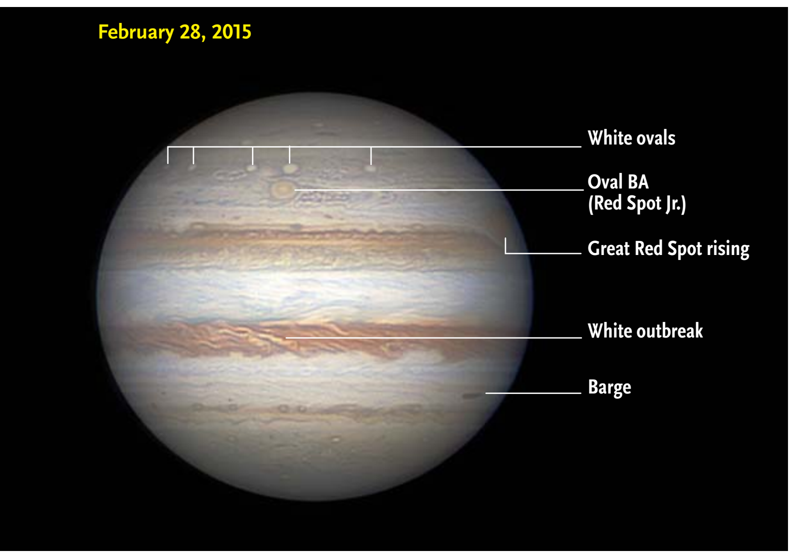
Even so, no other fully illuminated planet ever looms as big in a telescope, and none shows so many changeable features. Jupiter is all atmosphere, and a busy atmosphere it is.

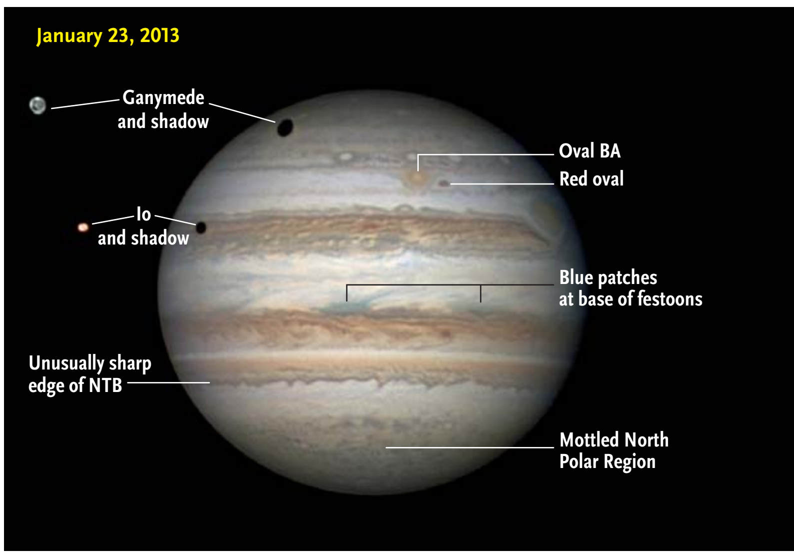
Sharp, high-contrast images like the ones here, taken by means of the modern stacked-video method, have spoiled a lot of visual observers for the subtler, more difficult views of Jupiter in a telescope's eyepiece. Instead of a computer sorting out the instants of sharpest seeing, you have to be alert to grab them with your eye

Stand way back, squint your eyes, and these super-sharp stacked-video images, taken by Damian Peach with a 14-inch scope, become more like what you can see visually.









Alan MacRobert

and brain. And instead of stacking these best instants digitally, your mind has to build up an impression the best it can using only brain-quality memory. Still, as Robert Burnham, Jr. famously wrote in his *Celestial Handbook,* "there is no privilege like that of being allowed to stand in the presence of the original."

What can you see of Jupiter with your scope? Of course it depends on the scope's size and optical quality, but also on the quality of the seeing and the long-term development of your own observing skill. So don't think you've reached your limits anytime soon.

Here are things to look for on Jupiter in rough order from easy to hard — depending, of course, on what the planet is actually displaying when you look.

Belts and zones. *Belts* are dark, *zones* are bright. The most prominent ones that are usually present are labeled at far left. (We show south up to match the view in many scopes.) The nomenclature extends to finer gradations, but fine belts and zones not only come and go, they move up and down a bit. So assigning names such as "North North Temperate Belt" versus "North North North Temperate Belt" becomes anyone's judgment call.

Even a 60-mm scope will usually show the two equatorial belts. Examine them for whatever difference you can see between them: width, darkness, color, irregularities.

Belt irregularities. The details most readily visible on Jupiter are often irregularities in edges of the equatorial belts.

Jupiter's rotation. If you can see any such discrete details, you can detect Jupiter's rapid rotation in less than 10 minutes of watching. Features rotate from celestial east ("following," *f*) to west ("preceding," *p*). It takes 50 minutes for a feature to rotate from Jupiter's central meridian halfway to the preceding limb.

Limb darkening. Sunlight near the planet's edges lights Jupiter's cloudtops at a low angle, and our own line of sight goes through thicker atmosphere there before reaching the cloudtops. So Jupiter is dimmer near the limb. This is especially obvious in photos. Around opposition, the limb darkening is uniform. At other times, the side of Jupiter farthest from the Sun in our sky is darkened more.

The Great Red Spot (GRS) is currently quite a strong orange-pink and much easier to see now than in the years when my wife called it the "Great Cottage Cheese Spot," when it was sometimes hard to recognize in my 12.5-inch.

The Red Spot Hollow (RSH) is the indentation in the South Equatorial Belt where the Great Red Spot lives. Sometimes it's white, sometimes tan or gray, sometimes hardly visible.

White ovals. These are especially common in the South Temperate Belt (STB).

Oval BA, "Red Spot Junior," is the long-lived product of the merger of three white ovals in the STB that had already lasted for decades beforehand. It's very pale tan; good luck.

Blue patches sometimes mark the edges of the equatorial belts against the Equatorial Zone. They seem to be areas of clear atmosphere between the clouds, blue for the same reason our own clear sky is blue. But the color is subtle.

Festoons often extend from blue patches into the Equatorial Zone, where they're blown sideways like banners in the wind.

The **Equatorial Band** is a thin, subtle line that occasionally forms right along the equator.

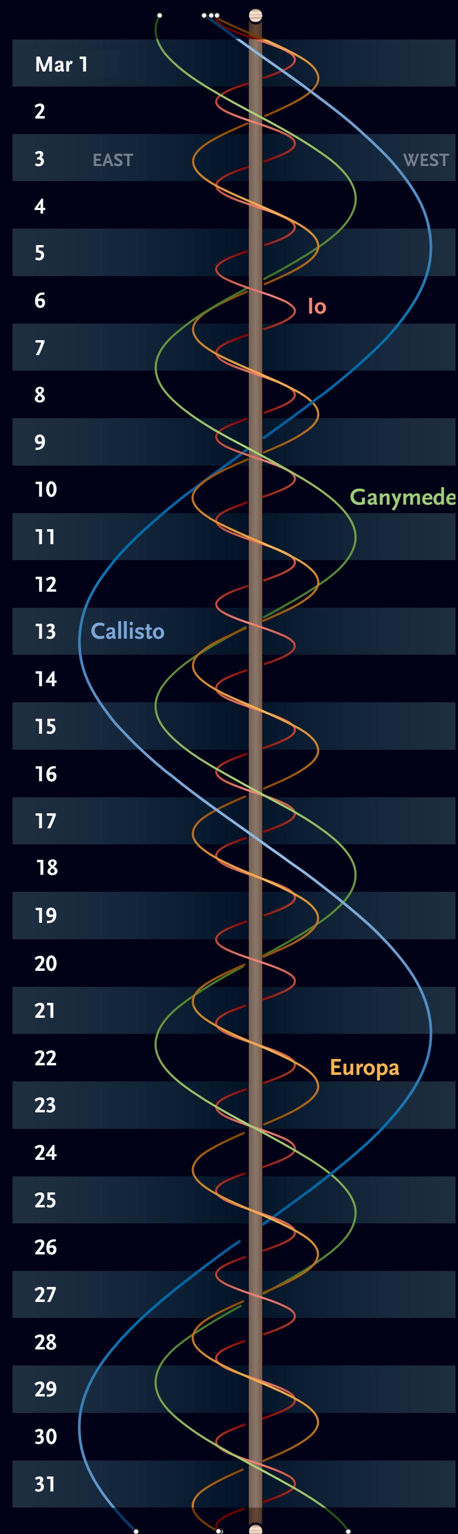
Red ovals are small but quite dark red.

Barges are also narrow and dark, but they're elongated east-west into line segments. They're often very red.

White outbreaks. Tiny, bright-white dots of fresh, upwelling material may evolve within days into thin white diagonal streaks, and occasionally into massive white turbulent areas extending far along inside a belt.

And of course you'll occasionally see the tiny black shadow of one of Jupiter's four big Galilean moons. The moons themselves are harder to see against Jupiter's face because of their lower contrast. Callisto, with the darkest surface, is the least difficult and in fact is easy to mistake for a shadow. See the timetable of the March satellites events on page 51.

Jupiter's Moons



The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites' positions east or west of Jupiter.

Daily Jupiter Events

Jupiter's four big Galilean moons are visible in any telescope. Binoculars almost always show at least two or three. Identify them by the diagram on the previous page.

All the March interactions between Jupiter and its satellites and their shadows are tabulated on the facing page. Eleven **double shadow transits** occur in March. Three happen when Jupiter is in good view from much of North America. These are on the night of March 14–15 from 10:22 p.m. to 12:34 a.m. Eastern Daylight Time; the night of March 21–22 from 12:23 to 2:31 a.m. EDT; and the morning of March 29th from 3:00 to 4:25 a.m. EDT. Subtract three hours from these times to get Pacific Daylight Time.

And here are all the times, in Universal Time, when Jupiter's Great Red Spot should cross the planet's central meridian. The dates, also in UT, are in bold. (Eastern Standard Time is UT minus 5 hours; Eastern Daylight time is UT – 4 hours.)

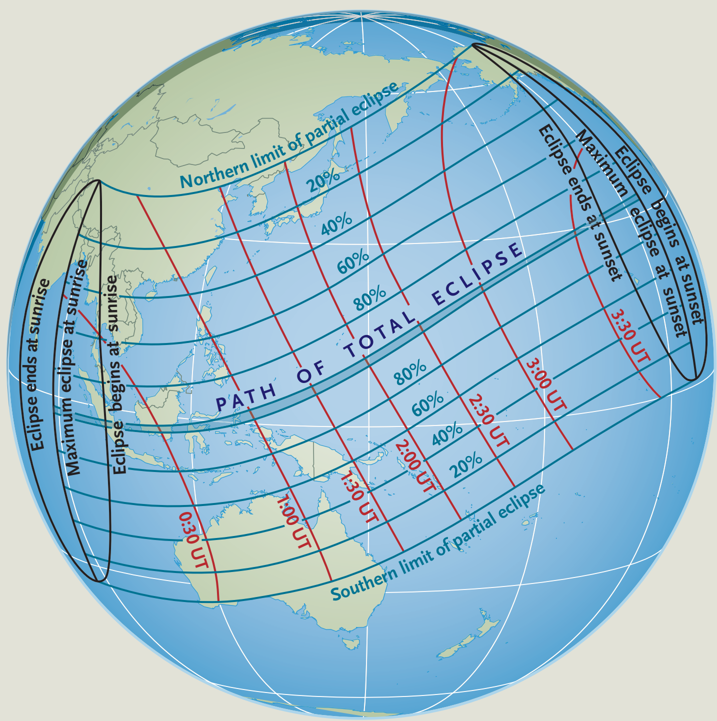
February 1, 4:28, 14:24; **2**, 0:19, 10:15, 20:11; **3**, 6:06, 16:02; **4**, 1:57, 11:53, 21:48; **5**, 7:44, 17:40; **6**, 3:35, 13:31, 23:26; **7**, 9:22, 19:18; **8**, 5:13, 15:09; **9**, 1:04, 11:00, 20:56; **10**, 6:51, 16:47; **11**, 2:42, 12:38, 22:33; **12**, 8:29, 18:25; **13**, 4:20, 14:16; **14**, 0:11, 10:07, 20:02; **15**, 5:58, 15:54; **16**, 1:49, 11:45, 21:40; **17**, 7:36, 17:32; **18**, 3:27, 13:23, 23:18; **19**, 9:14, 19:09; **20**, 5:05, 15:01; **21**, 0:56, 10:52, 20:47; **22**, 6:43, 16:38; **23**, 2:34, 12:30, 22:25; **24**, 8:21, 18:16; **25**, 4:12, 14:08; **26**, 0:03, 9:59, 19:54; **27**, 5:50, 15:45; **28**, 1:41, 11:37, 21:32; **29**, 7:28, 17:23.

March 1, 3:19, 13:14, 23:10; **2**, 9:06, 19:01; **3**, 4:57, 14:52; **4**, 0:48, 10:44, 20:39; **5**, 6:35, 16:30; **6**, 2:26, 12:21, 22:17; **7**, 8:13, 18:08; **8**, 4:04, 13:59, 23:55; **9**, 9:51, 19:46; **10**, 5:42, 15:37; **11**, 1:33, 11:29, 21:24; **12**, 7:20, 17:15; **13**, 3:11, 13:07, 23:02; **14**, 8:58, 18:53; **15**, 4:49, 14:44; **16**, 0:40, 10:36, 20:31; **17**, 6:27, 16:22; **18**, 2:18, 12:14, 22:09; **19**, 8:05, 18:00; **20**, 3:56, 13:52, 23:47; **21**, 9:43, 19:39; **22**, 5:34, 15:30; **23**, 1:25, 11:21, 21:17; **24**, 7:12, 17:08; **25**, 3:03, 12:59, 22:55; **26**, 8:50, 18:46; **27**, 4:41, 14:37; **28**, 0:33, 10:28, 20:24; **29**, 6:20, 16:15; **30**, 2:11, 12:06, 22:02; **31**, 7:58, 17:53.

These times assume that the Great Red Spot is still centered at System II longitude 230°. You'll find it transiting $1\frac{2}{3}$ minutes earlier for each degree that it's at less than 230° longitude, and $1\frac{2}{3}$ minutes later for each degree greater.

A light blue or green filter slightly helps the contrast and visibility of Jupiter's reddish and brownish features. An orange filter helps with the blues.

Indonesian Solar Eclipse



S&T: LEAH TISCIONE

On March 9th, a total eclipse of the Sun will cross parts of Sumatra, Borneo, Sulawesi, and the Pacific; the totally eclipsed Sun will rise in the Indian Ocean and set north of Hawai'i. The eclipse will be partial for a much wider area, including Southeast Asia, China, Japan, and parts of Australia. At any location, interpolate between the red lines to find the Universal Time of greatest eclipse. Interpolate between the blue lines to see what percent of the Sun's diameter the Moon will cover at that time. For more maps and further details, see http://is.gd/eclipse03092016.

Penumbral Lunar Eclipse

On the morning of March 23rd, skywatchers in western North America and Hawai'i can detect the southern side of the full Moon skimming through the pale penumbra (outer fringe) of Earth's shadow. This weak eclipse will be deepest at 11:47 UT (4:47 a.m. PDT, 5:47 a.m. MDT), when the Moon will intrude 78% of the way across the penumbra's width.

That's not far enough for the most obvious part of the penumbra to show, but it's far enough that you should have little trouble seeing that something is a bit amiss. Fainter penumbral shading may be detectable for nearly an hour before and after mid-eclipse.

For observers in Australia and East Asia, the event falls on the evening of March 23rd local date.

Sirius B Nears Its Maximum Separation

Each year, the white-dwarf companion of Sirius becomes a little less difficult to detect in amateur telescopes. It's currently 10.6″ east-northeast of Sirius A, which outshines it by 10,000 times. Their maximum separation will be 11.3″ in 2022.

See our tips for extracting Sirius B from the glare in the October 2014 issue, page 30. You can practice on Rigel, which outshines a companion star of its own, 9.5″ south-southwest of it, by only 1,000 times. ✦

Using a 14-inch reflector, John Hothersall took this stacked-video image on January 17, 2011, from Australia, where Sirius passes overhead. The Dog Star's "Pup" lies on the eastern (left) diffraction spike of Sirius A. "Visually I got the best results using a blue filter," he writes, "as the B component is a little bluer than the bright A component, cutting the glare ever so slightly." North is up.

Minima of Algol

Feb.	UT	Mar.	UT
1	22:54	1	15:07
4	19:44	4	11:57
7	16:33	7	8:46
10	13:22	10	5:35
13	10:12	13	2:25
16	7:01	15	23:14
19	3:50	18	20:03
22	0:39	21	16:52
24	21:29	24	13:41
27	18:18	27	10:31
		30	7:20

These geocentric predictions are from the new heliocentric elements Min. = JD 2440953.5087 + 2.8673075*E*, where *E* is any integer. Courtesy AAVSO. For a comparison-star chart and more info, see SkyandTelescope.com/algol.

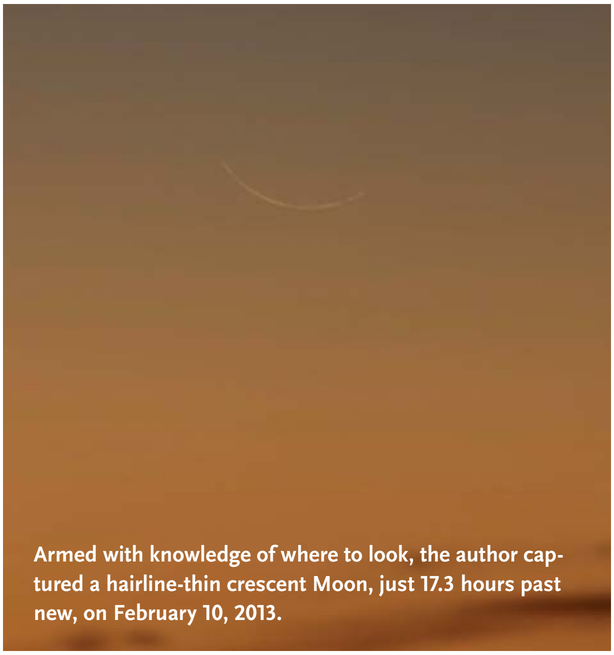
Phenomena of Jupiter's Moons, March 2016

Mar. 1	0:50	I.Sh.E
	1:00	I.Tr.E
	3:08	IV.Sh.I
	5:22	IV.Tr.I
	6:16	IV.Sh.E
	7:16	IV.Tr.E
	19:46	I.Ec.D
	22:12	I.Oc.R
Mar. 2	11:53	III.Sh.I
	12:33	III.Tr.I
	15:13	III.Sh.E
	15:19	II.Ec.D
	15:42	III.Tr.E
	17:02	I.Sh.I
	17:11	I.Tr.I
	18:21	II.Oc.R
	19:18	I.Sh.E
	19:25	I.Tr.E
Mar. 3	14:14	I.Ec.D
	16:38	I.Oc.R
Mar. 4	9:51	II.Sh.I
	10:04	II.Tr.I
	11:31	I.Sh.I
	11:37	I.Tr.I
	12:39	II.Sh.E
	12:49	II.Tr.E
	13:46	I.Sh.E
	13:51	I.Tr.E
Mar. 5	8:43	I.Ec.D
	11:04	I.Oc.R
Mar. 6	1:56	III.Ec.D
	4:36	II.Ec.D
	5:26	III.Oc.R
	5:59	I.Sh.I
	6:03	I.Tr.I
	7:27	II.Oc.R
	8:15	I.Sh.E
	8:17	I.Tr.E
Mar. 7	3:12	I.Ec.D
	5:30	I.Oc.R
	23:09	II.Sh.I
	23:12	II.Tr.I
Mar. 8	0:28	I.Sh.I
	0:29	I.Tr.I
	1:57	II.Tr.E
	1:58	II.Sh.E
	2:43	I.Tr.E
	2:43	I.Sh.E
	21:40	I.Oc.D
	23:57	I.Ec.R
Mar. 9	11:38	IV.Ec.D
	14:42	IV.Ec.R
	15:48	III.Tr.I
	15:51	III.Sh.I
	17:50	II.Oc.D
	18:54	I.Tr.I
	18:56	I.Sh.I
	18:58	III.Tr.E
	19:10	III.Sh.E
	20:39	II.Ec.R
	21:09	I.Tr.E
	21:12	I.Sh.E
Mar. 10	16:06	I.Oc.D
	18:26	I.Ec.R
Mar. 11	12:19	II.Tr.I
	12:27	II.Sh.I
	13:20	I.Tr.I
	13:25	I.Sh.I
	15:05	II.Tr.E
	15:16	II.Sh.E
	15:35	I.Tr.E
	15:40	I.Sh.E
Mar. 12	10:32	I.Oc.D
	12:54	I.Ec.R
Mar. 13	5:30	III.Oc.D
	6:57	II.Oc.D
	7:46	I.Tr.I
	7:53	I.Sh.I
	9:15	III.Ec.R
	9:56	II.Ec.R
	10:01	I.Tr.E
	10:08	I.Sh.E
Mar. 14	4:58	I.Oc.D
	7:23	I.Ec.R
Mar. 15	1:27	II.Tr.I
	1:46	II.Sh.I
	2:12	I.Tr.I
	2:22	I.Sh.I
	4:13	II.Tr.E
	4:27	I.Tr.E
	4:34	II.Sh.E
	4:37	I.Sh.E
	23:24	I.Oc.D
Mar. 16	1:51	I.Ec.R
	19:03	III.Tr.I
	19:49	III.Sh.I
	20:04	II.Oc.D
	20:38	I.Tr.I
	20:50	I.Sh.I
	22:14	III.Tr.E
	22:53	I.Tr.E
	23:05	I.Sh.E
	23:07	III.Sh.E
	23:13	II.Ec.R
Mar. 17	17:50	I.Oc.D
	19:24	IV.Tr.I
	20:20	I.Ec.R
	21:10	IV.Sh.I
	21:36	IV.Tr.E
Mar. 18	0:08	IV.Sh.E
	14:34	II.Tr.I
	15:04	II.Sh.I
	15:04	I.Tr.I
	15:18	I.Sh.I
	17:19	I.Tr.E
	17:21	II.Tr.E
	17:34	I.Sh.E
	17:52	II.Sh.E
Mar. 19	12:16	I.Oc.D
	14:49	I.Ec.R
Mar. 20	8:47	III.Oc.D
	9:10	II.Oc.D
	9:30	I.Tr.I
	9:47	I.Sh.I
	11:45	I.Tr.E
	12:02	I.Sh.E
	12:29	II.Ec.R
	13:14	III.Ec.R
Mar. 21	6:42	I.Oc.D
	9:17	I.Ec.R
Mar. 22	3:43	II.Tr.I
	3:56	I.Tr.I
	4:15	I.Sh.I
	4:23	II.Sh.I
	6:11	I.Tr.E
	6:29	II.Tr.E
	6:31	I.Sh.E
	7:11	II.Sh.E
Mar. 23	1:09	I.Oc.D
	3:46	I.Ec.R
	22:17	II.Oc.D
	22:20	III.Tr.I
	22:22	I.Tr.I
	22:44	I.Sh.I
	23:47	III.Sh.I
Mar. 24	0:37	I.Tr.E
	0:59	I.Sh.E
	1:32	III.Tr.E
	1:46	II.Ec.R
	3:05	III.Sh.E
	19:35	I.Oc.D
	22:15	I.Ec.R
Mar. 25	16:48	I.Tr.I
	16:51	II.Tr.I
	17:12	I.Sh.I
	17:41	II.Sh.I
	19:03	I.Tr.E
	19:28	I.Sh.E
	19:37	II.Tr.E
	20:29	II.Sh.E
Mar. 26	1:55	IV.Oc.D
	4:17	IV.Oc.R
	5:42	IV.Ec.D
	8:36	IV.Ec.R
	14:01	I.Oc.D
	16:43	I.Ec.R
Mar. 27	11:14	I.Tr.I
	11:25	II.Oc.D
	11:41	I.Sh.I
	12:05	III.Oc.D
	13:29	I.Tr.E
	13:56	I.Sh.E
	15:03	II.Ec.R
	17:12	III.Ec.R
Mar. 28	8:27	I.Oc.D
	11:12	I.Ec.R
Mar. 29	5:41	I.Tr.I
	6:00	II.Tr.I
	6:10	I.Sh.I
	7:00	II.Sh.I
	7:55	I.Tr.E
	8:25	I.Sh.E
	8:47	II.Tr.E
	9:47	II.Sh.E
Mar. 30	2:54	I.Oc.D
	5:41	I.Ec.R
Mar. 31	0:07	I.Tr.I
	0:32	II.Oc.D
	0:38	I.Sh.I
	1:39	III.Tr.I
	2:21	I.Tr.E
	2:53	I.Sh.E
	3:47	III.Sh.I
	4:20	II.Ec.R
	4:53	III.Tr.E
	7:03	III.Sh.E
	21:20	I.Oc.D

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of EST, 4 hours ahead of EDT). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Courtesy IMCCE.

Spotting Super-Thin Moons

Learn the where and when to look for dramatically thin lunar crescents.



Armed with knowledge of where to look, the author captured a hairline-thin crescent Moon, just 17.3 hours past new, on February 10, 2013.

Along with all the positive benefits we find in astronomy, observing challenges can add a certain spice to our experiences. Messier Marathons and splitting difficult double stars come to mind.

One of my particular favorites is locating extremely thin crescent Moons. Maybe you've tried this yourself but came up empty-handed. Or maybe you just didn't figure out when and where to look. Wouldn't it be nice to know just which criteria are useful to determine when the effort might be worthwhile?

First, let's tackle the situational geometry. The Moon moves eastward in the sky along its orbit by a distance roughly equal to its own diameter (½°) every hour. So 24 hours before or after new Moon, the lunar disk won't appear more than about 15° from the Sun. Therefore, you'll need the horizon to block the solar disk, and you need the darkest sky possible to help with contrast.

Ideally, the lunar crescent should be positioned directly above the Sun to provide the best possible elevation in a twilit sky. Since the Moon is never more than 5° away from the ecliptic, you'll want to pick times when this line intersects the horizon most nearly vertically. With this geometry in mind, the Northern Hemisphere offers two "seasons" to hunt for thin lunar crescents: February through April at dusk, and August through October before dawn. (Of course, you can attempt a sighting at other times, but doing so increases the difficulty.)

Here's an example of a successful hunt: On February 10, 2013, I spotted a very young Moon at 6:40 p.m. Central Standard Time. At the time, the Sun's altitude was –7° (sunset was 6:08 p.m.) and the Moon's was just under 3°. The lunar disk was also riding 5° north of the ecliptic, which gave a slightly better separation from the Sun. Since new Moon had occurred at 7:20 UT (1:20 a.m. CST), I saw and photographed the crescent when it was just 17 hours 20 minutes past new.

Guidelines for Optimum Viewing

If I can do it, you can too! For the purposes of this challenge, I've set the goal of spotting the lunar crescent 16 to 18 hours before or after new Moon. This is admittedly ambitious, even for practiced observers and especially if it's your first effort, but the guidelines presented here should improve your chances greatly.

First, you'll need the dates and Universal Times of new Moon. Here are this year's, as calculated by the United States Naval Observatory: January 10, 1:30; February 8, 14:39; March 9, 1:54; April 7, 11:24; May 6, 19:29; June 5, 3:00; July 4, 11:01; August 2, 20:44; September 1, 9:03; October 1, 0:11; October 30, 17:38; November 29, 12:18; and December 29, 6:53.

Next, compare the list above against the Universal Times below that correspond to the optimum crescent-viewing "window" for the four main U.S. time zones:

	Eastern	*Central*	*Mountain*	*Pacific*
Before New (dawn)	2^h–4^h	3^h–5^h	4^h–6^h	5^h–7^h
After New (dusk)	4^h–6^h	5^h–7^h	6^h–8^h	7^h–9^h

As you can see, only June (predawn, Eastern and Central), September (dusk, Pacific), and December (dusk, Central and Mountain) meet the criteria for viewing a 16- to 18-hour Moon anywhere from the continental U.S. But let's ease the requirements; the table below lists optimum times for a 21- to 24-hour Moon:

	Eastern	*Central*	*Mountain*	*Pacific*
Before New (dawn)	19^h–22^h	20^h–23^h	21^h–0^h	22^h–1^h
After New (dusk)	22^h–1^h	23^h–2^h	0^h–3^h	1^h–4^h

Broadening the observing window in this way yields several more opportunities during 2016 to hone your crescent-hunting skills. I'm not talking about setting a new record for sighting the thinnest possible Moon (*S&T:* Dec. 1996, p. 104), but rather pushing yourself in a way that will be immediately rewarding.

For example, the Moon is new at 1:54 UT on March 9th (coinciding with a total solar eclipse; see page 50). This timing fits the window for three of the four listed time zones. From my location in Texas, the Sun slips below the horizon at 6:31 p.m. on March 9th, and 20 minutes later it's at an altitude of –5°. The Sun's azimuth at sunset is 265°. At 6:51 p.m. the Moon's azimuth is the same and its altitude is 7° — making it an easy target. The Moon's age in this example is 22 hours 57 minutes.

Because these events are specific to your location, and particularly to where you are within your time zone, you'll want to preview the circumstances using *Stellarium* or some other sky-simulating program. This will give you the position of the Sun and Moon along the horizon.

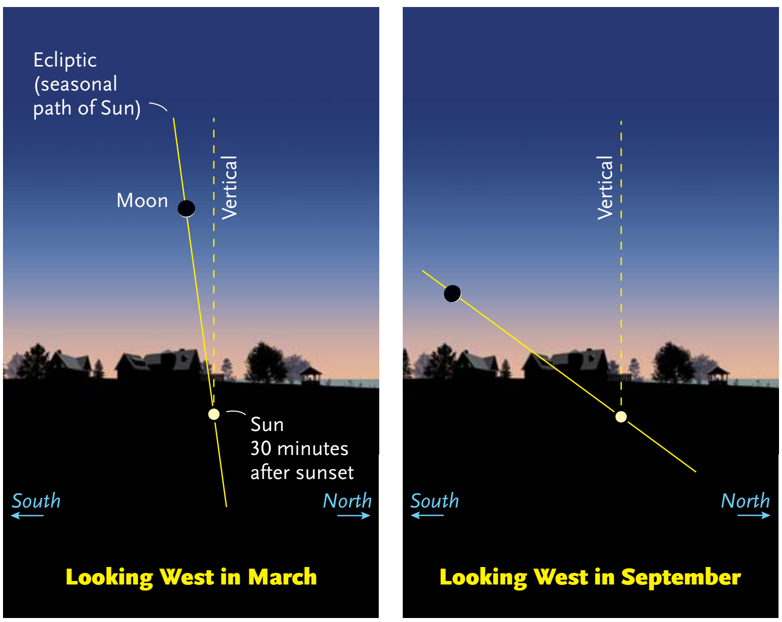
Use the program to note the Sun's azimuth at sunset, and then advance the time until the solar disk is about 4½° to 5° below the horizon. This provides a practical starting point to begin the search under normal atmospheric conditions. Next, note the position of the Moon relative to the sunset point as well as its altitude above the horizon. Then, once outside, use binoculars to place that horizon azimuth at the bottom of the field of view. For most circumstances, you should be able to spot the crescent Moon within the field. After spotting it in binoculars, you can then try using just your eyes.

Several variables can affect the outcome. Not surprisingly, atmospheric conditions play a huge part, especially the amount of water vapor contained in the air. I recall seeing an 18-hour-old Moon on January 9, 1978. A strong cold front had come through, leaving so little water vapor in its wake that I could pick up Boeing 727s cruising 150 miles away while scanning within 2° of the horizon with my 8-inch Newtonian.

Gaining altitude on a mountainside or hill can give you a "negative" (geometrically depressed) horizon and more time to find the Moon. Thinner air at higher altitudes is also an advantage. Cirrus cloud layers as far as 200 miles away can surprise you when they reveal themselves as the Sun sets.

Also, the ecliptic tips farther from vertical as your latitude increases, which narrows the rise or set interval between the Sun and Moon. If you try out a new location with a favorable horizon, try previewing the site 24 hours ahead of time to gauge its suitability.

There is a real thrill in seeing an extremely thin lunar crescent. Once acquired, it seems to jump out at you, and you wonder how you'd missed it a few minutes prior to discovery. And there's the added benefit of developing observing skills that you can apply to other observing endeavors. It's an experience you don't want to miss. ✦



Due to the tilt of the ecliptic at the horizon, very thin crescent Moons are easiest to see after sunset in March and most difficult in September. The reverse is true before dawn. Note: the Moon can be situated up to 5° above or below the ecliptic.

The Moon • March 2016

Phases

LAST QUARTER
March 1, 23:11 UT

NEW MOON
March 9, 1:54 UT

FIRST QUARTER
March 15, 17:03 UT

FULL MOON
March 23, 12:01 UT

LAST QUARTER
March 31, 15:17 UT

Distances

Perigee	March 10, 7ʰ UT
223,389 miles	diam. 33′ 14″
Apogee	March 25, 14ʰ UT
252,354 miles	diam. 29′ 25″

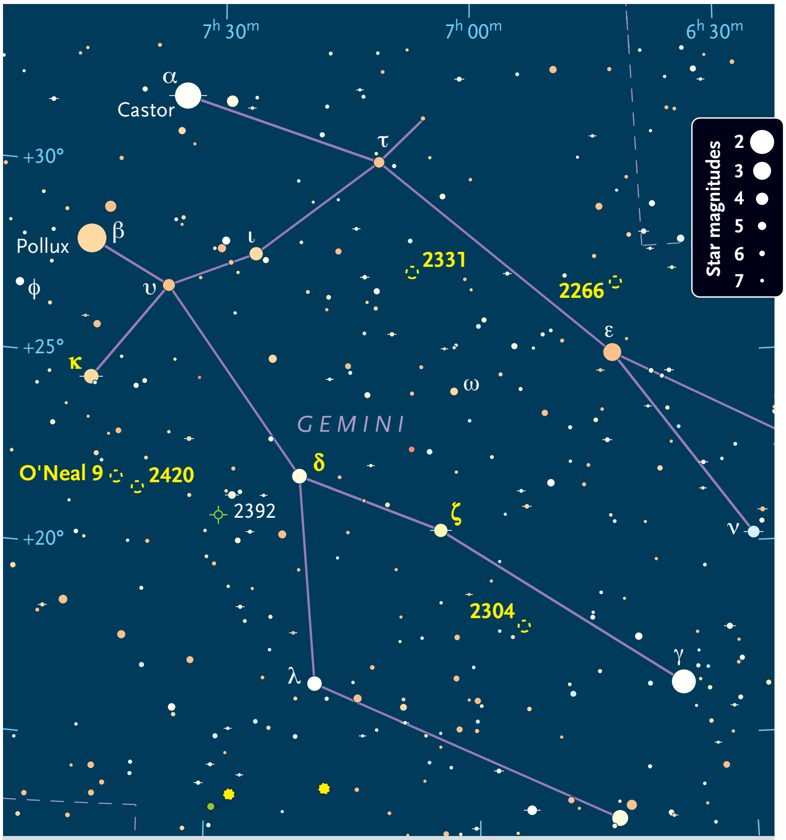
Favorable Librations

Pingré (crater)	March 3
Cusanus (crater)	March 12
Mare Marginis	March 18
Hausen (crater)	March 29

For key dates, yellow dots indicate which part of the Moon's limb is tipped the most toward Earth by libration under favorable illumination.

Isles of Light

Let the colorful stars of Gemini brighten your journey along the Milky Way.



The Lights of Gemini

Object	Type	Mag(v)	Size/Sep	RA	Dec.
ζ Gem	Double star	4.1, 7.7	1.7′	07h 04.1m	+20° 34′
NGC 2304	Open cluster	10.0	5.0′	06h 55.2m	+17° 59′
δ Gem	Double star	3.6, 8.2	5.5″	07h 20.1m	+21° 59′
κ Gem	Double star	3.7, 8.2	7.5″	07h 44.4m	+24° 24′
NGC 2420	Open cluster	8.3	6.0′	07h 38.4m	+21° 34′
O'Neal 9	Asterism	8.0	3.2′	07h 41.0m	+21° 49′
NGC 2331	Open cluster	8.5	19′	07h 07.0m	+27° 16′
NGC 2266	Open cluster	9.5	5.0′	06h 43.3m	+26° 58′

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

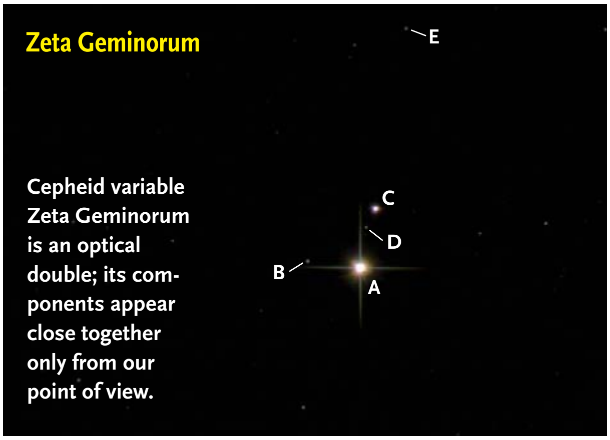
. . . the sky
Spreads like an ocean hung on high,
Bespangled with those isles of light,
So wildly, spiritually bright;
Who ever gazed upon them shining,
And turned to earth without repining,
Nor wished for wings to flee away,
And mix with their eternal ray?
— Lord Byron, *The Siege of Corinth*, 1816

Gemini, the Twins, is one of the most vividly starred constellations of the zodiac and well placed for Northern Hemisphere observers. Our Sun dwells in the Milky Way Galaxy near the inner edge of a spiral-arm segment known as the Orion Spur or Local Arm. When we gaze at Gemini, we're looking outward through this arm and are rewarded with the sight of many nearby stars brightly adorning our sky. All of Gemini's stars bearing Greek letter designations lie within the Orion Spur, the nearest being Pollux at 34 light-years, and the most distant being Omega (ω) Geminorum at roughly 1,500 light-years — near neighbors as galactic distances go.

Let's begin our journey through starry Gemini with **Zeta (ζ) Geminorum**, also known as Mekbuda. Viewed through my 130-mm refractor at 23×, Mekbuda is a very wide double star whose components gleam yellow. The 4.1-magnitude primary is attended by a 7.7-magnitude companion to the north-northwest. This is merely an optical double, with the companion considerably closer to us than the primary. These stars also have significantly different motions through space.

Zeta is a Cepheid variable star and, according to Daniel Majaess and colleagues (*Astrophysical Journal Letters*, 2012), a star-cluster member. Combined with recent measurements, the determination of this membership allowed the researchers to refine the distance to Zeta, yielding a weighted mean of 1,200 light-years. On the sky, the nearest likely cluster member to Zeta is the 11.5-magnitude star 1.5′ to its east.

On his website Stars (**stars.astro.illinois.edu/sow/sowlist.html**), astronomer Jim Kaler writes that Mekbuda should be 60 times our Sun's diameter. If Mekbuda replaced our Sun, it would span 30° in our sky (about the size of Gemini), but it would be far too toasty here on Earth to enjoy the view.



Zeta Geminorum

Cepheid variable Zeta Geminorum is an optical double; its components appear close together only from our point of view.

PETER WIENERROITHER

Swooping 3.3° southwest from Zeta leads to the open cluster **NGC 2304**, which marks the northern point of a nearly equilateral triangle it forms with two golden stars to the south, magnitudes 7 and 8. With sides about ⅓° long, the triangle easily fits in a low-power field of view. Through my 105-mm refractor at 28×, the cluster is a small but obvious fuzzy spot set amid a starry field. A magnification of 87× picks out 8 faint star flecks glittering in a foggy glow about 4′ across. In my 10-inch reflector at 43×, I see a granular haze that's brighter in the center, and at 68× the haze breaks up into a lovely group of pinpoint stars spanning 5′. I count 20 stars at 166×, and a touch of unresolved haze remains.

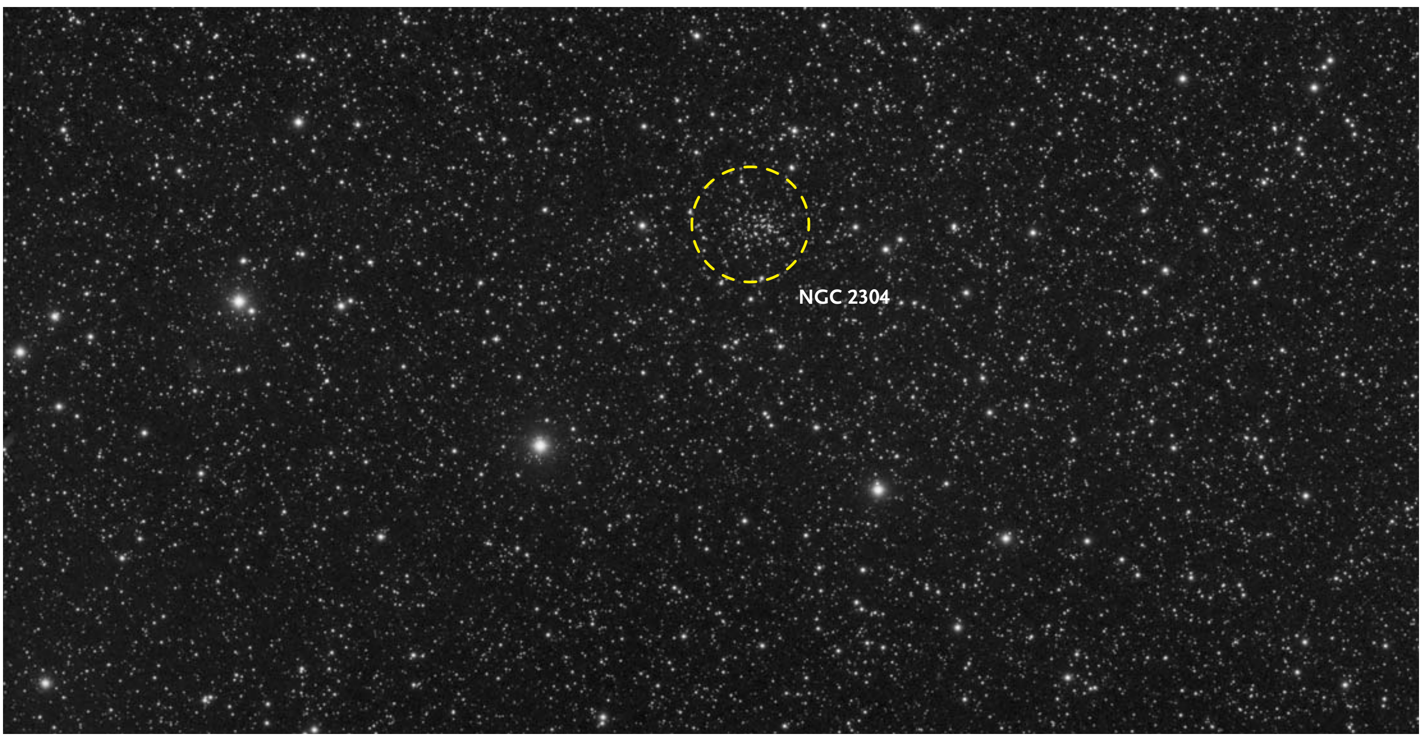
Recent professional sources give a diameter of 10′ for NGC 2304, but visually 4′ to 5′ is a more reasonable expectation. A study by İnci Akkaya Oralhan and colleagues (*New Astronomy*, 2015) indicates that this cluster is about 12,000 light-years distant and 900,000 years old.

In the star **Delta (δ) Geminorum**, also known as Wasat, we find a true binary with a 1,200-year orbit. The components are currently 5.5″ apart, closing to 3.4″ over the next century and a half. My 130-mm scope at 117× reveals a golden 8th-magnitude companion southwest of the bright, yellow-white primary.

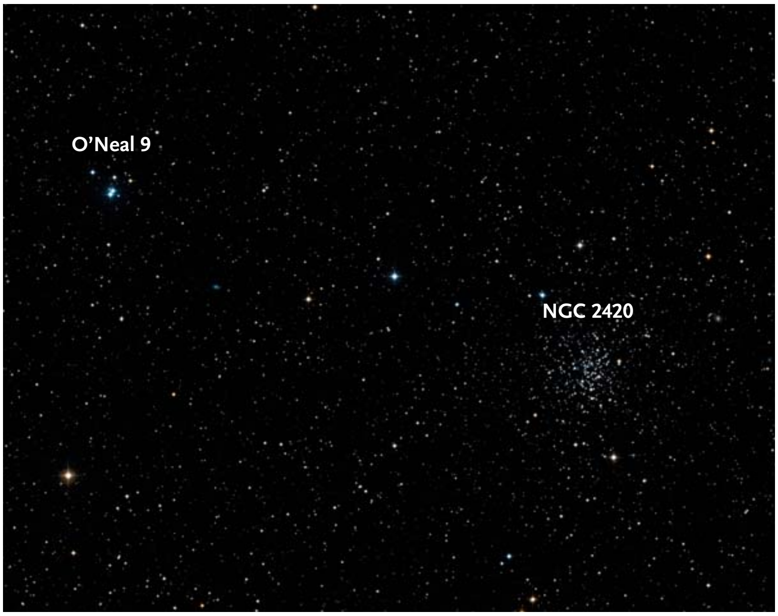
When Clyde Tombaugh discovered Pluto in 1930, it was quite close to Delta in the sky. His photographic plates made on January 23rd and 29th of that year showed Pluto as a very faint speck that had moved from about 42′ to 34′ east-southeast of the star.

Kappa (κ) Geminorum is another double star worth visiting. The 130-mm refractor at 91× shows a bright, deep-yellow primary with a much fainter companion close west-southwest. The stars are well separated at 117×, and the companion shines yellow. The bright star is a yellow giant, while the dimmer one is much like our Sun. As calculated by Jim Kaler, inhabitants of a hypothetical planet orbiting the Sun-like star would see the yellow giant brightening their sky with more light than a thousand full Moons.

Discovered by William Herschel in 1783, open cluster NGC 2304 appears as a small but obvious fuzzy spot in small telescopes.



DAN CROWSON



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

Open cluster NGC 2420 and asterism O'Neal 9 lie about 39′ apart, so at low power you should be able to fit them in the same field of view. Boost your magnification to resolve individual stars in the cluster.

About 2.9° south-southwest of Kappa we find the interesting juxtaposition of **NGC 2420** and **O'Neal 9**, an open cluster and an asterism. My 130-mm scope at 23× presents NGC 2420 as a fetching swarm of star motes set against a mist of unresolved stars stretched north-northwest to south-southeast and enshrined in a pretty starfield. Boosting the magnification to 63× enhances the richness of the cluster and exposes O'Neal 9 in the same field of view, 39′ to the east northeast. The asterism displays only three 11th-magnitude stars in a 3′-long line tilted north of east and two 9th-magnitude stars south of center and fairly close together. Examining NGC 2420 at 102×, I count 30 stars in a 6′-long collection entangled in haze.

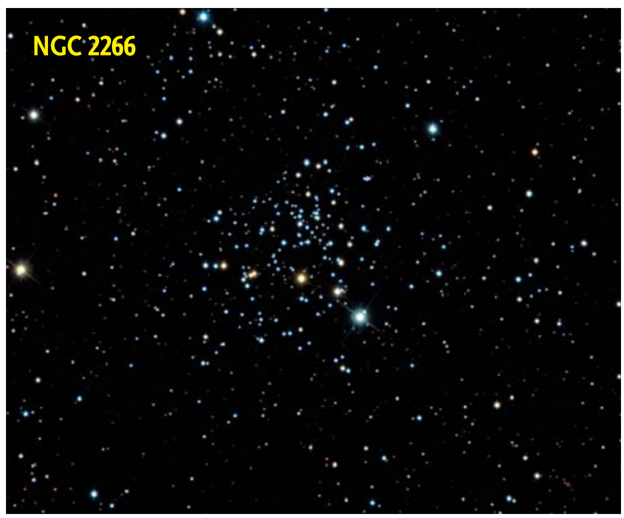
NGC 2420 is quite beautiful through my 10-inch reflector at 187×. Some of the brighter stars outline a circle with a ring around it, reminding me of Saturn. This pattern overlies a wealth of very faint to extremely faint stars. The cluster's core is about 5′ across with a concentrated center, but the more sparsely populated fringe that mantles this core nearly doubles the cluster's diameter. O'Neal 9 is a cute, boxy group of ten stars spread over a little more than 3′. Fortunately for me, NGC 2420 and O'Neal 9 are both detectable in the scope's 9×50 finder. When I last observed the pair, it was so gusty that the wind kept pushing my scope away from them.

William Herschel discovered NGC 2420 in 1783 with an 18.7-inch reflector that used a speculum metal mirror. He logged it as a "Cluster of stars very beautiful and close." Herschel adds that he counted at least 50 stars and suspected perhaps double that number. O'Neal 9 was found in 2005 by California amateur Mike O'Neal with a 16-inch reflector at 98×. It's included as an asterism in the database of the Deep Sky Hunters, a Yahoo group. Many such asterisms were spotted by DSH members as a by-product of their search for previously uncataloged open clusters.

Open cluster **NGC 2331** lies halfway between Tau (τ) and Omega Geminorum. In my 130-mm refractor at 37×, its suns form a striking starburst array, like an explosion frozen in a moment of time. The pattern slightly overspills the cluster's given 19′ size. At 48× I count 22 stars, 10th magnitude and fainter, within the 19′ boundary.

While NGC 2331 consists of loosely scattered stars, **NGC 2266** to its west is wonderfully crowded. Look for this little gem 1.8° north of Epsilon (ε) Geminorum. With my 130-mm scope at 23×, it looks like a fan-shaped comet with a star at the head (south-southwest) and a fainter one on the southeastern side. At 102× an arc of six stars beads the southeastern side, the bright one burning yellow. The wedge of haze tapering north-northwest from the arc is densest in the middle of its western side and dotted with about 15 very faint stars. A few stars shelter on the arc's opposite side, but the entire group covers only 5′. At 164× NGC 2266 sports 27 stars in total. This is a charming cluster in my 10-inch scope at 166×, harboring a splash of 45 diamond-chip stars.

NGC 2266 brings our tour to a delightful finish for visual observers, yet it's also a grand and colorful target for those who do deep imaging during starry nights. Why not give it a try? ✦



PETER SPOKES / ADAM BLOCK / NOAO / AURA / NSF

In a somewhat crowded star field, the arc of six colorful gems on the southeastern side of open cluster NGC 2266 stands out.

Ted Forte

Galaxies in the Beehive

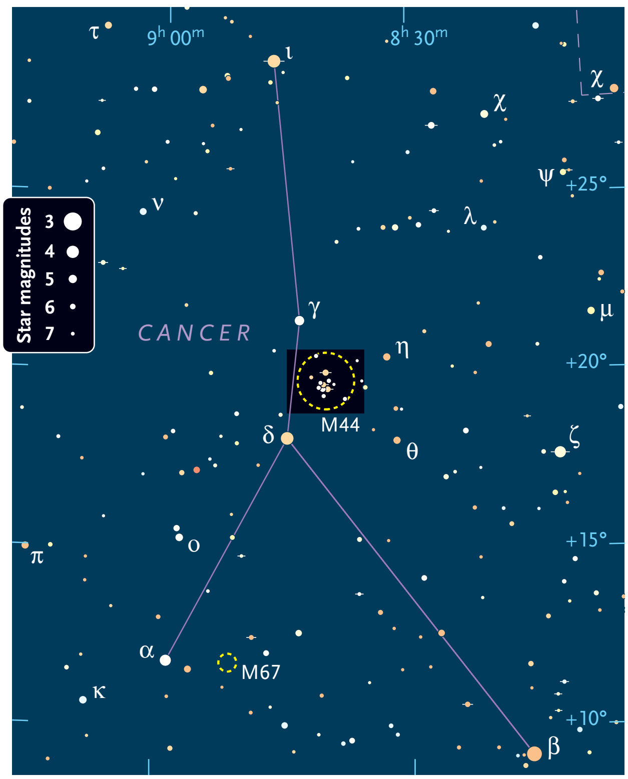
A small swarm buzzes inside the famous star cluster.

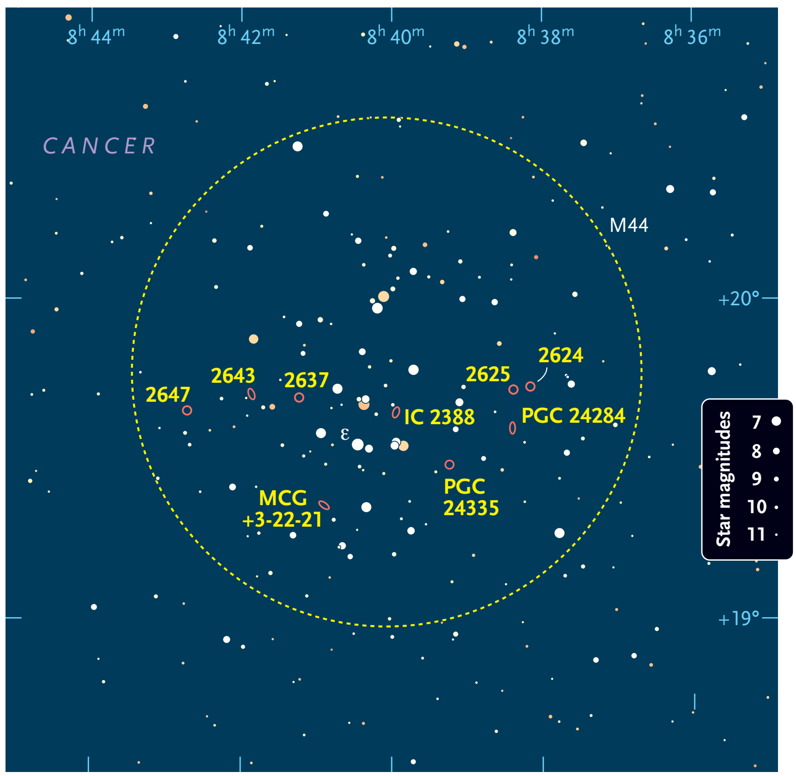
Sometimes a familiar celestial object turns out to be not so familiar after all.

Messier 44, the naked-eye patch of nebulosity in the constellation of Cancer, the Crab, has been under observation since antiquity. It may be better known as the *Beehive*, but it's had many names. The Greeks and Romans saw a manger here; the Latin *Praesepe* remains a popular label for the cluster. In China, the starry cluster was long interpreted as a group of captured spirits or demons, *Yugui*. Perhaps the most official is its designation as NGC 2632, or Collinder 189. It's relatively nearby, maybe 600 light-years distant, and composed of about 1,000 stars, the 50 or so brightest comprising the familiar cluster we observe in small telescopes. Many speculate that Charles Messier added it to his catalog, along with the Orion Nebula and the Pleiades, just to lengthen his first published list to 45 for some aesthetic or even prideful reason.

Observing guides uniformly instruct the viewer to enjoy M44 in binoculars or to employ low-power views in the telescope. It's little wonder that deep-sky observers often ignore it, dismissing it as unworthy of detailed study. Many might be surprised to learn that within the 1° field that the foreground cluster fills with bright stars lie several distant galaxies, all of which are very challenging targets.

My first attempt to explore deep between the stars of the Beehive was inspired by my friend Kent Blackwell, who arrived at our observing site one night in February 1998 ready to tackle the project with his 16-inch Dobsonian. The newly published *Millennium Star Atlas* showed four galaxies behind the cluster, and so we set a goal of observing them. My 8-inch Schmidt-Cassegrain proved to be mostly insufficient for the task, but that only intensified the challenge. I have since endeavored to peek behind the cluster with larger apertures and have



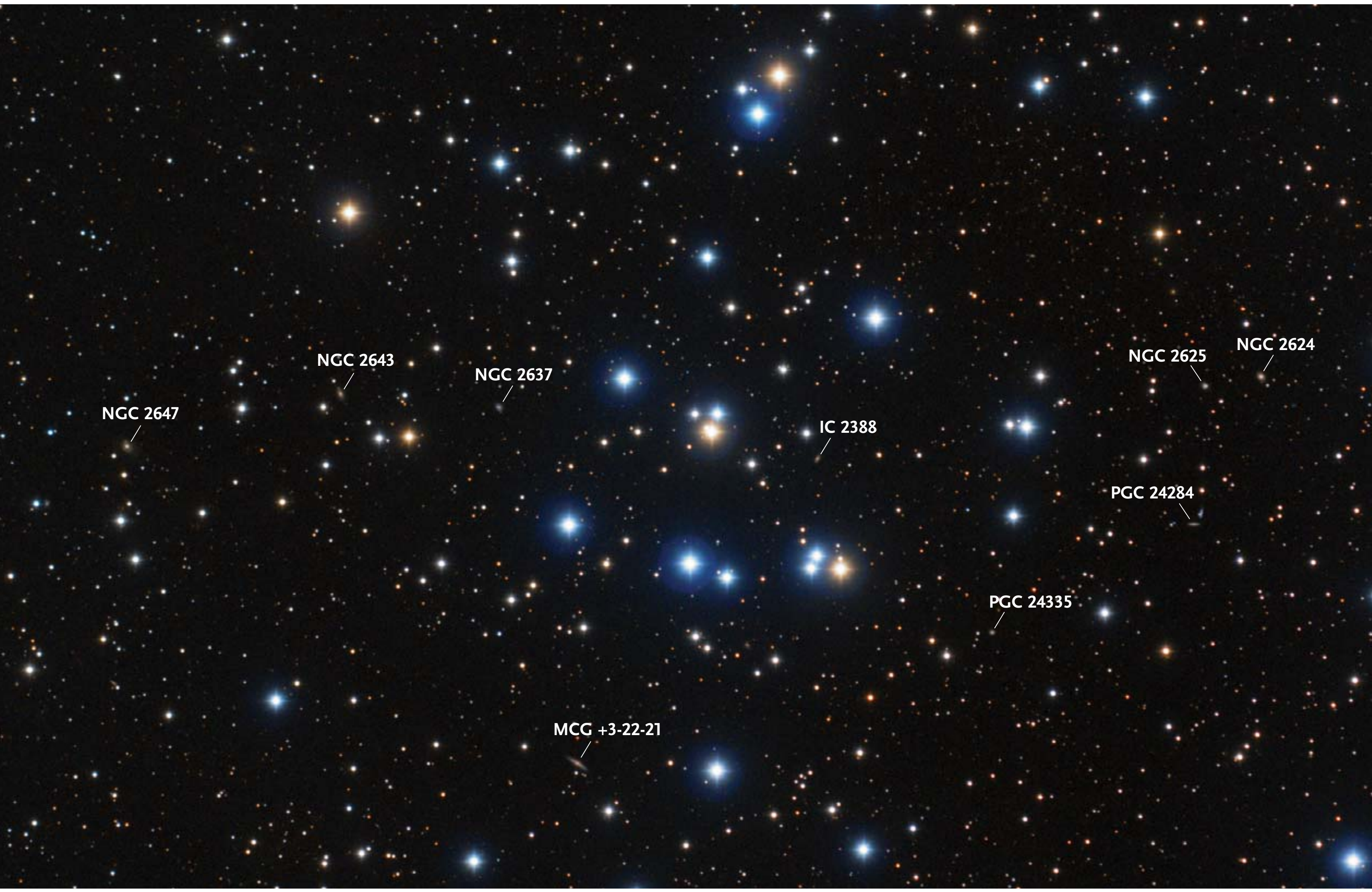


expanded the target list to include 9 objects. My best view of the hidden galaxies came over a few nights in January 2015 when I explored the area from my backyard observatory outside of Sierra Vista, Arizona.

NGC 2647 is the easternmost galaxy inside the boundaries of the bright cluster. At about 720 million light-years from Earth, the galaxy is more than a million times more distant than the cluster itself. At first glance, it appears as a small, concentrated spot, but with a little effort on the part of the observer, it reveals itself as a roundish halo with a brighter core. The galaxy is only a bit elongated along its northeast-southwest axis. You might expect dense star fields within a rich open cluster like the Beehive, but at high powers, the field of view isn't at all crowded. NGC 2647's immediate stellar neighbors are 12th and 13th magnitude and offer no real impediment to the detection of the galaxy. It sits just north of a pair of 12th-magnitude stars and about 1′ northwest of a 13.4-magnitude star. I used 300× and 390× in my 30-inch f/4.5 Dob to observe this elliptical, but detected it previously in smaller apertures without much difficulty.

Moving about 12.5′ west-northwest brings **NGC 2643** into view. This galaxy suffers from a bit of an identity crisis, with many sources equating it with IC 2390 and others questioning this identification. Albert Marth discovered the galaxy in 1864, and he apparently recorded an 11′ error in its position. IC 2390, which is almost certainly the same object, was discovered independently

Because of its size (at 95 arcminutes, it's about three times as broad as the full Moon), M44 is considered an ideal target for small telescopes and binoculars. But if you pump up the aperture and magnification, not to mention your determination and patience, you'll find a host of galaxies hiding between the cool blues and warm yellows of the cluster's stars.



BOB FRANKE

*Contributing Editor **Ted Forte** observes from his home near Sierra Vista, Arizona. He pens a monthly astronomy column for his local newspaper, the* Sierra Vista Herald.

A Small Swarm of Galaxies

Object	Alternate ID	Surface Brightness	Mag(v)	Size	RA	Dec.	Distance
NGC 2647	PGC 24463	13.2	14.3	48″ × 30″	08^h 42.7^m	+19° 39′	720 million l-y
NGC 2643	PGC 24434	13.3	14.9	42″ × 24″	08^h 41.9^m	+19° 42′	210 million l-y
NGC 2637	PGC 24409	14.2	15.4	48″ × 30″	08^h 41.2^m	+19° 41′	430 million l-y
IC 2388	PGC 24365	—	15.8	34″ × 19″	08^h 40.0^m	+19° 39′	446 million l-y
NGC 2625	Markarian 625	12.9	15.0	24″ × 24″	08^h 38.4^m	+19° 43′	200 million l-y
NGC 2624	MCG +3-22-21	12.6	14.1	36″ × 30″	08^h 38.2^m	+19° 44′	190 million l-y
PGC 24284	Leda 24284	—	15.0	29″ × 07″	08^h 38.4^m	+19° 36′	210 million l-y
PGC 24335	Leda 24335	—	15.9	23″ × 20″	08^h 39.2^m	+19° 29′	500 million l-y
MCG +3-22-21	UGC 4526	13.2	13.9	1.5′ × 0.4′	08^h 40.9^m	+19° 21′	200 million l-y

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

by E. E. Barnard. Marth discovered **NGC 2637** on the same night as NGC 2643. He recorded an offset position for it as well, which lends more weight to the NGC 2643/IC 2390 equivalence.

Lying 1′ 14″ northwest of an 11th-magnitude star, NGC 2643 is small and mostly round. It appears evenly illuminated, but after longer study, I saw hints of a slightly brighter core. I couldn't detect it at 177×; however, it made an appearance at 300× and looked its best at 390×. NGC 2637, about 9′ to the west in the same field of view, displays a similar size and brightness. I could just distinguish its faint, round shape at 177×. It was easier to see at 300× but showed no variations in brightness.

I used averted vision to detect **IC 2388**, and I was unable to hold it with direct vision even after spending several minutes under a black towel to eliminate all extraneous light. This small, faint spot of nebulosity sits rather close to the center of the cluster, so the field of view is populated with several 6th- and 7th-magnitude stars. The galaxy itself lies 1.5′ south of a 10th-magnitude star. I couldn't make out the elongation implied by the listed dimensions; its form remained round and smooth at all powers.

At the western edge of M44, three galaxies occupy the same small field of view. Just 3′ 13″ separate **NGC 2625** and **NGC 2624**, with the former to the east of the latter. The roundish NGC 2625 is probably a spiral seen nearly face-on. It appears small and dim and only slightly brighter toward its center. NGC 2624 was easier to detect. Its 30″ halo is elongated northeast-southwest and contains a considerably brighter core. I used a range of magnifications on the pair but had the most pleasing view at 300×.

The third galaxy here was a chore to find. I completely missed it on my first exploration of the area and had to revisit it a couple of nights later. Look 5′ directly south of NGC 2625 for a pair of 12.5-magnitude stars lying in a north-south line; they point the way to the 15th-magnitude edge-on galaxy **PGC 24284**. Small and slender, its dimensions inhibit detection even though it has a higher surface brightness than its more open-faced neighbors. Averted vision and 650× revealed its location, and once located, 390× provided a better view. Still, it's no more than a streak of light angled very nearly north-south. Deep Sky Survey images show an even fainter, slimmer companion at a right angle to it, but I saw no trace of it.

Moving 13′ 40″ southeast back across the cluster, you come to the tiny, faint, and round face-on spiral, **PGC 24335**. I detected it at 177×, but it took 300× for me to see it well. Just beyond the galaxy, another 50″ farther east, is a string of three 15th- and 16th-magnitude stars in a nearly north-south line.

A hop about 25′ southeast will center the most southern of M44's galaxies, **MCG +3-22-21**, in your eyepiece. This edge-on spiral stretches northeast-southwest and shares the field with a 14th-magnitude star about 30″ to the south. I had to pump up the power to detect this streak of light, but at 390× it was fairly easy to see.

Peeking between the stars of this well-known showpiece to discover the galaxies concealed behind it is a bit like pushing the coats aside in C. S. Lewis's wardrobe and finding a passage to a hidden world. Perhaps there are other observable galaxies behind the cluster. I don't yet know, but I'm certain that once you've explored these nine objects, the Beehive will never again seem ordinary or unchallenging. ✦

Alan Dyer

Sky-Watcher's Fast Astrograph

The Quattro reflector series promises photographic speed at an affordable price.

Sky-Watcher Quattro 8-inch Imaging Newtonian

U.S. price: $610

Available from skywatcherusa.com and dealers worldwide.

The Sky-Watcher Quattro 8 is an 8-inch f/4 Newtonian reflector designed primarily for deep-sky imaging with DSLR cameras. The unit tested had a standard steel tube finished in Sky-Watcher's trademark black-sparkle enamel paint.

ALL PHOTOS BY THE AUTHOR

ASTROPHOTOGRAPHERS pursuing deep-sky quarry often desire a generous focal length, which produces enough image scale to resolve small details in their targets, but would prefer not to sacrifice focal ratio to get it. A telescope with an f/ratio faster than f/6 is ideal for keeping exposure times short. This is especially desirable when shooting with DSLR cameras whose uncooled sensors always exhibit more noise than cooled astronomical CCD cameras.

While we can boost the ISO speed of DSLRs, this comes at the cost of increased noise in each photo. Lowering the ISO reduces noise but requires longer exposure times, meaning fewer images and targets shot

WHAT WE LIKE:

Fast, f/4 optics

Solid, precise focuser

Well-corrected field with optional coma corrector

Attractive price

WHAT WE DON'T LIKE:

Scratch-prone setscrews can mar accessories

Vignetting requires more care in processing per night. Fast optics are always nice to have, but they usually exact a premium price on your bank account.

To address that, Sky-Watcher introduced the Quattro Imaging Newtonian reflectors with 8-, 10-, and 12½-inch apertures. Each is f/4 (hence the Quattro name) and sells for $610, $770, and $1,199, respectively in the United States. However, as I found, to make them usable for imaging you need the optional Quattro Coma Corrector ($285). But even with that added cost, the Quattros remain bargains for fast astrographic systems.

How well do they work? I tested the 8-inch model, on loan from Pacific Telescopes in Richmond, Canada, and found that it worked very well indeed.

Solid Mechanics

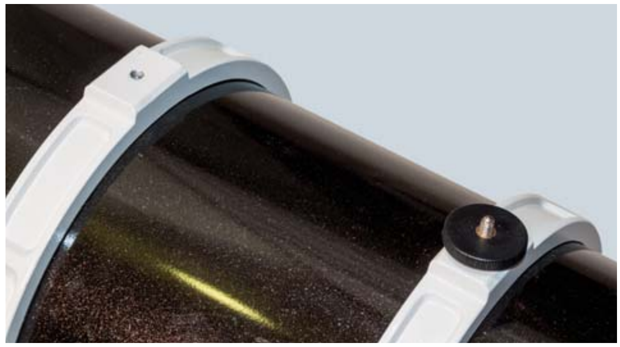
The 8-inch Quattro weighs 9.5 kg (21 lbs). Being a large, solid-tube Newtonian reflector, it's prone to catching the wind and thus needs to be on a sturdy mount for best performance. I tested it on my Astro-Physics Mach-1GTO German equatorial mount, which was somewhat overkill for this scope. In the Sky-Watcher line, I would recommend using the 8-inch Quattro with nothing less than the EQ6 or AZ-EQ6 mounts, and the heavier EQ8 SynScan GPS mount is an even better option.

Since the telescope is designed primarily for photography, key to its performance is the quality of the focuser. The Quattros use a Crayford-style focuser with a friction drive and 10:1 fine-speed motion. I found the focuser precise and rock solid. It locked down well and never slipped with the DSLR camera I used, nor with any of the heavy eyepieces I tried when observing through the instrument.

However, the camera and coma corrector are held in the focuser with two small setscrews that press directly on the barrel of the coma corrector. There is no compression ring, nor are the setscrews Nylon tipped, so they scratched the coma corrector's tube. I also found the small setscrews tough to get at and adjust. I was also concerned that they might not be sufficient to hold a heavy CCD camera if the focuser were angled down to the ground (a common orientation when imaging with Newtonians). But the Quattro focuser is ideal for DSLRs and most lightweight CCD cameras.

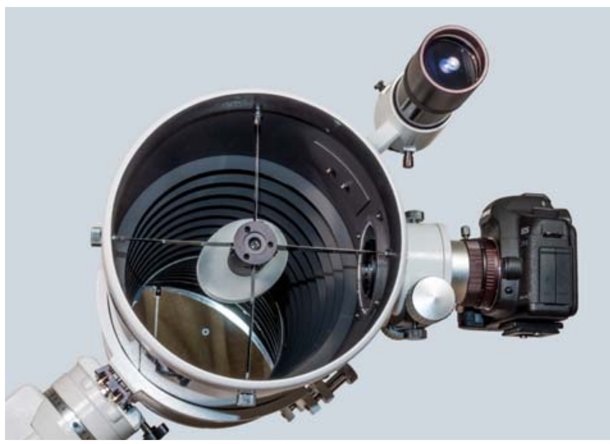
The Quattro's steel tube has an attractive black-sparkle finish common to many Sky-Watcher telescopes. On cool autumn nights, I never noticed any appreciable focus shift during the one to two hours I needed to capture a set of images of an object. Even so, it's a good idea to refocus periodically when imaging through any telescope, particularly when the temperature changes markedly throughout the night.

The 8-inch Quattro comes with a Vixen-style dovetail mounting bar. Its tube rings also include threaded holes for attaching an additional plate to the top of the scope. I had no problem bolting on my own, larger dovetail plate



The tube rings included with the Quattro are tapped with a single ¼-20 thread on both top and bottom, and one ring includes a ¼-20 threaded stud, suitable for attaching a ball head for piggyback photography.

The Quattro line includes an excellent 9x50 finderscope attached with a standard dovetail shoe, which can be replaced with a 50-mm guidescope for autoguiding. The Crayford-style focuser comes with adapters for 1¼- and 2-inch eyepieces. The 2-inch adapter is shown here.



The tube interior is well blackened and contains nine baffles, but does not extend farther than a standard Newtonian. Nevertheless, shooting from a dark site, the author didn't notice any stray light illuminating the field. The coma corrector does not protrude into the light path, and the only diffraction spikes in images were due to the four-vane spider.

The primary mirror cell is well ventilated and includes knurled collimation knobs that are easy to turn by hand and lock down securely. Note that they protrude beyond the end of the cell, requiring care in transport to ensure they do not get damaged.

needed for my mount, and another plate to the top for mounting my SBIG SG-4 autoguider.

You can loosen the tube rings to allow the telescope to rotate for placing the camera or eyepiece at a convenient angle. But this proved difficult to do without either shifting the mount or having the tube slide down the rings, compromising the balance. Instead, I settled on an orientation that worked well for all the imaging I did in the eastern and southern sky.

Imaging Performance

Without the optional coma corrector, the 8-inch Quattro presented a sharp field of view over a central 12-mm circle of the camera's frame, typical for an f/4 Newtonian. Outside of this small area, stars appear as progressively larger teardrop shapes radiating from the center. While this is sufficient for lunar photography with the small detectors typically found in high-speed video cameras used for lunar imaging, the optional Quattro Coma Corrector is an essential accessory for deep-sky imaging with any DSLR camera or today's CCD cameras with mid-sized detectors.

The Quattro Coma Corrector flattened the field almost completely, leaving star images ever so slightly elongated only at the extreme corners of a full-frame (24 × 36mm) DSLR sensor — performance that I consider more than acceptable. While this telescope has a large, 3-inch secondary mirror, there is still a significant amount of vignetting in the outer third of the field of a full-frame DSLR camera. Also apparent is a darkening along the bottom edge of the frame, and along the top to a lesser extent, caused by shadowing from the camera's rectangular mirror box. This isn't any fault of the Quattro — it's an effect that shows up in all full-frame DSLR cameras paired with fast astrograph systems. The faster the optics, the worse the shadowing effect, which can vary depending on the camera model. It is less of an issue for photographers using cameras with smaller, APS-size sensors.

Nevertheless, imagers should be prepared to record and apply flat-field calibration frames that eliminate most, if not all, of the vignetting. Just be warned, this is the price to pay for using fast focal-ratio astrograph systems with DSLRs, especially full-frame cameras.

Visual Use

Although the Quattro series is marketed primarily for imaging, an f/4 Newtonian makes an attractive "rich-field" visual telescope. I spent some nights observing with the scope to evaluate its visual performance.

Despite its small coma-free field, I never found the coma at the edge of the field to be objectionable even

Left: **Without the optional coma corrector, the Quattro exhibits strong coma on full-frame cameras, with sharp stars in only the central 12-mm of the frame.** ***Right:*** **While using the telescope with the Quattro Coma Corrector, some light falloff toward the corners is inevitable in such a fast system. In addition, the mirror box of a full-frame DSLR camera added shadowing along the top and bottom edges of the frame. This image is processed with increased contrast to better display the vignetting.**

This image of IC 5146, the Cocoon Nebula, was shot with the Quattro Coma Corrector and a modified full-frame Canon 5D MarkII camera. It shows nearly perfect star images at each corner.

with wide-field eyepieces. Views with many premium eyepieces, including Tele Vue's 41-mm Panoptic, 31-mm Nagler, and 17-mm Ethos eyepieces, looked stunning. Crisp, round stars were visible across all but the outer 25% or so of the field. (Note that the Sky-Watcher Quattro Coma Corrector cannot be used visually.)

At low magnifications the field of view was particularly impressive. The brighter eastern and western sections of the Veil Nebula (NGC 6992 and NGC 6960) just fit into the field of the Tele Vue 31-mm Nagler eyepiece. After slight tweaks to the telescope's collimation, the optics yielded classic Airy disk diffraction patterns around stars at high powers, and double stars such as Epsilon Lyrae were well resolved. There was no sign of astigmatism or spherical aberration.

But the large secondary mirror robs planetary views of contrast, so I wouldn't recommend the Quattro (or any f/4 Newtonian reflector) as a great planetary scope. For visual use, the Quattro excels at providing low-power, wide-field views.

For me, the benchmark of a fine telescope is how soon I stop fussing with the testing and just start enjoying it. After one or two moonlit nights of testing, I found myself shooting with the Quattro and using it to go after some remaining objects on my personal target list. It just worked! Being able to shoot at the low-noise setting of ISO 800 while keeping my exposures no longer than 8 minutes let me capture excellent detail in multiple targets each night with the scope's 800-mm focal length. It is a wonderful thing!

Even with the additional cost of the coma corrector and the need for accurate flat-field calibration images, the telescope performed admirably. I can recommend the 8-inch Quattro as a superb imaging system for under $1,000. Just be sure to match it to a substantial mount to do the telescope justice. ✦

Contributing Editor ***Alan Dyer*** *is author of the ebook* How to Photograph & Process Nightscapes and Time-Lapses, *available at* ***amazingsky.com/nightscapesbook.html.***

A 20-inch Dream Scope

This instrument is more than a Dobsonian alternative.

A LOT OF DOBSONIAN-STYLE telescopes have appeared in this department over the years, and for good reason. They're popular because they have the potential to deliver plenty of aperture in an effective, simple-to-use package. But another design that shares these attributes is the so-called ball scope. Indeed, but for one significant detail, they would probably be more popular than Dobs. And what is that detail? In a word, the ball. More about that in a moment.

The attributes of the ball-and-socket design are well demonstrated by this 20-inch, f/3.9 reflector built by Blainville, Quebec ATM Pierre Lemay. He describes it as his dream scope, and I suspect his dream is one shared by quite a few readers. For Pierre, the "dream" includes large aperture and motorized tracking in an instrument that is comfortable to use and lightweight enough to be easily transported and set up. But Pierre's dream took more than 20 years to come true.

PIERRE LEMAY

Building this 20-inch f/3.9 ball-and-socket telescope took Quebec telescope maker Pierre Lemay took more than 20 years. The fully assembled instrument tips the scales at 130 pounds, including its innovative, dual-axis-drive platform.

"The project began in 1990 when I saw a classified ad in *Sky & Telescope* for a 20-inch, conical Pyrex mirror blank advertised for $500," he says. "It was a rough cast piece of glass that needed a lot of work before grinding could even begin." First stop was a local tombstone maker's shop, where a curve of about the correct depth was generated by sandblasting. Next, Pierre attacked the rear surface of the blank with a grinding wheel and jig to thin it and take the edge thickness down from 1 to ½ inch. This reduced the mirror's weight from 50 to 32 pounds. Additionally, he perforated the center of the mirror to facilitate its mounting in the scope later. After that, it was simply a matter of grinding and polishing a 20-inch f/3.9 paraboloid!

Following the primary mirror, the next big hurdle was fabricating a "ball." This really is the make-or-break part of the design. Failing to find a suitable ready-made hemisphere, Pierre resigned himself to making one, or rather, *two*. "My first attempt recalls the joke about how the operation was a success, but the patient died," he says. "But I learned a lot and developed the methods I used in my second try."

To begin, Pierre made a crude sphere by stacking 2-inch-thick disks of Styrofoam in incrementally varying diameters — like a layer cake. He included an aluminum plate on the bottom (to support the mirror cell), and plywood ring on top for attaching the truss poles. Next, he used a router mounted in a large, pivoting jig to generate a smooth shape from the stair-step layers. The resulting Styrofoam hemisphere would serve merely as a form, over which Pierre applied auto-body filling putty. Once the putty hardened, the assembly went back into the jig for more routing and then sanding. The resulting hemisphere received eight coats of liquid epoxy resin (sanded between each coat) for a smooth, strong finish. All that remained was to separate the sphere from the form by breaking up the Styrofoam. "I was then left with a hollow, 3/16-inch-thick hemisphere weighing about 40 pounds," he says.

PIERRE LEMAY

Lemay made the scope's hemispheric "ball" using a Styrofoam form, which is shown here being shaped with a router mounted in a jig.

Although lighter than his first attempt, the new hemisphere was still heavier than desired. "I had made progress but was still heading for a 100-pound tube assembly," he notes. Then inspiration struck. "After carefully considering my options, it dawned on me that I could lop off part of the hemisphere without affecting the scope's motions." To accomplish this, Pierre put together another jig to accurately draw a cut line angled 30° from the top of the existing hemisphere. He made the cut freehand with a jigsaw. As he reports, "It worked — I eliminated 14 pounds of plastic!" With the two most difficult components completed, building the rest of the optical tube was little different from putting together a normal, truss Dobsonian.

Pierre's dream scope has a number of nifty refinements, including a motorized drive and an ingenious rotating double-eyepiece turret with helical focusers. Even so, future modifications are already looming. "I know it's a cliché, but when I 'finished' the scope two years ago, little did I realize it was only the beginning of the project!"

Additional details on the construction of Pierre's scope can be seen at his website: **telescopelemay.com**. ✦

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*Contributing editor **Gary Seronik** is an experienced telescope maker and has led the ATM department since 1998. You can contact him via his website, **garyseronik.com**.*

Electronic Eyes

Curtis Vincent Macchioni

Increase your telescope's reach with an astrovideo camera.

CURTIS MACCHIONI

GEARING UP **The author's typical setup includes a Celestron C9.25 Schmidt-Cassegrain telescope, Mallincam Xtreme camera, Phillips LCD monitor, and a DC power supply.**

Video-assisted observing has become increasingly popular among amateur astronomers in recent years. Part of this trend is due to the growing problem of light pollution; video can show you far more from a typical suburban backyard than the same telescope can from a dark site. In fact, enhancing your observing experience with an astrovideo camera reveals objects in the night sky as unambiguous galaxies, nebulae, and star clusters, rather than as the vague smudges they often appear in an eyepiece. But more than this, an astrovideo camera can virtually increase the aperture of your telescope by a factor of three or more at a fraction of the cost of a larger scope.

Amateurs have been mating their telescopes with video cameras since the early 1980s. Video cameras at the time weren't very sensitive and therefore were generally limited to objects like the Sun, Moon, and bright planets, or the occasional occultation of bright stars. It wasn't until the turn of the century that high-sensitivity video cameras began to enter the amateur arena and interest in video astronomy began to grow.

Today, analog video cameras designed for deep-sky observing are available from Mallincam (**mallincam.net**), Astro-Video Systems (**astro-video.com**), and Orion Telescopes & Binoculars (**oriontelescopes.com**), with prices starting around $100. Additionally, surveillance cameras can easily be adapted for video observing.

These cameras have several features in common that allow them to capture bright images of deep-sky objects (DSOs). The most important is their ability to

take longer exposures than a standard video camera. Even the most basic model astrovideo camera (for example, the Astro-Video DSO-1) can record exposures of several seconds, which can reveal thousands of targets in a small scope. Many also include the ability to integrate several exposures together in order to show even fainter targets, while simultaneously reducing noise in the signal.

Most of these astrovideo cameras are built around one of several high-sensitivity Sony CCD detectors in either ⅓- or ½-inch format, with a typical pixel array of 640 × 480 pixels, roughly equivalent to the standard resolution of analog television sets. These are significantly smaller than the CCDs used in conventional astrophotography because they are designed to display an image on a TV screen rather than produce high-resolution images.

All astrovideo cameras allow you to control basic functions like exposure, gain, and gamma. Some come bundled with everything necessary to get you up and running right out of the box, including video and power cables and the C-mount adapter needed to connect the camera to your telescope.

Some camera models include an S-video output in addition to the composite video output. S-Video provides better image quality over short distances, and it can be used to send the signal to a second monitor, which is especially useful when using your system to share the view with an audience. Another helpful option is a remote control that gives access to the camera's control menu; this is much better than having to manipulate the small buttons on the back of the camera, particularly in the dark.

Essential Equipment

Besides the camera and your telescope, you'll need only a few other important accessories to get started. Most models include a standard 1¼-inch nosepiece,

S&T: SEAN WALKER

LIVE VIEWING Video-assisted observing has become a popular way to enjoy the night sky. Detailed views of galaxies, nebulae, and star clusters are within reach of small telescopes when paired with these affordable devices.

CURTIS MACCHIONI

ROD MOLLISE

TINY BUTTONS ***Left:*** **The rear panel of the MallinCam Micro showing the camera control menu buttons. Most astrovideo cameras are far easier to operate with a wireless controller or computer.** ***Right:*** **Video camera detectors are small due to the format of analog television displays. But this has the benefit of being too small to reveal any off-axis optical aberrations inherent in many telescope designs.**

but if not, you'll need to purchase a C-to-1¼-inch adapter. Next, consider the screen with which you'll be viewing the video feed. Any old (CRT) television and most current LCD TVs accept a composite video input, so you might have a screen all ready to use. If you're concerned about portability, many small LCD screens are available for under $100; look for one with a 4:3 aspect ratio that matches your camera's output format.

A desktop computer or laptop can also be used to display the video feed with the addition of a video capture card and software such as *AmCap* or *SharpCap*. Additionally, using a computer with your astrovideo camera allows you to control many of the camera's functions on screen with the programs *MallinCam Control* or *AstroLive* (**astroprecisioninstruments.com**).

Your next concern is powering the camera. While some models come with an AC power transformer, a better option is a 12-volt DC battery, which is less likely to add noise to the video signal. Video cables should be routed away from power cables to further minimize any sources of electronic noise.

Let's consider the telescope's mount. A tracking mount is essential to the camera's performance — long exposures aren't very beneficial if your target is drifting across the detector during its exposure. While an equatorial mount gives the best results during long integrations, alt-az tracking mounts will work well for short integrations, depending upon the focal length of your telescope and the declination of the object being viewed. A Go To mount makes it much easier and quicker to place your target in the field of view, given the small CCD chips in these cameras.

Now it's time to consider the telescope. Again due to the small detectors in astrovideo cameras, a scope with a wide field of view is preferred to frame most objects. Focal lengths of 1,000 mm or shorter are best, so if you've got a typical 8-inch f/10 Schmidt-Cassegrain, you'll want to use a focal reducer.

One of the benefits of the small chip in every astrovideo camera is that they can utilize much more powerful focal reducers because, unlike large detectors, they only see a small area of the full telescopic field. This means you won't see distorted stars when using an f/3.3 reducer. You can even stack focal reducers together without seriously degrading the on-screen appearance of stars at the corners of the visible field.

CURTIS MACCHIONI

ELECTRIC EYES **Some popular camera models are** ***(left to right):*** **MallinCam Xtreme (with optional cooling fan and focal reducer); LNTech 300 (with C-to-1¼-inch adapter); Samsung SCB-2000; and Astro-Video Systems MKIV (with Bluetooth adapter and cooling fan).**

CURTIS MACCHIONI (2)

COLORFUL RESULTS Astrovideo observing is primarily geared toward revealing faint targets on your video monitor. These images of M20, the Trifid Nebula *(left)*, and the spiral galaxy M33 are typical of what to expect with a color camera and moderate aperture.

While not essential, a light-pollution filter can make a big difference in what you can see from typical light polluted sites. An infrared "cut filter" will also block unfocused infrared light to produce smaller stellar images.

Helpful Settings

Unless you're operating your camera with a computer, you'll need to access the camera's on-screen display (OSD) to adjust its menu settings. While each camera's OSD menu is slightly different, they all have the same general functions. The most important functions you'll change the most are Exposure, AGC (Automatic Gain Control), and Gamma. If your camera has a color chip, then you'll also have a White Balance setting.

Exposures are typically divided into two or three categories: 1⁄100-second or shorter exposures are best for solar, lunar, and planetary viewing. Shutter speeds of up to 2 seconds are most useful when focusing or adjusting your Go To pointing alignment, and they can even aid in collimating your telescope. Images of 3 seconds or longer are best for viewing deep-sky objects and the occasional near-Earth asteroid.

The AGC setting is similar to the ISO value on a DSLR camera. It increases the amplifier gain, thereby increasing image detail and reducing the required exposure time. But this comes at the expense of increased noise in your video, as well as noticeable "amp glow," caused when infrared radiation emitted from the readout amplifier is picked up by the camera's detector. Amp glow appears as a bright background at a corner or top of the video image, and it's more noticeable when using high-gain settings, long exposures, or a combination of both.

Gamma adjustments allow you to stretch the luminosity values in the image, which increases detail (but reduces contrast). A setting of 1 produces an unenhanced image, while lower values enhance fainter nebulosity but lighten the overall background of the video.

In a color camera, White Balance allows you to adjust the color balance in your video. Usually you're offered options for automatic or manual modes. In automatic mode, the camera adjusts the color to what it assumes is optimal; in manual you set the red and blue levels of the video feed until the image appears properly balanced.

Two other important settings are Brightness and Contrast, which are usually adjusted on the monitor itself or within the video-capture software. Brightness raises or lowers all parts of the image from dark to light equally. The Contrast setting changes the slope of the light curve from black to white while keeping the black point fixed, reducing the dynamic range of the image.

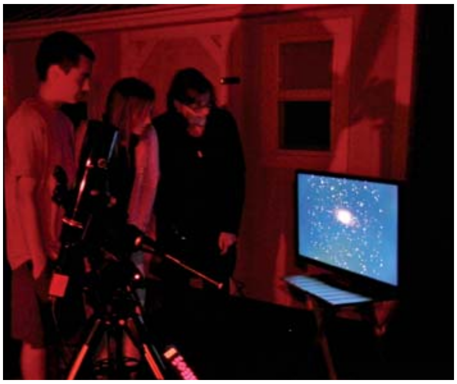
Under the Stars

Once you've geared up, here are some tips to start observing. After replacing your telescope's eyepiece with the astrovideo camera, be sure to secure the power and control cables to prevent snags when slewing to targets around the sky.

Start by focusing on a bright star with the Exposure set at about 2 seconds, Gamma at 0.3, and AGC at the midpoint; this should produce a bright image that refreshes quickly. Once focused, slew to a DSO of interest and take a test exposure of 10 seconds or so, depending upon the surface brightness of your target. Adjust

ROD MOLLISE

EXPANDED VIEW One benefit of the small detectors in astrovideo cameras is their ability to utilize strong focal reducers without producing objectionable distortions in stellar images. This allows you, for example, to convert your f/10 SCT into a fast f/3.3 wide-field instrument.



SHARING THE VIEW With the addition of a large TV or monitor, astrovideo cameras let you share the view with groups of observers.

the AGC and Gamma settings to make it easier to see and center your target in the field of view. Next, adjust the Brightness and Contrast to bring out the most detail possible without overexposing the brightest parts of the object. You might need to increase your exposure to find the best settings for your system. If the video image displays elongated stars, try reducing the Exposure and raise the AGC setting to compensate. However, too high an AGC setting may result in objectionable amp glow and noise; too low a Gamma setting might produce a background sky that's too bright.

If you have very dark skies or can utilize long exposures, you'll generally see less noise with a low AGC setting and the Gamma at 1. However, cameras with frame integration should be used with Stacking set for 5 frames and AGC on in order to activate the stacking process. Once again, take successive images with increasing exposure times until you obtain the best possible image. When satisfied, adjust the White Balance settings to obtain a pleasing color.

Getting the best image with a reasonable exposure time is a matter of tradeoffs that will vary with sky conditions, telescope, focal length, and the presence or absence of filters. Once you're happy with the image, you can hop from one DSO to another and use the same settings, varying only the exposure time. If you prefer to keep the Exposure short, use higher AGC and lower Gamma values. On the other hand, longer Exposure provides the most detailed images with the least noisy backgrounds.

While video won't produce the smooth backgrounds and subtle detail seen in dedicated long-exposure astrophotographs, you'll be pleasantly surprised at how fast and easy it is to obtain spectacular views of galaxies, nebulae, and star clusters. With a modest-size scope and a color astrovideo camera, you'll see color in bright nebulae like M8, dust lanes and star-forming regions in nearby galaxies like M33 and M31, and the central star in M57, the Ring Nebula. And as you get more involved in deep-sky observing with astrovideo cameras, chances are your eyepieces may soon begin collecting dust. ✦

***Curtis Macchioni** enjoys video-enhanced observing from the San Francisco Bay area. Visit his website at* **californiaskys.com**.

Pixel Count & Pixel Size

How can deep-sky video cameras produce recognizable pictures of galaxies in 10 seconds when a DSLR camera would need a minute or more? It's partly a matter of pixel size. The bigger the pixels on the light sensor, the more light falls on each pixel in a given exposure and the better the low-light sensitivity.

CURTIS MACCHIONI (2)

Point-and-shoot cameras are poor choices for deep-sky photography because they have tiny sensors (to keep their zoom lenses compact) divided into huge numbers of pixels — which is largely a marketing gimmick. A full-page photograph reproduced in this magazine needs just 6 to 8 megapixels.

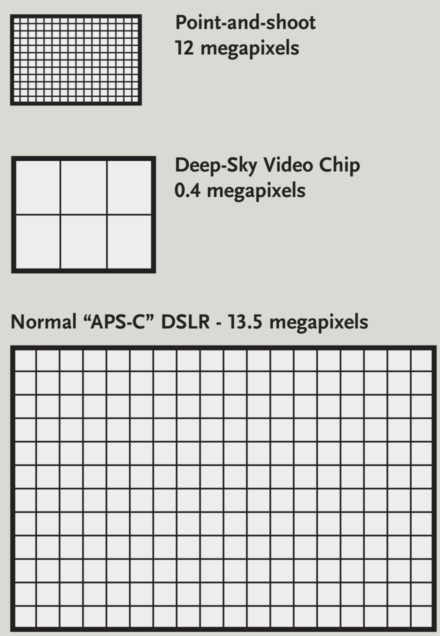
DSLRs have about the same pixel count as point-and-shoots, but their sensors are much bigger. That makes each pixel bigger, giving the camera very good sensitivity when operating in low-light levels.

The sensors in deep-sky video cameras are small, but they have very low pixel counts. That results in larger pixels, making them extremely sensitive to faint light, but at the cost of resolution.

—Tony Flanders

VERSATILE CAMERAS Observing with an astrovideo camera like the one shown here doesn't require much additional equipment to tow into the field. Besides the camera, you'll need a DC power source and a video monitor or a laptop computer to display your exposures. You can also use a variety of Barlows and focal reducers to tailor your field of view to each target, just like switching eyepieces when visually observing.

Typical Camera Sensor Chip & Pixel Sizes



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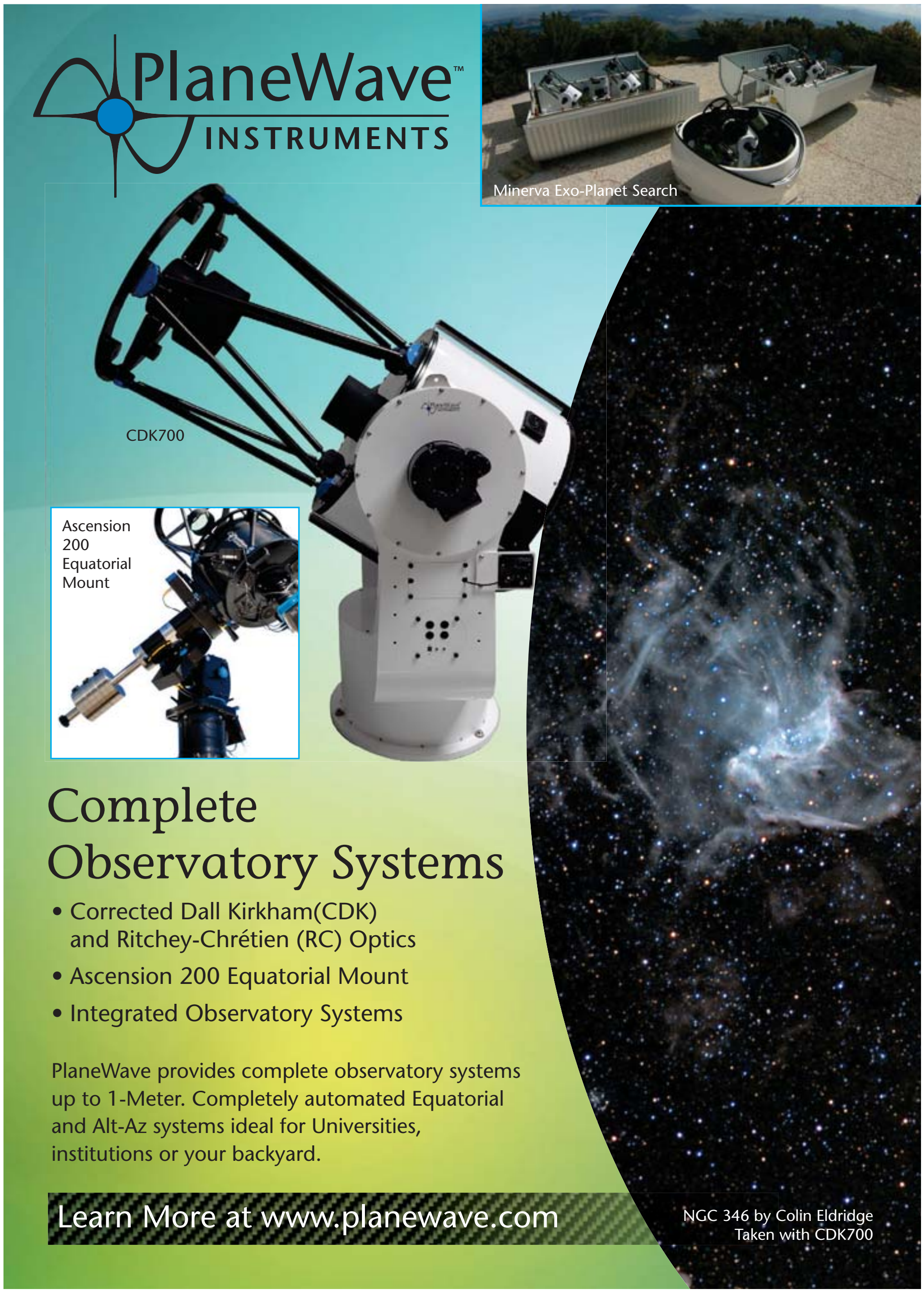
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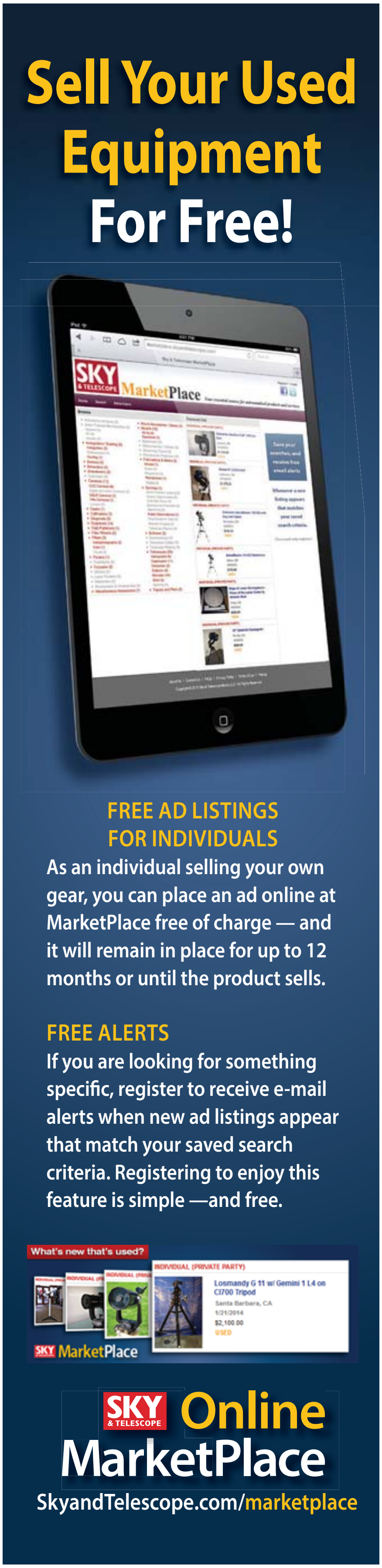
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◄ **STUNNING SIRIUS**

Greg Parker

A beacon that gleams in even the most light-polluted skies, Sirius is the brightest of all nighttime stars — in part due to its proximity, just 8.6 light-years away.

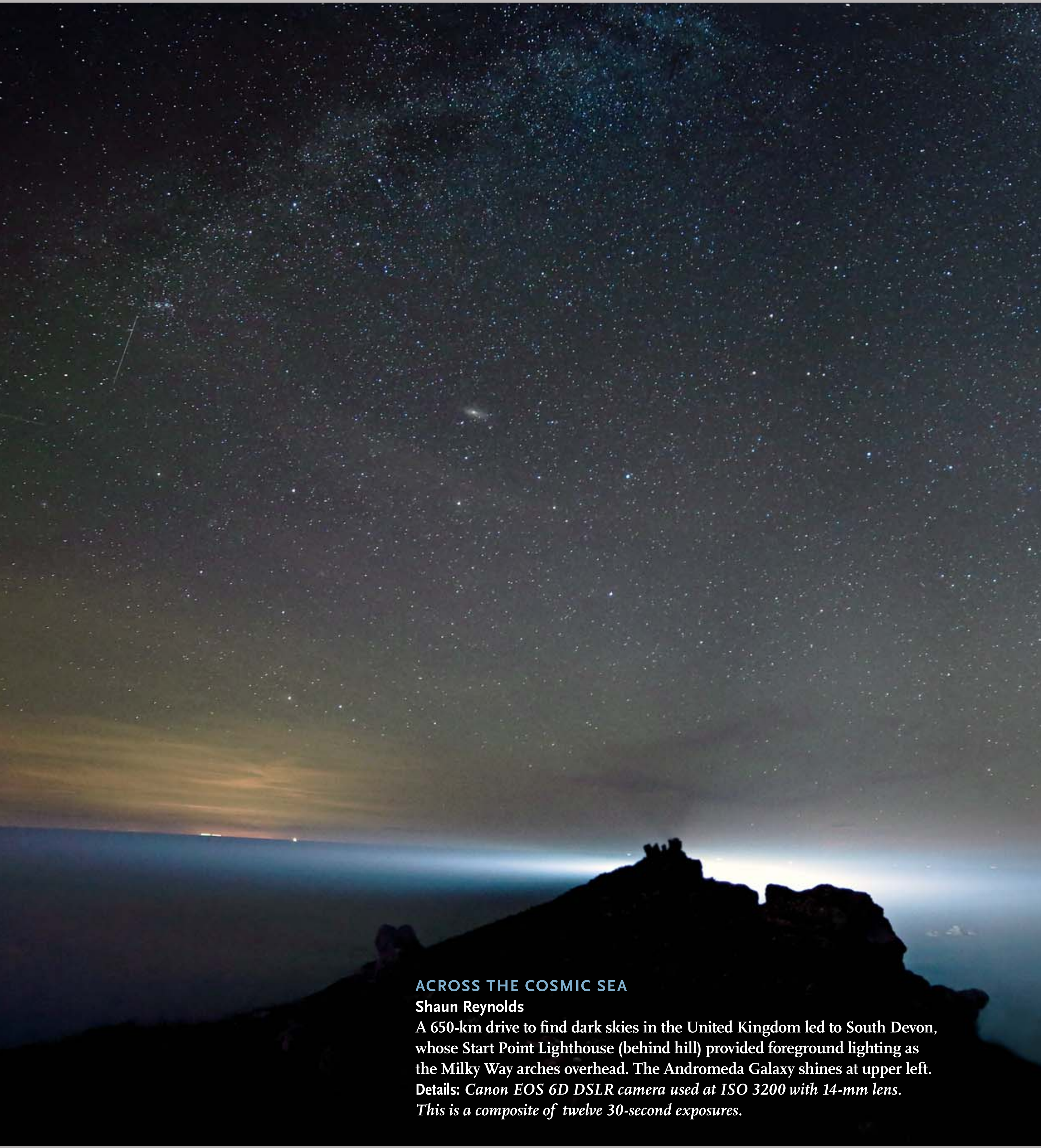
Details: *Takahashi Sky 90 apochromatic refractor and Starlight Xpress M26C CCD camera. Total exposure: 1 hour.*

▼ **AURORAL INTRUDER**

Matt Skinner

A fireball from the Taurid meteor shower adds more drama to an auroral display in the predawn sky near Anchorage, Alaska, on November 4, 2015. A waning crescent Moon (far right) illuminates the terrain.

Details: *Canon EOS 5D Mark III DSLR camera used at ISO 1250 with a 14-mm lens. Exposure: 2 seconds.*



ACROSS THE COSMIC SEA

Shaun Reynolds

A 650-km drive to find dark skies in the United Kingdom led to South Devon, whose Start Point Lighthouse (behind hill) provided foreground lighting as the Milky Way arches overhead. The Andromeda Galaxy shines at upper left.
Details: *Canon EOS 6D DSLR camera used at ISO 3200 with 14-mm lens. This is a composite of twelve 30-second exposures.*

▶ **ROSETTE PORTRAIT – I**

Kfir Simon

Imaged with the "Hubble palette" filter set, the Rosette Nebula in Monoceros shows intricate tendrils of gas and dust. **Details:** *16-inch Dream Astrograph and Apogee Alta U16M CCD camera with hydrogen-alpha, oxygen-III, and sulfur-II filters. Total exposure: 2½ hours.*

▶▼ **ROSETTE PORTRAIT – II**

Matt Dahl

Embedded within the Rosette, and forged from its raw materials, are young stars of the open cluster NGC 2244. The entire assemblage lies roughly 5,000 light-years away. **Details:** *Takahashi FSQ-85 astrograph and SBIG STT-8300M CCD camera with Baader filters. Total exposure: 13.4 hours.*

▼ **SEEING DOUBLE IN PERSEUS**

Jaspal Chadha

Often designated h and χ Persei, the well-known paired open clusters NGC 869 and 884 are some 7,500 light-years distant. Each contains hundreds of massive young stars. **Details:** *Sky-Watcher Esprit 100ED refractor, QHY9S CCD camera, and Chroma Technology filters. Total exposure: 1.7 hours.* ✦

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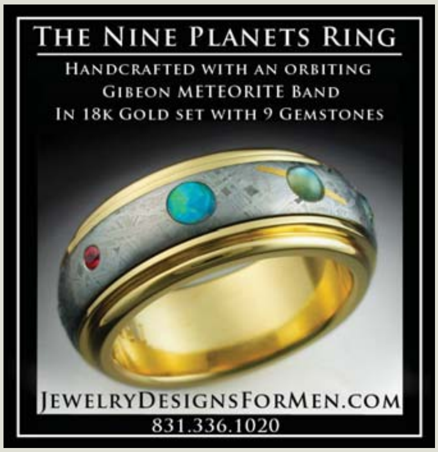

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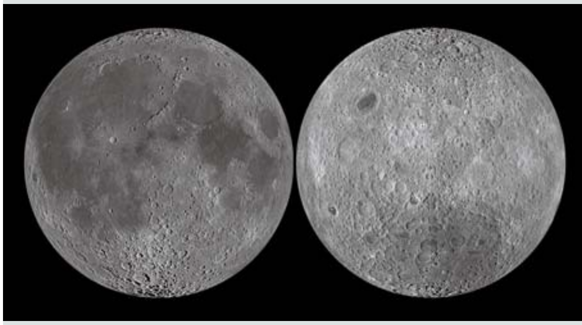

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William Sheehan

The Importance of Awe

Can kids today still experience the "11th emotion," the key to loving astronomy?

WHILE STRUGGLING in abject poverty in Nashville after the Civil War, future astronomer Edward Emerson Barnard received a Bible from his Sunday school teacher. He kept it his entire life, but apart from inscribing his name, he underlined but one passage (Job 38:31–32):

Canst thou bind the sweet influences of Pleiades, or loose the bands of Orion?
Canst thou bring forth Mazzaroth in his season, or . . . guide Arcturus and his sons?

When Barnard was a boy, it was still possible to see the Milky Way from downtown Nashville, and the sight of it filled him with awe. Today, in the U.S., less than 10 percent of children live in areas where views of the night sky are similar to those Barnard enjoyed. Would Barnard have felt the same sense of awe under the night sky that motivated him to underscore those verses of Job, and that inspired him to a passionate life of studying and observing the sky, if he had lived under light-polluted skies?

Awe, the emotion that lies at the heart of what motivates us to do astronomy, is only recently getting its due from psychologists. Less familiar than the "big ten" (love, fear, sadness, etc.), it has been called the 11th emotion. Humans may be the only species that can feel it, and some people may never experience it. Others, however, are intimately familiar with it and know well the accompanying tingling of the spine.

Neuropsychologist Paul Pearsall has defined awe as an "overwhelming and bewildering sense of connection with a startling universe that is usually far beyond the narrow band of our consciousness." No doubt many *S&T* readers can date the beginnings of their interest to a specific occasion of awe, perhaps the sight of a total eclipse or a majestic comet.

CATHY GENDRON

Do youth today still experience awe? Increasingly, the visible universe is in full retreat. Of course, virtual substitutes abound: Cassini views of Saturn's rings, Hubble Space Telescope images of distant galaxies, and so on. Stunning as they are, do they arouse the same profound, potentially life-changing emotion that a direct sense of connection to the universe supplies? How long does it take for them to go from "awe-some!" to "bor-ing"?

Perhaps Barnard, if he had lived today, instead of gazing in solitude at the nearby planets in his small telescope, would have invested his time in Facebook. Maybe then he would have had more self-esteem, for recent studies have shown that use of social media increases narcissism (self-love).

Awe, on the other hand, leads to a sense of a small self, says psychologist Paul Piff (University of California, Irvine), and it encourages those who feel it to exhibit more prosocial tendencies. They are more generous, empathic, and caring about others than their less awe-inspired peers.

This is an argument, in my view, for making astronomy — and exposure to other aspects of "wilderness" — central to schemes of child development and to educational core curricula. If we encourage awe, astronomy's core emotion, we will not only invite children to a lifelong passion to investigate the universe but encourage them to embrace kinder, more caring communities on Earth. ✦

Contributing Editor ***William Sheehan****, whose biography of E. E. Barnard,* The Immortal Fire Within*, came out in 1995, recently retired after three decades as a psychiatrist.*