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THE ESSENTIAL GUIDE TO ASTRONOMY

SKY & TELESCOPE

JANUARY 2016

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PL16803 image of Comet Lovejoy courtesy of Gerald Rhemann.

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January 2016 VOL. 131, NO. 1

On the cover:
In August 2017 the path of a total solar eclipse will cut across the continental U.S. Prepare now so you don't miss it.

PHOTO: FRED ESPENAK

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OBSERVING JANUARY

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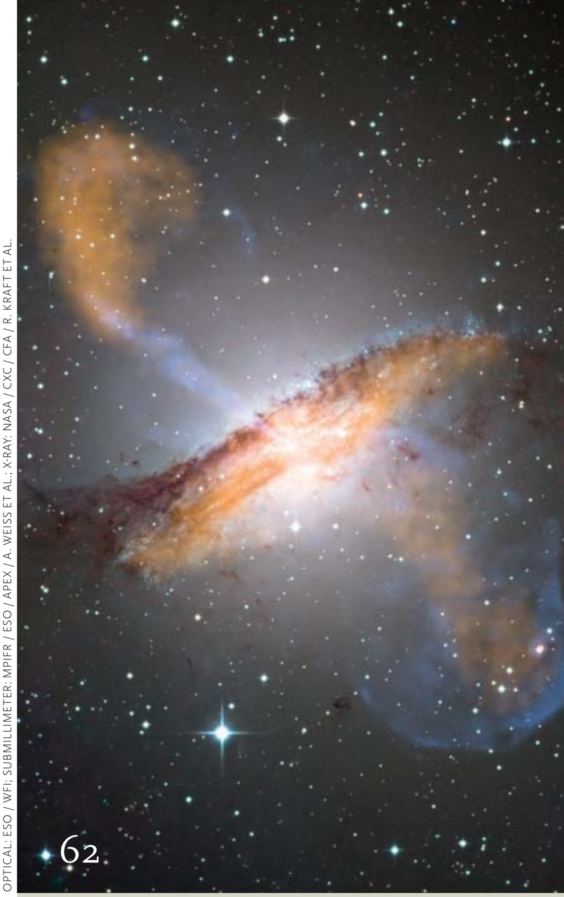

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OPTICAL: ESO / WFI; SUBMILLIMETER: MPIFR / ESO / APEX / A. WEISS ET AL.; X-RAY: NASA / CXC / CFA / R. KRAFT ET AL.

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Peter Tyson
Spectrum

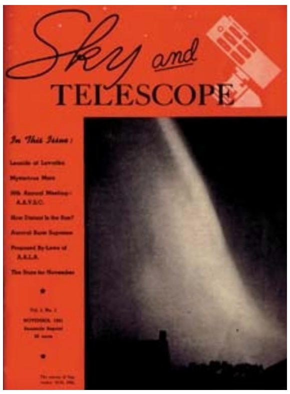
75 Years Young

THIS YEAR MARKS the 75th that *Sky & Telescope* has been in continuous publication. Our first issue appeared in November of 1941, so we have a few months to go before our actual anniversary. But in a news publication, you have a get a jump on things or you might miss out.

So I'd like to take this opportunity to congratulate and thank Charles Federer, Jr. and his wife Helen Spence Federer for launching this magazine and then shepherding it so expertly for 33 years. What Charlie wrote in the inaugural issue came true: "It is expected that *Sky and Telescope* will endure for many years to come, and play an important part in the development of the layman's interest in astronomy."

We in the *S&T* family would like to reiterate Charlie's statement regarding the next 75 years (though we might change "layman" to "layperson").

I believe we are well positioned to follow through on that declaration, in part because *S&T is* like a family. Three editors that Charlie himself hired before his retirement in 1974 are still intimately associated with the magazine: Senior Editor Kelly Beatty (who edited our 2017 eclipse features in this issue, pages 22 and 29) and former Senior Editor Dennis di Cicco (who coproduced our annual Hot Products feature, page 32, and continues to write regular *S&T* Test Reports), both joined the staff in 1974. Senior Contributing Editor Roger Sinnott began three years before them, in 1971.



Vol. 1, No. 1 of *S&T*

So, in a sense, we are only in the second generation of *S&T* editors — after three-quarters of a century. And those three long-time editors are only part of a very dedicated cadre of staff and contributing editors and designers, many of whom have also been in the *S&T* family for decades.

One of the things we're planning for our dodranscentennial (yes, that's the word for it) is a redesign of the magazine. Mostly this will be a freshening up of the look and feel, but we're also contemplating editorial changes.

In light of this, I'd like to ask you, our readers, the people for whom we publish this magazine, to send me your ideas of what you'd like to see us finesse or even entirely overhaul in *Sky & Telescope*. What's missing? What feels off base? What would you like to see more of? Less of?

I won't be able to respond to every suggestion, but you can be sure I'll read and consider them all. My email is **ptyson@skyandtelescope.com**.

Together with results from a recent reader survey that many of you completed (thank you), your comments will help us do a better job of giving you what you want and need to enhance your pursuit of our hobby in the years to come. ✦

Peter
Editor in Chief

SKY & TELESCOPE

Founded in 1941 by Charles A. Federer, Jr. and Helen Spence Federer

The Essential Guide to Astronomy

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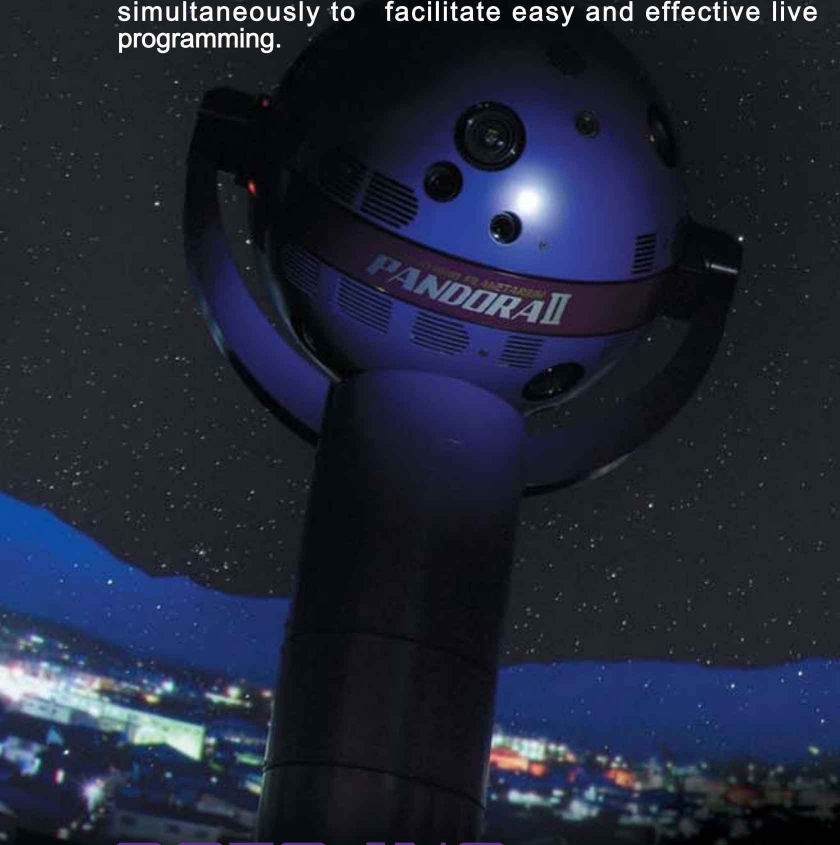
GOTO

Yonezawa helps children reach for the stars!

GOTO INC announces that the world's first PANDIA II has been successfully installed in Yonezawa Japan. The PANDIA II (called PANDORA II in Japan) is the latest in a long line of planetarium projectors designed for small and medium sized domes.

The Yonezawa Children's Hall Planetarium serves to cultivate independence and stimulate creativity in the city's children. The planetarium plays a role in reaching this goal by taking children from infancy through the third year of junior high on soaring trips through the Universe. Originally opened in 1983, the old, large projector was retired, and the new GOTO PANDIA II HYBRID system re-opened the totally renovated dome on May 2, 2015.

Besides new seats, new flooring, and a brand new dome, GOTO INC also coordinated the installation of the PANDIA II HYBRID, which includes not only the opto-mechanical PANDIA II, but also GOTO's own VIRTUARIUM X fulldome video system, and a manual control console which operates both the opto-mechanical and fulldome systems simultaneously to facilitate easy and effective live programming.



PANDIA II is contained in a 48cm (19 inch) diameter starball 1/5th the size of the old projector, allowing for a view of the sky with much less obstruction. PANDIA II shows a beautiful sky of 9,500 stars, plus a extremely realistic Milky Way made up of 40,000,000 micro-stars. A digital shutter system enables the operator to limit the stars to a horizontal horizon, or a tilted sky, a raised horizon for panoramas, and even an exciting "bath of stars" which totally floods the theater and seats!

All of this technology will allow Yonezawa to teach more effectively, to educate, entertain, and inspire for decades to come. Those decades will require much less maintenance than the previous ones, since the new PANDIA II utilizes 100% LED illumination. This means that lamps will not burn out, less energy is consumed, and since the machine is running much cooler than when hot light bulbs lit the stars, this projector will not require lubricating, cleaning, and mechanical adjustment nearly as often as the previous machine.

Other technical aspects of the PANDIA II include significantly smaller yet brighter stars than older models, due to the high-efficiency, high-output LEDs. A much more accurate sky is projected with more than 300 emission nebulae, clusters, galaxies, and even dark nebulae. There is even a telescoping lift built into the pedestal base of the PANDIA II to lower it for even more unobstructed views. The citizens of Yonezawa are thrilled with their new planetarium, and look forward to generations of family members enjoying even better trips through the Galaxy in the years ahead.

Please visit GOTO INC at www.goto.jp.co for more information about the new PANDIA II.

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January 2016 Digital Extra

BONUS WEB CONTENT

- **Monster Galaxies**
  Pursue these giant ellipticals and let us know how the chase goes!
- **Eclipse-Hunting and More**
  Travel the world and see astronomical wonders with *Sky & Telescope*.
- **New Black Hole**
  Read the full-length online story on the new black hole discovered in NGC 1313.

Photo Gallery

Image by José J. Chambó Bris

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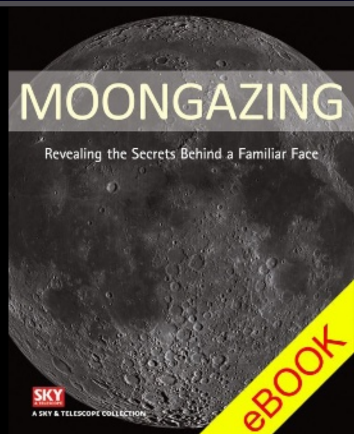

DIGITAL BACK ISSUES:

October, November, and December

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ONLINE PHOTO GALLERY

John Dolby captured Jupiter and Venus in this 13-second exposure through a Celestron CPC-1100. The moons to the right of Jupiter are, from left to right, Europa, Ganymede, and Callisto. The star below Jupiter is magnitude 8.4 (HD96658). An internal reflection caused the purple halo around Venus.

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Hubble's Anniversaries

When I received my June 2015 issue of *Sky & Telescope,* I was struck by its similarities to the June 2010 issue. Both had a cover story about the Hubble Space Telescope, and both featured a magnificent photo taken by HST.

The June 2010 issue was my first issue of *S&T*. Then only 13, I had just become interested (obsessed, actually) with astronomy. I paid for my subscription by doing odd jobs — everything from mulching trees to herding cows.

Once I had my hard-earned $34.95, I proudly ordered a subscription and began my mailbox vigil. Some weeks later, my first glossy issue arrived with the stunning photo of NGC 3603 emblazoned on the front. I read that issue repeatedly from cover to cover — and when it began to fall apart, I taped it together and read it again. I especially liked the observing articles; the maps helped me make many new discoveries — Jupiter, Uranus, and Comet McNaught (C/2009 R1), which was my first comet.

Since then I've enjoyed dozens of *S&T* issues, but none will ever be as special as that first one.

Nathan Zimmerman
Purdin, Missouri

The planned destruction of the Hubble telescope after it ceases operating would be a real shame — I dare say a tragedy. This unique instrument belongs in a museum, ideally the Smithsonian, instead of meeting an ignominious fate in a thousand pieces at the bottom of the Pacific Ocean.

Since the plan currently involves attaching a rocket to control HST's reentry trajectory, why not use that rocket to boost it to a higher orbit instead, maybe a thousand kilometers high, where it would represent little danger to other satellites or manned missions and where it could wait in relative safety until the technology to bring it back to Earth in one piece becomes available?

I seriously urge NASA to consider doing this instead of destroying one of the most significant and most appreciated scientific instruments of all time.

François Lacombe
Lévis, Québec

Kelly Beatty replies: *Good news, François! Raising HST to a higher orbit is definitely an option. In fact, some NASA managers think doing so would provide one last opportunity to refurbish the observatory. They'll likely make a final decision in about 5 years. Meanwhile, Hubble's systems and instruments remain in great shape.*

Bad Seeing? Add Cooling Fans!

Patience and perfect seeing conditions are keys to this hobby. This hard-learned truth comes to me from more than 30 years of looking at boiling blurs of light that eventually settle down into nice crisp images. I should mention that I live in the heat of Tucson, Arizona, and my Celestron 14-inch telescope lives inside a rooftop observatory. So this waiting game is endless.

Yet fighting the desert heat was not a problem for one of my friends, whose telescope has an open tube. The evening air just blows across the surface of his primary mirror as if to dust off all those blurry images. That's when I noticed small cooling fans along the back of his mirror, speeding things along toward that moment of ambient-temperature perfection.


MICHAEL SULLIVAN

Adding 10 cooling fans to this 14-inch telescope yielded a dramatic improvement in steadying the view.

Now, adding vibrationless computer fans to your telescope is not rocket science. But still, my wife cautioned, "If you break that telescope, you're not buying another one." After 32 years together, I believed her — but I charged ahead anyway, adding ten 40-mm-square, 12-volt DC fans that blow air across the front surface of the primary mirror. The resulting view through the eyepiece was nothing short of amazing. As the fans hummed along at 8,400 rpm, I was looking at a near-perfect image of Saturn. I was elated!

Today, telescope manufacturers are introducing new models that include vents to cool the tube assemblies. I predict that eventually they'll all market cooling fans as well — to breathe new life into telescopes.

Michael Sullivan
Tucson, Arizona

> Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send email to letters@SkyandTelescope.com. Please limit your comments to 250 words. Published letters may be edited for clarity and brevity. Due to the volume of mail, not all letters can receive personal responses.

Observatories in Crisis

Some observatories are in danger (*S&T:* Aug. 2015, p. 17) for no good reason. Luckily, grassroots efforts have intervened in some cases.

Five years ago, the Sperry Observatory at Union County College in Cranford, New Jersey, was scheduled to be shut down. At issue was the university's amazingly shortsighted view that (to paraphrase its argument) real science needs big scopes and dark skies. Sperry has two of the largest publicly accessible telescopes on the East Coast, operated by volunteers from Amateur Astronomers, Inc. (I among them). However, school

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administrators argued, what good science can AAI's volunteers do, especially with New Jersey's light-polluted skies? In its place, the school planned to add 80 classroom seats to a campus that already has 11,000 students.

This reasoning completely ignores the inestimable inspirational value of Sperry's Friday-night star parties. How often does someone get a chance to view Saturn through a 24-inch f/11 reflector or a 10-inch f/15 refractor?

UCC officials finally saw the light, and Sperry Observatory continues to be a source of wonder and inspiration.

Tom Sales
Somerset, New Jersey

Confusing Star Designations

I was very impressed with Ken Hewitt-White's "Cygnus in the City" (*S&T:* Sept. 2015, p. 58). I love articles that focus on using a small telescope — because that's what I use when observing.

But I have a question about his references to Omicron^1 and Omicron^2 Cygni. Doesn't such a notation imply that these are components of a double star? Yet they're visually distinct in the eyepiece, and Omicron^1 has a binary companion, 30 Cygni. Also, in my 1966 edition of *Norton's Star Atlas,* the star labeled Omicron^2 on your map is identified as 32 Cygni. Can you explain these notations?

Dale Patterson
Washington, New Jersey

JR replies: *It's a bit murky, as always. Wide double stars with Greek-letter designations (the use of which is attributed to Johannes Bayer) have superscript numbers. Usually the lowest number is the westernmost star in the system. But some stars have superscripts just because they're close together in a crowded field, not because they're really considered doubles (an example is Pi^1 and Pi^2 Orionis). The designations 30, 31, and 32 are Flamsteed numbers. John Flamsteed assigned higher numbers to stars with higher right-ascension values. However, as constellation maps and charting conventions have shifted over time, some of those designations no longer convey the story they were supposed to tell originally.*

DENNIS DI CICCO

Poodle in the Moon

Here's my addition to Alan MacRobert's list of naked-eye lunar details (*S&T:* May 2015, p. 50). Look for a poodle sitting upright on the eastern half of a full Moon.

Sheila Harrington
Cottonwood, Arizona

75, 50 & 25 Years Ago

Roger W. Sinnott

January 1941

Solar System Origin

"[Various 18th-century astronomers have] suggested that the sun and its attendant planets may have condensed from a huge rotating nebula. . . . This theory, known as the nebular hypothesis, unfortunately had to be discarded. . . . If the sun had ever been spinning sufficiently fast in nebular form to eject the matter now in the planets, its present velocity of rotation would be at least 50 times its observed value. . . .

"All variations of the [alternate] encounter theory assume that matter was torn out of the sun by a passing star. [However,] it has recently been demonstrated that . . . matter drawn forcibly out of a star cannot condense directly into planets. . . .

"Perhaps the origin of our solar system is one of the ultimates that we shall never know."

Lyman Spitzer, Jr., then at Yale University, was explaining his own refutation of the encounter theory. Current thinking has seesawed back to a refined version of the nebular hypothesis.

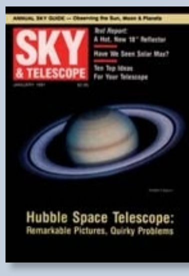
January 1966

Lunar Observatory

"Recently, Fritz Zwicky of California Institute of Technology reviewed advantages of making astronomical observations from the moon, once the practical problems have been met of transporting scientists there. . . .

"Because of the lack of lunar air, light of all wavelengths reaches the moon unimpeded, save for interstellar and intergalactic absorption. Many types of observations will be possible at gamma-ray, X-ray, ultraviolet, infrared, and radio wavelengths now inaccessible on the earth. Astronomical seeing will be perfect and the sky black. . . ."

No lunar base has ever come to pass, since it's been easier to make observations with space probes. But astronomers still eye the Moon, perhaps for setting up a huge optical interferometer to study exoplanets.



January 1991

Our Galaxy's Core

"Astronomers seeking the heart of the Milky Way galaxy have turned up two new candidates. In recent years attention has focused on a compact radio source called Sgr A* ('Sagittarius A star'). . . . Now Michael R. Rosa (European Southern Observatory) and his colleagues have made high-resolution CCD images with ESO's New Technology Telescope and discovered two pointlike sources of visible emission within ½ arc second of Sgr A* [, which is] thought by some to harbor a supermassive black hole. . . ."

Rosa's team was on the right track. The physical picture has since been refined by the detection of tight orbital motion in some of the stars near Sgr A, further evidence for the existence of a central black hole.*

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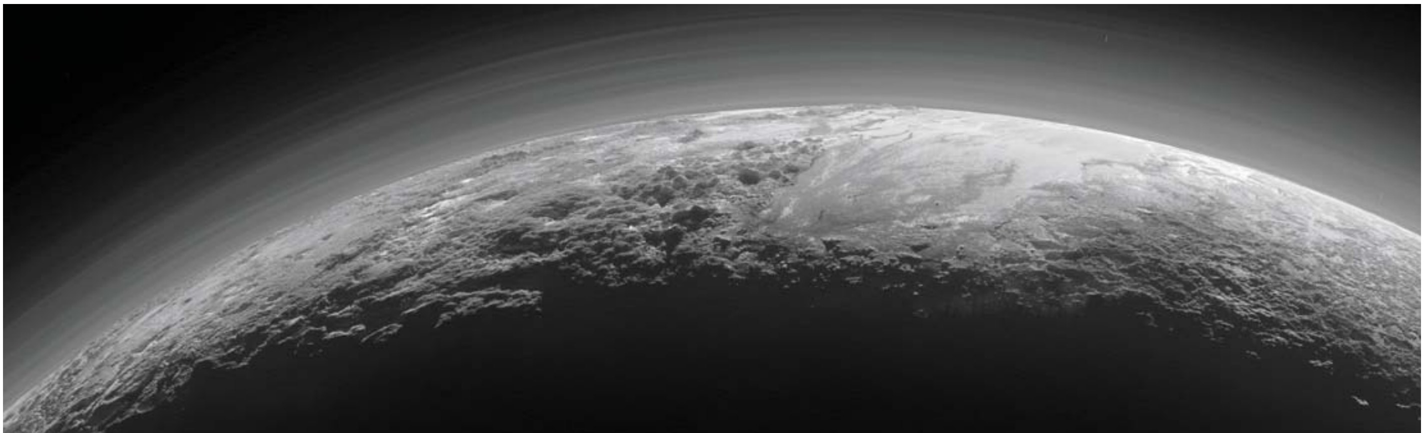

New Horizons recorded this oblique, backlit panorama of Pluto from 18,000 km (11,000 miles) away just 15 minutes after its closest approach on July 14, 2015. The rugged Norgay Montes are at left, and the smooth plain Sputnik Planum is at right.

NASA / JHU APL / SWRI (2)

It's going to take a year for NASA's New Horizons spacecraft to send back all the images and other data it collected as it swept past Pluto on July 14, 2015, and the mission team has repeatedly promised that watching those observations trickle in will be like getting birthday presents every week. Two of those "gifts" appear here.

The spectacular backlit panorama of Pluto provides an oblique perspective that accentuates this little world's surprisingly rugged and varied terrain. "This image really makes you feel you are there, at Pluto, surveying the landscape for yourself," comments principal investigator Alan Stern (Southwest Research Institute).

Yet, more than a pretty picture, the high-phase-angle lighting provides important insights into all that's going on down below. For example, even though Pluto's atmosphere is incredibly tenuous, it's stacked with more than a dozen thin haze layers that extend from the icy ground up to altitudes of 100 km (60 miles) or more. The angular peaks informally dubbed Norgay Montes, which dominate the left side of the panorama, rise to elevations of about 3½ km (11,000 feet) — far higher than anyone expected. "The randomly jumbled mountains might be huge blocks of hard water ice floating within a vast, denser, softer deposit of frozen nitrogen," suggests lead geologist Jeff Moore (NASA Ames). "Think Silly Putty."

Meanwhile, planetary geologists don't yet know how or when Pluto's largest moon came to exist. But this much is certain: Charon has had a rough time of it in the eons since. Exhibit A is an enormous system of fractures girding the moon's midsection for at least 1,600 km — four times the Grand Canyon's length and twice as deep in spots — and it likely continues onto Charon's farside. This crevasse chain has the look of a huge tear, like crustal rending seen on Earth (the East African Rift, for example) and Mars (Valles Marineris).

Canyons gird Charon's midsection, breaking up the moon's cratered terrain. To their south, the fractures give way to the smoother plain informally named Vulcan Planum. This scene, a combination of blue, red, and infrared images, resolves details as small as 0.8 km (0.5 mile).

"It looks like the entire crust of Charon has been split open," observes John Spencer (Southwest Research Institute), who serves as deputy lead for the mission's geology, geophysics, and imaging team. Such wholesale extension might have occurred, the New Horizons team speculates, if Charon once had an interior ocean of water that expanded as it froze long ago. The overlying crust would have cracked wide open to accommodate the increased volume. Whatever the cause, the faults and canyons indicate some kind of global geologic upheaval in Charon's past.

The enigmatic, red-stained depression at Charon's north pole also defies explanation. One early speculation held that the reddish material is a veneer of organic compounds, synthesized from methane that escaped from Pluto. But the new images suggest that most of the reddish terrain is partly bounded by a high-standing rim. That wouldn't happen if the red material came from transplutonian space. Instead, some or all of it might have come from Charon's interior. Read the team's *Science* paper at **http://is.gd/plutosci1015**.

■ **J. KELLY BEATTY**


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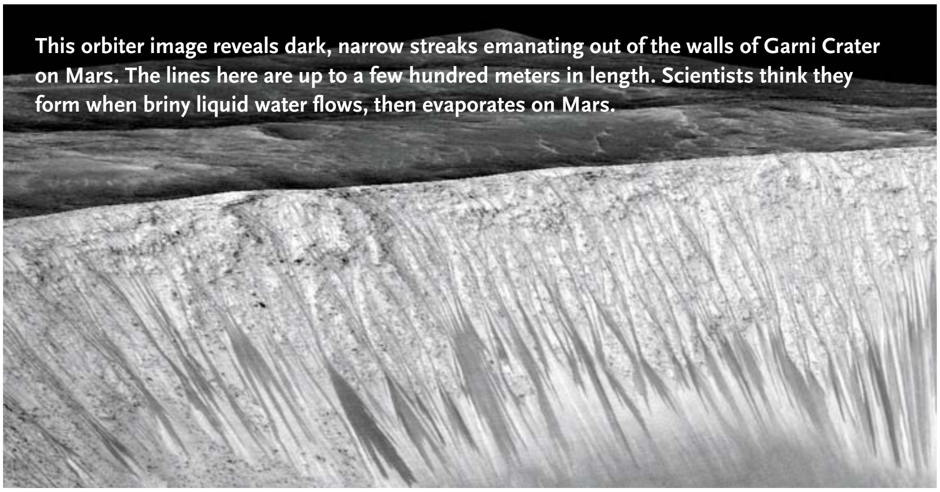
RED PLANET | Waterlogged Salts on Mars



This orbiter image reveals dark, narrow streaks emanating out of the walls of Garni Crater on Mars. The lines here are up to a few hundred meters in length. Scientists think they form when briny liquid water flows, then evaporates on Mars.

Scientists have confirmed that water-soaked salts create dark, seasonal streaks on Mars. These *recurring slope lineae* (RSL) appear on sloping ground — such as crater walls — during warmer months on the Red Planet. Growing up to hundreds of meters long, they then fade as the temperature cools, only to reappear when temperatures rise again.

Reaching midday highs of at least 250K (–9°F), these areas are too cold for pure liquid water to create downhill flows. Instead, planetary scientists suggest salty water is to blame: salts lower water's freezing point enough that water could melt, creating briny flows just beneath the soil's surface.

But scientists have looked for years without spotting definitive signs of liquid water or hydrated salts in areas containing RSL. Lujendra Ojha (Georgia Institute of Technology) and colleagues have now found the latter, using spectral observations by NASA's Mars Reconnaissance Orbiter. Instead of averaging spectra over large areas containing RSL, as done before, the researchers homed in on specific pixels dominated by the streaks. They looked at four RSL sites: the craters Palikir, Horowitz, and Hale, and the valley Coprates Chasma.

The team found spectral matches in all four locations to salts that incorporate water in their molecular structure. (The team didn't detect liquid water itself, but the spacecraft observed during local mid-afternoon, when conditions are likely to be driest.) The researchers report September 28th in *Nature Geoscience* that, based on the spectral lines seen, the salts appear to be perchlorates and chlorates.

NASA's Phoenix lander detected perchlorates in 2008 at its far-northern landing site, and other lander and rover data support their presence elsewhere. These salts are particularly good at dissolving in water. The water probably picks them up from the subsurface soil and then, as it reaches the surface and evaporates, redeposits the salts but in higher concentrations. As the brines build up, they change the surface's color and create the low-reflectivity streaks.

It's still unclear where the Martian water comes from. It might be from subsurface ice, though that shouldn't be buried at such shallow depths near the equator (which is generally where these streaks appear). Salty grains on the surface might instead grab so much water from the atmosphere that they dissolve and form a hyper-concentrated solution. Rovers have found Martian air is more humid than expected, but scientists don't know for sure whether the planet's atmosphere has enough water vapor for this grab-and-dissolve process, called *deliquescence*, to happen.

Wherever it's coming from, liquid water does seem to be flowing just below the surface of Mars.

■ **CAMILLE M. CARLISLE**

IN BRIEF

New Mid-size Black Hole. Astronomers think a bright X-ray source in the galaxy NGC 1313 is an intermediate-mass black hole (IMBH). These elusive objects should range from a few hundred to a hundred thousand solar masses. Most IMBH candidates are iffy contenders. In 2014, Dheeraj Pasham (NASA Goddard) and colleagues weighed a potential IMBH using *quasi-periodic oscillations* (QPOs), cyclic blips in a black hole's X-ray signal that astronomers suspect are related to the object's mass. The team calculated a mass of roughly 400 Suns for the object, which lies in the galaxy M82. Now, the team estimates that a QPO-producing object in the galaxy NGC 1313 has a mass between 3,700 and 6,300 Suns. This would easily put it in the IMBH family and add to growing evidence that black holes do indeed exist on all scales. The result appears in the September 20th *Astrophysical Journal Letters*. Read more about how the QPO method works at http://is.gd/qpoimbh.

■ **CAMILLE M. CARLISLE**

Brightest Galaxies Powered by Stars, Not Mergers. Astronomers long thought that major mergers were responsible for *submillimeter galaxies*, rare and brilliant stellar metropolises in the early universe that radiate powerfully as they create 500 to 1,000 Suns' worth of stellar mass every year. But new simulations reported in *Nature* by Desika Narayanan (Haverford College) and colleagues suggest otherwise. Tracking simulated galaxies' growth over about 2 billion years, the team found that the starburst (and submillimeter-emitting) phase isn't a short, merger-inspired flash but a prolonged, luminous chapter that lasts roughly 750 million years — too long to be supported by mergers. Instead, stellar feedback maintains the star-forming reservoir: aging and exploding stars drive gas outward, which then cools and rains back down in a galactic-scale cycle.

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COMETS | Churyumov-Gerasimenko Began as Two Comets

Rosetta observations confirm that the "rubber ducky" nucleus of Comet 67P/Churyumov-Gerasimenko was likely born when two individual objects in the outer solar system gently collided and stuck together.

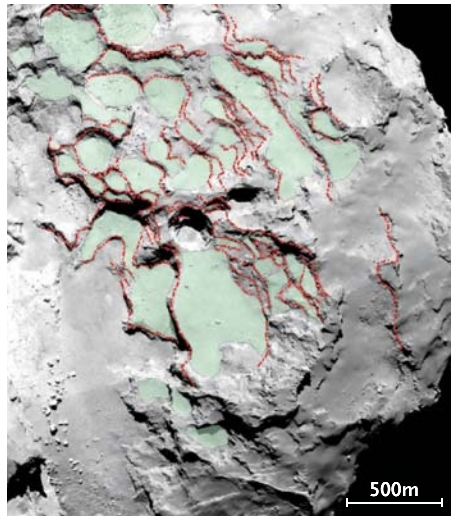
This image from Rosetta's navigation camera shows the two lobes and connecting "neck" of Comet 67P's nucleus. Mission scientists have now found layers suggesting that the oddball nucleus began as two bodies that later joined.

ESA / ROSETTA / NAVCAM

Matteo Massironi (University of Padova, Italy) and colleagues used images from Rosetta's Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) to investigate the nucleus's origin. The scientists peered down into pits and along terraces and cliffs across the nucleus. They found strata like those seen in sedimentary rock on Earth, built up as the bodies formed one layer at a time. In some places the layers reach 650 meters deep, a fair fraction of the kilometers-long nucleus. You can think of them like the layers in an onion, the team explains September 28th in *Nature*.

If Comet 67P's layering arose during the nucleus's formation (the most probable explanation), then the onion shells should form concentric rings around their parent body's center of mass. If the nucleus began as one object, then the strata in the duck's head and body would encircle a single center; if it began as two, then the body and head strata would have centers in their respective lobes.

The team found that the layers do encircle two different centers, one in each lobe. Thus, Comet 67P's nucleus began as two separate bodies. Layering observed in other comet nuclei during spacecraft flybys supports the idea that these objects likewise formed by accreting layers over time.



ESA / ROSETTA / MPS FOR OSIRIS TEAM MPS / UPD / LAM / IAA / SSO / INTA / UPM / DASP / IDA; M. MASSIRONI ET AL. 2015

This image from the Rosetta spacecraft shows terraces in the Seth region, near the nucleus's neck. Green marks main terraces and red dashed lines mark exposed layers.

■ **CAMILLE M. CARLISLE**

BLACK HOLES | New Evidence for Binary Quasar

Astronomers have confirmed that the quasar PG 1302-102 is probably a binary supermassive black hole, its components less than a tenth of a light-year apart.

Recently, Matthew Graham (Caltech) and colleagues found several dozen quasars glowing with regular beats, one of which was PG 1302-102 (*S&T:* May 2015, p. 14). This discovery surprised them, because black holes are usually fickle emitters. The best explanation for the periodic behavior was that the quasars are actually two black holes spiraling toward each other. The years between signals would then be the orbital period.

But scientists didn't know *why* the periodicity exists. Daniel D'Orazio (Columbia University) and colleagues now think they have the answer. They realized that, if a smaller black hole were circling a larger one, we would see a *Doppler boost* in the quasar's emission.

Doppler *shifts* are the change in light's wavelength because its source is moving toward (blueshifted) or away (redshifted) from us. Doppler boosting is this effect on steroids. With PG 1302-102's black holes so close together, the smaller one is whipping around its bigger sibling at 7% the speed of light. That dramatically shifts the wavelength by 14%. So if we're observing the quasar at an optical wavelength of 600 nm, that means that when the smaller black hole is moving toward us, we're actually seeing 700-nm light that's been blueshifted, but when it's moving away, we're seeing 530-nm light that's been redshifted.

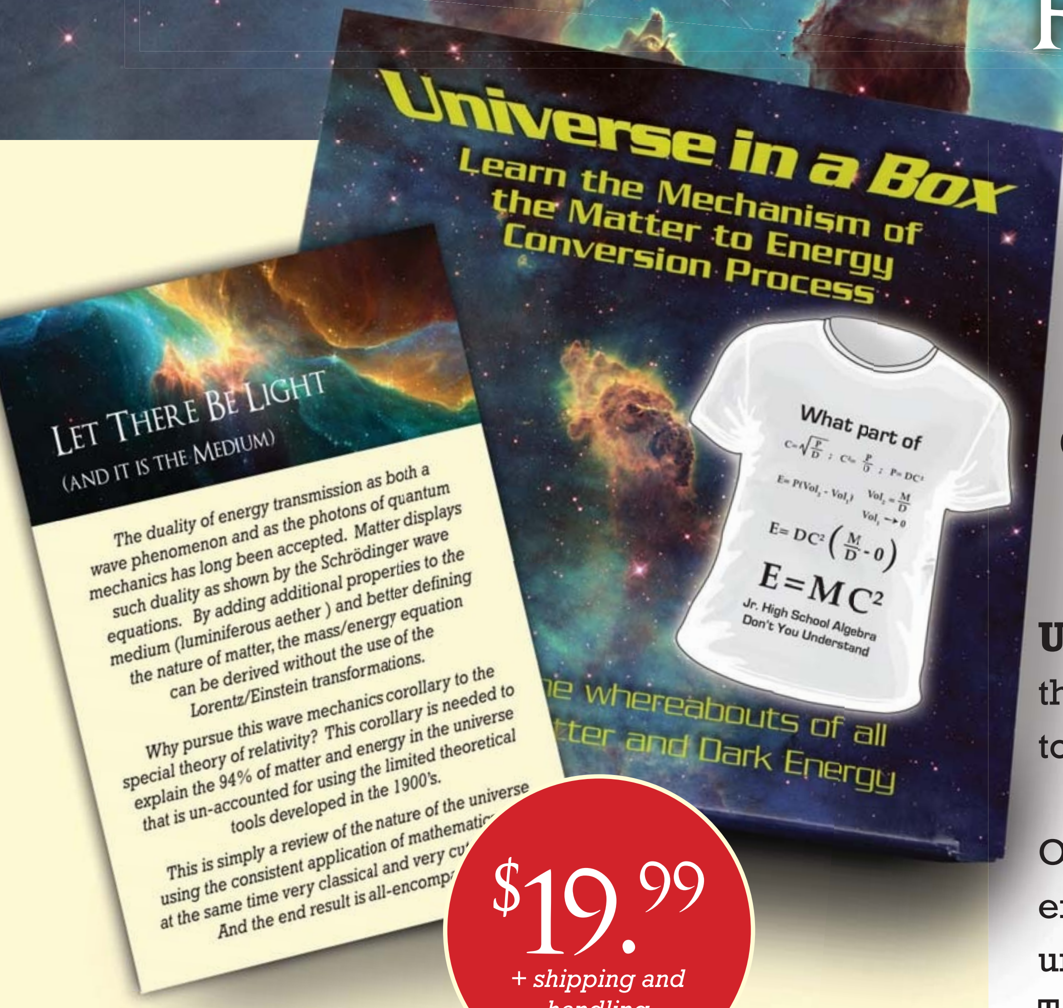
If the quasar's emission were the same intensity at all wavelengths, then we wouldn't notice a difference. But its intensity increases from optical to ultraviolet. So a 14% change in wavelength samples different intensities, meaning that as the small black hole orbits, we see a periodic change — the mysterious beat.

If this scenario is correct, the team reports in the September 17th *Nature*, then PG 1302-102's variations ought to be more than twice as large at ultraviolet wavelengths as at optical ones. That's because the quasar's emission doesn't just get brighter from optical to ultraviolet — it also brightens more rapidly with wavelength. So if the optical emission shifts toward a shorter wavelength, we'll see a bit of an increase in intensity, but if the ultraviolet emission shifts the same amount, we'll see a greater increase in intensity.

The team compared PG 1302-102's multiwavelength variations using archival spectra from the Hubble (optical) and Galaxy Evolution Explorer (ultraviolet) space telescopes. The astronomers found the expected extra oomph in ultraviolet.

■ **CAMILLE M. CARLISLE**

Where is all of the Dark Matter and Dark Energy… Really?



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SUN | Resonant Waves Might Heat Corona

Astronomers have detected waves working together in the solar atmosphere, creating turbulence that superheats the corona's ionized gas.

The Sun's corona is more than a hundred times hotter than the photosphere below it. One explanation for this temperature surge is *Alfvénic waves*, motions in the solar plasma governed by the magnetic field. The corona is essentially a sea of these waves. Solar physicists think that the waves carry enough energy to heat the corona — but pinning down how the magnetic motions do it has been tough.

New spacecraft observations, coupled with computer simulations, might solve the mystery. Takenori Okamoto (JAXA), Patrick Antolin (National Astronomical Observatory of Japan), and their team watched threads of superheated plasma wiggle in 3D in a coronal filament. These prominences are cooler and denser than the surrounding corona, making them easier to observe.

Using these data, the researchers realized it's how the waves add together that matters. Seen from the side, the threads vibrate with *transverse waves*, as a plucked guitar string does. But the threads also twist toward and away from us, just as your hand twists one way, then the other, on your wrist. When these two types of vibrations travel at the same speed, they resonate with the same beat.

Guided by simulations, the team suggests in two papers in the August 10th *Astrophysical Journal* that the waves' resonance causes the guitar-string waves to transfer their energy to the twist waves, pumping up their motion. This in turn exacerbates the shear between the threads' boundaries and the thinner, hotter gas in the atmosphere around them, creating eddies. The eddies combine to create larger-scale turbulence. And the turbulence, due to the friction and electrical currents it creates, steals the wave energy from the threads and dumps it into the coronal plasma, heating it.

■ **CAMILLE M. CARLISLE**

STELLAR | White Dwarfs with Hiccups

Observations of two cool white dwarfs show irregular outbursts in the stars' otherwise steady rhythm of pulsations. Pulsating white dwarfs, or ZZ Ceti stars, are a type of white dwarf that glows and fades in a steady rhythm. White dwarfs start to pulse when they cool from an initial temperature of around 100,000K to about 12,600K. The atmosphere becomes a mix of ionized and neutral hydrogen atoms, and this mix stores and releases energy in regular intervals of a few minutes, driving pulsations. These make the white dwarf brighten and fade by a few percent in regular beats, like a person's rhythmic breathing. The star continues to cool slowly over time, but once it falls below about 10,800K, it ceases pulsating altogether.

Using Kepler data, which has far fewer gaps than ground-based observations, J. J. Hermes (University of Warwick, UK) and colleagues tracked two pulsating white dwarfs, KIC 4552982 and PG 1149+057. The temperatures of the two stars are both about 11,000K, cooler than most ZZ Cetis previously studied. The team discovered that hiccups interrupted the dwarfs' otherwise even pulsations. Shooting high above the expected crests and falls in brightness every few minutes appeared sporadic outbursts lasting several hours. The regular pulsations change the stars' brightness by 1% to 3%, but KIC 4552982's outbursts were 2% to 17% above the norm, and PG 1149+057's hiccups spiked up to 45% above the star's mean brightness. As the researchers report in the August 10th *Astrophysical Journal* and September 1st *Astrophysical Journal Letters*, they don't know why these outbursts happen, but the surges might be the dwarfs' last gasps before pulsations shut down.

■ **NATALIA GUERRERO**

MISSIONS | India Launches First Astronomy Satellite

Indian astrophysics got a boost on September 28th when the Indian Space Research Organization (ISRO) launched the Astrosat spacecraft into a low-altitude orbit. The multipurpose observatory will study the universe across the X-ray spectrum, accompanied by simultaneous visible- and ultraviolet-light observations.

India has successfully sent spacecraft to the Moon and Mars and, more recently, has lofted X-ray detectors aboard high-altitude balloons and suborbital sounding rockets. But this is ISRO's first astronomical satellite. It's capable of studying everything from nearby white dwarfs, pulsars, and supernova remnants to faraway galaxy clusters. Its data will be available to the Indian astronomy community via proposals for observations.

Astrosat's five instruments each observes a different wavelength range. They comprise low-resolution X-ray spectral instruments, a binocular Ritchey-Chrétien telescope, and a detector with a huge 10°-by-90° field of view that will scan the sky for transient X-ray sources.

The project is essentially a combination of NASA's Swift and now-retired Rossi X-ray Timing Explorer (RXTE) satellites. Like Swift, Astrosat will hunt for X-ray transients and observe these sources across the visible-to-X-ray spectrum. And like RXTE, Astrosat will measure the arrival time of each photon. Its Large Area Xenon Proportional Counters (LAXPC) have the largest collecting area of any X-ray instrument ever built, and it's currently the only one capable of studying X-ray fluctuations over millisecond time scales.

Astrosat joins several other X-ray observatories already in orbit: Chandra makes out fine details in low-energy X-ray images, NuSTAR brings high-energy X-rays into sharp focus, Swift monitors the sky for distant explosions bright in X-rays and gamma rays, and ESA's XMM-Newton is a light bucket for low-energy X-rays. ✦

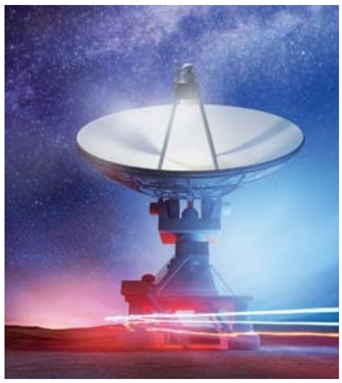
■ **DAVID DICKINSON**

No Need to Feel Lonely

Recent results do not support the conclusion that we are alone in the universe.

Scientists have found new evidence suggesting that we are, after all, quite possibly alone in the universe — or so you may have heard. Don't believe it.

The biggest discovery of our time is that planets are at least as common as stars. Strangely, some have interpreted this as implying that intelligent, technological, communicating life has not evolved elsewhere. One who has expressed this view recently is William Borucki, the just-retired principal investigator for NASA's remarkable Kepler spacecraft and thus the person most responsible for our recent bounty of knowledge about extrasolar planets. While in Hong Kong last September to receive the 2015 Shaw Prize in astronomy, Borucki told reporters that, given our new knowledge of so many worlds, we can conclude that intelligence has not evolved elsewhere. "Why haven't we been contacted?" he asked. His conclusion: "The evidence says, no one's out there."



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Borucki is a brilliant and wonderful man, and we are forever in his debt for the success of Kepler. But there is little basis for jumping to this conclusion. In fact, for decades, SETI had already operated under the considered assumption that planets around stars were common. At the first SETI conference in Green Bank, West Virginia in 1961, the attendees reached agreement on an estimate for the number of planets in the galaxy that was very close to the numbers scientists are now deriving from observations. While beautifully reducing the uncertainty, Kepler has also essentially validated the intuitive hunches about planets that the early SETI investigators held.

In the six decades since the first radio searches, we've learned that our galaxy is not bristling with civilizations broadcasting the kind of radio messages predicted by some physicists in the 1950s, and that our solar system is not so teeming with obvious interstellar probes that we would stumble upon one on our first fleeting forays to other planets. That is all we know. It's a far cry indeed from that to "we are alone."

Another recent headline touts a study showing that alien "supercivilizations" don't exist. The evidence? When we scan distant galaxies we don't see any that are radiating the kind of waste heat that would be seen if a civilization had overrun the galaxy, maximizing its population and consuming the energy of every star.

Seriously? What kind of supercivilization would behave in that manner? Only those conforming to some very primitive notions of what constitutes a civilization. The premise is that successful lifeforms will keep on multiplying indefinitely, and that successful civilizations will seek out and use more and more energy. But we are already learning here on Earth that true, sustainable intelligence may require thoughtful deviation from the drive to mindlessly propagate and utilize whatever resources we can get our hands on. It seems doubtful that any "advanced" civilization would act like that.

Finally, I keep hearing about the "great filter." Supposedly, some universal process exists that stops civilizations from continuing. According to this idea, "the great silence" means that our own days are numbered. When you carefully examine this argument, you find again that it rests on the false notion that we already have good evidence for the absence of other civilizations or on the argument that, if there were civilizations, they would make their presence so apparent that we couldn't possibly miss them. The detailed justifications always make wild, unsupported assumptions about the properties and behaviors of aliens.

These are all fun ideas to entertain, but people tend to get attached to certainty and start to believe they know the answer. The only clearly mistaken opinions on this beguiling question are those that are overconfident. We have to be comfortable with the uncertainty of not knowing, resist easy answers, and keep exploring the universe with open minds and all the tools and techniques we can muster. ✦

__David Grinspoon__ is an astrobiologist, author, and Senior Scientist at the Planetary Science Institute. Follow him on Twitter at @DrFunkySpoon.


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Get Ready for America's

Where will you be on August 21, 2017 — when a total solar eclipse will be seen from Oregon to South Carolina?

Fred Espenak & Jay Anderson

Most readers of this magazine associate "2017" with the next total eclipse of the Sun visible from the United States. The anticipation for this event is rapidly increasing and well warranted — after all, it's been four decades since the Moon's umbral shadow passed through the "Lower 48." But even that one, in February 1979, crossed only a handful of states in the Pacific Northwest.

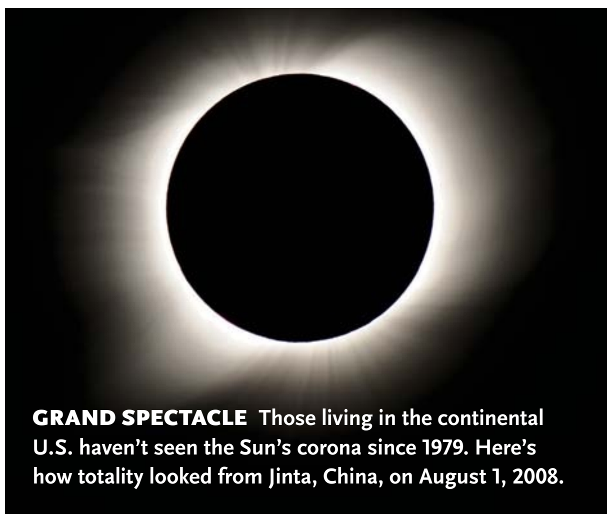
Not so with the total solar eclipse that's coming on August 21, 2017. The 68-mile-wide, 2,500-mile-long path crosses the breadth of the U.S. from coast to coast and touches a dozen states: Oregon, Idaho, Wyoming, Nebraska, Kansas, Missouri, Illinois, Kentucky, Tennessee, Georgia, North Carolina, and South Carolina.

Weather-wise, August should a good month for eclipse viewing across the U.S. The Moon's shadow arrives at a time of year when the peak of the thunderstorm season has passed and sunshine is generous, particularly west of the Missouri River. Although western states offer the most promising weather prospects, with a little care you'll find good eclipse-viewing sites all across the continent.

This article provides the basics for assessing where you might want to go to witness this grand celestial spectacle. *Sky & Telescope* chose to publish it now, more than 1½ years before the event, because accommodations at choice locations are filling up quickly. Excluding Alaska and Hawaii, more than 300 million U.S. citizens are within a 1- or 2-day drive of the central path, and international interest in this event is already keen. To make your assessment easier, we'll divide the eclipse path into five geographic regions.

Oregon and Idaho

After first touching down in the Pacific Ocean, the Moon's umbral shadow takes 28 minutes to travel 2,400



GRAND SPECTACLE Those living in the continental U.S. haven't seen the Sun's corona since 1979. Here's how totality looked from Jinta, China, on August 1, 2008.

FRED ESPENAK

Coast-to-Coast Eclipse

MICHAEL ZEILER / GREATAMERICANECLIPSE.COM

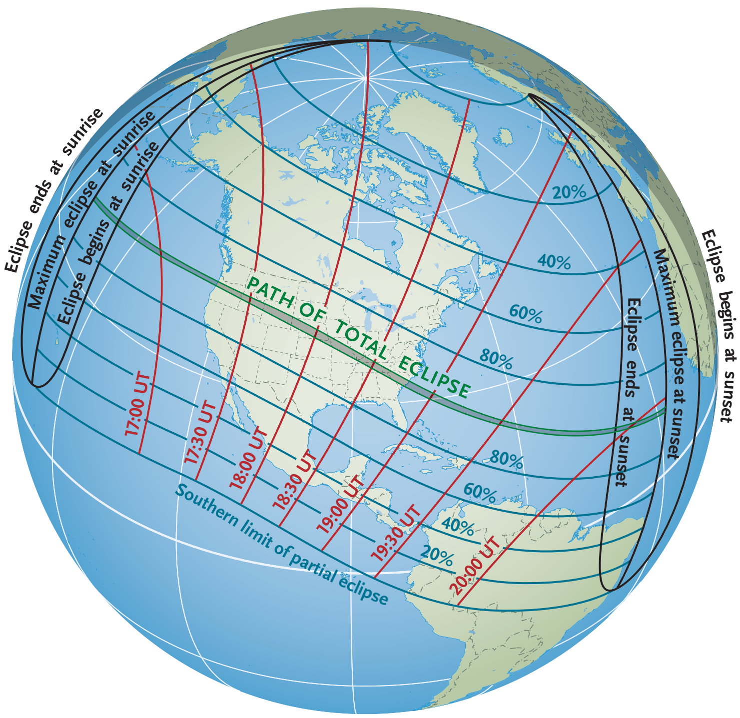
miles before it reaches Oregon's rugged coast. It'll be 10:16 a.m. PDT as the 62-mile-wide shadow track makes landfall at Lincoln Beach, with the midmorning Sun already 39° above the horizon. However, while Oregon's beaches will be first to experience the Moon's shadow, this fogbound coastline and the cold ocean current just offshore are not optimal for eclipse watching.

Rushing inland with a ground speed of 2,400 miles per hour, the Moon's umbra crosses the 3,000-foot-high Coast Range and enters the Willamette Valley. Salem, Oregon's capital, lies 9 miles north of the track's central line and enjoys totality for $1^m\ 55^s$. The neighboring cities of Albany ($1^m\ 51^s$) and Corvallis ($1^m\ 40^s$) are also deep in the path.

The Coast Range forces moist Pacific air upward to cool and condense into clouds. But the 3,000-foot elevation of these peaks is only partially successful at removing the moisture. It takes the much higher Cascade Range, on the east side of the Willamette Valley, to do that. Salem is representative of valley weather with an average cloud amount of 46%.

The shadow scales the 10,000-foot peaks of the Cascade Range before entering the Columbia Plateau — an open plain of farms and dry grasses. The town of Madras (population: 6,400) lies 5 miles south of the centerline, where totality lasts $2^m\ 3^s$. Ontario, Oregon, lies 8 miles north of the southern limit but is still deep enough in the path to witness 1½ minutes of totality.

After traversing all of Oregon in just 9 minutes, the umbra enters Idaho. Boise, its capital, lies 15 miles outside the path's southern limit. Although Boiseans only get to see a partial eclipse, it's an incredibly deep



TRANSCONTINENTAL EXPRESS ***Above:*** **The 8,600-mile-long track of the August 21, 2017, total solar eclipse begins at sunrise in the Pacific Ocean and ends at sunset in the Atlantic. About 30% of the path crosses the contiguous United States — the first time that's happened since 1918.** ***Top:*** **Averaging about 68 miles wide, the Moon's umbral shadow will cover about 5% of the area of the contiguous U.S. as it crosses or clips 12 states. Hundreds of millions of Americans will be within a 1- or 2-day drive of totality's path.**

S&T ILLUSTRATION, SOURCE: FRED ESPENAK

BIG SKY COUNTRY The surrounding mountain peaks are cloudy, but the Snake River Plain basks in sunshine in this view to the north from the Craters of the Moon National Monument in Idaho — one of the sunniest places along the eclipse path.

JAY ANDERSON

one: 99.6% of the Sun's disk area will be obscured. (This corresponds to an *eclipse magnitude* of 0.994, the fraction of the Sun's diameter to be covered.) Boise still makes a good starting point for the 85-mile drive via Interstate 84 to reach the centerline.

The eclipse track crosses the Sawtooth Range and descends onto the Snake River Plain. Although Idaho Falls is 21 miles south of the eclipse path's central line, it still enjoys 1¾ minutes of totality. Another 30 seconds can be gained by traveling to the path's midpoint.

"Great" eclipse weather should be the norm for the portion of the path on the lee side of the Cascade Range. Air flowing downward into the valleys warms and dries out, yielding the lowest average cloud cover along the entire track. Airport statistics show that mean cloudiness drops to roughly 25% in both Oregon's Columbia Basin and in Idaho's Snake River Plain. The percent of possible sunshine — the best measure of the true probability of seeing the eclipse — exceeds 80%.

Two Eclipse-Planning Essentials

Authors Fred Espenak and Jay Anderson have collaborated on many eclipse-related publications for more than 20 years. Now retired, they've reunited to publish *Eclipse Bulletin: Total Solar Eclipse of 2017 August 21*. It's filled with tables, charts, maps, weather data, and eclipse circumstances for more than 1,000 cities in the U.S. and elsewhere. Go to **eclipsewise.com/pubs/TSE2017.html** for more information.

Separately, Espenak recently published *Road Atlas for the Total Solar Eclipse of 2017*, a book of detailed road maps covering the entire path from Oregon to South Carolina. The track is plotted in 20-second steps, making it easy to estimate the duration of totality from any location along the eclipse path. To learn more, visit **eclipsewise.com/pubs/Atlas2017.html**.

Both of these useful publications are available from **ShopatSky.com**.

— *J. Kelly Beatty*

Wyoming and Nebraska

Next the umbra climbs over the Teton Range and enters Grand Teton National Park in Wyoming. The grandeur of the Tetons normally draws many thousands of visitors each summer — adding a total solar eclipse makes the region even more attractive as a travel destination. At Jackson Hole's airport, which lies right on the centerline, totality lasts $2^m\ 20^s$ centered on 11:36 a.m. MDT.

The shadow track crosses the Continental Divide in the Wind River Range and descends to the high plains of the Cowboy State. Casper is the largest Wyoming city in the path, and the centerline passes through the south side of the city, giving spectators a total eclipse lasting $2^m\ 26^s$. (Although the longest totality will be seen 980 miles farther east in Carbondale, Illinois, Casper's duration is only 14 seconds shy of it.)

Casper is well served by highways running east and west through the eclipse path. This gives eclipse chasers with mobility the option to move if weather becomes an issue. In fact, the Astronomical League has chosen Casper to hold its annual convention just days before the eclipse for this very reason (**astrocon2017.astroleague.org**).

Historical data suggest a gradual increase in cloudiness as the eclipse path moves eastward across Wyoming and into Nebraska. Some of this cloudiness comes from the influx of Gulf of Mexico moisture that dominates the Great Plains in summer and can spread westward to the area around Casper before being stopped by the gradually rising terrain.

The other major cloud producers are Wyoming's mountains, whose dark, forested hills absorb sunlight and frequently blossom with afternoon clouds and thundershowers. Fortunately, such convective clouds tend to arise later in the day, *after* the Moon's shadow will have come and gone. Note that forest fires occur all too often in these Rocky Mountain states during most summers, so be prepared to get out from under the thickest plumes if the fire season is grim.

As the umbra's track enters Nebraska, it leaves behind Wyoming's high-desert environment and gradually descends to the prairie topography of gently rolling grasslands and irrigated farms. Here you'll find a promising cloud climatology, wide-open landscape, and interstate highways that follow the general trend of the shadow's path. The amount of possible sunshine declines a bit traveling west to east, from about 75% to a little under 70%.

August is still thunderstorm season in Nebraska, but storms tend to be limited in areal extent and can be sidestepped by a quick move to a new location. The best conditions are in the western part of the state, where higher terrain and the Rockies' influence limits the influx of Gulf moisture.

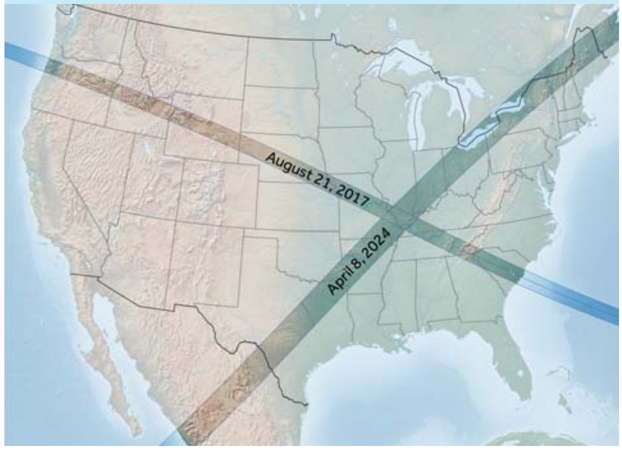
Alliance (population: 8,500) lies just north of the centerline and gets a $2^m\ 30^s$ total eclipse centered on 11:50 a.m. MDT, with the Sun 57° above the southeastern horizon. (Carhenge, a nearby replica of Stonehenge created from vintage American-made automobiles, will make a unique if somewhat tacky location from which to view totality.)

Midway across the Cornhusker State, the city of North Platte lies inside the path about 9 miles from the southern limit. Nevertheless, the duration there is still a respectable $1^m\ 46^s$, and North Platte's location along Interstate 80 makes it an easy destination to reach. But Grand Island might be an even better location, since it's near both the central line and I-80. The duration there — $2^m\ 36^s$ — is within 4 seconds of the event's maximum duration.

Lincoln, Nebraska's capital, is located just inside the northern limit (seeing totality for $1^m\ 13^s$), while larger

A CENTURY IN THE MAKING

The last time the Moon's umbral shadow crossed the U.S. coast to coast was June 8, 1918. The path was similar, starting in southern Washington and ending in central Florida.



MICHAEL ZEILER / GREATAMERICANECLIPSE.COM

GROUND ZERO After missing out since 1979, the mainland U.S. is getting two total solar eclipses in a span of 7 years. In fact, the paths for 2017 and 2024 cross at the southern tip of Illinois and southeasternmost Missouri.

JAY ANDERSON

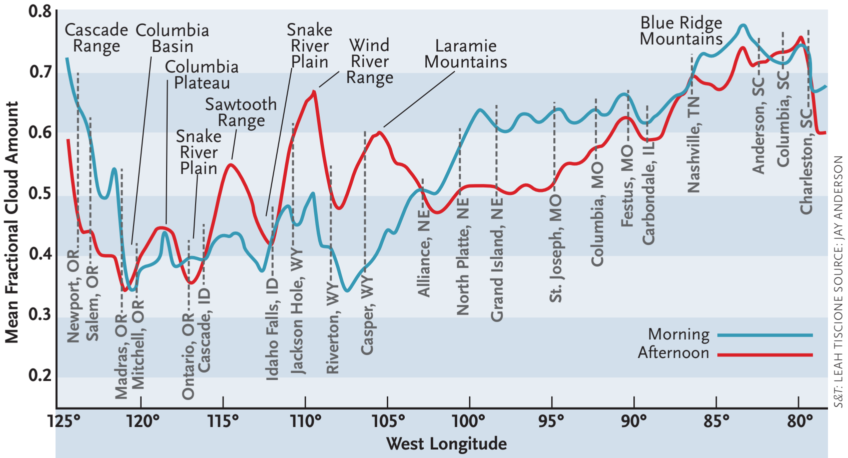
SUNNY SLOPES John Day Fossil Beds National Monument in Oregon provides a colorful vista from which to view the eclipse. The Sun will be 43° above the mountain from this vantage point.

Omaha, 40 miles north of the track, experiences a partial eclipse with 98.5% obscuration.

Kansas, Missouri, and Illinois

The eclipse track clips the far-northeastern corner of Kansas and crosses the twisty Missouri River three times while entering Missouri. The centerline runs through St. Joseph, where totality lasts 2^{m} 38^{s} centered on 1:08 p.m. CDT.

Eclipse Site Cloud Statistics



UPS AND DOWNS Twenty years of satellite data have yielded these plots of morning (blue) and afternoon (red) cloud cover along the eclipse centerline. Use these trends for comparative purposes — not as absolute probabilities. Go to www.eclipser.ca for more weather statistics.

Location	Clear	Few or scattered	Broken or overcast	Average cloud cover
Newport, OR	18.4	15.6	65.9	63
Salem, OR	36.7	18.3	45.0	46
Redmond, OR	50.4	25.2	24.2	27
Ontario, OR	77.4	6.5	16.1	16
Idaho Falls, ID	42.5	25.7	31.8	32
Jackson Hole/ Teton Village, WY	25.7	42.5	31.8	34
Casper, WY	25.5	36.2	38.2	42
Alliance, NE	32.6	32.8	34.5	35
Grand Island, NE	25.5	28.6	45.9	49
Kansas City/ Platte, MO	21.8	31.4	46.8	49
St Louis, MO	8.4	31.5	60.1	56
Nashville, TN	4.9	42.9	52.1	58
Anderson, SC	4.9	44.5	50.5	50
Charleston, SC	2.8	29.2	68.2	69

Data are derived from cloud-cover statistics gathered 1979–98 at weather stations (mostly airports) nearest to the listed location. The first three columns of values provide the likelihood (as percentages) of specific sky condition at time of eclipse during August. The final column lists the average fraction of the sky (as percentages) covered by cloud at eclipse time.

Eastward from St. Joseph, the protective influence of the western mountains largely comes to an end, and you can expect an environment that typically has a generous supply of subtropical moisture. Along the eclipse track through Missouri and Illinois, average afternoon cloud cover rises steadily toward the east, increasing from under 50% to a bit more than 60%. Yet available sunshine remains relatively constant, perhaps suggesting lots of semitransparent overcast.

Kansas City straddles the southern limit, so the duration of totality there ranges from zero (partial eclipse only) to more than 1 minute, depending on an observer's exact location within the city. A similar situation is true for St. Louis, which the eclipse path's northern limit bisects. As the umbral track follows the Missouri River, it crosses the St. Francois Mountains and descends to the Mississippi and Ohio river valleys and across the Big Muddy Watershed before entering Illinois.

Carbondale, Illinois, holds two unique distinctions. First, the path of the 2017 eclipse has its *greatest duration*, 2^{m} 40.3^{s}, at a point about 6 miles south of the town. Second, Carbondale also lies in the path on the next total solar eclipse to cross the U.S., in 2024. So it's no surprise that this small city is billing itself as the "Eclipse Crossroads of America."

Satellite data show that cloudiness decreases a lot from morning to afternoon in Nebraska, Kansas, and Missouri. This poses a bit of a dilemma for site selection, as the time of the eclipse is close to local noon. Keep in mind that the arrival of the Moon's shadow will be heralded by a drop in temperature, suggesting that the morning curve in the graph at upper left might be the more appropriate.

From a purely weather standpoint, the overall best sites along this portion of the path are in western Missouri. But Carbondale lies in the lowlands of the Ohio and Mississippi rivers, giving this community the (statistically) least-frequent cloud cover in the eastern part of the region.

Kentucky, Tennessee, and Georgia

As it crosses the Ohio River, the Moon's shadow enters Kentucky. It's here that, at 1:25:31 p.m. CDT, the axis of the lunar umbra passes closest to the center of Earth — an instant known as *greatest eclipse*. The exact location is a humble sorghum field about 12 miles northwest of Hopkinsville, Kentucky. At that moment the Sun's altitude is 64° and the path of totality 71.3 miles wide. Although the ground speed of the shadow is near its minimum — 1,447 mph — it's still nearly twice the speed of sound.

The duration of totality here is just 0.13 second less than at the point of greatest duration near Carbondale, Illinois, but that distinction seems to make a lot of difference to some communities promoting themselves as the best place to watch the eclipse.

The truth is that any place along the eclipse track

BRAGGING RIGHTS Low hills and open fields dominate the scenery in Illinois at the site of greatest eclipse. The owner of this field noted that visitors arrived to view the location "every day" — even in 2013, when this photo was taken.

JAY ANDERSON

with a clear sky on August 21, 2017, is a winner.

Kentucky is a landscape of small, rolling hills, tree-lined roads, and numerous farms. As the eclipse track enters Tennessee, the terrain begins to rise, crossing the low hills of the Highland Rim before dropping into the Nashville Basin. The average cloud cover in this stretch ranges between 60% and 70% in satellite data and about 10% lower than that based on airport observations.

Nashville itself lies within the umbral track about 25 miles south of its centerline. At 1:28 p.m. CDT, eclipse watchers in "Music City" will be treated to $1^m\ 55^s$ of totality, though they'll gain 45 seconds more by traveling to the centerline. The eclipse-day percentage of possible sunshine at Nashville is a decent 63% — a promising value for August, though about 20% lower than the best sites in Oregon and Idaho.

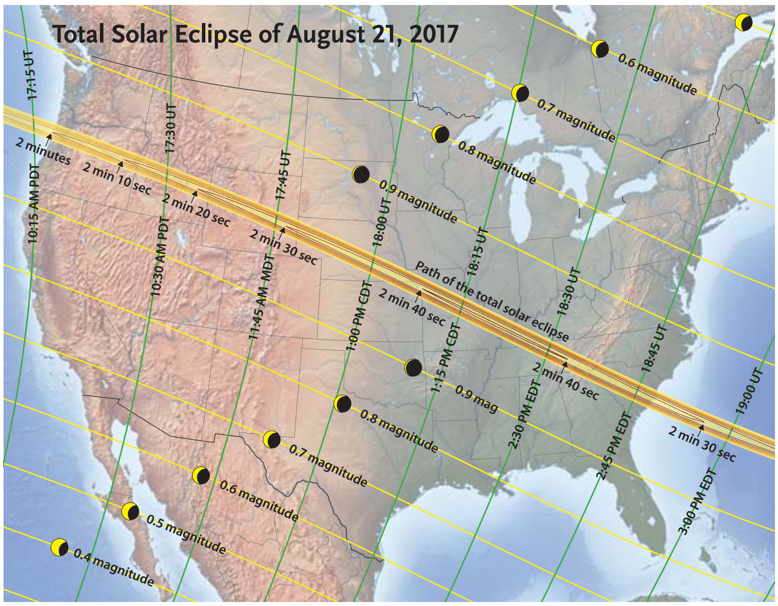
East of Nashville, the countryside becomes more heavily forested as it transforms into the ridge-and-valley Appalachians. Unfortunately, Knoxville and Chattanooga both lie outside the path and get 99% partial eclipses. The path of totality also clips the mountainous northeastern corner of Georgia; Atlantans will see a 97% partial eclipse.

The Carolinas

In the final 14 minutes of its transcontinental journey, the lunar shadow races across North and South Carolina. The downward trend of the terrain's elevation accelerates as the path approaches the Atlantic Ocean. Along the way, some sizable cities become immersed in the lunar shadow, including Anderson ($2^m\ 34^s$), Greenville ($2^m\ 11^s$), and Columbia ($2^m\ 30^s$). Historic Charleston lies just inside the southern limit, experiencing $1^m\ 32^s$ of totality centered on 2:47 p.m. EDT. Head to the centerline, 30 miles to the northeast, to get a duration of $2^m\ 34^s$ — still within 6 seconds of the event's maximum.

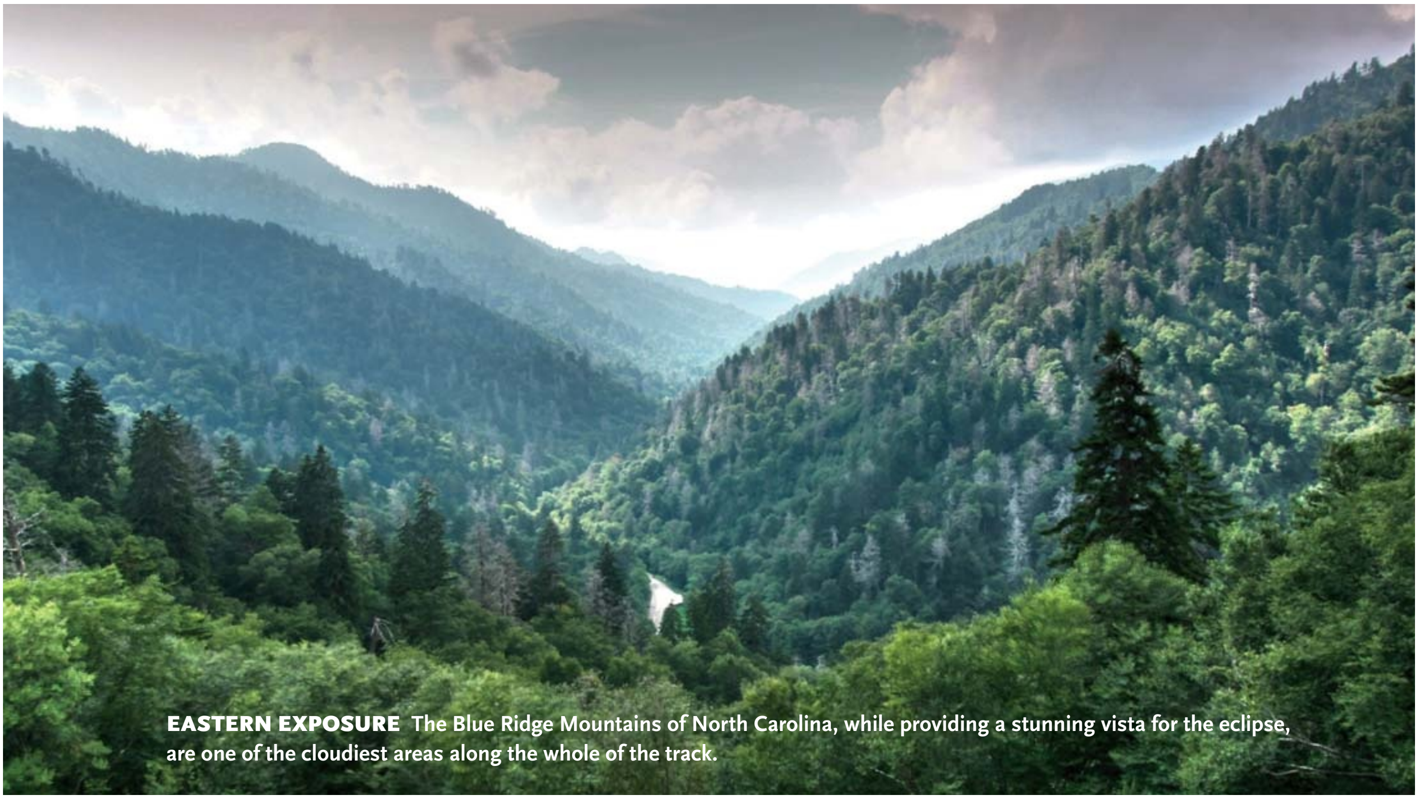
Weather prospects are most daunting at the eastern end of the eclipse track. Unlike in the western mountains, there is no strong pattern of windward cloudiness and leeward clearing here. Instead, ever-present humidity, supplied by the tropical Atlantic waters, fuels a patchwork quilt of convective clouds that blossom nearly every afternoon. Fortunately, the cooling that comes with the gradual blocking of the Sun should help to erode the small- and medium-size cloud buildups that might occur on eclipse day.

Average cloud cover in the Carolinas ranges between 60% and 70%, and the likelihood of sunshine at eclipse time hovers around 65%. Prospects are a bit better along the South Carolina coast, courtesy of the afternoon sea breezes that subdue the cloudiness for a few miles inland. Similar benefits might be had along the margins of Lake



MICHAEL ZEILER / GREATAMERICANECLIPSE.COM

NATIONWIDE EVENT Weather permitting, everyone in North America gets to see at least a partial solar eclipse on August 21, 2017. *Eclipse magnitude* is the fraction of the Sun's diameter covered by the Moon.



EASTERN EXPOSURE The Blue Ridge Mountains of North Carolina, while providing a stunning vista for the eclipse, are one of the cloudiest areas along the whole of the track.

JAY ANDERSON

Marion, near Santee, where there's ready access to Interstates 95 and 26 if a run for clearer skies is warranted.

Some Final Notes

There's no question that excitement is building about the 2017 eclipse. One key reason: it's close to home for thousands of diehard umbraphiles. And since August 21st occurs during the summer vacation season, this total solar eclipse holds the potential to be seen by more people than any other in history.

Climatology might dictate where early planners head for this event, but in the days ahead of the eclipse, your attention should turn to weather forecasts for August 21st itself. You'll find that information is readily available on the Web, and reliable predictions — reliable enough for serious decision making — can be had a week in advance.

Meanwhile, even if they haven't thronged to the eclipse path, everyone in North America (and in northern South America) will see something grand that day. Looking up from Los Angeles at mid-eclipse — using safe viewing techniques, of course — people will see 62% of the solar disk covered by the Moon. From Boston, it'll be 63%. It'll be worth viewing the partially eclipsed Sun even from such widely separated locations as Anchorage (46%), Honolulu (27%), and Bogotá (24%).

If you're reading this article, you're perhaps already making eclipse plans. But the challenge, for all of us, is to convince family, friends, and neighbors that this isn't just an event for astronomers — it's something everyone should see. And maybe, just maybe, seeing the 2017 eclipse may inspire some child to become the next Einstein, Newton, or Galileo! ✦

Astronomer ***Fred Espenak*** *coauthored (with Mark Littmann and Ken Willcox)* Totality — Eclipses of the Sun. *He manages the websites* ***eclipsewise.com*** *and* ***MrEclipse.com.*** *Meteorologist* ***Jay Anderson*** *(University of Manitoba) has researched eclipse weather forecasts since 1979 and has journeyed worldwide to confirm his predictions in person.*

MAGIC DAY This'll be a common scene on August 21, 2017.

FRED ESPENAK

WANTED:
90 Minutes of Totality

Solar scientists hope an armada of amateur astrophotographers can record the inner corona's evolution throughout the 2017 total solar eclipse.

NATIONAL SOLAR OBSERVATORY

Matt Penn

Rosebud, Missouri, will see day turn to night just after lunch on August 21, 2017. The spectacle of a total solar eclipse will interrupt daily activities for about 2½ minutes, as the Moon blocks the bright solar surface to reveal the faint, delicate, and filamentary solar corona. Such an extraordinary event hasn't been seen in the continental United States since 1979. But on that Monday in 2017, millions of Americans will see this rare event and experience firsthand the strangeness of having the Sun disappear from the sky.

If all goes well, a small group of volunteers in Rosebud will collect images of the eclipse for a unique project called the Citizen Continental-America Telescopic Eclipse Experiment. The Citizen CATE Experiment intends to open a new window through which to study the dynamics of the inner solar corona.

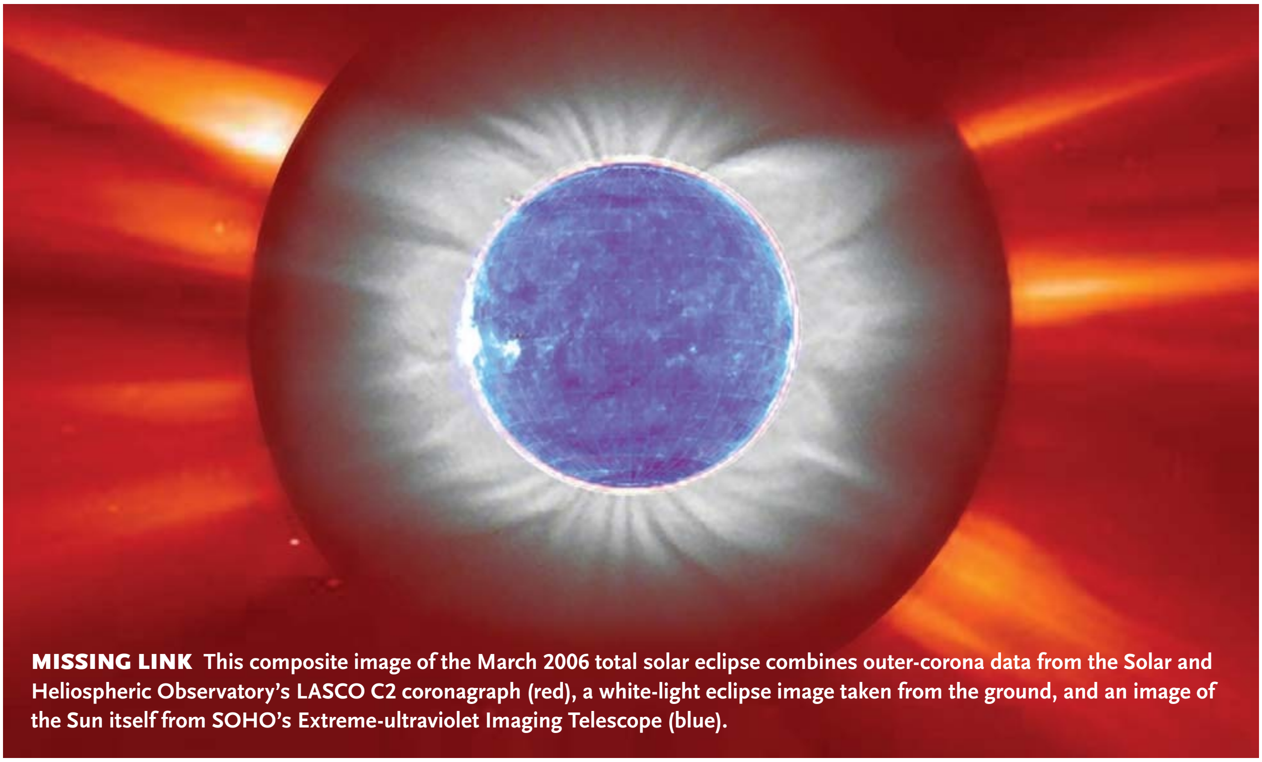
Given all the ground- and space-based telescopes involved in solar research, you might think there's no need for such an effort. After all, telescopes from the National Solar Observatory (NSO) regularly observe the corona near the photosphere up to a height of about 1.3 solar radii. The Daniel K. Inouye Solar Telescope, now under construction on Maui, will observe this range with faster imaging and better spatial resolution. Meanwhile, spaceborne telescopes study the corona over a range from about 2.2 out to 30 solar radii and beyond.

But this coverage leaves an unprobed gap in our star's atmopshere from about 1.3 to 2.2 solar radii. Fortunately, whenever the Moon completely blocks the surface of the Sun, the sky brightness as seen from the ground drops by a factor of 10,000 or more, making it easy for us to see and study this region of the solar corona.

A Golden Opportunity

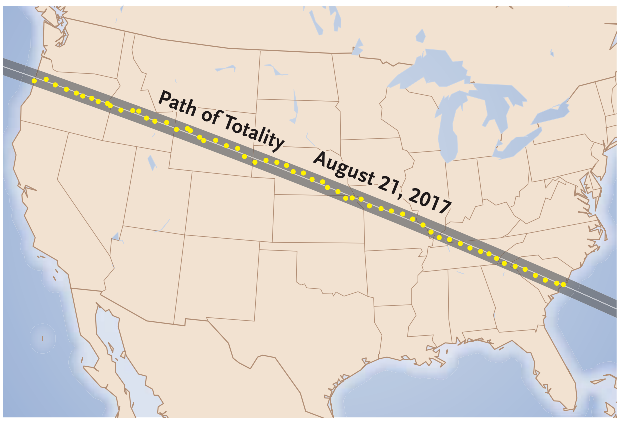
The shadow of the Moon will hurtle across the United States at supersonic speeds, crossing the 2,400 miles from Oregon to South Carolina in about 90 minutes. Most viewers along this path will see the solar corona for only about 2 minutes. During totality they'll likely see two broad coronal streamers extending east and west above the solar equator, plus a collection of thin filaments called *polar plumes* above the north and south poles of the Sun (pictured on the next page). Changes in the density of these delicate structures occur on time scales of 5 to 15 minutes, so while the 2017 total eclipse allows us to view polar plumes with excellent clarity, any given observer will get a frustratingly short glimpse of them.

To extend their time in totality, some astronomers have flown under the Moon's shadow using supersonic aircraft, while others have established networks of telescopes on the ground along an eclipse path. Often, however, an eclipse path spans remote regions of the world or crosses



INNER-OUTER IMAGES: NASA / SOHO; MIDDLE IMAGE: JOHN BROWN & ROBERT ARNOLD

MISSING LINK This composite image of the March 2006 total solar eclipse combines outer-corona data from the Solar and Heliospheric Observatory's LASCO C2 coronagraph (red), a white-light eclipse image taken from the ground, and an image of the Sun itself from SOHO's Extreme-ultraviolet Imaging Telescope (blue).



S&T: GREGG DINDERMAN, SOURCE: NATIONAL SOLAR OBSERVATORY

SOLAR RELAY The planned observing sites for the Citizen CATE Experiment (yellow dots) are spaced to provide continuous observation of the solar corona as the Moon's shadow whisks across the continent from Oregon to South Carolina.

Corporate Sponsors Needed

Two companies have generously contributed to the Citizen CATE project. DayStar Filters will supply the telescope optical tube assemblies and neutral-density filters for capturing partial phases. MathWorks has agreed to provide software for image acquisition and processing, as well as funding to cover equipment and other costs for the project. The project has funds for about 35% of a 60-site experiment and is seeking more sponsors to make this unique citizen-science experiment a success.

vast oceans, so establishing even just two or three sites within the lunar shadow is a logistical challenge.

In contrast, the path of totality in 2017 will be accessible from thousands of convenient locations. In a 2012 paper titled "The U.S. Eclipse Megamovie in 2017," researchers Hugh Hudson, Scott McIntosh, and others explain how citizen scientists positioned at various locations along totality's path could collect images of the eclipse and combine them into a continuous video of the event. The Citizen CATE Experiment builds on the ideas introduced in that creative paper.

Instead of scattering themselves randomly across the eclipse path, our observers will be positioned at regular intervals, such that as the shadow of the Moon leaves one observer, it will fall on the next one to the east. In this way, Citizen CATE establishes a "relay race" of coronal observations, with one group of observers passing the baton to the next group every 2 minutes or so. Alexandra Hart, an accomplished solar imager from England, compiled the initial list of observing sites and found that, after accounting for access, the effort will require roughly 60 locations to assure continuous coverage or totality. After the eclipse ends, we'll align and interleave the observers' images and then assemble them into a continuous movie to reveal the dynamics of polar plumes for a full 90 minutes.

Since the small community of professional solar astronomers in the U.S. can't possibly staff 60 observing sites, we'll rely heavily on the help of amateur astronomers (see the box on the facing page).

We're now compiling a list of diverse volunteers, and we will begin training this team in early 2017. One of the first Citizen CATE volunteers, retired professor Fred Isberner, has already taken eclipse data with our prototype telescope and detector. With no previous experience with digital astronomy imaging, Isberner learned to use the prototype telescope with assistance from Bob Baer at Southern Illinois University, Carbondale. Then, with help from TravelQuest International and 62N, we shipped the telescope to the Faroe Islands — where Isberner was vacationing — for the March 2015 solar eclipse. Braving poor weather, he set up the instrument and captured 30 seconds of totality between clouds! His experiences have provided invaluable lessons about training, technical issues, and logistics.

Sixty Telescopes, One Design

Co-aligning thousands of images from 60 telescopes will involve a significant effort, but one way to minimize the required processing is to make the telescopes as similar as possible.

The fully portable eclipse instrument will likely use a 90-mm f/5.5 doublet refractor and an equatorial mount on a tripod with a battery-powered right ascension drive. At the prime focus will be a 4-megapixel, rapid-readout detector, powered by a laptop collecting images at roughly 10 frames per second. Each CATE observer will also take calibration data to determine image orientation, which requires a white-light solar filter. Finally, user-friendly software will be provided to facilitate instrument setup, focus, calibration, and data collection, as well as to make a first-look movie of the combined images on eclipse day.

Our last chance to practice taking solar eclipse data before the August 2017 event is coming up soon. On March 9, 2016, the Moon's shadow will cross parts of Indonesia and the Pacific Ocean. With funding from NASA, and in collaboration with my colleagues from the University of Wyoming, Southern Illinois University in Carbondale, Western Kentucky University, and South Carolina State University, we will be making further tests and collecting coronal data during this eclipse.

Our plan is to train undergraduate students at each of these schools (which, not coincidentally, are all located along the path of the 2017 eclipse) to take images with CATE prototype instruments. But perhaps more importantly, the students will become experts with the equipment. They'll return to their home states to train volunteers well in advance of the U.S. eclipse, and each will travel along the eclipse path to a second state to train more volunteers.

After the 2017 eclipse is over, I hope our volunteers can take ownership of the instruments and bring them home. After all, these modestly sized telescopes can address various other citizen-science projects, such as observing sunspots, variable stars, and the occasional comet. In order to transfer ownership to the volunteers, the Citizen CATE Experiment cannot rely on public funds to purchase the equipment. Therefore, we're seeking donations from private and corporate sources (see the box on page 30).

Having these instruments remain in the hands of the CATE volunteers is the best way to ensure that they'll continue to be used after the eclipse. Our hope is that the fleet of instruments and the team of volunteers from Citizen CATE will jump-start advanced citizen-science astronomy efforts across the U.S. ✦

***Matt Penn** became an avid amateur astronomer at age 10 using a 3-inch reflector. He's currently an associate astronomer with the NSO and telescope scientist for the McMath-Pierce Solar Facility on Kitt Peak in Arizona, and he specializes in infrared spectropolarimetric observations and instrumentation. NSO is operated by AURA under contract to the National Science Foundation.*

Join Our Team!

The Citizen CATE Experiment is seeking motivated volunteers to make observations across the U.S. on the day of the 2017 eclipse. Some experience with astronomical observing is preferred. Each volunteer will be expected to take part in several teleconferences and time-sensitive practice observing campaigns in the months leading up to the solar eclipse. You'll also be expected to make your own travel arrangements and to get to your assigned observing site at your own expense.

In return, the CATE project will teach its volunteers how to collect scientific data with the instrument and detector. If our fundraising efforts are successful, ownership of the CATE instruments will be transferred to the volunteers after the eclipse. These observers will also be recognized on each scientific paper that results from the experiment and be offered a selection of follow-up citizen-science projects to work on after the 2017 eclipse.

More details about the eclipse and post-eclipse citizen-science projects are described at our website: **sites.google.com/site/citizencateexperiment/**. Or contact author Matt Penn via email at **mpenn@nso.edu**.

BOB BAER

TESTING THE GEAR Fred Isberner trains with the CATE prototype telescope on the roof of the physics department at Southern Illinois University in Carbondale.

HOT Products for 2016

By the Editors of *Sky & Telescope*

Each year S&T *editors scour the marketplace searching for what we consider to be some of the year's most exciting new products. To make our list, a product must not only be new but should also introduce new technologies or processes, provide a solution to an old problem, or simply deliver exceptional value. Our Hot Products list for 2016 includes a variety of gadgets ranging from robotic telescope mounts to cameras, observing aids, and, of course, telescopes and eyepieces. This year many products caught our eye because of their exceptional value — equipment that offers features and performance at a cost well below that of similar items in the past. We hope you enjoy reading about these innovative products that piqued our interest as of late 2015.*

1 PARAMOUNT TAURUS

Software Bisque bisque.com

With their ability to track the sky uninterrupted from horizon to horizon without having to "flip" the telescope at the meridian, fork mounts have long been a favorite of astrophotographers. The Paramount Taurus, the first-ever fork mount from Software Bisque, is designed for today's astrographs in the 20- to 24-inch range (0.5- to 0.6-meter) and weighing up to 400 pounds (180 kg). It has all of the robotics and advanced features available throughout the storied Paramount line of German equatorial mounts.

U.S. price: starting at $35,000

② QUATTRO IMAGING NEWTONIANS

Sky-Watcher USA skywatcherusa.com

As with visual observing, Newtonian reflectors have traditionally delivered the biggest bang for the buck when it comes to astrophotography. Coupled with the latest coma correctors, Newtonians deliver deep-sky imaging performance on par with premium astrographs. And this line of 8-, 10-, and 12-inch f/4 Imaging Newtonians offers outstanding value. Look for our test report later this year.

U.S. price: $610, $770, and $1,199

③ ZWO ASI224MC CAMERA

ZWO astronomy-imaging-camera.com

Built around Sony's IMX224 digital sensor with 3.75-micron pixels and extended near-infrared sensitivity, this 1.2-megapixel, color, USB 3.0 camera has quickly become the camera de jour for planetary imagers. We've been especially wowed by images of the gas giants Jupiter, Saturn, Uranus, and Neptune made with the ASI224MC shooting through ZWO's new $99 CH4 methane-band filter, which, like the camera, is an exceptional value.

U.S. price: $359

④ LOW-COST BAHTINOV FOCUSING MASKS

Farpoint Astronomical Research farpointastro.com

Designed for astrophotographers shooting with conventional lenses on DSLR cameras, these plastic focusing masks will ensure your images have pinpoint stars. Masks are available for lenses that accept standard thread-in filters from 52- to 82-millimeter diameters. We've seen comparable products costing 4 to 5 times more.

U.S. price: $12.95

⑤ SPECTRA-L200

JTW Astronomy jtwastronomy.com

Spectroscopy is a small but growing aspect of amateur astronomy. The new Spectra-L200 compact spectrograph delivers a level of performance similar to units costing considerably more. It works with a wide range of astronomical CCD cameras and autoguiders.

U.S. price: 1,650 euros (about $1,850)

6

VLB LASER COLLIMATOR ACCESSORY

Howie Glatter collimator.com

Laser collimators are great for aligning telescope optics, but as anyone who has used one knows, sometimes the laser beam's brightness can be so overpowering that it makes alignment difficult. Enter Howie Glatter's variable-laser-brightness accessory. This modified battery cap/switch fits all past and present Glatter laser collimators and lets you tune the laser's brightness to an appropriate level for the task at hand.

U.S. price: starting at $20

7

TRUSS-TUBE DOBSONIANS

Explore Scientific explorescientific.com

This trio of well-designed Dobsonians promises to pack a lot of observing pleasure into scopes that break down into easily managed pieces for transport and storage, thanks in part to sub-assemblies that nest within larger components. The line includes 10- and 12-inch f/5 models and a 16-inch f/4.5.

U.S. price: $700, $1,000, and $1,950, respectively

8

ULTRASTAR

Starlight Xpress www.sxccd.com

Starlight Xpress has a well-deserved reputation for its line of high-quality, compact autoguiders that slip into standard 1¼-inch focusers. The newest addition to the line, Ultrastar uses Sony's 1.45-megapixel ICX825 CCD with an impressive 75% quantum efficiency and a generous 8.98-by-6.71-mm imaging area. The low-noise chip allows the camera to double as a deep-sky imager.

U.S. price: $995

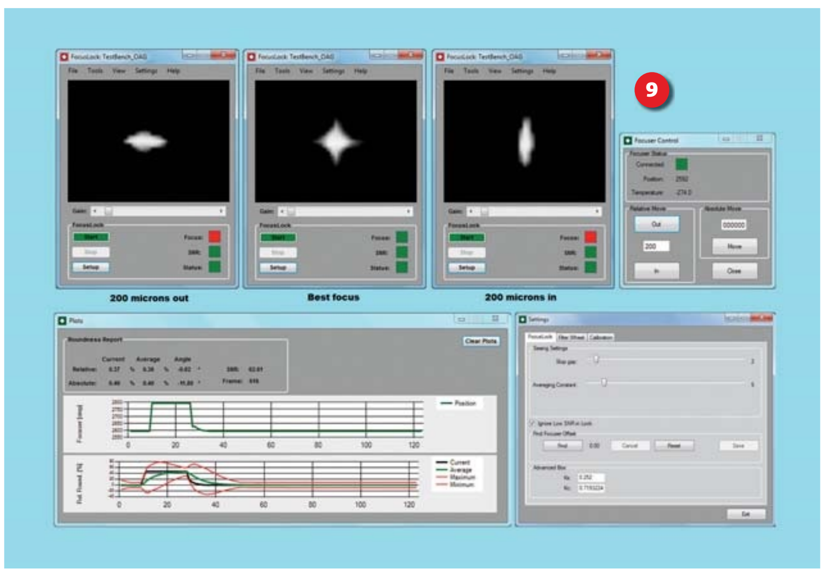
9

SHARPLOCK SOFTWARE

Innovations Foresight innovationsforesight.com

Anyone doing imaging with Innovations Foresight's ONAG on-axis guider (a 2012 Hot Product, which was reviewed in our December 2012 issue, page 60) can now shoot pictures with autofocusing maintained throughout the exposure. Unlike other systems that rely on predetermined focus settings, *SharpLock* software monitors a real-time star image in the field being photographed and issues corrections to any ASCOM-compliant focuser.

U.S. price: $100 software license after a 60-day free trial



10

10 DELITE EYEPIECES

Tele Vue televue.com

While the DeLite name is a nod to these eyepieces' origins as smaller and more economical versions of Tele Vue's highly acclaimed Delos eyepieces, the name also describes observers' reactions to using them. Reviewed in our September 2015 issue, page 64, the DeLites feature long eye relief, 62° apparent fields, and the superb optical performance we've come to expect from Tele Vue.

U.S. price: $250

11

11 ASTRO-TECH ED TRIPLET REFRACTORS

Astronomics astronomics.com

Every year brings a wave of new refractors to the astronomy market, but these models in the Astro-Tech line stand out for their feature/cost ratio. Having three-element objectives made with extra-low dispersion glass, these 80-mm f/6, 115- and 130-mm f/7 refractors are priced well below the competition. All come with a 2-inch, dual-speed focuser, 2-inch dielectric-coated mirror diagonal, tube rings, and a Vixen-style dovetail bar.

U.S. price: $749, $1,299, and $1,799, respectively

12

12 IPANO CAMERA PLATFORM

iOptron ioptron.com

This programmable, robotic camera platform is designed for photographers shooting the new breed of large-scale, gigapixel panoramas, but it is equally well suited to astrophotographers seeking to assemble night-sky time-lapse sequences and panoramas from their DSLR frames. It will carry cameras and lenses weighing up to 11 pounds (5 kg) and is powered by internal rechargeable batteries.

U.S. price: $999

13

13 ANNALS OF THE DEEP SKY

Willmann-Bell willbell.com

Annals of the Deep Sky is destined to become an observing guide that ranks among such 19th-century classics as Smyth's *Cycle of Celestial Objects* and Webb's *Celestial Objects for Common Telescopes*. Billed by some as the next-generation *Celestial Handbook* (Robert Burnham's 20th-century opus), *Annals* is reviewed in our December 2015 issue, page 65. Authors Jeff Kanipe and Dennis Webb go far beyond what is seen in the eyepiece and cover the history, lore, and scientific background of the objects they write about. The first two volumes of *Annals* are out, and more are on the way.

U.S. price: $24.95 each

GEMINI FOCUSING ROTATOR 14

Optec optecinc.com

High-end imaging systems often include a motorized focuser and a camera rotator to help compose images and locate suitable guide stars. This ASCOM-compliant combination focuser/rotator from Optec is noteworthy for its robust construction, generous 3¾-inch aperture, and extremely low profile, requiring just 2¼ inches of back focus in the imaging train, making it a particularly useful accessory for remote imagers.

U.S. price: $2,995

INFINITY 90 REFRACTOR 15

Meade Instruments meade.com

We're always on the lookout for quality, entry-level telescopes within the price range of beginning amateur astronomers. As our Test Report in the December 2015 issue, page 54, explains, this 90-mm f/6.7 refractor fills the bill, especially considering that it comes ready to use with a sturdy tripod and a good selection of accessories well suited to viewing the Moon, planets, brighter deep-sky objects, and terrestrial scenes.

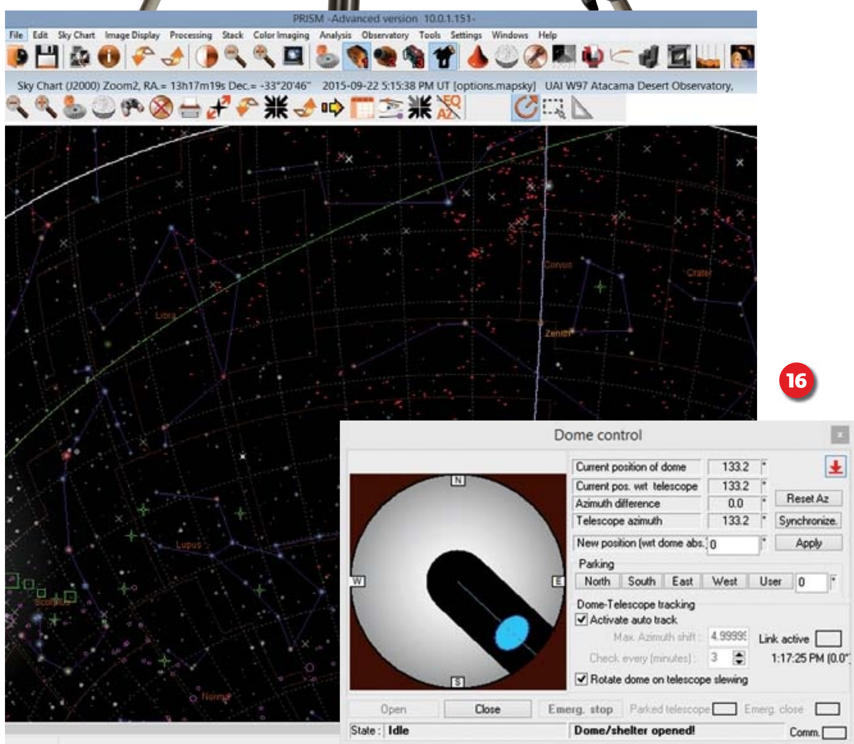
U.S. street price: about $200

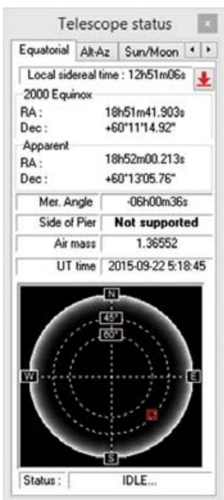
PRISM+ SOFTWARE 16

Prism America prism-america.com

Long an extremely popular program in France, *Prism+* is now available with a newly revamped English-language interface. The richly featured program does everything from help plan observations to controlling telescopes, cameras, and complete observatories. And once your observations are done, *Prism+* will help process and analyze the data. There are algorithms for doing astrometry, photometry, image blinking, supernova searches, and much more.

U.S. price: from $299





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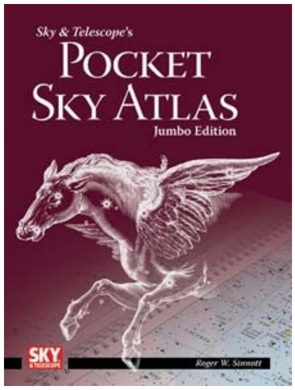


18

19

20

17 TRUSS-TUBE IMAGING NEWTONIANS

Astronomics astronomics.com

As alluded to earlier, Newtonian reflectors are experiencing a revival for deep-sky astrophotography thanks to modern, high-performance coma correctors. These 10- and 12-inch f/4 Newtonians are designed for imaging. Each features a carbon-fiber truss-tube assembly for focus stability in changing temperatures, quartz mirrors with enhanced-aluminum coatings offering 96% reflectivity, and a pair of Losmandy-style dovetail mounting bars.

U.S. price: $1,795 and $2,195, respectively

18 JUMBO POCKET SKY ATLAS

Sky & Telescope skyandtelescope.com

It wouldn't be Hot Products if it didn't include something from our own fold, and this year we're especially proud of our newest release, the jumbo edition of our highly popular *Pocket Star Atlas*. In addition to all the features of the original printed on larger, 8¼-by-11½-inch pages, the new edition has six additional close-up charts of particularly interesting star fields.

U.S. price: $39.99

19 NIKON D810A CAMERA

Nikon nikon.com

Nikon has released its first-ever DSLR made especially for the astronomy market. Based on its flagship "prosumer" model, the 36.3-megapixel D810A has extended red sensitivity for capturing the astronomically important hydrogen-alpha wavelength. Special features such as low-light live preview for focusing, and pre-set exposures up to 15 minutes, are just two of the new astrophotography-friendly aspects of the camera. Look for our Test Report on the D810A in next month's issue.

U.S. price: $3,800, body only

20 IOPTRON CEM25-EC

iOptron ioptron.com

This updated version of the ZEQ25 equatorial mount that was favorably reviewed in our March 2014 issue, page 61, is now available with high-resolution encoders and new electronics that reduce the drive's periodic error to less than 0.5 arcsecond. It has the potential to eliminate the need for guiding with modest-focal-length setups and multiminute exposures, making it a possible game changer for some types of astrophotography.

U.S. price: $1,899

MINI LIGHTBRIDGE
Meade Instruments meade.com

Meade's popular line of LightBridge Dobsonian reflectors is shrinking, but only in terms of aperture and price! Three new tabletop models, with parabolic primary mirror apertures of 82-, 114-, and 130-mm, promise to put a lot of observing pleasure in a compact, portable, and easy-to-use package. Each features a 1¼-inch rack-and-pinion focuser, a red-dot finder, and two eyepieces. And there's also Meade's reputation for quality.

U.S. price: approximately $60, $150, and $200, respectively

MORPHEUS EYEPIECES
Baader Planetarium baader-planetarium.de

Another eyepiece design that caught our attention this year is the Morpheus series from Baader Planetarium. These dual-format (1¼- and 2-inch) oculars are available in 4.5-, 6.5-, 9, 12.5, 14-, and 17.5-mm focal lengths that boast a generous 76° apparent field. Additional features in the series include glow-in-the-dark markings and T-threads beneath the rubber eyeguard.

U.S. price: $239

2017 SOLAR ECLIPSE BOOKS
Astropixels Publishing
astropixels.com/pubs

As every amateur astronomer knows, the continental United States will experience its first total solar eclipse in more than 38 years when the Moon's shadow sweeps a path from Oregon to South Carolina on August 21, 2017. Whether you're an experienced eclipse chaser planning to go on your own or as part of an organized tour, or just someone curious about the event (and all of its associated hoopla), you'll find what you need to know in one or more of these expertly done books.

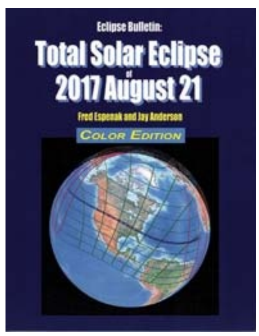
U.S. price: $14.99 to $34.99

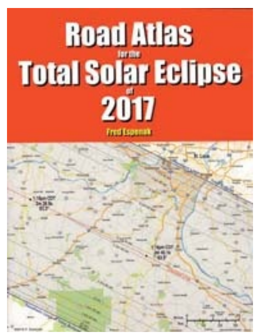
SOLAR OBSERVING HOOD
TeleGizmos telegizmos.com

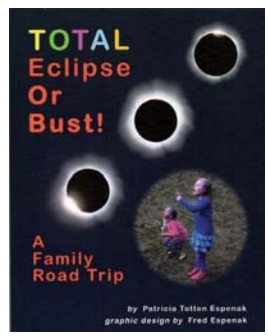
Simple, effective, and downright cool in more ways than one, this dual-layer cover has a polyethylene outer surface that reflects the Sun's heat and an opaque inner layer that provides a darkened environment for solar observers and photographers. It is especially helpful for those people working with hydrogen-alpha scopes.

U.S. price: $34.95

23







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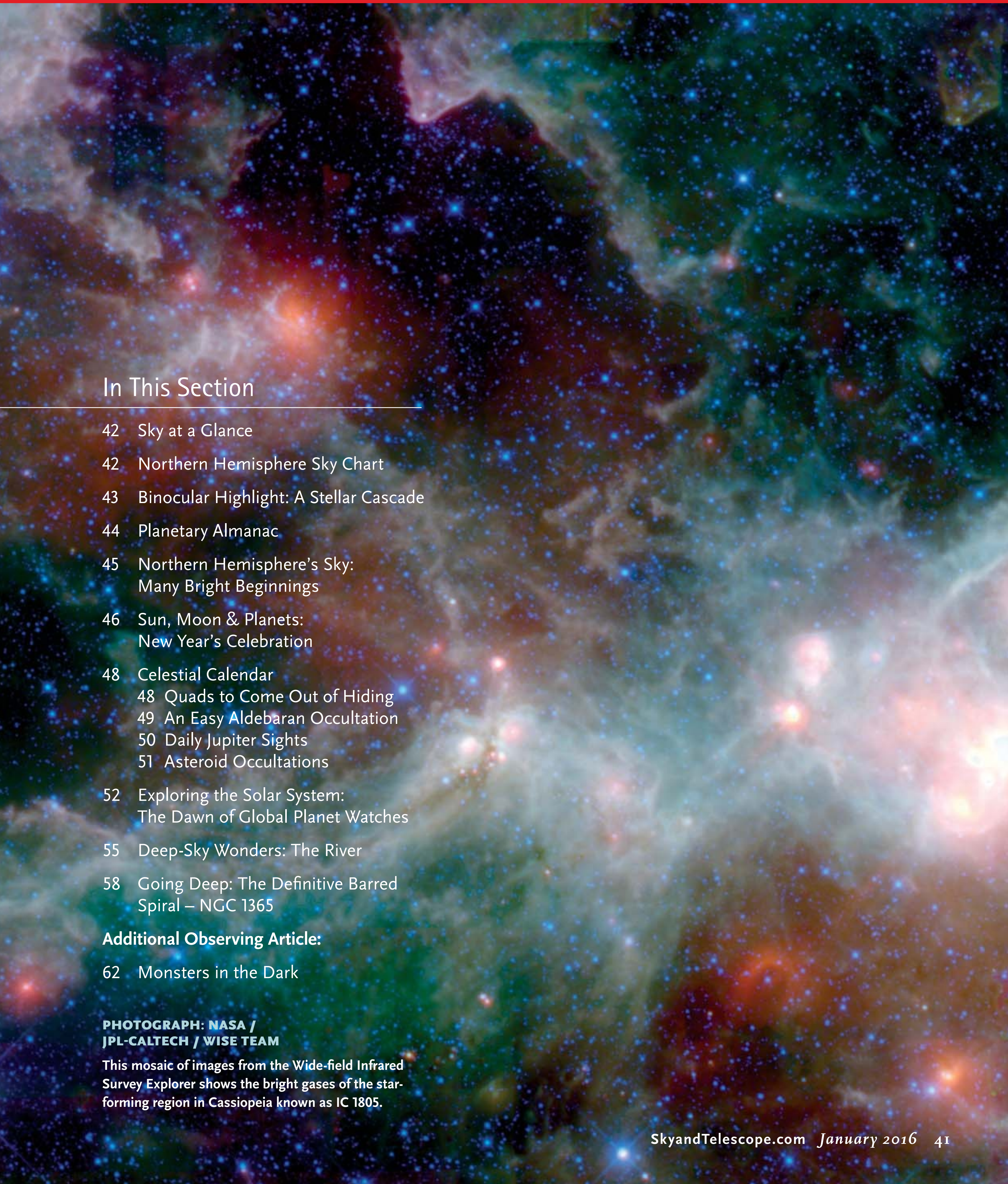


In This Section

PHOTOGRAPH: NASA / JPL-CALTECH / WISE TEAM

This mosaic of images from the Wide-field Infrared Survey Explorer shows the bright gases of the star-forming region in Cassiopeia known as IC 1805.

Sky at a Glance

JANUARY 2016

3 **MORNING**: The Moon forms a modest triangle with little red Mars and blue-white Spica, nearly alike in brightness.

3–4 **NIGHT**: The Quadrantid meteors should peak around 3 a.m. EST on the 4th. The rise of the waning crescent Moon won't interfere with late-night viewing of the shower; see page 48.

6 **NIGHT**: Algol shines at minimum brightness for roughly two hours centered at 10:31 p.m. EST (7:31 p.m. PST); see page 50.

7 **DAWN**: The thin waning crescent Moon hangs low in the southeast, left or lower left of Venus and Saturn, which are less than 2° apart.

9 **DAWN**: Look low in the southeast before sunrise to find Venus and Saturn less than ½° apart. Antares winks red about 7° right or lower right of the planetary duo.

19 **EVENING**: The waxing gibbous Moon occults Aldebaran for viewers in much of North America; see page 49.

25 **NIGHT**: Regulus, the brightest star in Leo, shines through the glare of the waning gibbous Moon, about 3° to its right for viewers in North America.

27 **NIGHT**: The Moon shines about 4° below Jupiter, which can be found off the hind foot of Leo.

29 **NIGHT**: Algol shines at minimum brightness for roughly two hours centered at 9:05 p.m. EST.

30 **DAWN**: The waning gibbous Moon is about 4° upper left of Spica. Mars is about 1.5° from fainter Alpha (α) Librae.

Planet Visibility SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

Planet	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury		Visible beginning Jan 23	SE
Venus			SE
Mars		E	S
Jupiter		E S	SW
Saturn			SE

Moon Phases

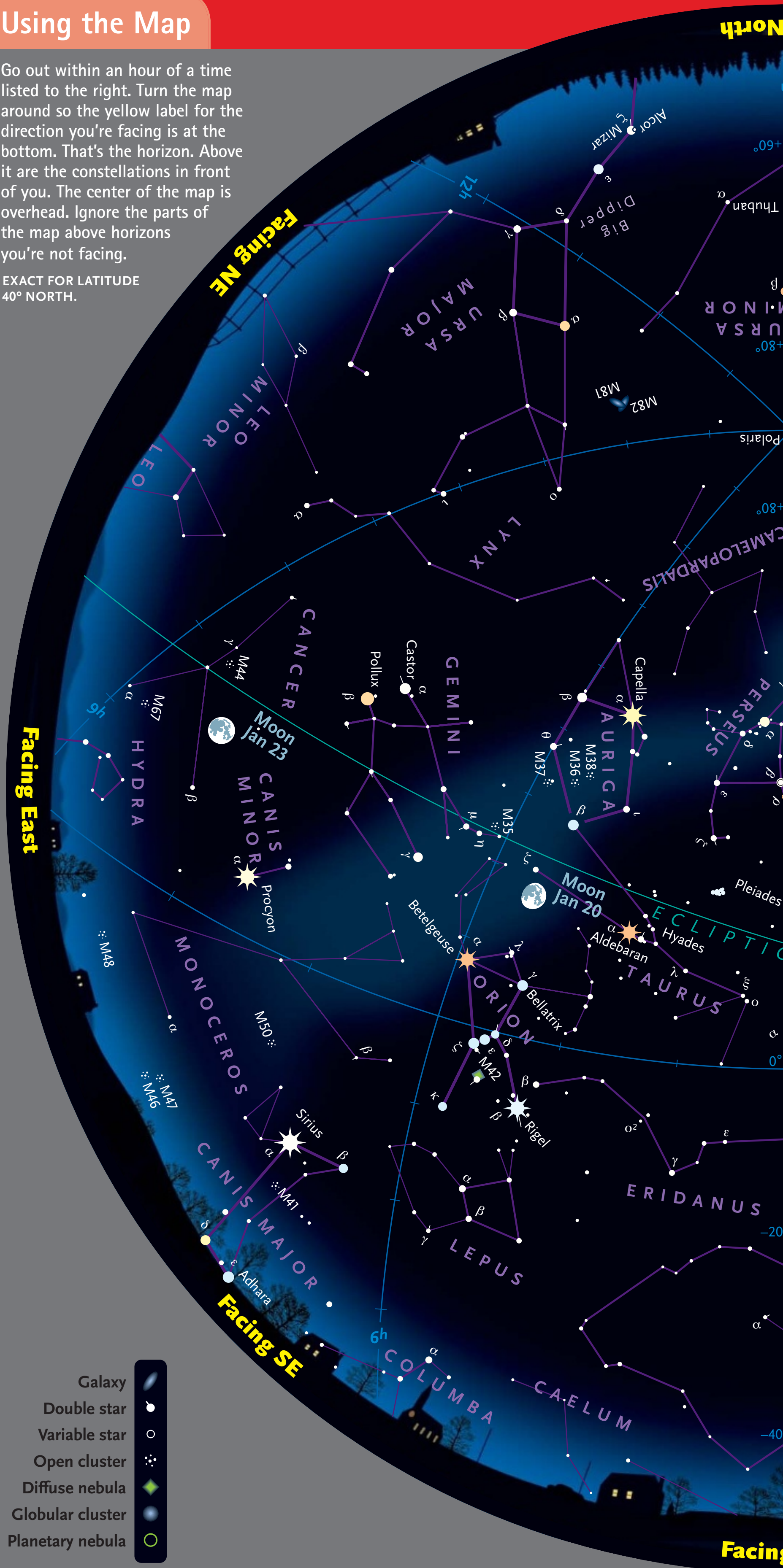
- Last Qtr January 2 12:30 a.m. EST
- New January 9 8:30 p.m. EST
- First Qtr January 16 6:26 p.m. EST
- Full January 23 8:46 p.m. EST
- Last Qtr January 31 10:28 p.m. EST

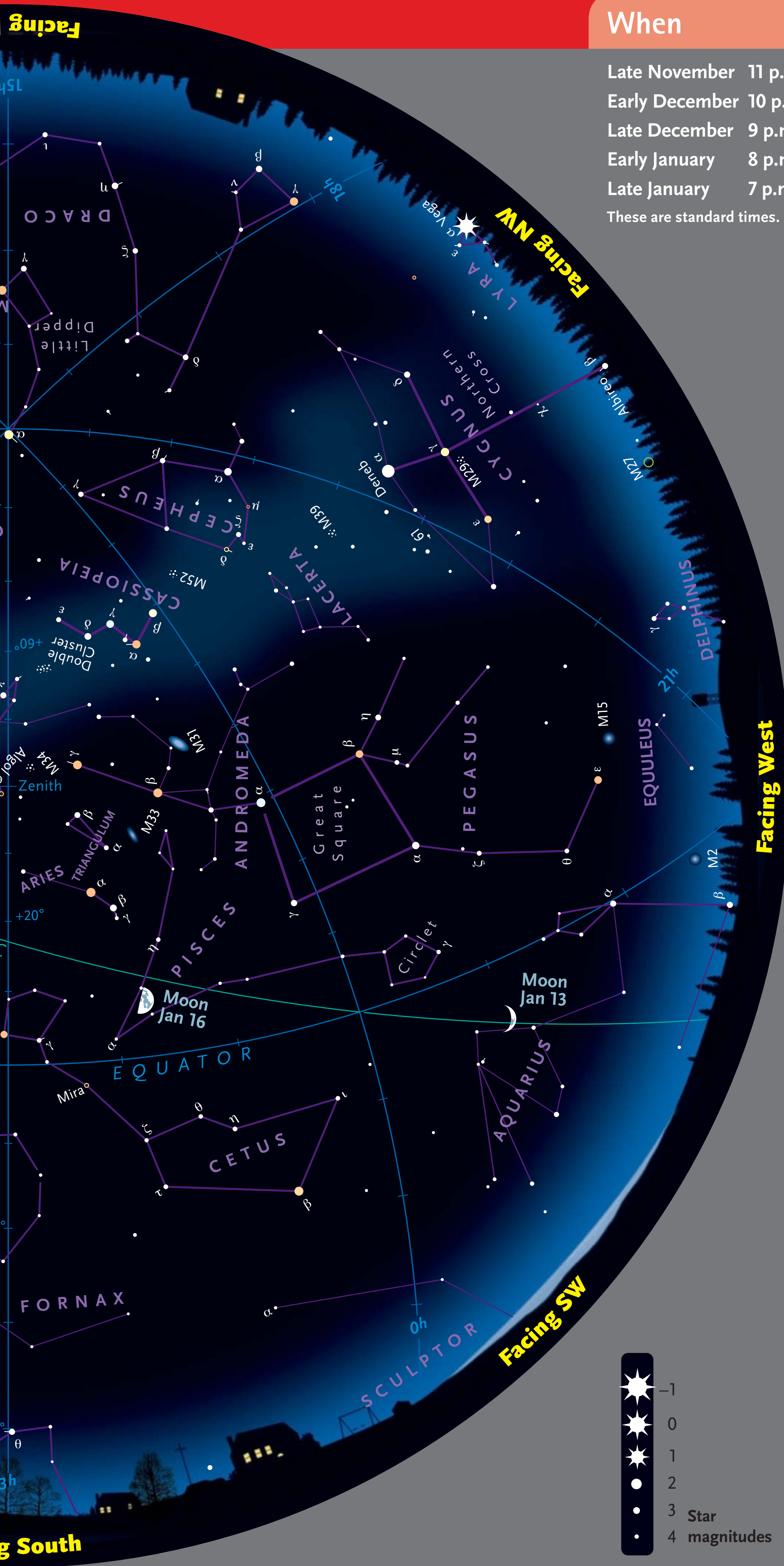
SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24 / 31	25	26	27	28	29	30

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 November	11 p.m.
Early December	10 p.m.
Late December	9 p.m.
Early January	8 p.m.
Late January	7 p.m.

These are standard times.

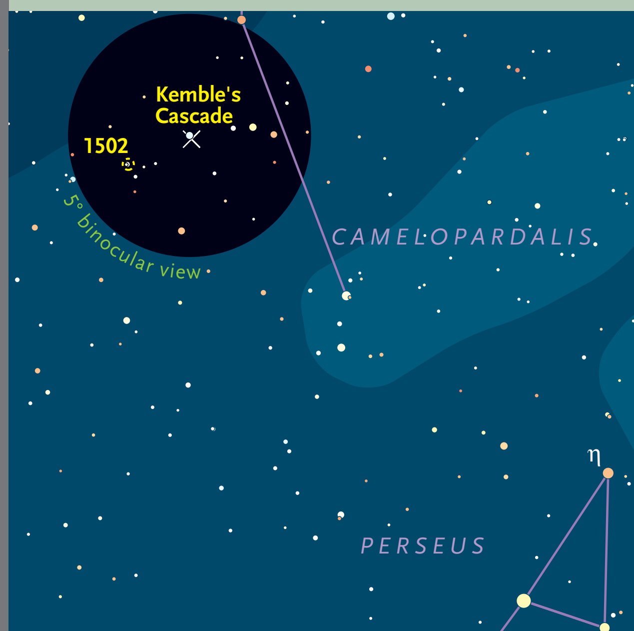
Gary Seronik

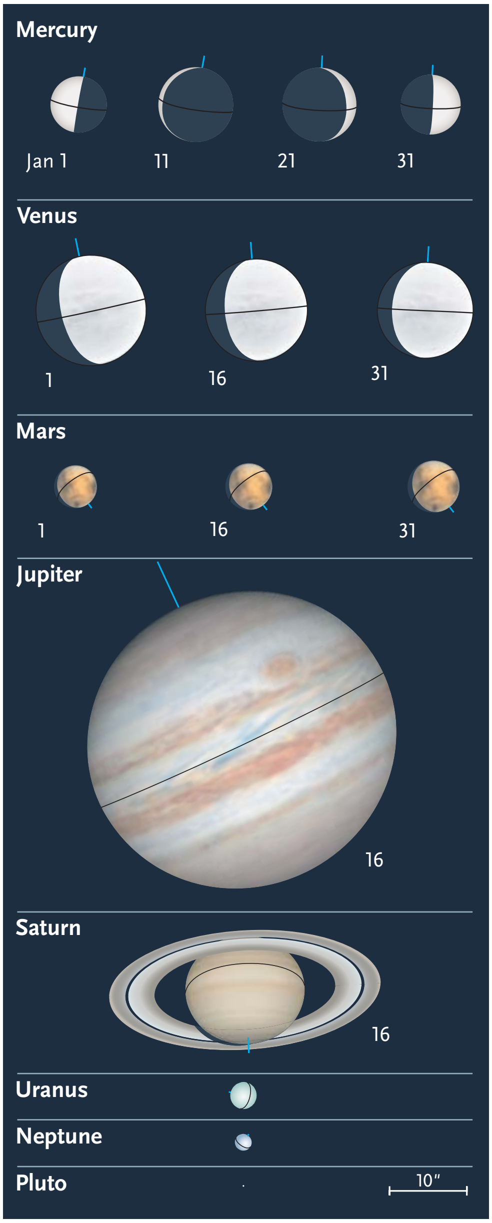
A Stellar Cascade

Admit it. There's something vaguely disappointing about sweeping up a group of stars that look like a cluster, but turn out to be just a bunch of stars. Millions of years of evolution have made us remarkably adept at finding order in chaos — an ability we use when we see patterns in randomly distributed points of light. Good thing, though, or there'd be no constellations. Add binoculars to the equation and a whole new door opens for connecting the dots. We call these asterisms — eye-catching groups of stars that *look* like they belong together, yet have no physical relationship to one another.

The difficulty with most asterisms is their very existence often lies exclusively in the eye of the beholder. I occasionally get e-mails from observers describing "incredibly obvious" asterisms that completely elude me. But there are a few notable exceptions. One of the most striking is **Kemble's Cascade**, which lies in the dim constellation Camelopardalis. Indeed, it's easily the constellation's finest binocular treasure. Camelopardalis is so indistinct that the easiest way to find Kemble's Cascade is to start at Eta (η) Persei, then scan the sky two binocular fields northeast of Eta.

Kemble's Cascade is a linear arrangement of 8th- and 9th-magnitude stars with a 5th-magnitude sun at its middle. The chain is so distinctive I can make it out in my 10×30 image-stabilized binoculars even from the suburbs. If you have dark skies, inspect the eastern end of the cascade carefully. There you'll find magnitude-6.9 NGC 1502. In binoculars it looks like a single, 7th-magnitude star enveloped in a compact haze. But unlike Kemble's Cascade, NGC 1502 is a true cluster of stars. ✦





Sun and Planets, January 2016

	January	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h\ 42.5^m$	–23° 05′	—	–26.8	32′ 32″	—	0.983
	31	$20^h\ 51.0^m$	–17° 39′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$20^h\ 05.5^m$	–21° 06′	19° Ev	–0.4	7.3″	49%	0.921
	11	$19^h\ 58.4^m$	–18° 29′	8° Ev	+3.1	9.6″	6%	0.698
	21	$19^h\ 09.6^m$	–19° 03′	14° Mo	+1.7	9.6″	14%	0.702
	31	$19^h\ 09.4^m$	–20° 31′	24° Mo	0.0	7.7″	46%	0.868
Venus	1	$16^h\ 00.6^m$	–18° 34′	38° Mo	–4.0	14.3″	77%	1.166
	11	$16^h\ 51.5^m$	–20° 51′	36° Mo	–4.0	13.6″	80%	1.228
	21	$17^h\ 43.9^m$	–22° 10′	34° Mo	–4.0	13.0″	83%	1.288
	31	$18^h\ 37.1^m$	–22° 25′	32° Mo	–3.9	12.4″	85%	1.344
Mars	1	$13^h\ 47.5^m$	–9° 29′	71° Mo	+1.3	5.6″	91%	1.684
	16	$14^h\ 18.7^m$	–12° 16′	79° Mo	+1.1	6.1″	91%	1.535
	31	$14^h\ 48.9^m$	–14° 42′	86° Mo	+0.8	6.8″	90%	1.382
Jupiter	1	$11^h\ 36.0^m$	+3° 57′	107° Mo	–2.2	39.0″	99%	5.049
	31	$11^h\ 33.5^m$	+4° 22′	138° Mo	–2.4	42.4″	100%	4.648
Saturn	1	$16^h\ 38.4^m$	–20° 28′	29° Mo	+0.5	15.3″	100%	10.860
	31	$16^h\ 50.7^m$	–20° 49′	56° Mo	+0.5	15.8″	100%	10.525
Uranus	16	$1^h\ 01.9^m$	+5° 55′	81° Ev	+5.8	3.5″	100%	20.096
Neptune	16	$22^h\ 38.8^m$	–9° 24′	43° Ev	+7.9	2.2″	100%	30.675
Pluto	16	$19^h\ 05.9^m$	–21° 00′	10° Mo	+14.3	0.1″	100%	33.992

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-January; 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

Many Bright Beginnings

The sky offers a number of choices for marking the start of your year.

Are you ready to celebrate a happy New Year? In today's international secular calendar, the first day of the year is, of course, January 1st.

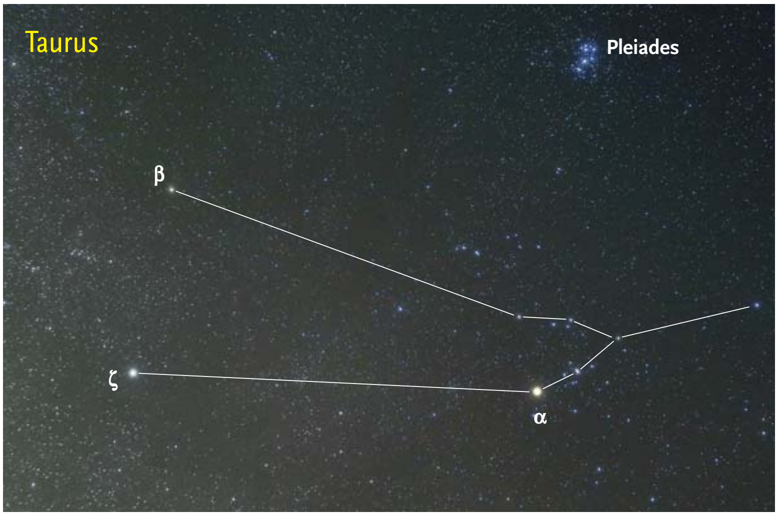
But this has been far from the case in many individual cultures and times. Let's take a look at a few of these — they're all based on astronomy and a few on the positions of very specific stellar objects. Then let's see how, during a January evening of observing, we can celebrate several different times we might regard as a fitting start of a celestial calendar or clock.

Welcome to January, the eleventh month. The ancient Roman calendar began with March. That's why September through December have the root words for seven through ten in their names: they were the seventh through tenth months of the year. (The fifth and sixth months were Quintilis and Sextilis; they were renamed to honor Julius Caesar and Augustus Caesar — and became our July and August.) In England and its American colonies, the year began with March until 1752.

So what — or who — is January named after? The ancient Roman god Janus, who literally had two faces, one looking forward and the other backward through the door. That seems wonderfully appropriate for the start of a calendar because it's a time when all of us cast a look back to the old year and forward to the new. But this persumably wasn't what the Romans intended, given that their January (Januarius) was the 11th month of the year.

A modern astronomical twist is that one of Saturn's moons, Janus, has a two-part, forward-and-backward connection not realized when it was named. Janus is one of two broken halves of an earlier Saturnian moon. The other "half" is Epimetheus and, amazingly, it trades places with Janus, switching which moon leads and which one trails, as they orbit near the rings.

The Sirius-based and Pleiades-based years. Several cultures based their year on positions of nighttime stellar objects — objects that happen to be splendidly visible on January evenings. The ancient Egyptians noted that the heliacal (dawn) rising of Sirius coincided with the annual summer flooding of the Nile — so this rising became the marker of the Egyptian New Year. The Druids chose the mid-autumn acronychal (sunset) rising of the Pleiades, probably when the year's agriculture ended, to mark their New Year (a holiday that eventually transformed into Halloween).



BOB KING

Four beginnings on a winter evening. But we could pick several sidereal times that occur on January evenings to be our own unofficial start of the starry year.

First, nightfall in early January. Which hour of right ascension is on or near the meridian? The zero hour. Last month we looked at this state of the heavens in the evenings of November and December. M31, the Andromeda Galaxy, nears the zenith. Orion is just risen — indeed, my 40° N version of Skygazer's Almanac indicates that Betelgeuse rises at sunset on December 31st.

But suppose we go out four hours after nightfall. Now on the meridian is noble Taurus, featuring the Hyades, Pleiades, Crab Nebula, and more. Regulus has risen, Deneb is setting. And why is this an appropriate "starting time" for the heavens? "A" may be the first letter of our alphabet because its original upside-down form was a little picture of Taurus and his horns — and something like 4,000 years ago Taurus contained the vernal equinox and was therefore the first constellation of the zodiac.

Six hours after nightfall, Leo is fully risen, Pegasus is setting, but what's on the meridian makes this another candidate for being our starting-time-of-the-stars hour: Orion, the brightest constellation.

We finally reach seven hours after New Year's nightfall — midnight — and what's on the meridian? Marvelously, the brightest star by far, mighty Sirius — making this another grand stellar beginning. ✦

New Year's Celebration

Venus and Saturn come together for a close conjunction early in January.

The year begins with only one bright planet, Mercury, visible at dusk — and that for only about a week. But two brightening superior planets, Jupiter and Mars, come up as the night progresses, Jupiter in the second half of the evening, Mars in the middle of the night.

Then, before morning twilight, two more bright planets rise: Venus and Saturn. They engage in a spectacularly close conjunction on January 9th with Antares to their lower right, then rapidly pull away from each other for the rest of the month. In the last week of January, Mercury emerges at dawn and climbs to end the month not far lower left of Venus — making all five bright classical planets visible at once in the sky.

DUSK

Mercury shines at magnitude –0.4 on New Year's Day, about 10° above the southwest horizon some 30 minutes after sunset for viewers at mid-northern latitudes. By the American evening of January 8th, it's only up to 5°, sets less than an hour after the Sun, and has dimmed to a perhaps unobservably faint +1.8. Mercury races through inferior conjunction, 3° south of the Sun, on January 14th. At its next inferior conjunction, on May 9th, we'll see it pass right across the Sun for its first transit in 10 years.

As dusk fades to full night, **Uranus** is just past the meridian, **Neptune** much farther past. Find them in Pisces and Aquarius, respectively, using the charts on page 49 in the September 2015 issue or at **skypub.com/urnep**.

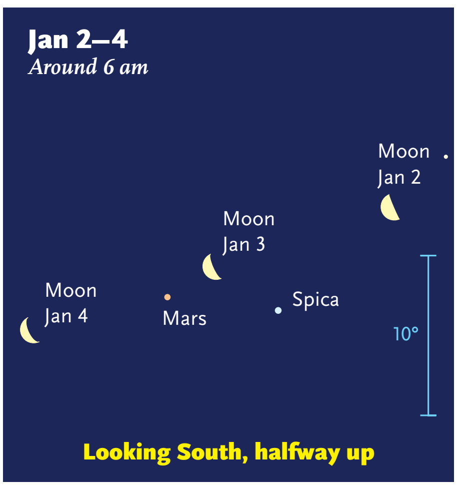
EVENING TO DAWN

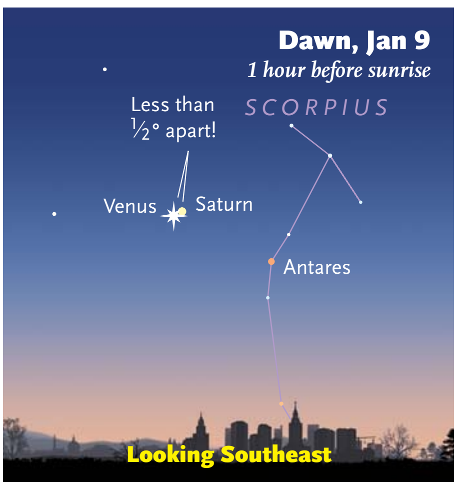
Jupiter marches onto the sky's stage earlier each evening, rising around 10:30 p.m. on January 1st but around 8:30 p.m. by January 31st. This means that it crosses the meridian in darkness a little before 5 a.m. as the month begins, a little before 3 a.m. as it ends. The big planet brightens from magnitude –2.2 to –2.4 this month. It's stationary in right ascension in extreme southeastern Leo on January 8th, then slowly begins to creep westward with retrograde motion. Commencement of this motion means that its opposition and closest approach to Earth are just two months away. Jupiter's apparent equatorial diameter increases from 39″ to more than 42″ over the course of the month.

Mars comes up around 1:30 a.m. on New Year's Day and little more than half an hour earlier as January closes. The orange dot of the planet begins the year 6° from slightly brighter Spica, but moves rapidly east from Virgo into Libra around mid-month. It ends January just 1.3° north of double star Alpha (α) Librae (Zubenelgenubi). While Mars makes this trek, it brightens noticeably, improving by half a magnitude to +0.8. Telescopes show its diameter grow from 5.6″ to a still rather diminutive 6.8″ this month. At its opposition in May, the Red Planet will appear about three times wider.

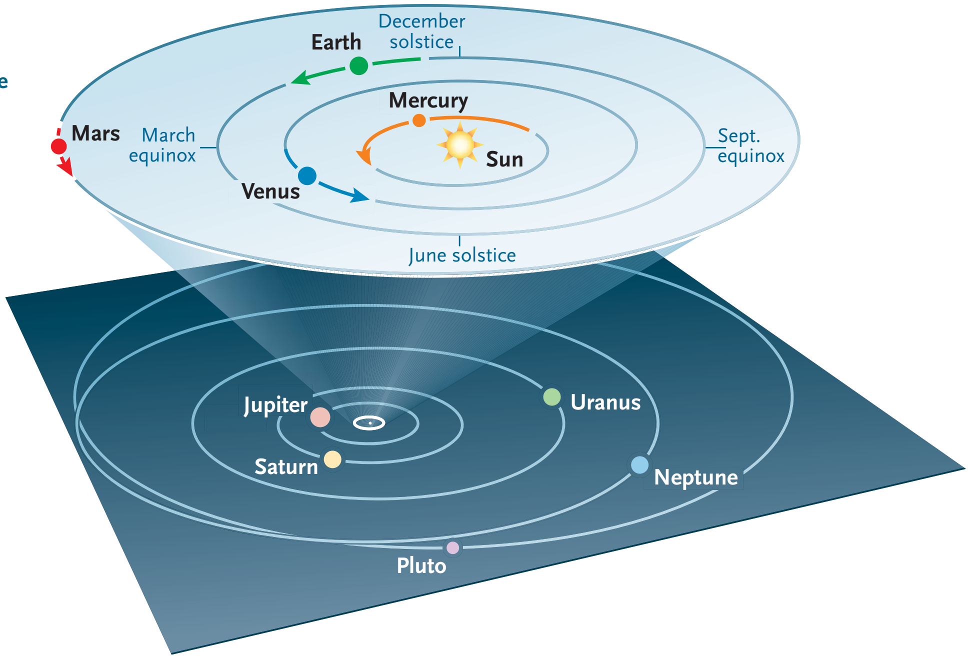
Venus rises around 3 hours before the Sun on New Year's Day, but only 2 hours before by month's end. Watch as the gap rapidly closes between it and **Saturn** in the first week of 2016. The Moon poses near the planetary pair on January 6th and 7th (see below). On the dawn of January 9th, Saturn shines less than ½° upper right of Venus for observers in North America. Venus and Saturn fit together in a medium-power telescopic view that morning. At magnitude –4.0 Venus burns about 60 times brighter than does Saturn at magnitude +0.5. But Saturn is noticeably brighter than Antares, 7° lower right of them. Dazzling gibbous Venus (79% sunlit) appears slightly less than 14″ tall, and comparatively pale Saturn appears more than 15″ wide, encircled by well-tilted rings that span 35″.

Venus moves with great apparent speed this month, and soon after its conjunction





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. 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.



ORBITS OF THE PLANETS
The curved arrows show each planet's movement during January 2016. The outer planets don't change position enough in a month to notice at this scale.

with Saturn opens up a sizable gap. Starting January hardly more than 1° from Beta (β) Scorpii, Venus races deep into Sagittarius, passes near M20 (the Trifid Nebula) on January 24th, and arrives north of the Teapot's handle by month's end.

DAWN

Mercury emerges into dawn visibility in the final week or so of January, its zero-magnitude light pulling to within 8° lower left of Venus.

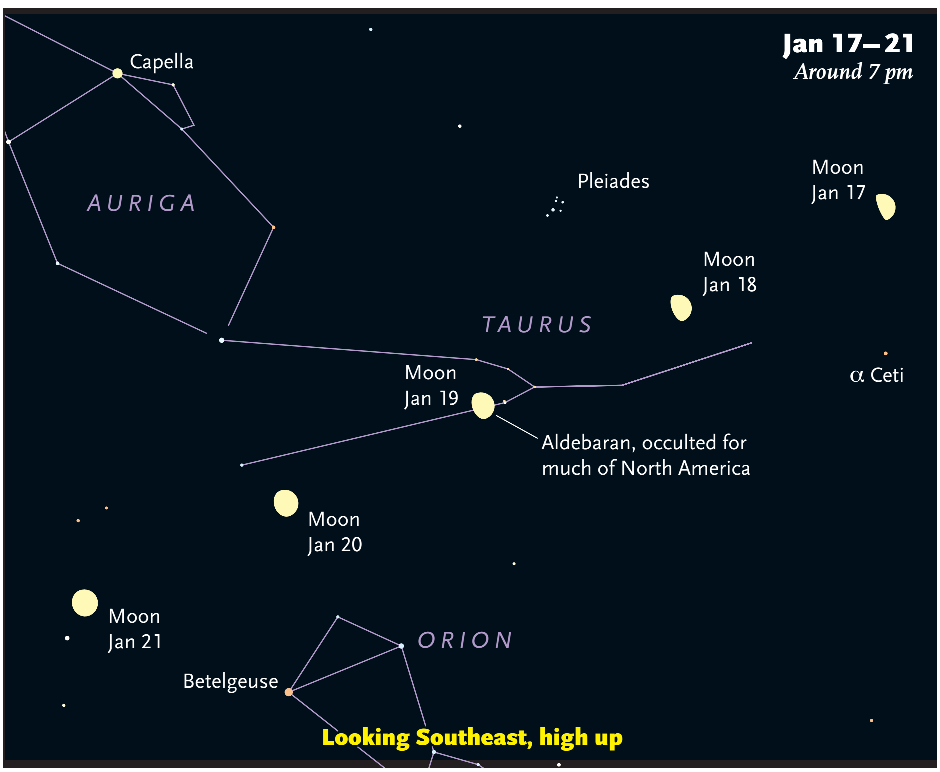
Pluto is at conjunction with the Sun on January 6th and unobservable all month.

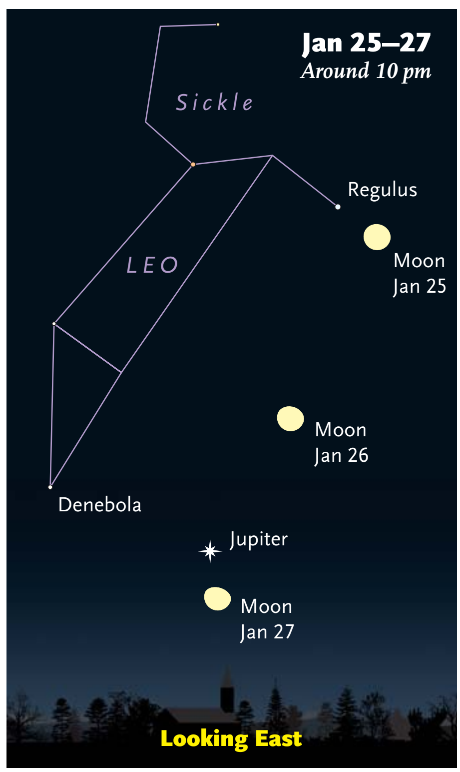
EARTH AND MOON

Earth reaches perihelion, the closest we come to the Sun each year, on January 2nd, when it's only 98% of its average distance from the Sun.

The **Moon** is a thick waning crescent just a few degrees from Mars and Spica on the morning of January 3rd. A much thinner lunar slice hangs above the Venus–Saturn pair on January 6th and closer to the lower left of them on January 7th.

Back in the evening sky, the waxing gibbous Moon passes through the Hyades and occults Aldebaran for much of North America on January 19th; see page 49. The waning gibbous Moon is left or lower left of Regulus late on the evening of January 25th. On January 27th, it rises just below Jupiter. ✦





Quads to Come Out of Hiding

The least-observed major meteor shower should be in plain sight this year.

Will this be the January you add another major meteor shower to your life list? If the Quadrantids have eluded you up to now, you're not alone.

Maybe you've read that they're one of the richest annual showers, with peak rates variously quoted as 60 to 200 visible per hour under ideal conditions. And maybe you've gone out and been skunked. Their maximum lasts just a few hours, and if it doesn't fall between midnight and dawn for your part of the world, you miss it.

Brian Emfinger of Arkansas caught an early Quadrantid fireball on the morning of January 3, 2012. Unlike most meteors, it began close to the radiant — meaning it flew nearly toward the camera, moving very far through the atmosphere before ending in a terminal burst. The Big Dipper is above it. A shower's radiant is the perspective point where all its meteors would appear to come from if you could see them long before they hit Earth's atmosphere.

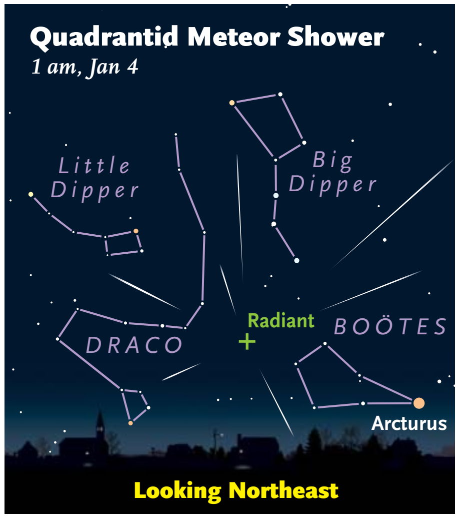
This year North Americans should be in luck. The International Meteor Organization (IMO) predicts that the shower's peak will be centered around 8^h Universal Time January 4th (3 a.m. that morning Eastern Standard Time; midnight January 3–4 PST). That prediction is based on a few well-observed showers since 1992. But a model by Jérémie Vaubaillon predicts a Quadrantid peak about 8 hours earlier, which would be optimal for observers in Europe.

Complicating things, mass sorting in the meteoroid stream means that faint meteors are their most abundant before the visual peak, and bright ones after.

The Moon will be a thick waning crescent on the morning of Monday the 4th. It will rise around 2 a.m. local time but shouldn't pose any great problem.

The Quads are under-studied by amateur meteor counters, especially in the hours and days away from the peak, no doubt because of the late-night January cold. (Only in northern latitudes does the shower's radiant rise high.) So think adventure. To keep warm, snugify in many layers from head to feet with no pinches or thin spots. An electric hot pad buttoned inside your clothes will help.

The shower's radiant is in the obsolete constellation Quadrans Muralis (the mural quadrant), off the handle of the Big Dipper between the head of Boötes and the arched back of Draco. It's reasonably well up in the northeast after about 1 a.m.



Not until early morning does the Quadrantid radiant start to rise high. (And don't expect to see several meteors at once!)

local time and climbs higher until dawn. The higher a shower's radiant, the more meteors appear all over the sky.

You can join amateurs doing scientific meteor counts for the IMO if you have at least a moderately dark sky and an hour or more to commit. You'll need to follow the standardized method, which includes determining your faintest naked-eye stars in the part of the sky you're watching. Your latitude and longitude, the time every half hour or so, any minor obstructions by clouds or trees, and time spent looking away also need to be recorded so the IMO can correct your observed rate to the standardized zenithal hourly rate. This way, observers' counts from around the world can be compared to track what the shower does throughout its duration — if enough people participate! For the instructions and how to report, see **imo.net/visual/major**.

FOLLOW THE SHOWER ONLINE As Quadrantid observers report their counts to the International Meteor Organization, you can watch this year's activity curve develop hour by hour on the homepage of imo.net.

An Easy Aldebaran Occultation

It happens in the evening. High in the sky. On the Moon's dark limb rather than the bright limb. For almost all of the U.S. and Canada. What's not to like?

On the evening of January 19th, the Moon performs another in its series of 49 monthly Aldebaran blackouts that will continue through September 2018. But most of them don't happen for wherever you are, and nearly half of those that do occur in daylight. (Though don't let that stop you. Telescope users had little trouble viewing and imaging Aldebaran next to the Moon's bright limb for its daylight occultation on October 2nd.)

The Moon on the evening of January 19th will be waxing gibbous. A waxing Moon leads with its dark edge as it moves along its orbit against the starry background. So Aldebaran will disappear on a dark background away from the dazzling glare of the sunlit lunar surface.

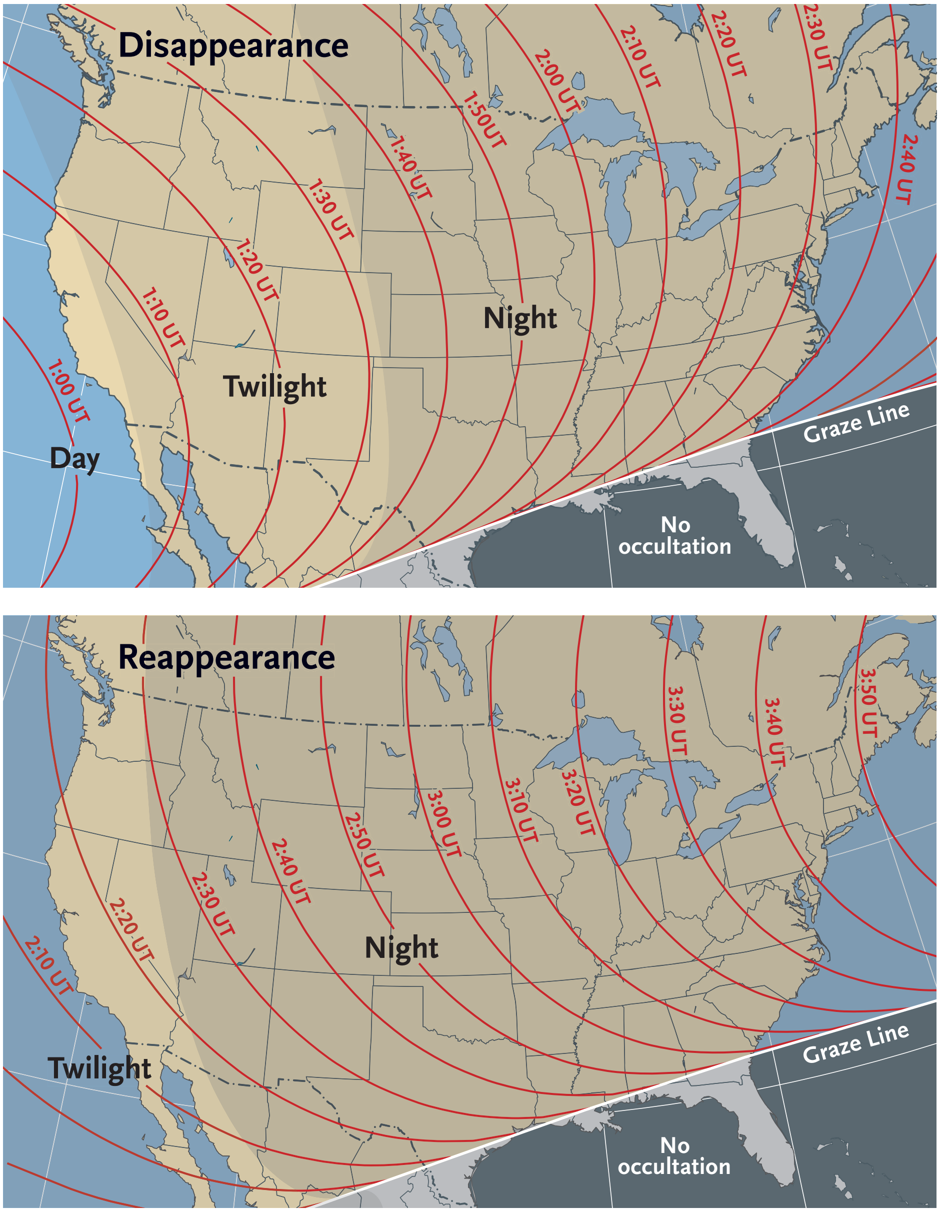
With the Moon 82% illuminated, its night portion will probably be too weakly Earthlit to show in a scope. So this occultation is not as ideally easy as one where you can watch the Earthlit limb creep right up against the star. To catch the moment Aldebaran vanishes, you'll have to keep steady watch on it as the time draws near.

Its reappearance on the bright limb will be less obvious, but still easy to see if you're watching.

You can find when the star will disappear and reappear for your location from the charts here. Or you can refer to the detailed timetables for many locations at **lunar-occultations.com/iota/bstar/bstar.htm** as the date approaches. (Note that the text file you get consists of three separate tables: for the disappearance, the reappearance, and the locations of cities.)

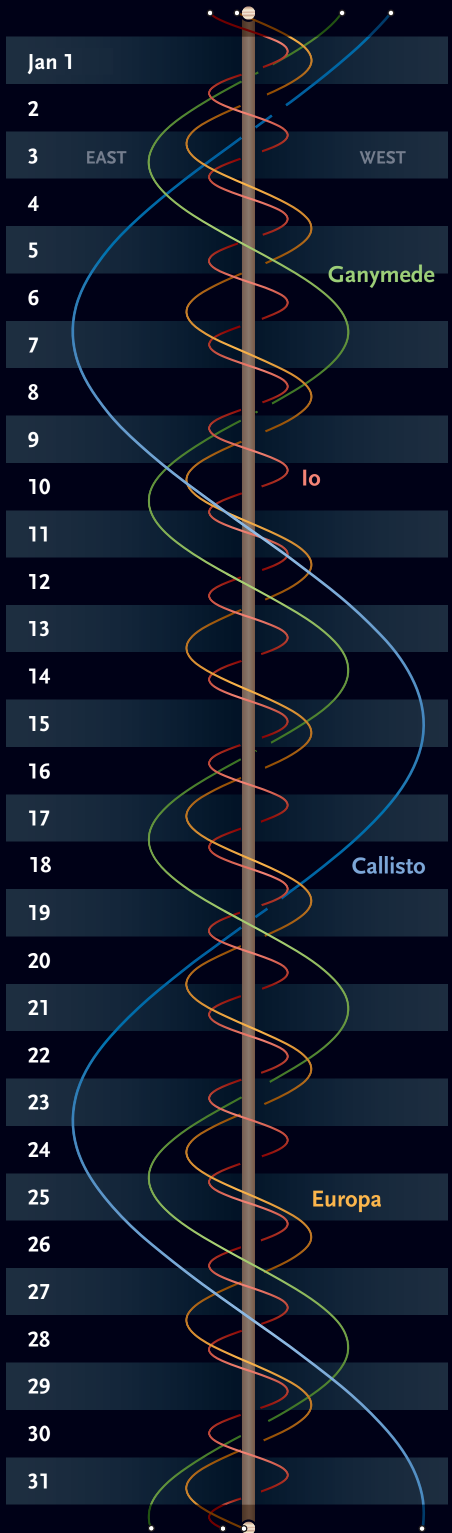
The occultation's southern limit — the *graze line* where the star skims the Moon's southern limb — runs from south Georgia near the Gulf Coast and across south Texas. Along this line you might see the star wink out and back more than once as it skims behind lunar hills and valleys along the southern limb. Aldebaran has a large apparent disk as stars go, 21 milliarcseconds wide. That's as big as a pea seen from just 15 miles (25 km) away. So you may observe Aldebaran fading and reappearing not quite instantaneously if the Moon's edge skims it at a low angle from your location.

A grazing occultation is the only way an amateur can ever "resolve" the face of a star other than the Sun. A nearby orange or red giant like Aldebaran offers your best chance.



Mark your location, then interpolate between the red lines to find the Universal Time of Aldebaran's disappearance or reappearance. (Remember, 0:00 UT is 7:00 p.m. January 19th EST, or 4:00 p.m. PST.) The Moon and Aldebaran will be high in the sky for observers across the map.

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 Sights

Jupiter in January grows from 39 to 42 arcseconds wide, crossing my personal dividing line from "small Jupiter" to "big Jupiter." But it still doesn't shine very high until well after midnight.

Any telescope shows Jupiter's four big Galilean moons. Binoculars almost always show at least two or three. Identify them using the diagram at left.

All the January interactions between Jupiter and its satellites and their shadows are tabulated on the facing page.

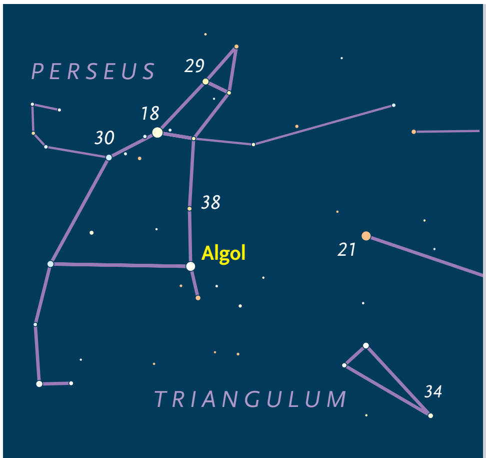
Below are the times, in Universal Time, when Jupiter's Great Red Spot should rotate across the planet's central meridian. The dates, also in UT, are in bold. (Eastern Standard Time is UT minus 5 hours.)

December 1, 3:22, 13:18, 23:13; **2,** 9:09, 19:05; **3,** 5:00, 14:56; **4,** 0:52, 10:48, 20:43; **5,** 6:39, 16:35; **6,** 2:30, 12:26, 22:22; **7,** 8:17, 18:13; **8,** 4:09, 14:04; **9,** 0:00, 9:56, 19:51; **10,** 5:47, 15:43; **11,** 1:39, 11:34, 21:30; **12,** 7:26, 17:21; **13,** 3:17, 13:13, 23:08; **14,** 9:04, 19:00; **15,** 4:55, 14:51; **16,** 0:47, 10:42, 20:38; **17,** 6:34, 16:29; **18,** 2:25, 12:21, 22:16; **19,** 8:12, 18:08; **20,** 4:03, 13:59, 23:55; **21,** 9:50, 19:46; **22,** 5:42, 15:37; **23,** 1:33, 11:29, 21:24; **24,** 7:20, 17:16; **25,** 3:11, 13:07, 23:03; **26,** 8:58, 18:54; **27,** 4:49, 14:45; **28,** 0:41, 10:36, 20:32; **29,** 6:28, 16:23; **30,** 2:19, 12:15, 22:10; **31,** 8:06, 18:02.

January 1, 3:57, 13:53, 23:48; **2,** 9:44, 19:40; **3,** 5:35, 15:31; **4,** 1:27, 11:22, 21:18; **5,** 7:14, 17:09; **6,** 3:05, 13:00, 22:56; **7,** 8:52, 18:47; **8,** 4:43, 14:39; **9,** 0:34, 10:30, 20:25; **10,** 6:21, 16:17; **11,** 2:12, 12:08, 22:04; **12,** 7:59, 17:55; **13,** 3:50, 13:46, 23:42; **14,** 9:37, 19:33; **15,** 5:29, 15:24; **16,** 1:20, 11:15, 21:11; **17,** 7:07, 17:02; **18,** 2:58, 12:53, 22:49; **19,** 8:45, 18:40; **20,** 4:36, 14:31; **21,** 0:27, 10:23, 20:18; **22,** 6:14, 16:09; **23,** 2:05, 12:01, 21:56; **24,** 7:52, 17:47; **25,** 3:43, 13:39, 23:34; **26,** 9:30, 19:25; **27,** 5:21, 15:17; **28,** 1:12, 11:08, 21:03; **29,** 6:59, 16:55; **30,** 2:50, 12:46, 22:41; **31,** 8:37, 18:33.

These times assume that the spot will be centered at System II longitude 230°. It will transit 1⅔ minutes earlier for each degree less than 230°, and 1⅔ minutes later for each degree greater than 230°. Features on Jupiter appear closer to the planet's central meridian than to the limb for 50 minutes before and after they transit.

A light blue or green filter slightly improves the clarity of Jupiter's reddish and brownish markings.



The predictions at right come from new information about Algol's changing period from the AAVSO. They're based on the heliocentric elements Min. = JD 2440953.5087 + 2.867307$5E$, where E is any integer.

Minima of Algol

Dec.	UT	Jan.	UT
3	17:41	1	9:53
6	14:30	4	6:42
9	11:20	7	3:31
12	8:09	10	0:20
15	4:58	12	21:09
18	1:48	15	17:59
20	22:37	18	14:48
23	19:26	21	11:37
26	15:15	24	8:26
29	12:04	27	5:16
		30	2:05

Asteroid Occultations

On the night of January 1–2, telescope users from southern Georgia to San Diego can watch for an 8.8-magnitude star in the feet of Gemini to be occulted by the faint asteroid 1173 Anchises for up to 7 seconds.

On the night of January 21–22, the 9.9-magnitude asteroid 115 Thyra will occult a 9.0-magnitude star near the heads of Gemini along a narrow track from southern New Jersey through the San Diego area. Watch them merge, before their combined light drops by 1.3 magnitudes for up to 7 seconds.

On the evening of January 23rd, along a track from southern New Jersey to northern California, faint 866 Fatme will occult a 9.5-magnitude yellow star in central Gemini for up to 5 seconds.

Late on the evening of January 27th, observers from eastern Massachusetts northwestward through the Ottawa area may see a 9.5-magnitude star at the Orion-Monoceros border being blacked out for up to 7 seconds by 329 Svea.

For maps, time predictions, and finder charts for the stars to be occulted, see **asteroidoccultation.com/IndexAll.htm**.

For how to time these events and where to report, see **asteroidoccultation.com/observations**.

Videorecording yields the desired accuracy, and it's not as expensive or difficult as you may think; see the "Equipment" heading on that page.

For advice and help, join the International Occultation Timing Association (IOTA) discussion group at **groups.yahoo.com/neo/groups/IOTAoccultations**. ✦

Phenomena of Jupiter's Moons, January 2016

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

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 4 hours ahead of Eastern Daylight Time). 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. Predictions courtesy IMCCE / Paris Observatory.

The Dawn of Global Planet Watches

The International Planetary Patrol Program used a worldwide network of astronomers to keep vigil on the planets in the 1970s.

These days the pages of *Sky & Telescope* are packed with colorful views of solar system bodies. Many come from spacecraft, of course, but amateur observers around the world also compete for our attention with spectacular images they've acquired using off-the-shelf equipment set up in their backyards and driveways. We celebrate the patience and skill of these talented observers, and professional planetary scientists work closely with them to keep track of planetary goings-on.

But let's also remember that it wasn't always so easy to obtain sharp, detailed images.

In the late 1960s, at the dawn of the Space Age but well before the Digital Age, astronomers at Lowell Observatory spearheaded a remarkably ambitious planetary-observing effort. Dubbed the International Planetary Patrol Program (IPPP), the project aimed to monitor atmospheric and other changes on all major planets continuously. Funded by NASA, it established a network of eight observatories around the world and equipped them with customized cameras and dedicated telescopes designed to produce identical image scales. No collaborative effort of this extent had been attempted before. In fact, during 1969–70, its first year of operation, the patrol obtained as many usable images of Mars and Jupiter as had been taken during the preceding half century.

S&T: GREGG DINDERMAN

The International Planetary Patrol Program established a global network of observatories that could monitor planetary activity around the clock.

International Planetary Patrol Program Observatories

1. Lowell Observatory, Flagstaff, Arizona
2. Mauna Kea Observatory, Hilo, Hawai'i
3. Mount Stromlo Observatory, Canberra, Australia
4. Perth Observatory, Bickley, Australia
5. Astrophysical Observatory, Kodaikanal, India
6. Republic Observatory, Johannesburg, South Africa
7. Cerro Tololo Inter-American Observatory, Chile
8. Magdalena Peak Station, New Mexico State University, Las Cruces

It's important to appreciate the scientific and technological context in which the program was conceived. Professional astronomers had largely abandoned studies of the Moon and planets in the first half of the 20th century in favor of galactic astronomy and astrophysics. Consequently, by the early 1960s, we lacked precise rotation periods for Mercury and Venus, nor did we fully understand the circulation of Venus's opaque cloud deck. Despite more than a century of visual and photographic work by amateurs and some professionals, astronomers still lacked quantitative information regarding many aspects of Jupiter's atmosphere, such as oscillations in the Great Red Spot and the change in rotation period of the Jovian cloud deck as a function of latitude. Similar uncertainty existed about Saturn's atmosphere and ring system. The advent of the Space Age, however, triggered renewed interest in solar system astronomy and led to observational efforts like the IPPP.

Our understanding of Mars in the early 1960s was also at a crossroads. We didn't understand the nature of the planet's variegated surface features, its clouds, dust storms, or the true composition and seasonal variations of its polar caps. As William Sheehan points out in *The Planet Mars: A History of Observation & Discovery,* although Percival Lowell's canal theory had largely fallen into disrepute, his notions about water, atmosphere, and vegetation on Mars still persisted, at least in popular imagination. This, coupled with the start of the space

Klaus Brasch *got interested in astronomy as a teenager around the time of Sputnik 1 and has been a keen lunar and planetary observer ever since.*

Klaus Brasch

The global IPPP network routinely recorded the planets on a nearly hourly cadence. This sequence shows Mars on May 27–28, 1969.

race and the promise of human exploration to the Moon and later Mars, left a glimmer of hope that the Martian environment might be relatively benign. Hence, as late as 1965, the idea persisted that the color and apparent seasonal darkening of some Martian features might be due to lichen or similar vegetation.

Solar System Sentinels

William A. Baum (1924–2012), a remarkably versatile investigator and pioneer in many areas of astronomy, led the IPPP team. Other key contributors included cartographers Leonard J. Martin (1930–97) and Jay L. Inge (1943–2014). Probably best known to seasoned Mars observers and to *Sky & Telescope* readers was astronomer Charles "Chick" Capen (1926–86).

The IPPP had a very specific goal: to secure and archive uninterrupted planetary observations in support of the soon-to-follow NASA planetary space missions. The global network consisted of six and later eight observatories equipped with telescopes having 24- to 26½-inch apertures, including classical refractors like Lowell's 24-inch Clark and four specially built 24-inch f/75 Cassegrain reflectors.

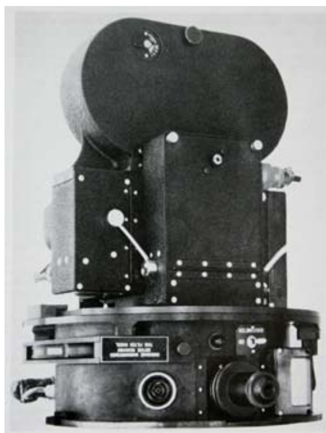
Baum's team also designed advanced 35-mm film cameras that incorporated innovative focusing, guiding, color-filter selection, and calibration. Whenever possible, observers recorded the planets hourly at each station on Kodak 2498 RAR film, in 14-exposure sequences through red, green, blue, and ultraviolet filters, along with the date, time, observer, location, and color on each frame. Later, technicians in Flagstaff developed all the film under tightly controlled conditions. By the time the IPPP ended in the late 1970s, its observers had obtained some 1.2 million individual planetary images.

While IPPP participants monitored all major planets, their most productive results involved Mars. A half century of prior visual and photographic work had documented numerous atmospheric phenomena, including yellow, white, and blue clouds; dust storms; polar hazes; and a recurring W-shaped cloud over the Tharsis region. Since analysts were unsure about the exact nature of most Martian atmospheric features at the time, they classified them on the basis of the color or wavelength at which they appeared most prominent.

To learn more about the project's key players, visit http://is.gd/IPPP_extras.

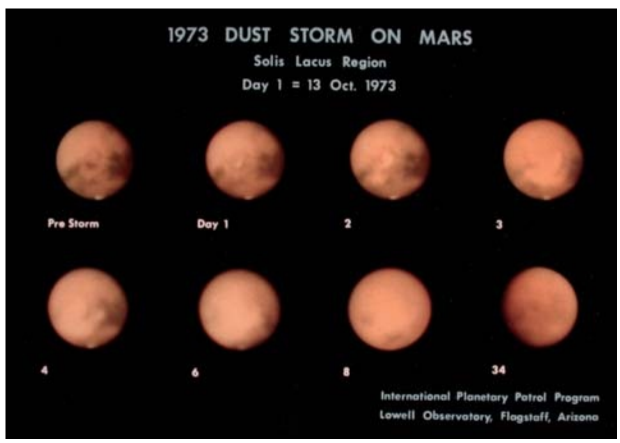
The IPPP's observers documented major dust storms in 1971 and 1973 and continued to scrutinize the Red Planet up to the Vikings' 1976 arrivals. The earlier storm coincided with the arrival of Mariner 9 and blanketed the orbiter's view of the Martian surface for several weeks. IPPP imagery helped establish not only the dynamics and speed of the storm's development but also enabled understanding of climatic changes on the planet, including cloud formation and seasonal variations in the polar caps.

We learned to distinguish between polar ice and the often more extensive polar "hood" of clouds that extended



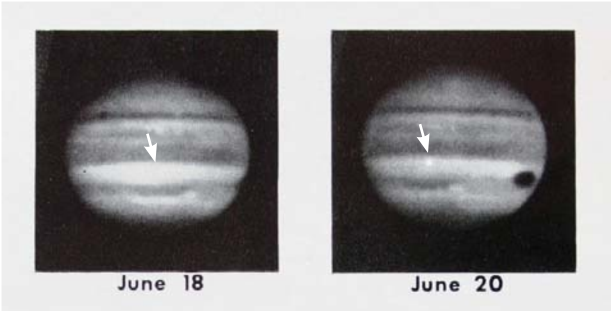
Left: **Observers used this custom-designed, semi-automated, 35-mm film camera for all IPPP planetary photography.**

Below: **The Solis Lacus region on Mars erupts with a major dust storm in this month-long sequence of IPPP tri-color composite images. Day 1 is October 13, 1973.**



LOWELL OBSERVATORY (3)

The author thanks Lowell archivist Lauren Amundson and former director Robert Millis for invaluable assistance.



LOWELL OBSERVATORY

A sequence of ultraviolet-filtered images shows the development of a disturbance (arrowed) in Jupiter's South Equatorial Belt. The dark oval (June 20th, far right) is the Great Red Spot.

to lower latitudes. Results also showed conclusively that the "seasonal" variations in the albedo features — the ones that had so intrigued earlier observers — resulted entirely from changes in wind patterns and local features revealed and obscured by blowing dust. When planetary astronomers compared the familiar features studied telescopically for more than three centuries with spacecraft-derived images, they found only minimal correlation with Martian topography — and no indication of surface vegetation or the contentious "canals."

Images of Jupiter constituted more than half of the IPPP's database, yielding a wealth of information about the planet's cloud deck. The results confirmed both abrupt and gradual atmospheric changes, including large- and small-scale disturbances, a 90-day oscillation in the longitude of the Great Red Spot, and rotational velocities in cloud features that correlated with both their color and latitude. IPPP coverage overlapped with the Pioneer 10 and 11 flybys of Jupiter in 1973 and 1974, respectively, showing that many dark features are the tops of vertical convection cells. These data formed the basis for future studies and modeling of Jupiter's dynamic atmosphere.

Observers also examined Saturn's ring system to probe the light-scattering properties of its particulate constituents. This effort revealed that particles in the A and B rings have similar compositions but different densities, information that anticipated the arrival of Pioneer 11 at Saturn and its passage through the planet's rings.

The program collected far fewer photographs of Venus than of Mars or Jupiter, due to the inherent difficulty of observing this planet well. However, some excellent ultraviolet sequences helped confirm previous reports that the planet's upper atmosphere exhibited retrograde rotation, as did the planet's globe, but with a period of just 4 days rather than the 243 days of Venus itself. This laid the groundwork for subsequent modeling of the planet's unusual wind-shear patterns.

This pioneering program wound down in the late 1970s, superseded both by better electronic imaging and photometric technology and by close-up exploration with space probes and landers. Nevertheless, the IPPP provided crucial information that helped get the maximum return from those missions. Moreover, its broad, extensive international cooperation became the model for the host of global astronomical collaborations that would follow. ✦

Viewing the Planets in 2016

This coming year offers the following opportunities to view the solar system's major planets at their best — as well as a transit of Mercury on May 9th.

Mercury	Greatest western (morning) elongations: February 7 (best), June 5, September 28 Greatest eastern (evening) elongations: April 15, August 16 (best), December 11
Venus	Greatest western elongation (39°): January 1 Greatest eastern elongation (47°): December 31
Mars	Opposition: May 22 (diameter: 22″; declination: –22°)
Jupiter	Opposition: March 8 (diameter: 44″; declination: +6°)
Saturn	Opposition: June 3 (diameter with rings: 43″; declination: –21°)

The Moon • January 2016

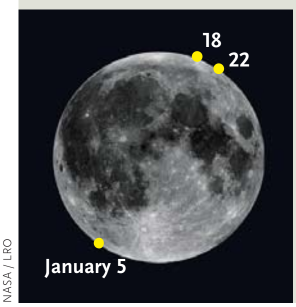
Phases

LAST QUARTER
January 2, 5:30 UT

NEW MOON
January 10, 1:30 UT

FIRST QUARTER
January 16, 23:26 UT

FULL MOON
January 24, 1:46 UT



NASA / LRO

Distances

Apogee 251,235 miles	**January 2, 12ʰ UT** diam. 29′ 33″
Perigee 231,796 miles	**January 15, 2ʰ UT** diam. 32′ 2″
Apogee 249,609 miles	**January 30, 9ʰ UT** diam. 29′ 45″

Favorable Librations

Montes Cordillera	**January 5**
Petermann (crater)	**January 18**
Mare Humboldtianum	**January 22**

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

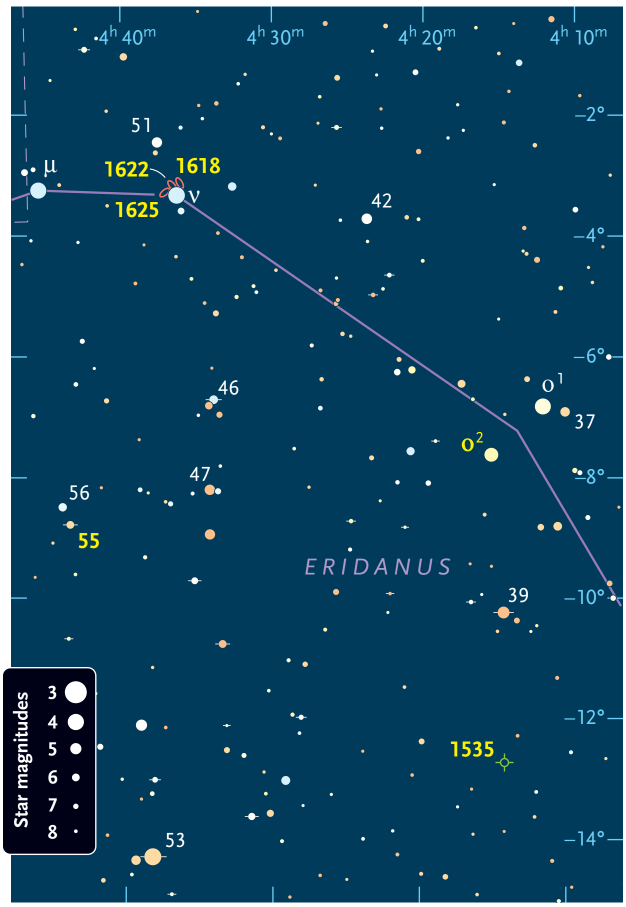
The River

Plumb the hidden depths of an ancient celestial waterway.

The long and winding constellation of Eridanus, the River, begins west of brilliant Rigel, meandering southward in great loops until it plunges below the horizon for those of us at mid-northern latitudes. The river is mythologically tied to Phaethon, the mortal son of Helios, who tried to drive the Sun across the sky in his father's chariot. Phaethon couldn't manage the fiery steeds that pulled the chariot nor fierce beasts such as Taurus and Leo that dwelt in the sky. The horses ran wild, soaring high into the heavens and endangering the palaces of the gods, then plunged close to the ground, setting the Earth afire. To end this disastrous ride, Zeus loosed a thunderbolt at the chariot. Ill-fated Phaethon plummeted from the sky, his charred remains falling into the river Eridanus.

Let's begin our river ride with the beautiful and intriguing triple star system **Omicron^2 (o^2) Eridani**, located 15° west of Rigel. As a handy measure, spread your index finger and pinky finger as far apart as possible. If you hold them at arm's length, they'll span about 15° of sky. Through my 130-mm refractor at 23×, the lovely golden primary watches over a much dimmer companion a spacious 1.4′ to its east-southeast. The companion star is separated into two components when I up the magnification to 63×, although I need to use higher powers when the seeing (atmospheric steadiness) is poor. The brighter star appears white, while the fainter one only 9″ to its north-northwest is, well, not white. It's simply too dim for me to determine the color. However, my 10-inch scope reveals a smoldering reddish ember.

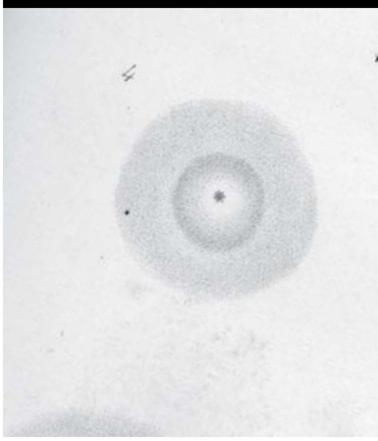
The snowy companion is a white dwarf star, the easiest one to view through a small telescope. It's only 16.2 light-years away from us and separated from its primary



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

The elongated, nearly edge-on spiral galaxies NGC 1618, NGC 1622, and NGC 1625 form a tiara above the brighter jewel Nu Eridani.

ADAM BLOCK / NOAO / AURA / NSF



MEMOIRS OF THE ROYAL ASTRONOMICAL SOCIETY

After observing NGC 1535 on multiple evenings in the winter of 1862 with a 48-inch reflector, William Lassell described it as "a very remarkable Planetary Nebula," with a nucleus that didn't "seem stellar, but a small patch of bright light."

by at least 400 times the Earth-Sun distance, a combination that keeps the dwarf well out of the primary's glare from our vantage point on Earth. This petite star is only 1½ times the diameter of the Earth, yet it weighs in at half the mass of the Sun. A white dwarf is the collapsed core of a low- to intermediate-mass star that shed much of its substance during the late stages of its life. No longer generating heat, a white dwarf will cool until it becomes a "black dwarf." This process takes such an incredibly long time that our universe isn't yet old enough to contain any black dwarf stars.

The ruddy companion is a red dwarf star merely one-fifth the mass of our Sun. The red dwarf and the system's primary are both main-sequence stars, still fusing hydrogen to helium in their cores. Since high-mass stars have shorter main-sequence lives than low mass stars, the burned-out white dwarf must once have been the trinary's brightest and most massive star.

The golden primary star holds a pop-culture claim to fame. In the world of science fiction, it's the star that the planet Vulcan orbits in the television and movie universe of *Star Trek*.

South of Omicron^2 you'll find yellow-orange 39 Eridani, and if you drop the same distance southward again, you'll come to a splendid planetary nebula, **NGC 1535**. It bears the captivating nickname Cleopatra's Eye, coined by amateur/professional astronomer Greg Crinklaw. Let's see why.

Cleopatra's Eye announces its presence in the form of a tiny, bluish disk through my 130-mm scope at 23×. At 164× it shows a fairly bright central star in a bright, slightly oval (northeast-southwest) ring that's nested in a wide, modestly bright, outer halo. The nebula is very pretty at 234×. Its central star is plainly visible, and its ring has an ashen, blue-green cast. The ring's outer border is well-defined, but its inner edge is rather indistinct. I estimate the nebula's dimensions as roughly ¾′ × ⅔′. Switching to my 10-inch reflector at 220×, the hollow surrounding the central star doesn't seem to be a uniform, round hole so much as a region mottled with darker patches. Can you imagine Cleopatra's blue and green eye shadow and the seductive star-twinkle in her eye?

Swimming in the Celestial Stream

Object	Type	Mag(v)	Size/Sep	RA	Dec.
o^2 Eri	Triple star	4.5, 10.0, 11.5	82″ (A, BC), 9.0″ (BC)	04^h 15.3^m	–07° 39′
NGC 1535	Planetary nebula	9.6	48″ × 42″	04^h 14.3^m	–12° 44′
NGC 1618	Spiral galaxy	12.7	2.3′ × 0.8′	04^h 36.1^m	–03° 09′
NGC 1622	Spiral galaxy	12.5	3.6′ × 0.7′	04^h 46.6^m	–03° 11′
NGC 1625	Spiral galaxy	12.3	2.1′ × 0.5′	04^h 37.1^m	–03° 18′
55 Eri	Double star	6.7, 6.8	9.3″	04^h 43.6^m	–08° 48′
NGC 1421	Spiral galaxy	11.4	3.5′ × 0.9′	03^h 42.5^m	–13° 29′

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.

Sue French welcomes your comments at scfrench@nycap.rr.com.

The renowned British observer William Herschel discovered NGC 1535 with his 18.7-inch reflector on the night of February 1, 1785. His log reads, "A very curious planetary. Very bright, of a uniform brightness all but the edges, which are ill defined; about half a minute in diameter . . . perfectly round or perhaps a very little elliptical." In 1862 William Lassell sketched NGC 1535 as seen through his 48-inch reflector and called it "An extraordinary and beautiful Planetary Nebula." Both observers used telescopes with speculum-metal mirrors, which were considerably less reflective than today's aluminum-on-glass mirrors.

NGC 1618, **NGC 1622**, and **NGC 1625** gather near dazzling Nu (ν) Eridani like moths to a flame (see also the chart on page 64). All three are spiral galaxies whose disks are seen nearly edge on, so they appear quite slender in our sky. This amazing array is certainly visible at 117× through my 130-mm refractor, but the 10-inch scope at 90× gives a more compelling view. NGC 1625 appears fairly bright and intensifies considerably toward the center. NGC 1622 is longer but has faint extremities, and NGC 1618 looks shorter with less difference in brightness between its center and tips.

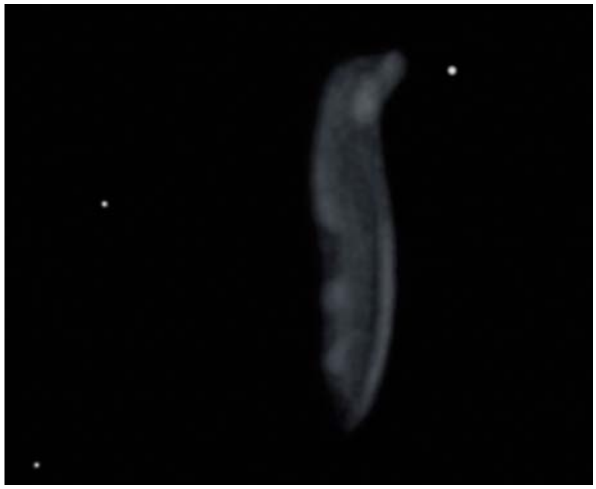
Despite their proximity in the sky, these galaxies were each discovered by a different observer. NGC 1618 was found first, by William Herschel exactly one year to the day after discovering NGC 1535. His son, John Herschel, turned up NGC 1625 some 41 years later. Another 23 years would pass before George Johnstone Stoney, working in Ireland under Lord Rosse, discovered NGC 1622 with the great 72-inch "Leviathan" of Parsonstown. This unusual galaxy trio dwells about 200 million light-years away from us.

Sitting 6° degrees south-southeast of the galaxy triplet, **55 Eridani** is a delightful double star. My 130-mm scope at 23× reveals tightly spaced stars with almost equal magnitudes. They're quite striking at 63×. The slightly brighter star glows buttercup yellow, while its companion to northeast shines with the hue of a pale yellow primrose.

The distance to 55 Eridani is poorly known. According to the Extended Hipparcos Compilation (XHIP), it has a 68% probability of being somewhere between 323 and 460 light-years.

William Herschel discovered **NGC 1421** on the same night as NGC 1535. This edge-on spiral galaxy rests 1.6° south-southwest of reddish orange Pi (π) Eridani (see chart on page 63). Equipped with a wide-angle eyepiece, my 130-mm refractor at 63× shows a nice little north-south slash of light off the southwestern side of a ½° circlet of fairly bright stars. It presents a slim 3′ × ½′ profile and has a 12th-magnitude star 3′ west of its northern tip.

POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY



BERTRAND LAVILLE

Top: **NGC 1421 is seen almost edge-on from our vantage point, making it difficult to discern the (possible) central bar. Large apertures may reveal primary or secondary arms.**

Bottom: **In the eyepiece, NGC 1421 appears as a subtle celestial slug, elongated north-south. Look for the 12th-magnitude star west of the distortion characterizing the galaxy's north end.**

Through my 10-inch reflector at 118×, NGC 1421 displays an odd brightness pattern, rather like a dark lane but more irregular. A magnification of 220× gives a very nice view of this interplay of light and dark, as well as a bright patch on the western side of the galaxy's northern tip.

NGC 1421 is about 84 million light-years distant, much closer to us than the galaxy trio discussed above. In their book *The de Vaucouleurs Atlas of Galaxies*, Ronald Buta, Harold Corwin, and Stephen Odewahn write that NGC 1421's features imply a galaxy with a highly foreshortened bar, or perhaps one that has undergone some type of interaction. Galaxies may become highly disheveled due to tidal interactions or mergers with other galaxies. In a 2005 paper in *Astronomy & Astrophysics*, Frédéric Bournaud and colleagues suggest that this also occurs when galaxies accrete gas from over-dense filaments that thread our universe. The amount of gas accumulated over a few billion years can be a significant fraction of the mass of a galaxy's entire disk. The galaxy becomes visibly distorted if the gas accretes asymmetrically and triggers star formation. This could help explain the frequency of strongly lopsided disks among isolated galaxies such as NGC 1421. ✦

The Definitive Barred Spiral

The only thing as amazing as a supermassive black hole is the galaxy that surrounds it.

"Of all the barred spirals I've looked at, NGC 1365 is the only one that looked like one. It's really quite faint, but the detail was evident, especially with averted vision. It's on the edge of a dense galaxy cluster, which is full of bright galaxies." — September 18, 1993, 20" f/5, 182×

ALTHOUGH I'VE SEEN other galaxies that look like barred spirals since I wrote this observing note in 1993, **NGC 1365** is still my favorite. Sure, it presents a serious challenge to get a satisfying view, but the classic symmetry of its spiral arms is simply irresistible. It also has a remarkable supermassive black hole in its center that mangles both spacetime and the imagination. For the observer with a moderately sized telescope and the willingness to try a difficult observation, what's not to like?

ESO / IDA / DANISH 1.5-M / R. GENDLER, J.-E. OVALDSEN, C. THÖNE, AND C. FERON

Images like the ESO photo shown here prove 1365's visual appeal, and the science of how the black hole might interact with the rest of the galaxy is a fascinating topic all its own. But what exactly makes 1365 difficult to see with amateur-sized telescopes? Location.

Consider this thought experiment: imagine what M51, a near twin to 1365 in apparent size and brightness, might look like in your telescope if it were as far south as the two stinger stars of Scorpius, Shaula and Lesath. For many northern observers, atmospheric extinction reduces its visibility by several magnitudes. Would you even consider observing it this low in the sky?

You might if it never got any higher above the horizon, and that's exactly the case if you want to see 1365 from much of the Northern Hemisphere. In addition to pointing your scope nearly horizontally, you need to wait for the clearest and most transparent nights to give yourself the best chance for a good view — and it's still a challenging observation.

So even though 1365's visual properties are nearly identical to M51's, it's understandably overlooked by observers because of its –36° declination in Fornax. Nonetheless, its gracefully curved and pleasingly symmetrical spiral arms, attached to the ends of a short central bar, are probably familiar anyway because it's so photogenic. It's the very definition of a barred spiral galaxy — in fact, if you Google "barred spiral galaxy," the first entry is an image of 1365.

It's a member of the Abell Galaxy Cluster S373, but it easily stands out as the most visually interesting galaxy of the group. At 56 million light-years away, it's apparently on the near side of the cluster, which averages 62 million light-years distant. At approximately 200,000 light-years across, 1365 is twice the size of our Milky Way. Incredibly, in 2013 its two million-solar-mass central black hole was found to be spinning relativistically by the Nuclear Spectroscopic Telescope Array (NuSTAR) and the European Space Agency's XMM-Newton X-ray satellites (more about this amazing discovery later).

Howard Banich *can be reached at howard.banich@nike.com where he's daydreaming about observing NGC 1365 near the zenith in a very dark, very transparent sky.*

Howard Banich

— NGC 1365

But what can Northern Hemisphere observers do to get a decent visual observation of 1365? Aside from packing your bags or getting a larger telescope, persistence and luck are workable alternatives. Just keep at it — the more often you observe, the more likely you are to see as much as possible from your location.

Most importantly, make a careful sketch because the process of drawing insures you'll see as much as you can at your eyepiece.

The Spiral Arms

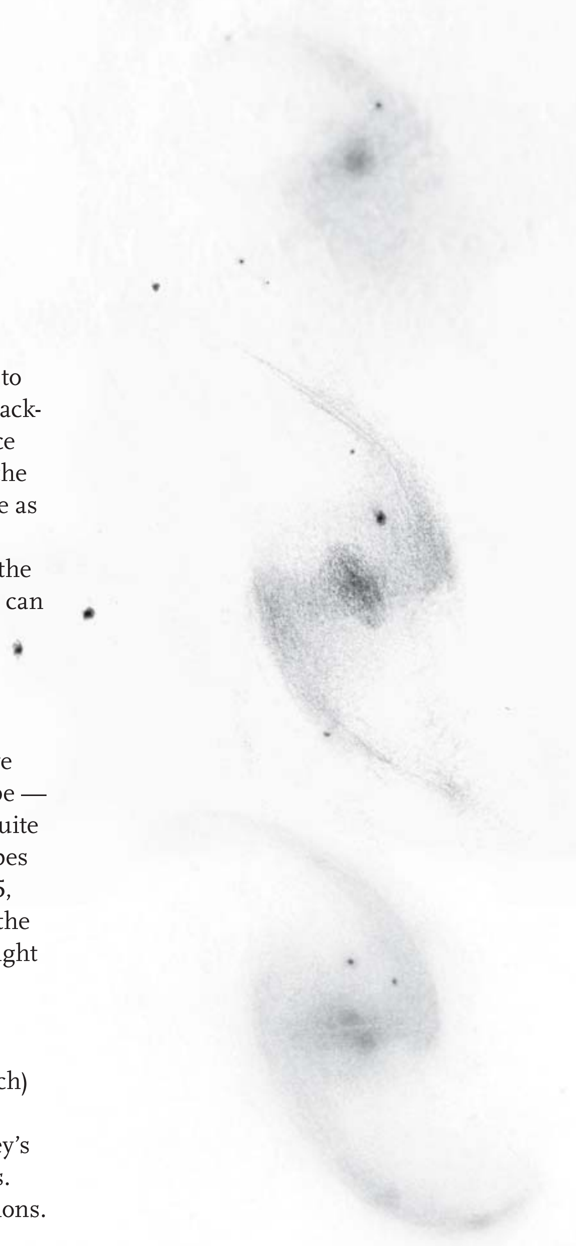
I love seeing spiral arms in unimaginably distant galaxies, and in my book 1365 has two of the best. I've detected the brighter northern arm in an 8-inch scope — see my sketch and observing note — but I couldn't quite tease out the southern arm. However, in 10-inch scopes and larger, both arms can be seen (see *S&T:* Jan. 2015, p. 56). They're the most distinctive part of 1365, and the brightest segments of the arms appear as rather straight brackets on either side of the core.

My series of sketches show the arms at various lengths depending on the conditions and size of the scope. I made both the 2014 (8-inch) and 2008 (28-inch) observations in nearly ideal conditions, but my most detailed view to date was in 2013 through Jimi Lowrey's 48-inch f/4 telescope at his home in Fort Davis, Texas. Unfortunately, it was made under rather poor conditions.

Even so, the view was impressive, easily offering detail that was beyond what I've seen in my own scopes and tantalizing with the promise of more. The long, gracefully curved spiral arms hinted at considerable internal detail with two bright knots in the southern arm, which also showed slightly more of its fainter curved extensions than the northern arm.

These knots don't align with any H II regions of ionized atomic hydrogen, but rather appear to be star clouds. Also note that the base of each spiral arm extends slightly beyond each end of the bar.

I should mention that my sketch was made immediately after coming down the ladder from the eyepiece of Lowrey's 48-inch scope, and although it was a quick-look impression on a sub-par night, this observation sparked an acute case of aperture fever.



"The core is quite bright but the spiral arms are exceedingly dim — I can barely detect the brighter northern arm. The best view is with the 2× Barlow and 13-mm eyepiece, and I'll bet the southern arm will be visible with less moisture in the air." November 16, 2014, 8" f3.3, 103×, 21.50 SQM

"Wow, this is my best view of this terrific galaxy *ever*. The spiral arms get very long when I gently rock the scope back and forth, plus there's some detail in the arms as well. Excellent contrast for being a few degrees above the horizon — a terrific view really, but one day I've got to see this thing from the southern hemisphere!" September 28, 2008, 28" f4, 253× and 408×, 21.95 SQM

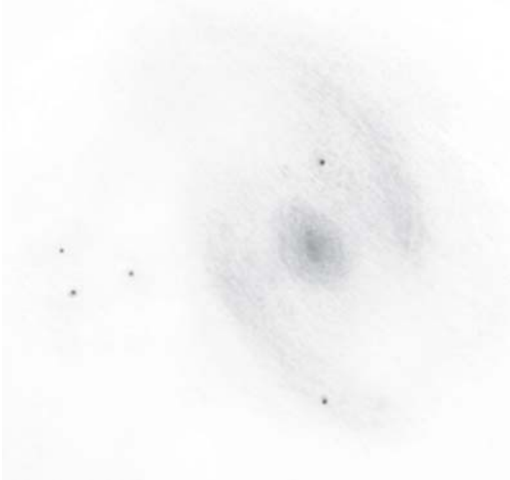
"Horrible, terrible seeing is ruining the view so we only took a quick look. Dang . . ." November 2, 2013, 48" f4, 375×, 21.28 SQM

ALL SKETCHES BY THE AUTHOR

How could it not? Now I can't help but imagine seeing each arm curving all the way around in bits and tufts, flanking its counterpart.

The Central Bar

My observing notes consistently state that 1365's central bar is fainter than the spiral arms and is much fainter than the core. Even so, both portions of the bar are much easier to see than M51's "bridge." Interestingly, murky sky conditions can mask the bar and produce a view —



"My first thought was 'supernova!' but a quick check of last year's sketch shows the same star enclosed by the spiral arms. Oh well, it's still a cool sight. The arms are subtle but the core is blazing." October 8, 2002, 20" f5, 375×

Composite drawing of NGC 1365 made by combining the author's sketches from his 20-inch and 28-inch telescopes and those made from Jimi Lowrey's 48-inch.

like the 2002 sketch above — that looks like the spiral arms aren't attached to the core.

Usually, though, the bar appears as a rather broad and evenly illuminated connection to the core. More precisely, the bar is in two sections, east and west. Although visually faint — I have yet to detect any detail within the bar itself — recent findings suggest gas and dust from the spiral arms is being funneled through the bar toward the core, forming new stars along the way. This may also feed the central black hole and could be part of the process that made it supermassive.

Finally, there's a faint foreground star tucked in near where the northern spiral arm connects with the central bar, and I've mistaken it for a supernova more than once. There's an even fainter star right at the point where the bar really does connect with the spiral arm, but it took the 48-inch scope to see it.

The Core

"Dim but distinct — the definitive barred spiral. The arms are more distinct than the bar, with the nucleus the brightest of all." September 21, 1998, 20" f/5, 282×

". . . (Note the split core!)" November 2, 2013, 48" f/4, 375×, 21.28 SQM

Aside from the spectacularly curved spiral arms, the egg-shaped core was obviously split by a dark lane in the 48-inch scope, and under poor conditions no less.

Nonetheless, the core appears oblong and at somewhat of an angle to the brightest, straighter portions of the spiral arms. But as more of the arms become visible the more obvious it is that the major axis of the core lines up with the overall shape of 1365.

This is the brightest part of the galaxy, and inside lives the relativistically spinning two million-solar-mass supermassive black hole I mentioned earlier — whirling at 84% the speed of light.

. . . Wait — what? 1365's supermassive black hole is spinning at 84% the speed of light?

Apparently so. Think about that for a moment.

It can't be seen visually, of course, but just knowing it's there — and trying to imagine the relativistic environment around it — is fascinating in the most delightfully mind-boggling way.

Aside from the outrageously twisted spacetime this implies, it also suggests the black hole has grown in a fairly orderly manner, because random growth would tend to slow its spin. Perhaps it's spinning so fast because of how the bar funnels gas and dust toward the core from the spiral arms, but that's unclear just yet. Still, it's tempting to speculate that 1365 is shaped the way it is because of how it feeds the black hole.

However, the fact that you can see the core that surrounds this beast with your own telescope — not to mention the bar and spiral arms that might be fueling it — is nearly as amazing as a relativistically spinning supermassive black hole existing in the same universe as we do.

Keep this in mind the next time you observe 1365, and regardless of how much you see I guarantee it will look more interesting.

Can you imagine? ✦

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and expect the
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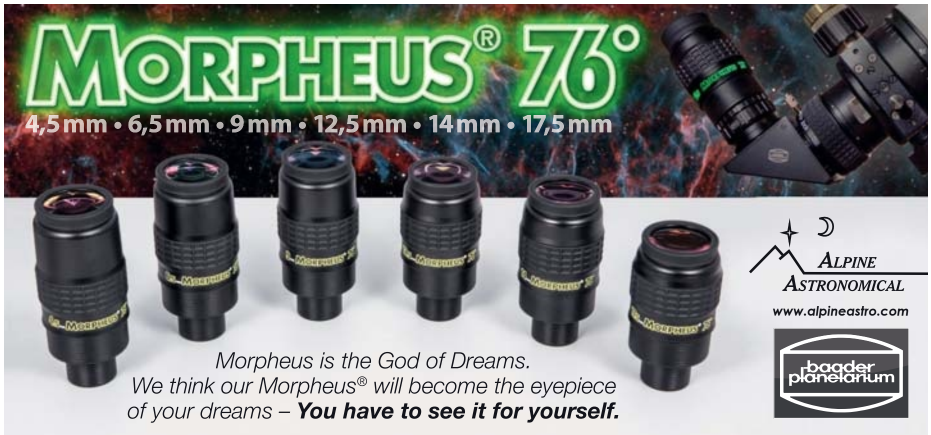

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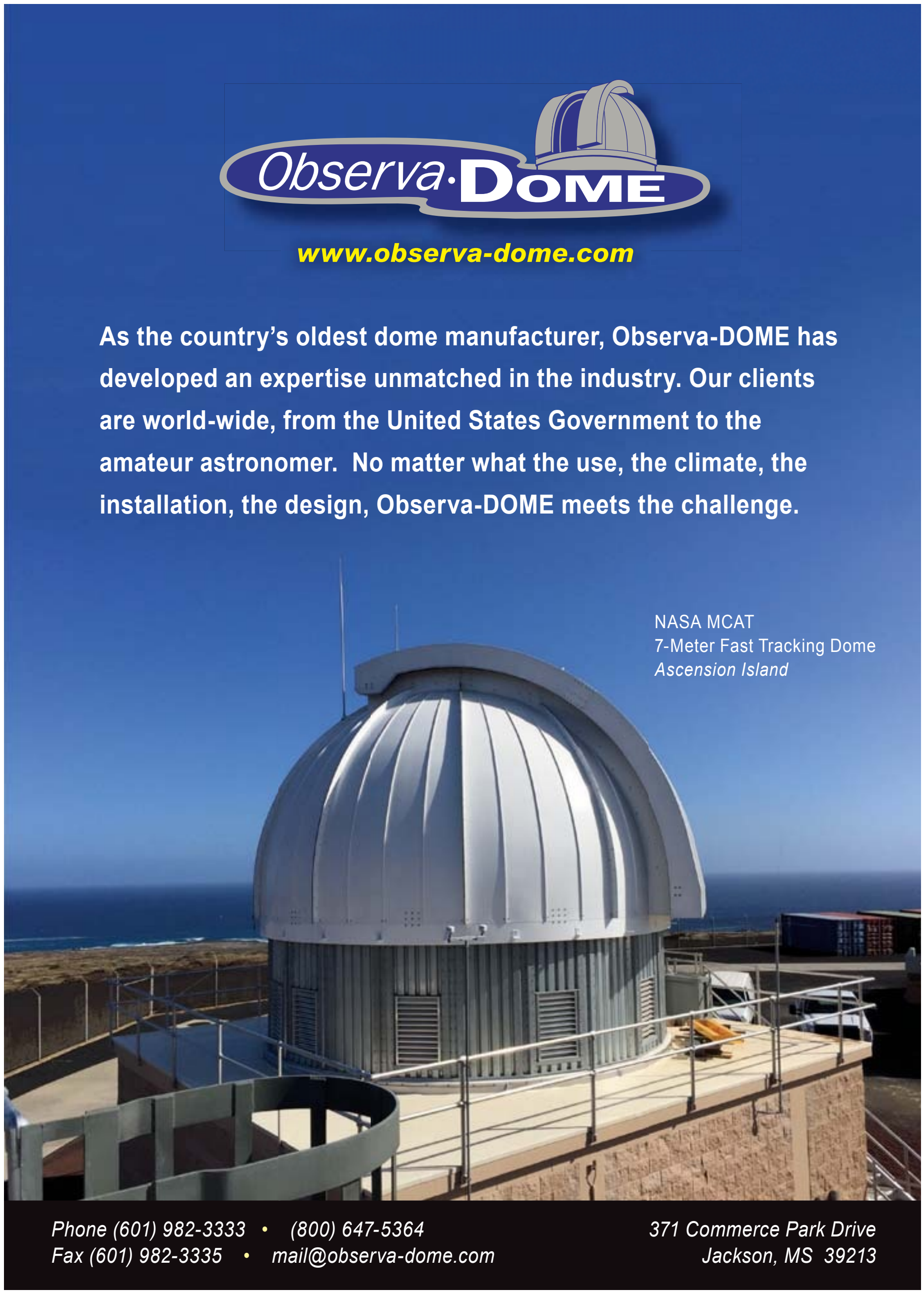

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Monsters in the

Despite their size, there's no need to fear giant elliptical and cD galaxies.

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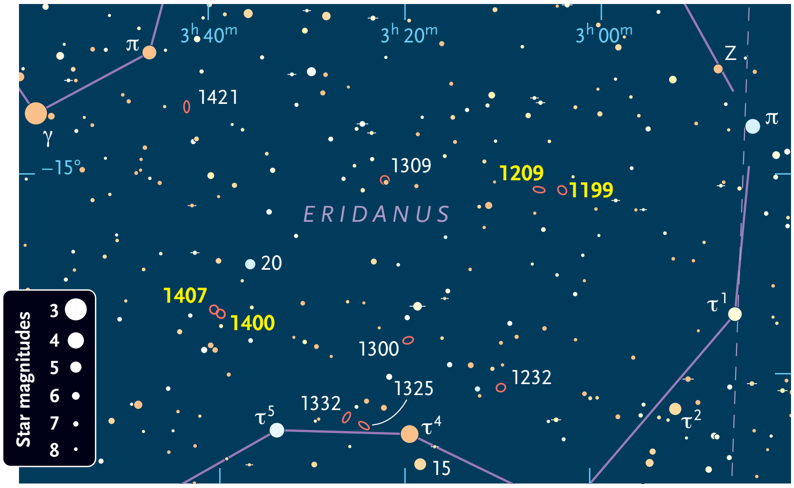
Dark

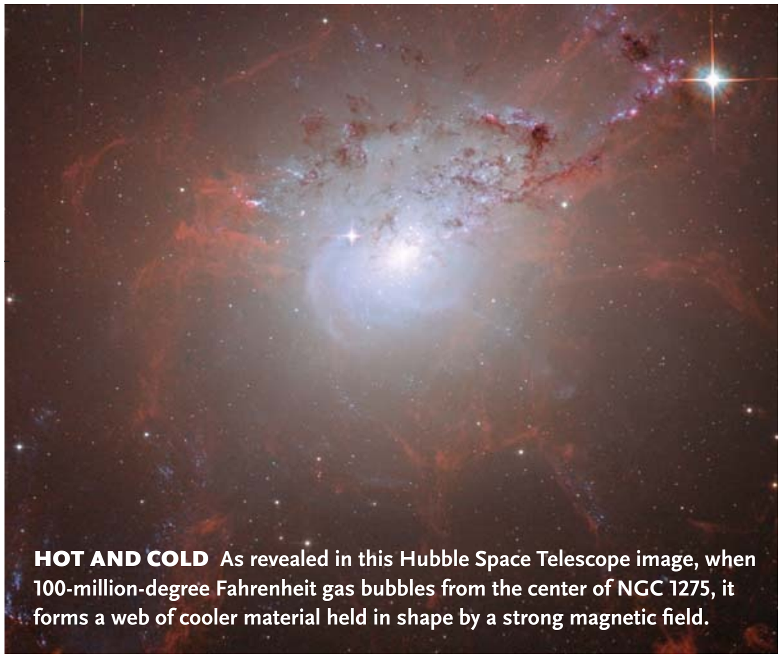


BOB FRANKE

Richard Jakiel

GIANT ELLIPTICALS and their close cousins, the supergiant cD ("central diffuse") galaxies, are the most massive and luminous galaxies in the universe. Their sheer size can dominate a galaxy cluster's evolution and dynamics. In general, these galaxies have a relatively high surface brightness, making them prime targets even in areas suffering from urban light pollution. Though perhaps not as photogenic as spirals, giant ellipticals offer a challenge, both visual and intellectual, to observers at the eyepiece or camera.

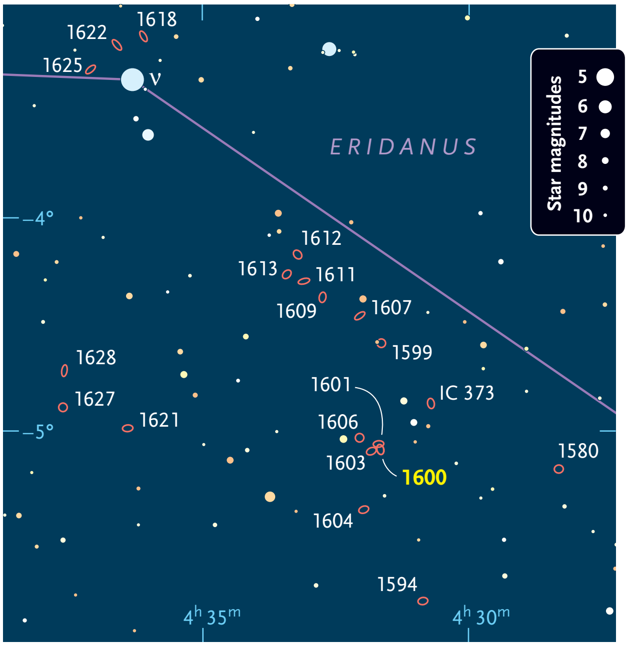
In Edwin Hubble's original "tuning fork" scheme of galaxy classification (1926), ellipticals were thought of as simple systems and classified according to shape from spherical (E0) to a highly flattened ellipse (E7). However, many of these galaxies may be triaxial, like footballs instead of well-defined ellipses, depending on the dynamics of their stellar populations. Most of these gigantic systems are thought to be the end result of galactic mergers. Using CCDs to map the isophotes of these galaxies has revealed some interesting structures. Those with a well-defined internal rotation have "disky" isophotes, while those with motions resembling a random swarm of bees have "boxy" isophote profiles. Throw in huge arc-like shells, supermassive black holes, powerful jets, and cannibalism on a galactic scale, and the picture changes radically. Once considered to be huge, static balls of ancient stars with little ongoing star formation, these giant galaxies are really highly dynamic systems that control the evolution of large clusters of galaxies.

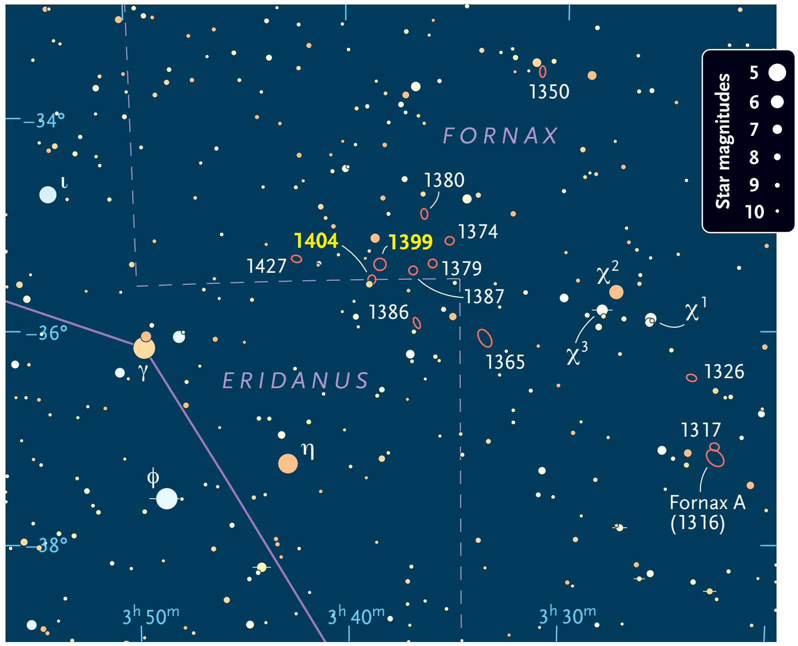


HOT AND COLD As revealed in this Hubble Space Telescope image, when 100-million-degree Fahrenheit gas bubbles from the center of NGC 1275, it forms a web of cooler material held in shape by a strong magnetic field.

NASA / ESA / THE HUBBLE HERITAGE (STSCI / AURA) / ESA–HUBBLE COLLABORATION

The numerous galaxy groups and clusters associated with Eridanus make an excellent starting point for visually observing these systems. Let's begin with **NGC 1407**, an E0 giant that dominates the core of a small galaxy group located approximately 92 million light-years from Earth. NGC 1407 is a huge spheroid of ancient stars, around 50,000 light-years in diameter, with a mass approaching a trillion Suns. In the galaxy's core lurks a black hole with a mass estimated at 1.03 billion solar masses. Nearby is **NGC 1400**, a slightly smaller E1/S0 system. Though these galaxies are in a sparse star field, star-hopping to them isn't difficult. I find it easiest to start at Tau^5 (19 Eridani), and move the scope about 2° to the northeast, until I see a nice triangle of 7th-magnitude stars in the finder scope. From there, it's a 45′ jaunt due north in the eyepiece. Visually, the galaxies make an interesting pair. NGC 1407 appears as a fairly





bright, round 10th-magnitude haze about 4′ across with a dense, stellar core. NGC 1400 shines a bit fainter as an 11th-magnitude, slightly oval spot about 12′ southwest of NGC 1407. With a larger scope and/or darker skies, a number of other fainter systems in this cluster also become viable observing targets.

NGC 1199 is the brightest member of Hickson Compact Group (HCG) 22, located about 2° northeast of Tau[1] (1 Eridani). To get there, it's easiest to follow a nice dipper-like asterism of 7th-magnitude stars. Just off the end of the dipper are HCG 22 and NGC 1199. Classified as an E3, this galaxy's degree of flattening is a bit more noticeable than with NGC 1400 or NGC 1407. In my 13.1-inch Dobsonian, NGC 1199 appears as an oval measuring 2′ × 1.5′ with a bright core, oriented roughly northeast-southwest. Make sure to check out the other fainter cluster members as well. About 35′ to the east of NGC 1199 lies **NGC 1209**, a strongly elongated E6 galaxy. It's been described as "disky," as images reveal a hint of an equatorial disk. In my 11-inch Schmidt-Cassegrain at 155×, it appears as a moderately faint 1.5′ × 1′ oval haze oriented east-west.

A classic example of a "boxy" elliptical lies in the northeast corner of Eridanus, near the Orion border, about 2° southwest of Nu (ν) Eridani. A nice chain of 6th- to 8th-magnitude stars leads from Nu to **NGC 1600**, an impressive system even for one of these monsters. Though at a distance of about 209 million light-years, this trillion-solar-mass E3-E4 galaxy shines at magnitude 10.9 and is at least 3 magnitudes brighter than the surrounding galaxies. Visually, it's a 2′ × 1.5′ oval oriented nearly north-south, with a moderately concentrated core and surrounded by several much fainter systems.

Outsize ellipticals like NGC 1600 are extremely rare and generally found in the cores of rich galaxy clusters. These massive supergiants are sometimes called cD (for "central diffuse") galaxies as they are often embedded in faint, diffuse halos than can exceed a million light-years in radius. These giants are thought to be the product of "galactic cannibalism," a gravitational merger between two or more galaxies. Many of the resultant galaxies sport multiple nuclei, vast numbers of globular clusters, and other physical remnants of these violent encounters.

Winter skies hold a few good examples of this rare class of galaxy; they're relatively low in the south when they transit the meridian, but still within reach of observers in mid-northern latitudes. For example, in the core of the Fornax Galaxy Cluster lies a spectacular pair of giant ellipticals, **NGC 1399** and **NGC 1404**. Finding this pair of galaxies isn't difficult: first locate the bright triangle of stars — g, f, and h Eridani — then sweep about 2° west from the northernmost star (g). NGC 1399 is a classic cD galaxy, displaying a huge diffuse halo with upwards of 7,000 globular clusters in orbit. It's the second brightest galaxy in the cluster at magnitude 9.6. Slightly smaller and dimmer NGC 1404 lies a mere 8′ to the southeast. In my 13.1-inch scope at 150×, both appear as bright, round, diffuse spots about 3′ across with condensed cores. NGC 1399 also shows a faint field star just north of the nucleus, leading to the impression of a "supernova" or double nuclei.

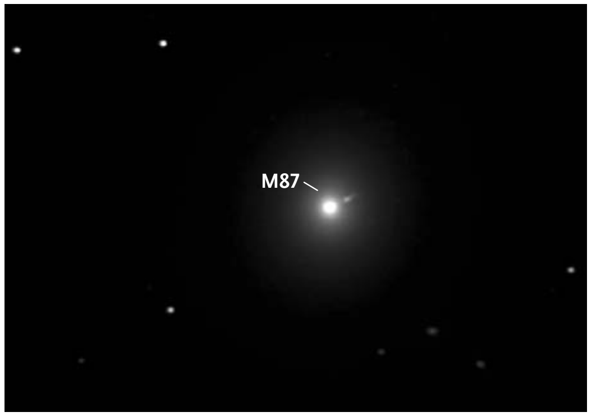
Much better placed for northern observers is the exotic **NGC 1275**, also known as Perseus A. Located in the heart of the Perseus Cluster, this cD giant harbors an active galactic nucleus (AGN) typical of a type 1.5 Seyfert galaxy. Superimposed on NGC 1275 (from our point of view) is a smaller spiral galaxy, or "high-velocity system," that's being torn apart as it dashes "headlong" towards the massive elliptical. To find NGC 1275, start at Beta (β) Perseus (Algol), and star-hop 2° to the east-northeast through the Perseus Cluster. Measuring 2′ × 1.5′, it takes a fairly large scope to detect some of the irregularities in its structure and appearance.

As we move toward springtime in the Northern Hemisphere, make plans to expand your observations to include the Coma and Virgo galaxy clusters. The core of the Coma Cluster (Abell 1656) harbors two massive ellipticals — **NGC 4874** and **NGC 4889** — supergiant galaxies that have long dominated the cluster's evolution. The view here is particularly striking in a large scope, showing dozens of smaller systems surrounding these central giants. To star-hop to the core region, locate 4th-magnitude Beta Coma Berenici then sweep 2° due west.

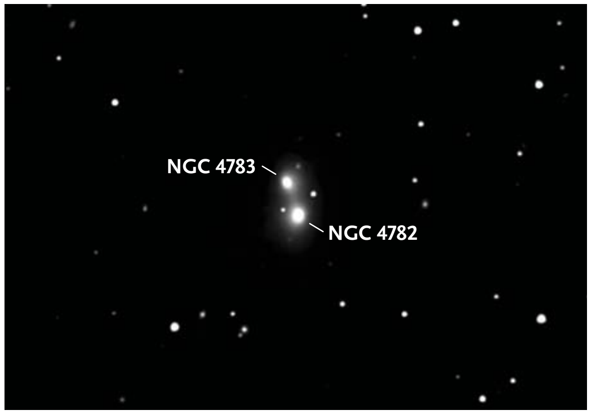
Perhaps the most famous supergiant elliptical galaxy of all is **M87**, lying near the center of the Virgo Cluster. One of the largest galaxies in the universe, it dwarfs our Milky Way in every aspect. By the numbers, it's a huge spheroid approximately 130,000 light-years across, tipping the scales at *2.7 trillion Suns* by some estimates, with over 12,000 globular clusters in orbit. But its most amazing feature is the relativistic jet of gas and dust being ejected from the (at least) 3 billion-solar-mass black hole at its core. First detected by Heber Curtis of Lick Observatory in 1918, the ray was reportedly observed visually by Otto Struve using the 100-inch at Mount Wilson. A practiced observer — under excellent conditions — can detect the jet with a 15-inch or larger scope at high magnification. In a 24-inch scope at 457×, it looks like a low contrast "spike" less than 20″ long trending slightly north of west.

Interacting galaxies **NGC 4782** and **NGC 4783** comprise a very unusual giant elliptical system located about 6° west of Spica, near the Corvus–Virgo border. Together, they're the brightest member(s) of the very rare class of co-rotating giant elliptical galaxies (similar systems include NGC 545 and NGC 547, and NGC 750 and NGC 751). In the eyepiece of my 17-inch scope at 150×, the duo presents as a distinctly dumbbell-shaped object, the galaxies' outer halos partially merged.

Much farther to the south is the closest and brightest giant radio galaxy, **NGC 5128**, also called Centaurus A. Discovered in 1826 by James Dunlop, it's the 5th-brightest galaxy in the sky. Just like M87, it harbors a gigantic black hole at its core from which vast relativistic jets of dust and gas are ejected. A trillion-solar-mass monster, it's been devouring a smaller spiral galaxy over the past several hundred million years. This is a tough target for northern observers, but I've picked it up — just above the horizon — with an 8-inch reflector from upstate New York. Its unusual appearance is evident even in small telescopes. In large instruments from low latitudes, the view is stunning, showing a huge, intricate dust band cutting diagonally across the bright oval disk.

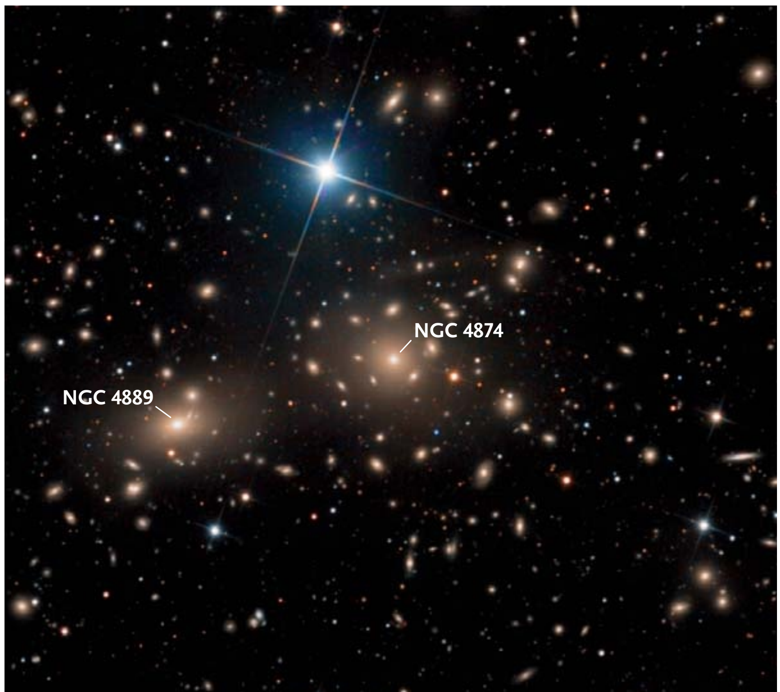


A MIGHTY JET A jet of gas and dust, visible here to the northwest (right) of M87, blasts from the black hole at the center of the galaxy at nearly the speed of light; it extends at least 5,000 light-years from its source.



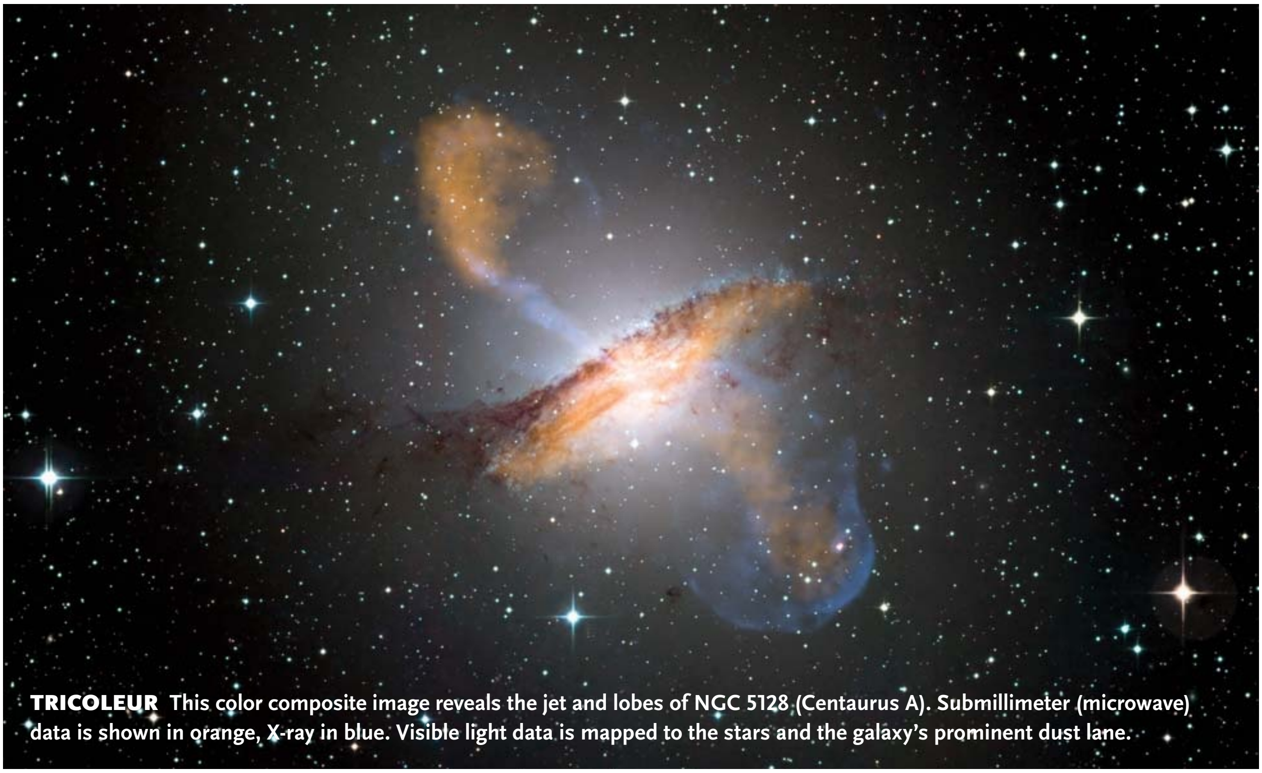
RICHARD JAKIEL (2)

NEAR COLLISION Ellipticals NGC 4782 and NGC 4783 started life as separate objects, but a high-speed near collision left behind a loosely bound interacting system resembling a dumbbell in the eyepiece.



GALACTIC OVERLORDS Though massive — the black hole at the center of NGC 4889 is estimated to equal 21 billion solar masses, and NGC 4874 holds more than 30,000 globular clusters in orbit — this pair requires 10 inches of aperture or more in good seeing under dark skies.

BOB FRANKE



ESO / WFI (OPTICAL); MPIFR / ESO / APEX / A. WEISS ET AL. (SUBMILLIMETER); NASA / CXC / CFA / R. KRAFT ET AL. (X-RAY)

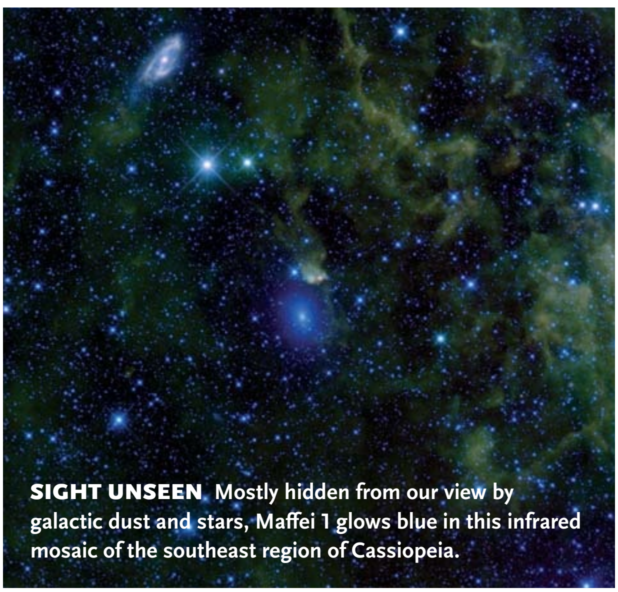
TRICOLEUR This color composite image reveals the jet and lobes of NGC 5128 (Centaurus A). Submillimeter (microwave) data is shown in orange, X-ray in blue. Visible light data is mapped to the stars and the galaxy's prominent dust lane.

The Greek hero Hercules also carries one of these hungry "monsters." Lying about 4° northwest of M13 near the core of Abell 2199, the supermassive cD **NGC 6166** has a long history of consuming its smaller brethren. It's been suffering a bit of "indigestion," with the remnants of several "victims" still evident as smaller nuclei nested deep within the main galaxy. My best view of NGC 6166 was with a 20-inch scope at 254×, which revealed the multiple cores of this galaxy as bright knots embedded in the oval halo.

So far, nearly all the ellipticals in this survey have been high surface brightness objects that can be seen under suburban skies. But the nearest example of this class, **Maffei 1**, is heavily obscured by intervening stars and the dust of our own galaxy, so although it's rivaled only by Centaurus A in size, it's difficult to see. Look for Maffei 1 about 6.5° southeast of Epsilon (ε) Cassiopeiae and 2° south of IC 1805 (the Heart Nebula). Although it was originally classified as an emission nebula, Paolo Maffei identified it as a galaxy in 1968. Today, astronomers consider it a "boxy" E3 giant; it would be one of the brightest galaxies in the sky if it didn't suffer from about 5 magnitudes of extinction from gas and dust. It shines at magnitude 11.1, but its low surface brightness makes it a challenge to observe. However, if you have access to a large scope and dark skies, go for it. With a 20-inch scope at 254×, I can discern a diffuse, misty patch 3′ × 2′ across off the eastern side of the weak open cluster Czernik 11.

With their (mostly) high surface brightness, quite a few giant ellipticals and cD galaxies are well within the range of the typical backyard observer. To start your journey, check the core regions of large galaxy groups for potential targets. With a little research and planning, you'll be ready to conquer even the most monstrous of these giant galaxies. ✦

To view a table of giant elliptical and cD galaxies, visit http://is.gd/monstergalaxies.

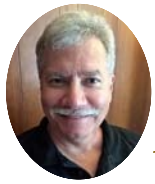


NASA / JPL-CALTECH / WISE TEAM

SIGHT UNSEEN Mostly hidden from our view by galactic dust and stars, Maffei 1 glows blue in this infrared mosaic of the southeast region of Cassiopeia.

Richard Jakiel is an experienced observer and astrophotographer living in a suburb of Atlanta, Georgia.

The Tale of the Brashear Time Capsule



Al Paslow

A collapsed building spits out pieces of America's telescope history.

During the night of last March 16th, the north wall of an abandoned 19th-century factory in Pittsburgh suddenly collapsed, spilling brick and mortar into an adjoining apartment complex. The next morning local officials ruled the remainder of the building unsafe and ordered an emergency demolition.

I was working in rural West Virginia when news of the collapse appeared in the local media. To most, the four-story building was just a derelict hulk. But in its prime, I knew, it had been the John A. Brashear Factory, the source of many of America's finest and largest telescopes a century and more ago. The name, at least, remained locally famous. One of Pittsburgh's high schools is named for John Brashear, and I have fond memories of grinding mirrors and machining telescope mountings at the Brashear Association workshop during my youth. Saddened by the news, I returned home to Pittsburgh with plans to visit the site that weekend.

John Brashear was a self-educated astronomer and precision-instrument maker who manufactured state-of-the-art telescopes, optics, and scientific apparatus in the factory he built just behind his home. The structure, once visited by scientists and educators from around the world, had fallen into disrepair during 20 years of abandonment. The City of Pittsburgh acquired it in 2012 for nonpayment of taxes and registered it as a National Historic Building, but didn't maintain it.

I arrived on the site that Sunday morning, guided by a massive excavator deafening the neighborhood as it dumped tons of debris into a container truck. I cau-

tiously parked and walked to the ruins of the factory.

The demolition was being carried out by a family business named Jadell Minniefield Construction Services, Inc. Jadell Minniefield himself was running heavy equipment with great expertise. After I introduced myself and my intentions, he and his brothers were gracious enough to let me to look around, take pictures, and examine the site for possible artifacts. In the process I became interested in buying brick from the factory as a keepsake. By the end of the day I felt sure that anything remarkable or souvenir-worthy had been lost to time.

But I returned that Tuesday for more brick and a last poke through the rubble of the great astronomical instrument company. Once more it was a perfect spring day under beautiful blue skies. For the final time I gained permission to enter the site.

After being there for about an hour, I noticed Jadell spending much time on the phone, then shaking his head in disbelief. He explained to me that he had discovered what must be a time capsule in the north or northwestern wall of the building on the Sunday of my visit. However, calls to local historical organizations and societies had failed to arouse any interest in gathering a group to open the capsule. Minniefield was convinced that something this important should be met with interest and was troubled by the lack of response. Additionally, he believed that he legally owned the time capsule by salvage rights.

So the decision was made to open it. I would document the contents in pictures and serve as a witness for a historical accounting. On Tuesday, March 24th, a group consisting of three demolition crew and myself proceeded to unlock whatever secrets were held in the relic.

The time capsule is a brass or bronze box about 8 by 10 inches in size and 4 inches deep. The lid was lead-soldered to the bottom. To open it was a simple matter of breaking this seal. All eyes were transfixed as the contents of a box hidden for nearly 121 years were revealed.

DISCOVERERS Jadell Minniefield (center) and two of his demolition crew with the metal box they found sealed in a cornerstone.

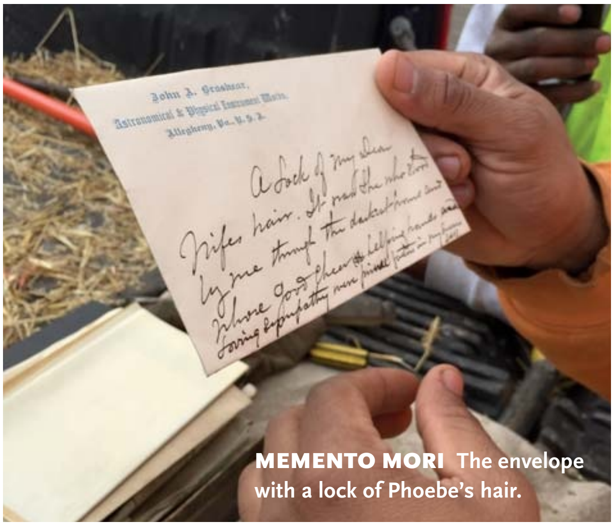
ALL ONSITE PHOTOS BY AL PASLOW

LOOK ON MY WORKS A week after the Brashear Factory's partial collapse, and the day before the time capsule was opened, the author took this panorama of the site. Instrument maker John Brashear and his family lived in the house at far right behind the near tree.

Immediately greeting us was a letter from John A. Brashear stating that the cornerstone was placed on August 14, 1894. Furthermore, we read in Brashear's flowing script, "I have a wish to express, and that is that in this building devoted to the advance of scientific research that every piece of work shall be made as perfect as human hands and human brains can make it. No excuse ever to be made for imperfect work. I hope when I am gone that these precepts will never be forgotten by those in whose hands I leave it."

Neatly tucked inside were newspapers dating from 1891 to a few days before the stone was laid. Nestled between them was a cloudy slab with the inscription, "One of the first pieces of optical glass made in America."

A small leather book elegantly titled *In Memoriam William Thaw* detailed, with pictures, the magnate who funded much of Brashear's life work. A multitude of photographs followed. There were portraits of Brashear's mother, Julia Smith Brashear, and perhaps the only known photo of his father, Basil. We turned over prints of lightning photographed by Brashear in June 1894, the company's exhibit at the World's Columbian Exposition dated 1892, Brashear's famous spectrograph attached to the tailpiece of the 30-inch Thaw refractor at Allegheny Observatory, and more.



MEMENTO MORI The envelope with a lock of Phoebe's hair.

One of the most shocking and remarkable items had once belonged to Phoebe Brashear. On a small, sealed envelope was the following inscription: "A lock of my dear wife's hair. It was she who stood by me through the darkest hours *[see below]* and whose good cheer, helping hands and loving sympathy were prime factors in my success. JAB." A lock of hair was visible inside when we held the envelope up to the sky.

Personal letters were abundant. On Warner & Swasey stationery, the builders of giant telescopes Worcester Warner and Ambrose Swasey wrote to Brashear on July 31, 1894, with congratulations on the new factory. Professor Hermann von Helmholtz, the great physicist and polymath of thermodynamics fame, requested two flat metal mirrors in his native German. A typed and signed letter from Samuel Pierpont Langley, on Smithsonian letterhead dated July 19, 1894, noted the quality of Brashear's large prisms, lenses, and mirrors.

After our short review and partial documentation, we returned in order all the contents removed to their original position. Most of the 70 or so items we examined were in immaculate condition.

That afternoon a cameraman from a local TV news company asked to see the capsule, and it was opened for

John Alfred Brashear 1849–1920

John and Phoebe Stewart Brashear when they were married in 1862.
ALLEGHENY OBSERVATORY / UNIV. OF PITTSBURGH

The son of a saddle maker and a schoolteacher, John Brashear was born in his grandfather's tavern in Brownsville, Pennsylvania. As a boy of nine he viewed the Moon and Saturn through a telescope owned by a traveling showman. The experience kindled a passionate interest in astronomy that transformed his life.

The young Brashear went to work as a machinist in the steel mills of Pittsburgh, where he soon gained a reputation as one of the city's most skilled millwrights. For years, after working 12-hour days, he labored until midnight in a coal shed behind his house that he had converted into an optical workshop. Assisted by his supportive wife, Phoebe, he spent hundreds of nights making a 5-inch refractor lens. And then, as he was removing it from a polishing lathe, it dropped and broke.

He and Phoebe started over. They completed a fine 5-inch refractor in 1875. The director of the nearby Allegheny Observatory, Samuel Pierpont Langley, was impressed by Brashear's handiwork and encouraged him to try his hand at making a larger reflector.

Brashear laboriously ground, polished, and figured a 12-inch mirror of plate glass — only to have the disk shatter from thermal stress when he immersed it in the warm chemical solution used to deposit its final coating of silver. This second disaster might have broken a less determined man. "I slept little or none that night," he wrote. "I went to the mill the following morning; walked around like a crazy man." When he came home he found that Phoebe had prepared everything to start again. "The little shop in prime order, a fire burning under the boiler, engine oiled ready to start, and the extra [glass] disk in the lathe ready to have its edge turned with the diamond tool and its surface roughed out to the approximate curve. Could anyone have done more? The memory of that moment, filled with the love and confidence of the one who was more than life to me, I can never forget."

the last time. When the cameraman finished filming, Jadell wrapped the box safely in a heavy towel and placed everything in the cab of a Minniefield company truck.

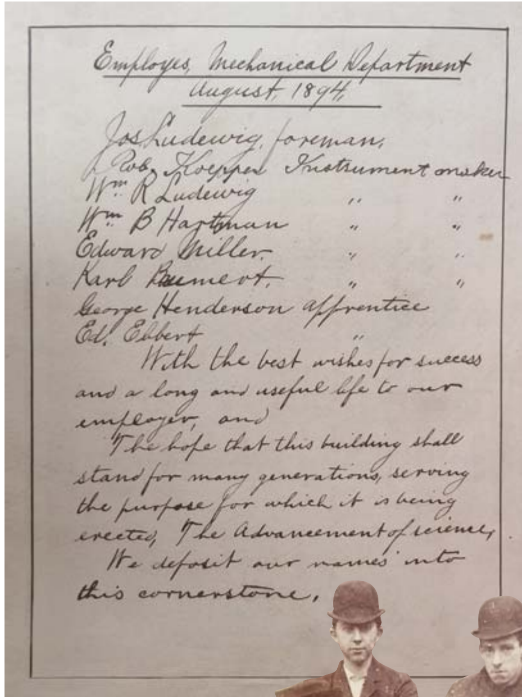
The story ran briefly on the news that evening. Working late into that night, I posted the afternoon's photos on my website and wrote captions for them, then sent announcements to astronomy-history blogs and websites.

The next morning brought a flurry of internet activity followed by calls not only from the media but the legal department of the City of Pittsburgh! By evening the story and my photos were on the front page of the *Pittsburgh Post-Gazette*. The press and television were soon asking, "Who owns the Brashear Time Capsule: the Minniefields by salvage contract, or the City of Pittsburgh as a historic artifact?" Mayor Bill Peduto demanded the box and filed a court order to obtain it.

As the controversy continued, journalists tended to portray the mayor as a hero attempting to save the time capsule from some unknown and disastrous fate. In my estimation this was misguided; Jadell Minniefield and his brothers are honorable businessmen and kept the time capsule safe under lock and key awaiting a response from the courts.

After months of negotiation, the claims were settled in a private agreement between Minniefield Construction and the City of Pittsburgh. The Brashear Time Capsule and its contents now rest timelessly in the Heinz History Center for future generations to view and admire.

***Al Paslow** is a member of the Antique Telescope Society and is currently building an 8-inch refractor. Many more of his images from the box's opening are at **al-paslow.smugmug.com**.*


Employes, Mechanical Department
August 1894
Jos Ludewig, foreman,
Rob. Hoppe Instrument maker
Wm R Ludewig " "
Wm B Hartman " "
Edward Miller " "
Karl Baemeot, " "
George Henderson apprentice
Ed. Ebbert "
With the best wishes for success and a long and useful life to our employer, and The hope that this building shall stand for many generations, serving the purpose for which it is being erected, The Advancement of science, We deposit our names into this cornerstone,

THE MECHANICAL DEPARTMENT
The company's machinists wrote on the back of their photo, "With the best wishes for success and a long and useful life to our employer, and The hope that this building shall stand for many generations, serving the purpose for which it is being erected, The Advancement of science, We deposit our names into this cornerstone."

Brashear not only finished the replacement mirror but also developed a novel room-temperature recipe for silvering mirrors. He shared it widely and refused to patent it. It became the preferred method until the advent of vacuum-deposited aluminum coatings in the 1930s made chemical silvering obsolete.

In 1881, exhausted by the killing schedule of working as a mill foreman by day and telescope maker by night, Brashear suffered a breakdown. Langley came to his rescue by introducing Brashear to the wealthy Pittsburgh industrialist and philanthropist William Thaw, who paid off the mortgage on Brashear's house, provided him with a larger, well-equipped workshop, and placed his fledgling instrument-making firm on a solid financial footing.

Brashear's firm soon began turning out telescopes of great precision and excellence, optically and mechanically. They eventually included 18 refractors from 12 to 30 inches aperture and four reflectors from 30 to 72 inches.

The Brashear Company also made many of the instruments that gave rise to the infant science of astrophysics, notably:

- The spectroheliograph invented by George Ellery Hale that revolutionized the study of the Sun.
- The optical components of the interferometer used by Michelson and Morley in 1887 to disprove the existence of the "ether" that was supposed to carry light waves, laying the foundation for Einstein's theory of relativity.
- The spectrograph later modified and used by Vesto Slipher at Lowell Observatory to detect the first Doppler shifts of galaxies.

In his later years Brashear received many honorary degrees from the world's most respected universities and scientific societies. He served as acting director of Allegheny Observatory, chancellor of what is now the University of Pittsburgh, and a trustee of the Carnegie Institute.

His ashes and Phoebe's lie beneath the James Keeler Telescope at Allegheny Observatory. Their epitaph, adapted from the classic line in Sarah Williams' 1868 poem "The Old Astronomer," reads, "We have loved the stars too fondly to be fearful of the night." ✦

— Tom Dobbins

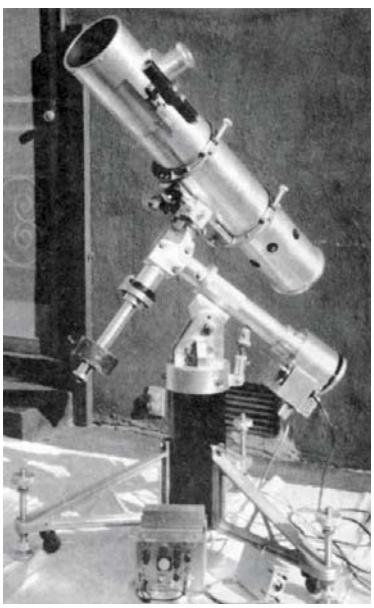
Telescope Making Then and Now

Are amateur telescope makers as good as they were 50 years ago?

I'VE BEEN TAKING CARE of this magazine's telescope-making department since 1998, and even during my relatively brief tenure, there's been a dizzying number of changes in the hobby. I'm constantly impressed by the creativity and thirst for innovation that ATMs so often display. Indeed, to invoke a well-worn truism, change is the only constant. That becomes more obvious the farther back we look. To illustrate the point, let's travel back 50 years in time and look at telescope making as it was practiced in 1966.

If you were an active amateur astronomer in the mid-1960s, chances are you spent a lot of time looking at the Moon and planets. You may have also enjoyed splitting double stars, monitoring a few variables, and probably even hunting down the Messier objects. In all likelihood your telescope was a small refractor or a 6- to 8-inch equatorial reflector. If you were well-heeled, you could have bought a basic 6-inch f/8 Cave reflector on an equatorial mount for the equivalent of $1,500 in 2016 dollars. In 1966 telescopes were generally expensive to buy, leading many amateurs to make their own. If you were fortunate, you might find someone in your local club who could show you the ropes. Or you relied on books like *Making Your Own Telescope* by Allyn J. Thompson (if you were lucky) or the much older three-volume *Amateur Telescope Making* published by Scientific American (if you weren't).

The Gleanings for ATMs department in the October 1966 issue featured the article "An Engineering Student Builds a Mounting." Not the most enticing title, but such was the flavor of the magazine back then. That student's telescope was a symphony of gleaming metal, from the aluminum tube housing a long-focus 6-inch Newtonian optical train, to the massive German equatorial mount complete with a (presumably homemade) motorized, variable-speed drive. Many of the mount's components were machined from blocks of aluminum. It was an ambitious project but far from a rarity. Look in that year's January issue and you'll see a fine, home-built 10-inch f/7.5 Newtonian riding on a steel equatorial horseshoe mount, all housed in a miniature Palomar-



S&T ARCHIVE: VICTOR NICKOLASHIN

GARY SERONIK

Far left: **Victor Nickolashin's beautiful 6-inch reflector was featured in the October 1966 issue of this magazine. Its detailed machining is representative of home-built instruments from this era.**

Left: **Described in the February 2013 issue, Albert Highe's 24-inch f/3.3 ably demonstrates the current state of the ATM art. Built to gather light — and lots of it — but retain portability, scopes like this were unimaginable in 1966.**

style domed observatory. Impressive.

Some readers doubtlessly regard these as examples from a kind of "golden age" for telescope making — an era in which you not only had to have the skill to grind and polish your own mirror, but also the talent and equipment needed to fabricate the rest. But not everyone did, even in 1966. A less fondly remembered product of the era was the abundance of mediocre optics mounted on shaky pipe mounts.

Over the years I've received letters bemoaning the current state of the telescope making art with its cardboard-tubed light buckets. But in my view, telescope making has simply moved on. It's undeniably the case that today fewer amateurs machine their own mounts or even grind their own mirrors. But it's also true that no one in 1966 was acquainted with the virtues of big Dobsonians! For the current state of affairs to be lamentable you'd have to see the past as being intrinsically superior to the present. I for one do not.

It's important to keep in mind that we live in an extraordinary time in which you can purchase a decent 8-inch reflector for roughly half of what a bare-bones 2.4-inch Unitron refractor sold for in 1966. As a result, there simply isn't the same financial incentive to build a scope today. Yes, that means fewer people are making them, but it also means that when they do, quite often they make something not commercially available. That could be an instrument designed for extreme portability, or a really big/fast telescope that would be prohibitively expensive to buy. We even see new optical designs popping up, thanks to computerized ray-tracing software. Doesn't that seem like a new golden age?

As always, we continue to make scopes to observe with, and generally see far more thanks to the big, simple reflectors that are today's standard ATM fare. And if you could go back in time 50 years to ask that engineering student whether he'd rather observe with his beautifully machined 6-inch or one of today's 24-inch Dobs, I have a hunch that he'd jump at the chance to use the big scope. ✦

*Contributing editor **Gary Seronik** can be contacted via his website, **garyseronik.com**.*

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▶ DEER LICK GROUP

Brian McGaffney

Anchored by the 10th-magnitude spiral galaxy NGC 7331 (Caldwell 30), this pretty grouping in Pegasus purportedly got its name after being seen particularly well from Deer Lick Gap in North Carolina.

Details: *Ceravolo Optical Systems Astrograph 300 and Apogee U16M CCD camera with Baader filters. Total exposure: 28 hours.*

▼ ECLIPSE OVER JOSHUA TREE

Pauline Acalin

The lunar eclipse of September 27, 2015, was well under way when the Moon rose over the rugged landscape at Joshua Tree, California.

Details: *Canon EOS 50D DSLR camera used at ISO 200 and 400-mm f/6.3 lens. Exposure: 1⁄40 second.*

SPOT THE RUNNING MAN

Chuck Manges

In a scene dominated by Orion's Great Nebula, the reflection nebulae NGC 1977, 1975, and 1973 to its right (north) form a linked set of dark lanes known as the Running Man Nebula.

Details: *Celestron 11-inch EdgeHD astrograph, Hyperstar, and QHY23M CCD camera, as well as Astro-Tech AT65EDQ refractor and QHY9M CCD camera. Total exposure: 3.6 hours.*

▶ **ECLIPSE TRYPTYCH**

Christoph Rollwagen

September's total lunar eclipse proved darker than average. This composite from Germany captures the Moon's appearance at the beginning of totality (lower right), mid-eclipse, and totality's end. **Details:** *GSO Instruments 200-mm f/5 reflector and Canon EOS 50D DSLR camera. Exposures: 8 seconds at ISO 200, 800, and 100, respectively.*

▼ **FESTIVE NEBULAE**

César Blanco González

NGC 2264, the Cone and Christmas Tree nebulae, is a feathery 4th-magnitude splash in Monoceros. **Details:** *Takahashi FSQ-106ED astrograph and QSI 583ws CCD camera with Astronomik Hα, O III, and S II filters. Total exposure: 5¼ hours.* ✦

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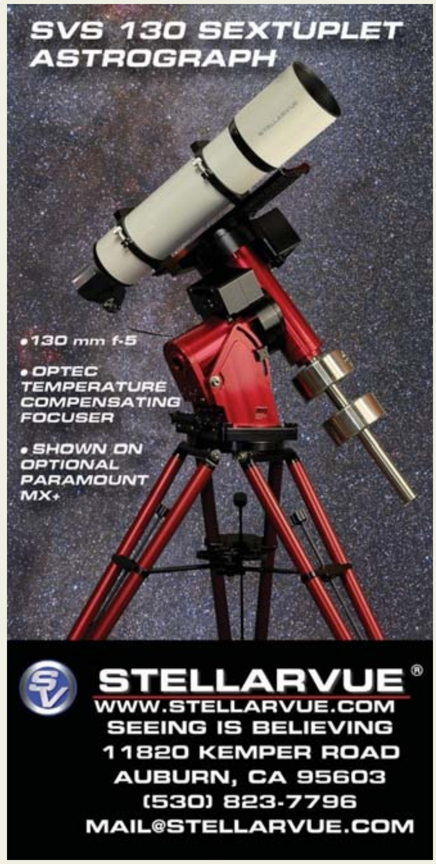

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Night Fright

Our societal fearfulness exacts a toll on astronomy.

In June 2005, an 11-year-old Boy Scout in Utah strayed onto the wrong trail and was lost for four days. He scrupulously followed all the advice grown-ups had given him, and it nearly killed him. He stayed on the trail, which was good advice. But he'd also been told never to talk to strangers, so any time a rescue party came near, he hid in the bushes. Finally, common sense got the better of caution, and he revealed himself to a rescuer.

How attitudes have changed! When I was an 11-year-old, my parents let me go just about anywhere I wanted alone, and that was in New York City. Back then that was pretty much the norm, though a few parents were more cautious. But parents who were considered comically overprotective in the '50s and '60s might be judged reckless by today's standards.

It's not that the world has become more dangerous — if anything, the opposite is true. Crime rates in most categories are just about the same as they were 50 years ago, and accident rates have dropped significantly. Few places have ever been as safe as America today. Yet in the past half century, we have become a deeply fearful society.

What does this have to do with astronomy? A great deal, unfortunately. Fear is a major driving force behind light pollution — in particular, behind those blinding "security lights" that defile untold acres of otherwise pristine rural land. And fear is one of the main reasons that it's so hard to find a good observing site near my city home. Almost every plot of public land within a 30-mile drive has a sign saying that access is prohibited from sunset to sunrise.

When my parents were born, life was genuinely dangerous. Women often died in childbirth, infants died of measles, millions had just been killed in World War I, and far more would soon die in World War II. Even the richest family was vulnerable to infectious disease.

Only in my lifetime has the idea taken root that life can or should be lived completely free of risk. But that's an illusion. In pursuit of that goal, we confine ourselves to environments that we can rigidly control: the home and backyard, the car and the mall. Thus we end up with the diseases of civilization: obesity, arteriosclerosis, and diabetes, which kill far more people than the dangers that we're hiding from.

Small wonder that people don't enjoy the marvels of nature — stars included. Small wonder that people want to make the outdoors just like the indoors, to pave it or plant it with well-manicured grass, to fence out all intruders, to light up every square inch so that night is turned to day. Small wonder that 90% of people live where skyglow obscures the Milky Way — and that many of the rest haven't seen the Milky Way either, because they're afraid to turn off their porch lights.

At a deeper level, I've had several people tell me that the stars scare them. Frankly, I can sympathize with that sentiment. The stars are utterly alien, completely and forever beyond our control. Awe and fear are intimately related. And there's nothing wrong with that. Fear is a perfectly healthy response — unless you run away from it. ✦

S&T: LEAH TISCIONE

*S&T Contributing Editor **Tony Flanders** loves to explore cities and wilderness by day and by night.*

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Skygazer's Almanac 30°S 2016

FOR LATITUDES NEAR 30° SOUTH

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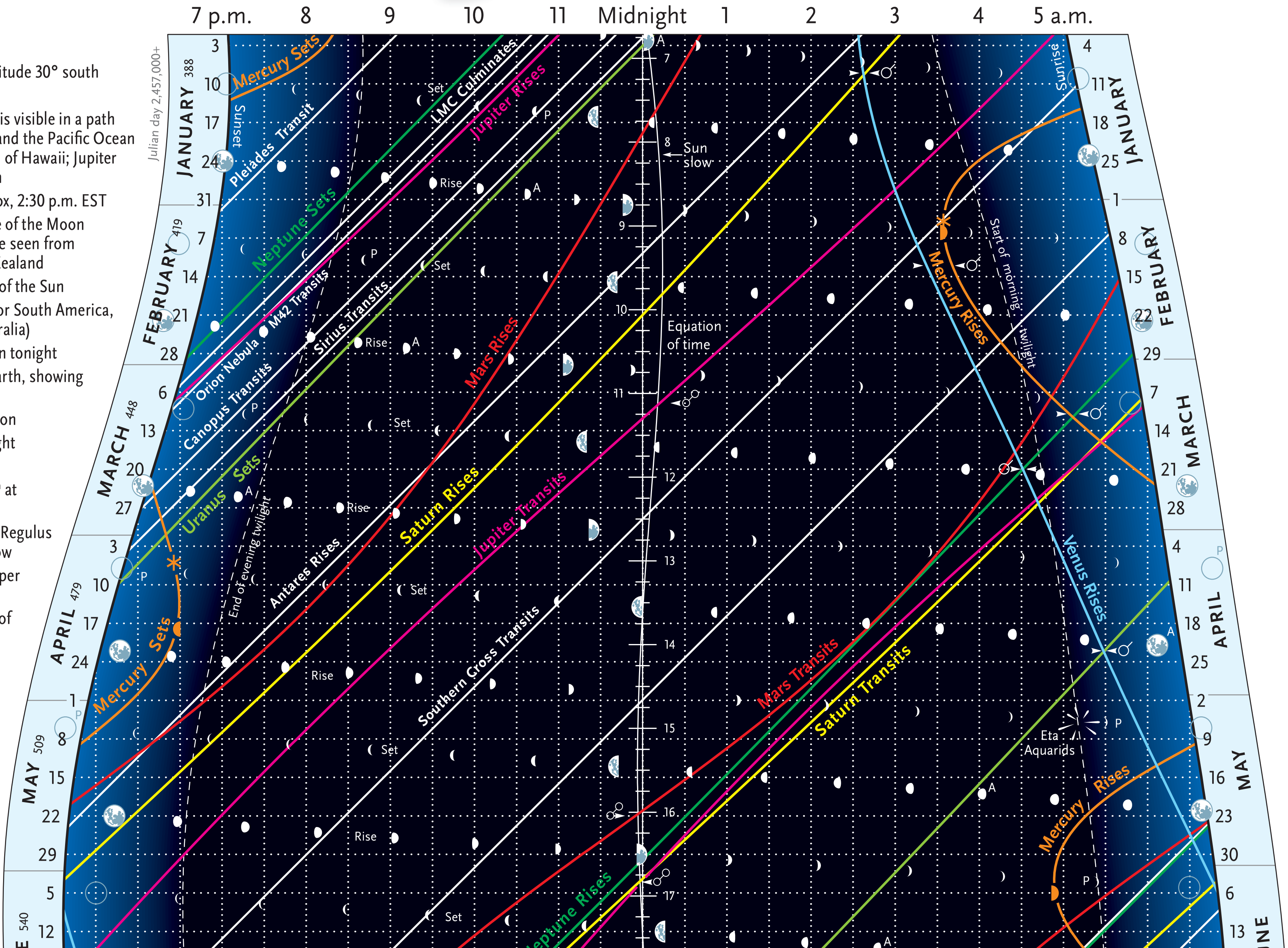


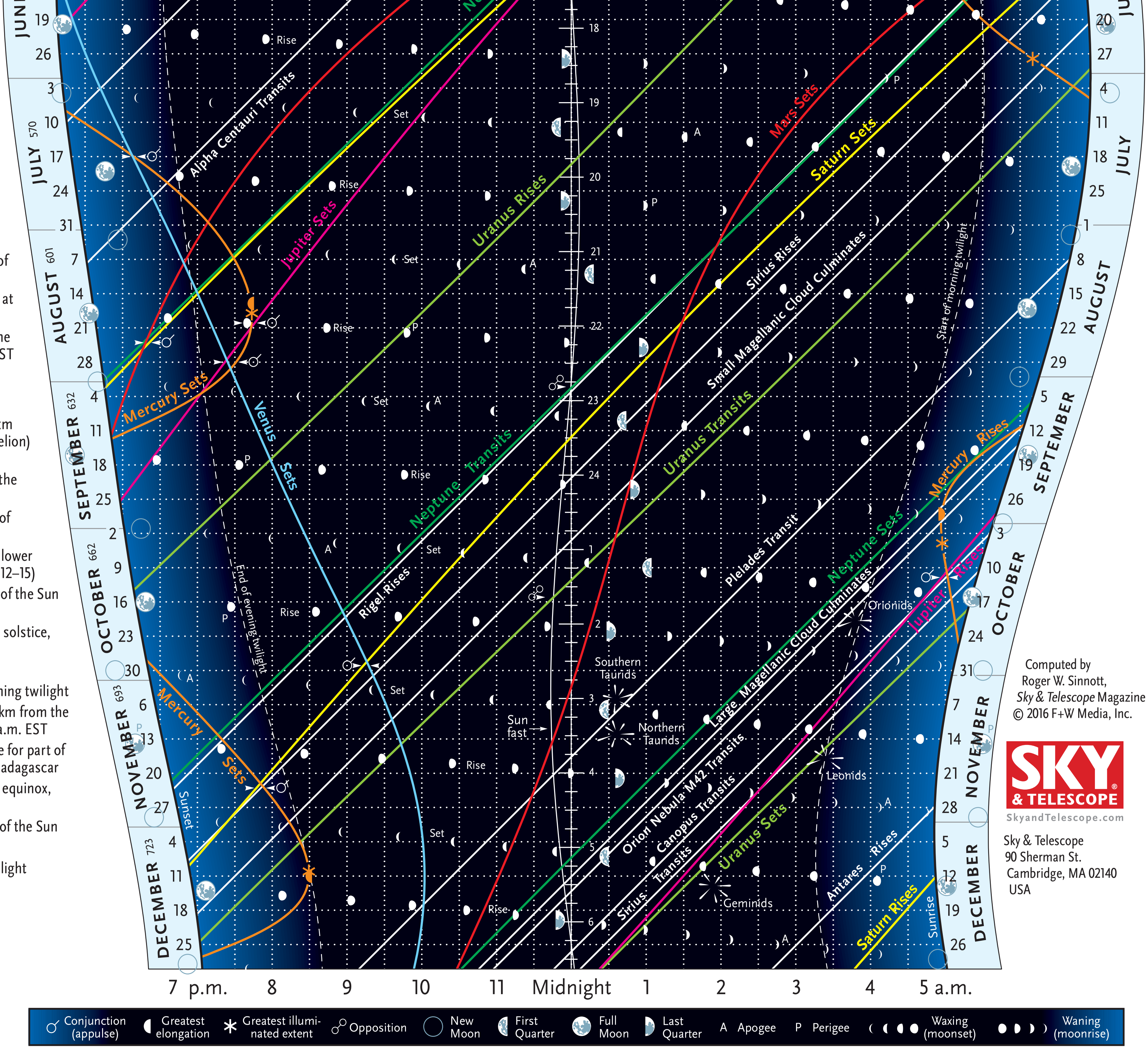
Evening Sky

Jan 4 Latest twilight in latitude 30° south
Jan 10 Latest sunset
Mar 9 A total solar eclipse is visible in a path crossing Indonesia and the Pacific Ocean to a point well north of Hawaii; Jupiter comes to opposition
Mar 20 Fall begins at equinox, 2:30 p.m. EST
Mar 23 A penumbral eclipse of the Moon around 12^h UT can be seen from Australia and New Zealand
Apr 18 Mercury is 20° east of the Sun
May 9 Transit of Mercury for South America, Africa (but not Australia)
May 22 Mars is at opposition tonight
May 30 Mars is closest to Earth, showing an 18.6″ disk
Jun 3 Saturn is at opposition
Jun 7 Earliest end of twilight
Jun 10 Earliest sunset
Jun 21 Shortest day, 10^h 13^m at latitude 30° south
Jul 30 Mercury is 1° below Regulus tonight and tomorrow
Aug 5 Regulus is 1.1° to upper left of Venus
Aug 16 Mercury is 27° east of the Sun tonight and tomorrow
Aug 18 An unobservable penumbral lunar eclipse near 10^h UT
Aug 20 Mercury is 3.8° to the left of Jupiter
Aug 24 Mars and Saturn are 4.4° apart, with Antares 1.8° from Mars
Aug 28 Venus has Jupiter ½° below it and Mercury 5.1° to its upper left

Sep 2 Neptune reaches opposition
Sep 16 Penumbral lunar eclipse for Africa, most shading near 19ʰ UT
Sep 18 Spica is 2.5° left of Venus tonight and tomorrow
Oct 15 Uranus' opposition
Oct 29 Saturn is 3.0° to the right of Venus tonight and tomorrow
Dec 11 Mercury is 21° east of the Sun
Dec 21 Longest day, $14^h 05^m$ at latitude 30° south
Dec 21 Summer begins at the solstice, 8:44 p.m. EST

Morning Sky

Jan 3 Earth is 147,100,176 km from the Sun (perihelion) at 9 a.m. EST
Jan 9 Saturn is just ½° to the lower right of Venus
Feb 7 Mercury is 26° west of the Sun
Feb 13 Mercury is 4° to the lower right of Venus (Feb. 12–15)
Jun 6 Mercury is 24° west of the Sun this morning
Jun 21 Winter begins at the solstice, 8:34 a.m. EST
Jul 1 Latest sunrise
Jul 4 Latest onset of morning twilight
Jul 5 Earth is 152,103,776 km from the Sun (aphelion) at 2 a.m. EST
Sep 1 Annular solar eclipse for part of central Africa and Madagascar
Sep 23 Spring begins at the equinox, 12:21 a.m. EST
Sep 29 Mercury is 18° west of the Sun
Dec 3 Earliest sunrise
Dec 8 Earliest morning twilight



Computed by Roger W. Sinnott, *Sky & Telescope* Magazine

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Skygazer's Almanac 30°S 2016

FOR LATITUDES NEAR 30° SOUTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time is moonrise?

Welcome to the *Skygazer's Almanac 2016* — a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 30° south — in Australia, southern Africa, and the southern cone of South America.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart, you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 17, 2016.

First find "January" and "17" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 17–18 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 17–18 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 17th occurs at 7:05 p.m. *Local Mean Time*. (All times read from the chart are Local Mean Time, which can differ from your standard clock time by many minutes. More on this later.)

Moving to the right we see that at 8:03 p.m. the Pleiades transit the meridian, meaning the famous star cluster is then highest in the sky. But the sky is not yet fully dark, because evening twilight doesn't technically end until 8:38, when the Sun is 18° below the horizon.

At 9:38 p.m. the Large Magellanic Cloud culminates (another way of saying it transits). Then the Orion Nebula (Messier 42) transits at 9:51, shortly before Jupiter rises. The two brightest nighttime stars, Canopus and Sirius, transit at 10:39 and 11:00, respectively. Transit times of such celestial landmarks keep us aware of the march of constellations through the night sky.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 17–18 this is $7^h\,46^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due north. On January 17th the Sun runs slow, transiting at 12:10 p.m. This variation is caused by the tilt of Earth's axis and ellipticity of its orbit.

At 12:07 we see a Moon symbol, and the legend at the chart's bottom indicates it is at gibbous phase, setting. (So we've had bright moonlight until now.)

In the predawn hours Antares, a star we usually associate with later seasons, climbs above the horizon at 1:34 a.m. The ringed planet Saturn rises at 2:06, and then brilliant Venus at 2:45.

The first hint of dawn — the start of morning twilight — comes at 3:43 a.m. Jupiter transits very soon thereafter, so it's still an excellent time to check its satellites and cloud belts in a telescope. The Sun finally peeks above the eastern horizon at 5:15 a.m. on the morning of January 18th.

Other Charted Information

Many of the year's most important astronomical events are listed in the chart's left-hand margin. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are indicated on the chart by a ☌ symbol on the planets' event lines.

Local Mean Time Corrections

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Canberra	+4	Sydney	–4
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Durban	–3	Port Elizabeth	+18
Harare	–4	Pretoria	+8
Asunción	–10	Rio de Janeiro	–7
Buenos Aires	+54	Santiago	+43
Montevideo	+45	São Paulo	+6

Here, conjunctions are considered to occur when the planets actually appear closest together in the sky (at appulse), not merely when they share the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol. For instance, Jupiter reaches opposition on the night of March 8–9 this year.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces left (waxing Moon sets) or right (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury never strays much outside the twilight bands. Its dates of greatest elongation from the Sun are shown by ◗ symbols on its rising or setting curves, and asterisks mark when Mercury shows its greatest illuminated extent in square arcseconds. (The same symbols can appear on the curves for Venus, but not in 2016.)

Meteor showers are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant (point of origin) is highest in the night sky. This often occurs just before morning twilight begins.

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2457, as indicated just off the chart's upper left margin. To find the last three digits for days in January, add 388 to the date. For instance, on January 17th we have 388 + 17 = 405, so the Julian day is 2,457,405.

Note that the Julian day doesn't change to this value until 12:00 Universal Time (UT). In Australia, 12:00 UT falls during the evening of the same day (at 10 p.m. Eastern Standard Time, EST). Before that time, subtract 1 from the Julian day number just obtained.

Rising or Setting Corrections

South Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
10°	0	8	16	24	33	43
15°	0	6	12	19	26	33
20°	0	4	8	13	18	23
25°	0	2	4	7	9	12
30°	0	0	0	0	0	0
35°	0	2	5	7	10	13
40°	0	5	10	16	22	29
45°	1	8	17	26	37	49
50°	1	12	25	39	54	72

Time Corrections

All events on this southern version of the *Skygazer's Almanac* are plotted for an observer at 135° east longitude and 30° south latitude. However, you need not live near McDouall Peak, South Australia, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's south temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in decreasing order of importance.

• **DAYLIGHT-SAVING TIME ("SUMMER TIME").** When this is in effect, add one hour to any time read from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by many minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Australia are 150° E for the eastern states (which use Eastern Standard Time, EST), and 142.5° E for the two central states (an odd value that puts the minute hands of their clocks 30 minutes out of joint with most of the rest of the world).

If your longitude is very close to your standard time-zone meridian, luck is with you and your LMT correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it. You can look up your longitude on a map.

For instance, Melbourne, Australia (longitude 145°), is 5° west of its time-zone meridian (150°). So at Melbourne, add 20 minutes to any time obtained from the chart. The result is standard time.

Find your Local Mean Time correction and memorize it; you will use it always. The table below at far left has the corrections, in minutes, for some major cities.

• **RISING AND SETTING.** Times of rising and setting need correction if your latitude differs from 30° south. This effect depends strongly on a star or planet's declination. (The changing declinations of the Sun and planets can be found in each month's *Sky & Telescope*, on the Planetary Almanac page.)

If your site is *south* of latitude 30° S, then an object with a south declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), while one with a north declination spends less time above the horizon. At a site *north* of 30° S, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table above.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 135° E. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of central Australia, and two minutes later for each time zone west of there. Observers in southern Africa can simply shift the Moon symbol a third of the way to the one for the following date. Observers in South America can shift it about halfway there.

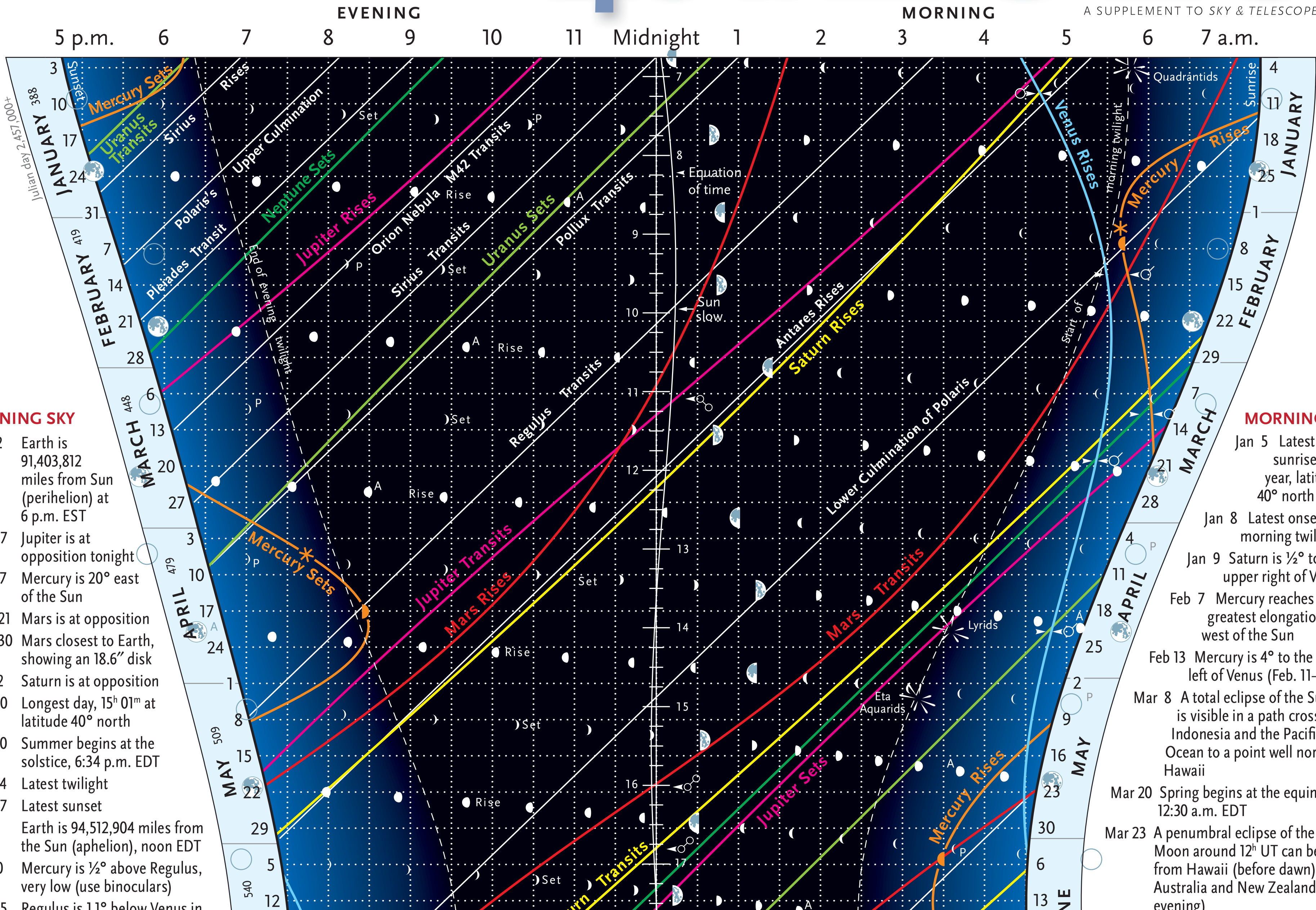
For reprints (item SGA16S, $5.95 each postpaid) or to order a similar chart for north latitude 40° or 50°, contact *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140, USA; phone +1 617-864-7360, fax +1 617-864-6117. You can send an e-mail to skyprodservice@skyandtelescope.com, as well as visit our online store at SkyandTelescope.com.

SkyandTelescope.com

Skygazer's Almanac 40°N 2016

FOR LATITUDES NEAR 40° NORTH

A SUPPLEMENT TO *SKY & TELESCOPE*



EVENING SKY

Jan 2 Earth is 91,403,812 miles from Sun (perihelion) at 6 p.m. EST

Mar 7 Jupiter is at opposition tonight

Apr 17 Mercury is 20° east of the Sun

May 21 Mars is at opposition

May 30 Mars closest to Earth, showing an 18.6″ disk

Jun 2 Saturn is at opposition

Jun 20 Longest day, 15h 01m at latitude 40° north

Jun 20 Summer begins at the solstice, 6:34 p.m. EDT

Jun 24 Latest twilight

Jun 27 Latest sunset

Jul 4 Earth is 94,512,904 miles from the Sun (aphelion), noon EDT

Jul 30 Mercury is ½° above Regulus, very low (use binoculars)

Aug 5 Regulus is 1.1° below Venus in

MORNING SKY

Jan 5 Latest sunrise of year, latitude 40° north

Jan 8 Latest onset of morning twilight

Jan 9 Saturn is ½° to upper right of Venus

Feb 7 Mercury reaches greatest elongation, 26° west of the Sun

Feb 13 Mercury is 4° to the lower left of Venus (Feb. 11–15)

Mar 8 A total eclipse of the Sun is visible in a path crossing Indonesia and the Pacific Ocean to a point well north of Hawaii

Mar 20 Spring begins at the equinox, 12:30 a.m. EDT

Mar 23 A penumbral eclipse of the Moon around 12h UT can be seen from Hawaii (before dawn) and Australia and New Zealand (late evening)

Aug 5 Regulus is 1.1° below Venus in the twilight (use binoculars)

Aug 16 Mercury reaches greatest elongation, 27° east of the Sun

Aug 19 Mercury is 3.8° below Jupiter

Aug 23 Mars has Saturn 4.4° to its upper right and Antares 1.8° below it

Aug 27 Venus and Jupiter, low in bright twilight, are just 0.2° apart!

Sep 2 Neptune is at opposition

Sep 16 A penumbral eclipse of the Moon, with most shading near 19h UT (Europe, Asia)

Sep 18 Spica is 2.4° to the lower left of Venus (use binoculars)

Oct 14 Uranus is at opposition

Oct 29 Saturn is 3.0° to the upper right of Venus

Dec 4 Earliest end of evening twilight

Dec 7 Earliest sunset

Dec 10 Mercury is 21° east of Sun

Dec 21 Shortest day, 9h 20m at latitude 40° north

evening)

May 9 A transit of Mercury is widely visible in the Americas, Europe, and Asia (except the Far East)

Jun 5 Mercury is at greatest elongation, 24° west of the Sun

Jun 13 Earliest sunrise

Jun 17 Earliest morning twilight

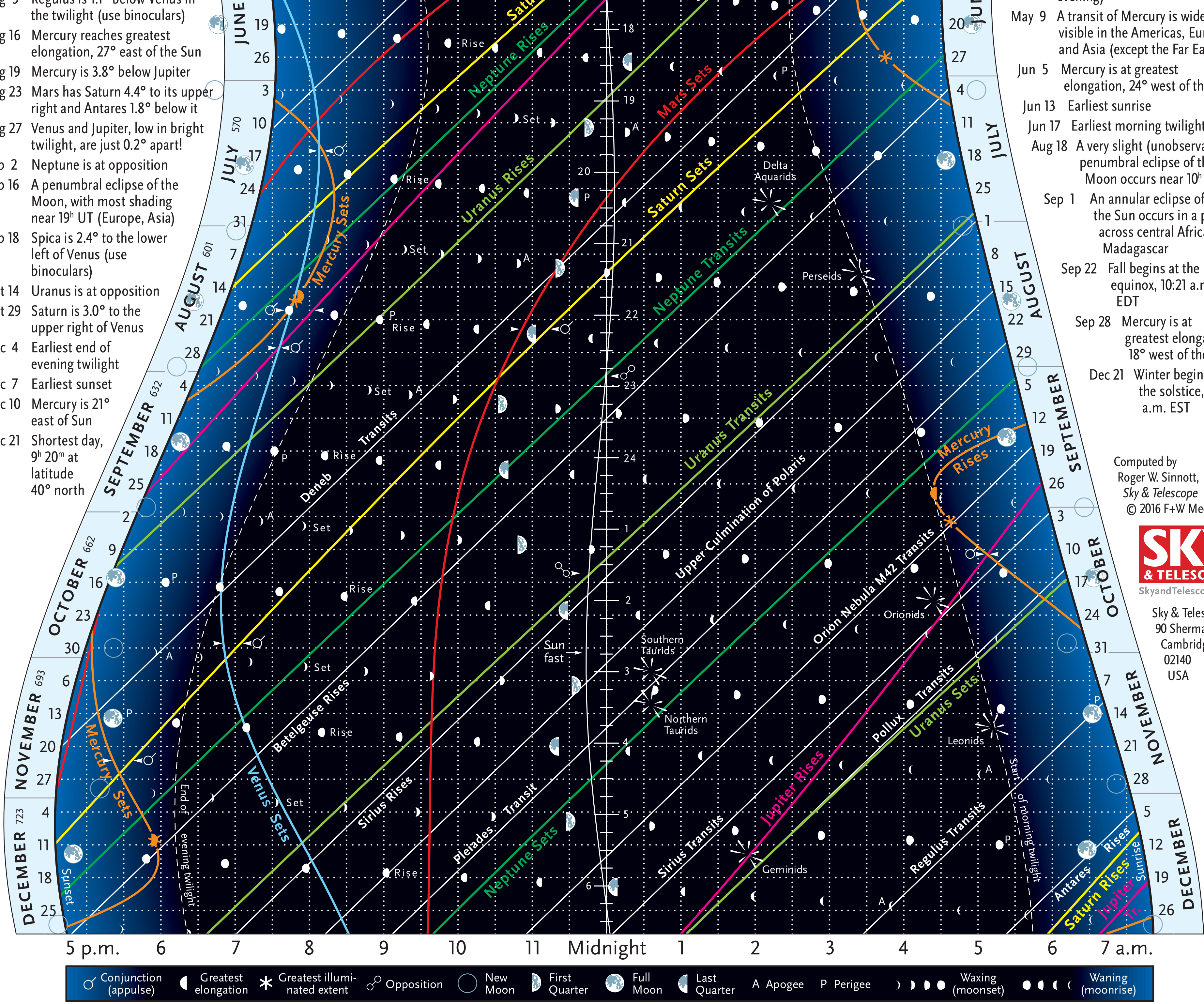
Aug 18 A very slight (unobservable) penumbral eclipse of the Moon occurs near 10h UT

Sep 1 An annular eclipse of the Sun occurs in a path across central Africa and Madagascar

Sep 22 Fall begins at the equinox, 10:21 a.m. EDT

Sep 28 Mercury is at greatest elongation, 18° west of the Sun

Dec 21 Winter begins at the solstice, 5:44 a.m. EST



Computed by Roger W. Sinnott, *Sky & Telescope*

SKY & TELESCOPE
SkyandTelescope.com

Sky & Telescope
90 Sherman St.
Cambridge, MA
02140
USA

Skygazer's Almanac 40°N 2016

FOR LATITUDES NEAR 40° NORTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2016* — a handy chart that answers these and many other questions for every night of the year. It is plotted for skywatchers near latitude 40° north — in the United States, Mediterranean countries, Japan, and much of China.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 17, 2016.

First find "January" and "17" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 17–18 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 17–18 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 17th occurs at 5:01 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your standard clock time. More on this later.)

Moving to the right, we see that the bright star Sirius rises at 5:54 p.m. Evening twilight ends at 6:36, marking the time when the Sun is 18° below the horizon and the sky is fully dark.

At 7:05 p.m. Polaris, the North Star, is at upper culmination. This is when Polaris stands directly above the north celestial pole (by 40′ this year), a good time to check the alignment of an equatorial telescope.

At 8:00 the Pleiades transit the meridian, meaning the famous star cluster is then due south and highest in the sky. Neptune sets at 8:24, so we can cross it off our observing list for tonight.

Jupiter rises in the east at 9:32 p.m. The Great Orion Nebula (Messier 42) transits the meridian at 9:48, as does Sirius at 10:58. Transits of celestial landmarks help indicate when they are best placed for viewing, and where the constellations are during the night.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 17–18 this is $7^h\,48^m$. To find the sidereal time at any other time and date on the chart, locate that point and draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 17th the Sun runs slow, transiting at 12:10 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

Mars rises at 1:16 a.m., a sign it will be in fine view later this year. Then at 1:49 we see a Moon symbol, and the legend at the chart's bottom tells us it is at waxing gibbous phase, and setting. (So the night until now has been brightly moonlit.) Jupiter reaches its high point in the sky at 3:48. Then at 4:08 the ringed planet Saturn rises in the east, followed in 8 minutes by Antares, a star we usually associate with a much later season.

Brilliant Venus rises in a dark sky at 4:58 a.m. The first hint of dawn — the start of morning twilight — comes at 5:44. The Sun finally peeks above the horizon at 7:19 a.m. on January 18th.

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are indicated on the chart by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest together in the sky (at appulse), not merely when they share the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol, as for

Jupiter on the night of March 7–8.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

The elusive planet Mercury never strays far outside the twilight bands. Its dates of greatest elongation from the Sun are shown by ◗ symbols on its rising or setting curves. Asterisks mark the dates when it shows its greatest illuminated extent in square arcseconds. (The same symbols can also appear on Venus's curves, but not in 2016.)

Meteor showers are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant is highest in the night sky. This is often just as morning twilight begins.

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2457, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 388 to the date. For instance, on the evening of January 17th we have 388 + 17 = 405, so the Julian day is 2,457,405. For North American observers this number applies all night, because the next Julian day always begins at 12:00 Universal Time (6:00 a.m. Central Standard Time).

Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at 90° west longitude and 40° north latitude, near the population center of North America. However, you need not live near Peoria, Illinois, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

To convert the charted time of an event to your civil (clock) time, the following corrections must be made. They are listed in decreasing importance:

• **DAYLIGHT-SAVING TIME.** When this is in effect, add one hour to any time obtained from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in North America are Eastern Time, 75° W; Central, 90°; Mountain, 105°; and Pacific, 120°. If your longitude is very close to one of these (as is true for New Orleans and Denver), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Washington, DC (longitude 77°), is 2° west of the Eastern Time meridian. So at Washington, add 8 minutes to any time obtained from the chart. The result is Eastern Standard Time.

Find your time adjustment and memorize it. The table below shows the corrections from local to standard time, in minutes, for some major cities.

Local Mean Time Corrections

Atlanta	+38	Los Angeles	–7
Boise	+45	Memphis	0
Boston	–16	Miami	+21
Buffalo	+15	Minneapolis	+13
Chicago	–10	New Orleans	0
Cleveland	+27	New York	–4
Dallas	+27	Philadelphia	+1
Denver	0	Phoenix	+28
Detroit	+32	Pittsburgh	+20
El Paso	+6	St. Louis	+1
Helena	+28	Salt Lake City	+28
Honolulu	+31	San Francisco	+10
Houston	+21	Santa Fe	+4
Indianapolis	+44	Seattle	+10
Jacksonville	+27	Tulsa	+24
Kansas City	+18	Washington	+8
Athens	+25	Lisbon	+36
Baghdad	+3	Madrid	+75
Beijing	+14	New Delhi	+21
Belgrade	–22	Rome	+10
Cairo	–8	Seoul	+32
Istanbul	+4	Tehran	+4
Jerusalem	–21	Tokyo	–19

• **RISING AND SETTING.** Times of rising and setting need correction if your latitude differs from 40° north. This effect depends strongly on a star or planet's declination. (The declinations of the Sun and planets are given in each month's *Sky & Telescope*.)

If your site is *north* of latitude 40°, then an object with a north declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), whereas one with a south declination spends less time above the horizon. At a site *south* of 40°, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table above.

Rising or Setting Corrections

North Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
50°	0	7	14	23	32	43
45°	0	3	7	10	14	19
40°	0	0	0	0	0	0
35°	0	3	6	9	12	16
30°	0	5	11	16	23	30
25°	0	8	16	24	32	42

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 90° west. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Central Time, and two minutes later for each time zone west of Central Time. European observers can simply shift each rising or setting Moon symbol leftward a quarter of the way toward the one for the previous night.

For reprints (item SGA16R, $4.95 each postpaid) or to order a similar chart for latitude 50° north or 30° south, contact *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140, USA; phone 800-253-0245, fax 617-864-6117. You can send e-mail to skyprodservice@skyandtelescope.com, or visit our online store at SkyandTelescope.com.

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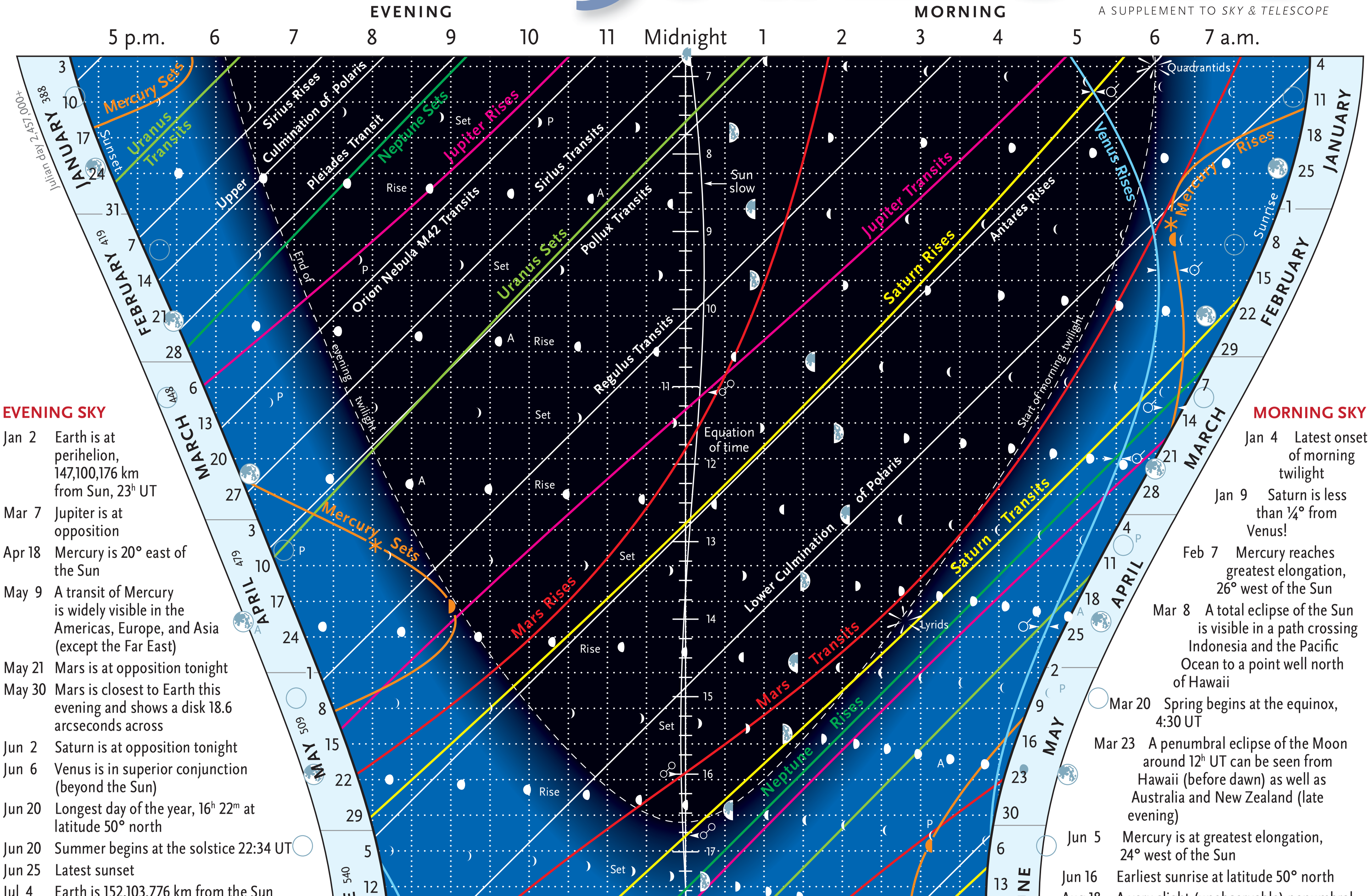
SkyandTelescope.com

Skygazer's Almanac 50° N 2016

FOR LATITUDES NEAR 50° NORTH

A SUPPLEMENT TO *SKY & TELESCOPE*



EVENING SKY

- Jan 2 Earth is at perihelion, 147,100,176 km from Sun, 23h UT
- Mar 7 Jupiter is at opposition
- Apr 18 Mercury is 20° east of the Sun
- May 9 A transit of Mercury is widely visible in the Americas, Europe, and Asia (except the Far East)
- May 21 Mars is at opposition tonight
- May 30 Mars is closest to Earth this evening and shows a disk 18.6 arcseconds across
- Jun 2 Saturn is at opposition tonight
- Jun 6 Venus is in superior conjunction (beyond the Sun)
- Jun 20 Longest day of the year, 16h 22m at latitude 50° north
- Jun 20 Summer begins at the solstice 22:34 UT
- Jun 25 Latest sunset
- Jul 4 Earth is 152,103,776 km from the Sun

MORNING SKY

- Jan 4 Latest onset of morning twilight
- Jan 9 Saturn is less than ¼° from Venus!
- Feb 7 Mercury reaches greatest elongation, 26° west of the Sun
- Mar 8 A total eclipse of the Sun is visible in a path crossing Indonesia and the Pacific Ocean to a point well north of Hawaii
- Mar 20 Spring begins at the equinox, 4:30 UT
- Mar 23 A penumbral eclipse of the Moon around 12h UT can be seen from Hawaii (before dawn) as well as Australia and New Zealand (late evening)
- Jun 5 Mercury is at greatest elongation, 24° west of the Sun
- Jun 16 Earliest sunrise at latitude 50° north
- Jun 18 A very slight (unobservable) penumbral

(aphelion) at 16h UT

Aug 16 Mercury stands at greatest elongation, 27° east of the Sun

Aug 24 Mars has Saturn 4.4° above it and Antares 1.8° below it

Sep 2 Neptune is at opposition tonight

Sep 16 A penumbral eclipse of the Moon occurs with the most shading near 19h UT for Europe and Asia

Sep 22 Fall begins at the equinox, 14:21 UT

Oct 14 Uranus is at opposition tonight

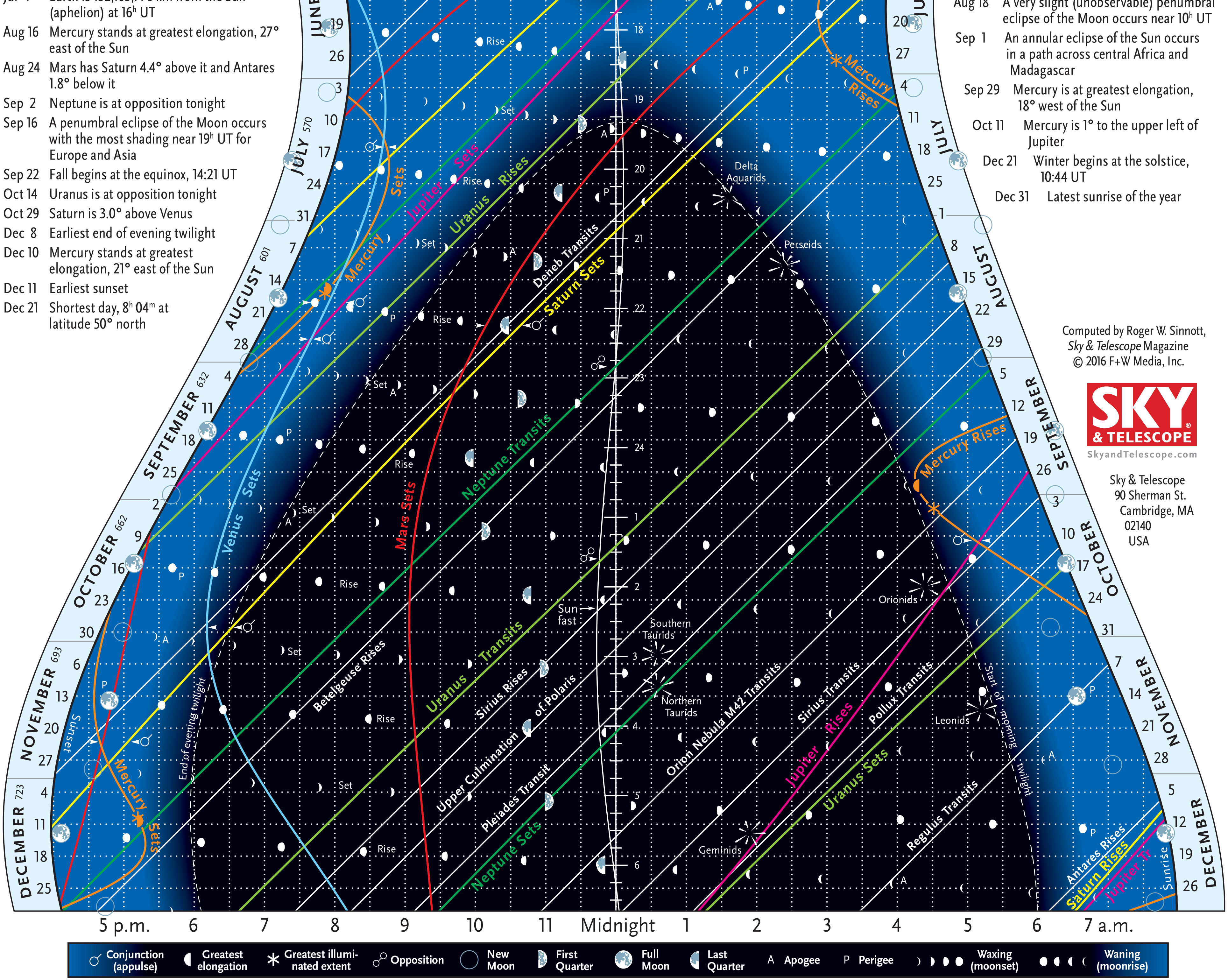
Oct 29 Saturn is 3.0° above Venus

Dec 8 Earliest end of evening twilight

Dec 10 Mercury stands at greatest elongation, 21° east of the Sun

Dec 11 Earliest sunset

Dec 21 Shortest day, 8h 04m at latitude 50° north



Aug 18 A very slight (unobservable) penumbral eclipse of the Moon occurs near 10h UT

Sep 1 An annular eclipse of the Sun occurs in a path across central Africa and Madagascar

Sep 29 Mercury is at greatest elongation, 18° west of the Sun

Oct 11 Mercury is 1° to the upper left of Jupiter

Dec 21 Winter begins at the solstice, 10:44 UT

Dec 31 Latest sunrise of the year

Computed by Roger W. Sinnott, *Sky & Telescope* Magazine

SkyandTelescope.com

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USA

Skygazer's Almanac 50°N 2016

FOR LATITUDES NEAR 50° NORTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2016* — a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 50° north — in the United Kingdom, northern Europe, Canada, and Russia.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 17, 2016.

First find "January" and "17" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 17–18 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 17–18 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 17th occurs at 4:29 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your standard clock time by many minutes. More on this later.)

Moving to the right, we see that the bright star Sirius rises at 6:19 p.m. Evening twilight ends at 6:24, marking the time when the Sun is 18° below the horizon and the sky is fully dark.

At 7:06 p.m. Polaris, the North Star, reaches upper culmination. This is when Polaris stands directly above the north celestial pole (by 40′ this year), a good opportunity to check the alignment of an equatorial telescope.

The Pleiades transit the meridian at 8:01 p.m., followed by the famous Orion Nebula at 9:49 and Sirius at 10:59. Transits of celestial landmarks mark their high points in the sky and remind us where constellations are throughout the night.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 17–18 this is $7^h\,47^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 17th the Sun runs slow, transiting at 12:10 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit around the Sun.

Mars rises at 1:35 a.m., a sure sign it will become prominent in the evening sky later this year. Then near 1:51 we see a Moon symbol, and the legend at the chart's bottom tells us it is at gibbous phase, setting. (That is, we've had bright moonlight this evening up to now.)

Jupiter transits at 3:49 a.m., an ideal time to check on its moons and cloud belts with a telescope. The ringed planet Saturn rises at 4:42, and then a star we usually associate with a later season, Antares, comes up at 5:03. Brilliant Venus appears at 5:32.

The first hint of dawn — the start of morning twilight — comes at 5:55 a.m. The Sun finally peeks above the eastern horizon at 7:51 a.m. on the morning of January 18th.

Local Mean Time Corrections

Amsterdam	+40	Manchester	+8
Belfast	+24	Montreal	–6
Berlin	+6	Moscow	+26
Bordeaux	+62	Munich	+14
Bremen	+24	Oslo	+17
Brussels	+44	Ottawa	+3
Bucharest	+16	Paris	+51
Budapest	–16	Prague	+2
Calgary	+36	Quebec	–15
Copenhagen	+10	Regina	+58
Dublin	+25	Reykjavik	+88
Geneva	+35	St. John's	+1
Glasgow	+16	Stockholm	–12
Halifax	+14	Toronto	+18
Hamburg	+20	Vancouver	+12
Helsinki	+20	Vienna	–5
Kiev	–2	Warsaw	–24
London	0	Winnipeg	+29
Lyons	+41	Zurich	+24

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are indicated on the chart by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest together in the sky (at appulse), not merely when they share the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol. For instance, Jupiter reaches opposition on the night of March 7–8 this year.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury almost never strays outside the twilight bands. Its dates of greatest elongation from the Sun are shown by ◗ symbols on its rising or setting curves, and asterisks mark the dates when Mercury shows its greatest illuminated extent in square arcseconds. (The same symbols can also appear on Venus's curves, but the events for that planet don't occur in 2016.)

Meteor showers are marked by a starburst symbol at the date of peak activity and the time when the shower's radiant is highest in the night sky. This is often just as twilight begins before dawn.

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2457, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 388 to the date. For instance, on the evening of January 17th we have 388 + 17 = 405, so the Julian day is 2,457,405. For European observers this number applies all night, because the next Julian day always begins at 12:00 Universal Time (noon Greenwich Mean Time).

Rising or Setting Corrections

North Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
60°	1	11	23	36	53	80
55°	0	5	10	16	23	32
50°	0	0	0	0	0	0
45°	0	4	8	13	18	24
40°	1	8	15	23	32	43
35°	1	10	20	31	44	68
30°	1	12	25	39	54	72
25°	1	15	30	46	64	84

Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at 0° longitude and 50° north latitude, a reasonable compromise for the countries of northern and central Europe. However, you need not be on a boat in the English Channel to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in decreasing order of importance:

• **DAYLIGHT-SAVING TIME (OR "SUMMER TIME").** When this is in effect, add one hour to any time that you obtain from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Europe are Greenwich Mean Time (or Universal Time), 0°; Central European Time, 15° E; and East European Time, 30°. If your longitude is very close to one of these (as is true for London), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it. You can look up your longitude on a map.

For instance, Copenhagen (longitude 12.5° east) is 2.5° west of the Central European Time meridian. So at Copenhagen, add 10 minutes to any time obtained from the chart. The result is Central European Standard Time.

Find your local-time correction and memorize it; you will use it always. In the table below at far left are the corrections from local to standard time, in minutes, for some major cities.

• **RISING AND SETTING.** Times of rising and setting need correction if your latitude differs from 50° north. This effect depends strongly on a star or planet's declination. (The changing declinations of the Sun and planets can be found in each issue of *Sky & Telescope*.)

If your site is north of latitude 50°, then an object with a north declination stays above the horizon longer than the chart shows (it rises earlier and sets later), while one with a south declination spends less time above the horizon. At a site south of 50°, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table at upper left.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 0°. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Greenwich Mean Time, and two minutes later for each time zone west of Greenwich Mean Time.

For reprints (item SGA16E, $5.95 each postpaid) or to order a similar chart for latitude 40° north or 30° south, contact *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140, USA; phone +1 617-864-7360, fax +1 617-864-6117. Send e-mail to skyprodservice@skyandtelescope.com, or visit our online store at SkyandTelescope.com.

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