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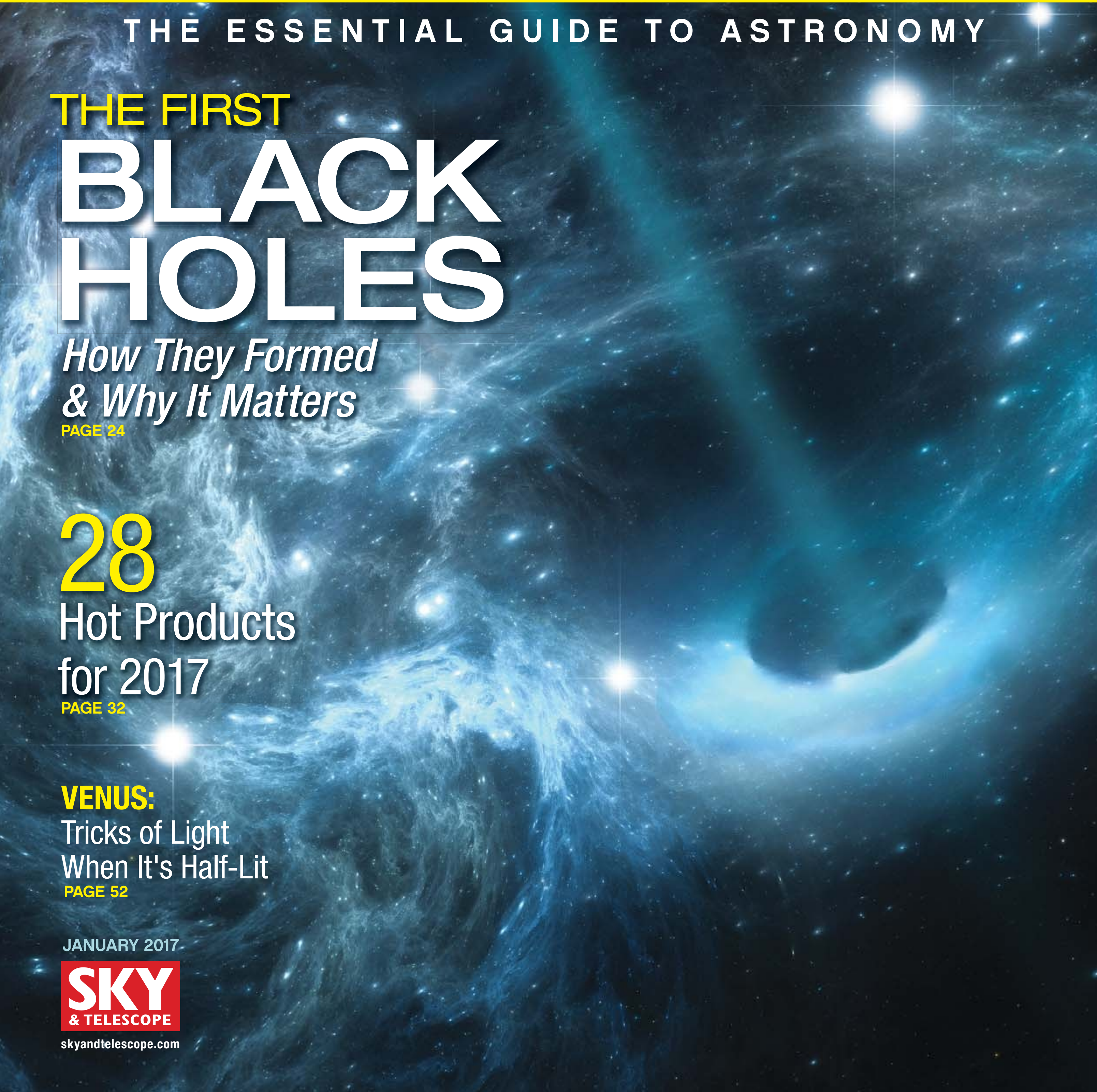
SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY



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JANUARY 2017
SKY & TELESCOPE
skyandtelescope.com

Tele Vue APO refractors earn a high yield of happy owners. 35 years of hand-building scopes with care and dedication is why we see comments like: "Thanks to all at Tele Vue for such wonderful products."

The care that goes into building every Tele Vue telescope is evident from the first time you focus an image. What goes unseen are the hours of work that led to that moment. Hand-fitted rack & pinion focusers must withstand 10lb. deflection testing along their travel, yet operate buttery-smooth, without gear lash or image shift. Optics are fitted, spaced, and aligned using proprietary techniques to form breathtaking low-power views, spectacular high-power planetary performance, or stunning wide-field images. When you purchase a Tele Vue telescope you're not so much buying a telescope as acquiring a lifetime observing companion.

Comments from recent warranty cards

- (TV60) "I cannot thank you enough for providing me with such quality! This scope will give me a **lifetime** of observing **happiness**." —M.E.,Canada
- (TV76) "I've wanted a TV scope for 40 years. Finally! And, I'm overwhelmed! **Love**, **Love**, **Love** it!!"—D.H.,OK
- (TV85) "**Perfect** form, **perfect** function, **perfect** telescope, and I didn't have to wait 5 years to get it!"—R.C.,TX
- (TV85) "Thank you for making such **beautiful** equipment available. The build quality is **superb**. It is a **treasured** telescope."—J.C.,UK
- (NP101is) "Great job! Assembly **A++**, Team **A++**. Thank you Al and Team."—N.O.,CA
- (NP127is) "I own three other Tele Vues. They are **the best**." —K.M.,CA
- (NP127is) "I wanted a rugged, **high-quality**, transportable APO that was affordable. Thanks for making such a great scope. I look forward to many years of enjoyment."—R.H.,OH


TV-60


TV-76


TV-85


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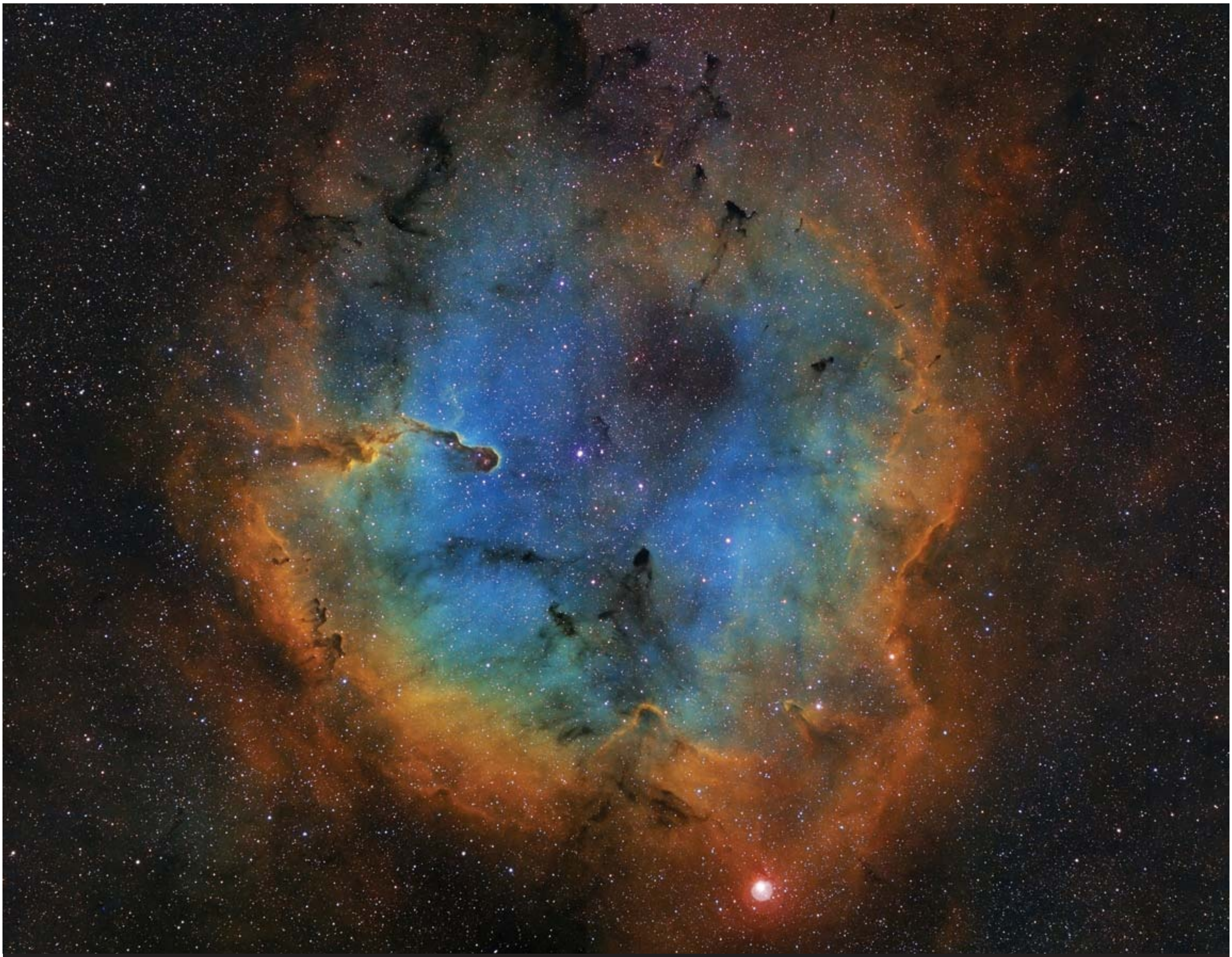

IC 1396. FLI camera with 50 megapixel KAF-50100 sensor. Image Courtesy Wolfgang Promper.

50 Megapixels: The New Standard

The new standard for high resolution astrophotography is the KAF-50100 sensor, the result of a year-long collaborative effort between ON Semiconductor and Finger Lakes Instrumentation. Our goal: to create a sensor with both high resolution and excellent quantum efficiency. The significantly boosted QE of the new KAF-50100 sensor brings it in line with popular full frame sensors such as the KAF-16803 but with much higher spatial resolution.

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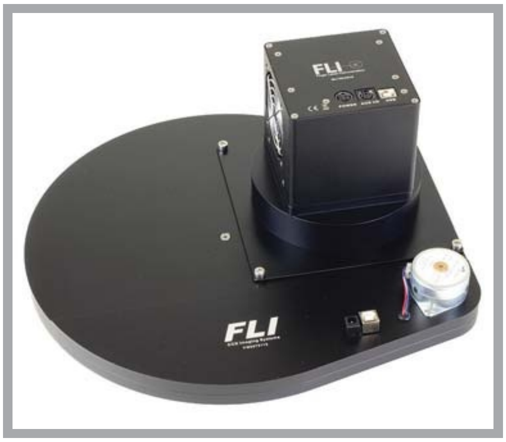
Visit us at flicamera.com for more information about our cooled CCD cameras, focusers, and color filter wheels.

HOT PRODUCT 2015 SKY & TELESCOPE



MicroLine ML50100 Camera on CFW10-7 Filter Wheel

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SKY&TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

ROBERT GENDLER

January 2017

VOL. 133, NO. 1

FEATURES

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OBSERVING

COLUMNS / DEPARTMENTS

ON THE COVER

Swathed in gas, the first black holes formed either from, or irradiated by, early stars.

© BIGSTOCKPHOTOS.COM / PITRIS

ONLINE

TIPS FOR BEGINNERS
New to the hobby of astronomy? Here's everything you need to jump into the fun.
skyandtelescope.com/letsgo

EXPLORE THE NIGHT BLOG
Follow Contributing Editor Bob King each week as he takes readers on an adventure through the night sky.
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WEBINARS
Join *S&T* staff and contributors to learn about astrophotography, equipment, constellations, and more.
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Introducing the capable new SkyTracker™ Pro for astroscapes

The SkyTracker Pro is designed for photographers seeking to bring their astroscape imaging to the next level. It offers unique features in a compact, rugged, user-friendly design. The polar finder scope has a a variable brightness illuminated reticle that, combined with fine-tuning controls on the alt-azimuth base, make set up and alignment a breeze. Pointing and framing the camera are now assisted by a bidirectional quick slew control. A stable precise movement with 4 tracking rates (1x, 1/2x, lunar, solar) and a built-in rechargeable power source offering 24 hours of continuous operation round off some of the exciting new features. The SkyTracker Pro, available online or at iOptron dealers worldwide.

The iPano AllView Pro, a precise computerized robotic camera platform that serves to automate the tedious image capture steps needed to create gigapixel panoramic, hemispherical, and spherical images, as well as panning time lapse movies. The iPano doesn't only point the camera and trigger the shutter, it automatically calculates the number and position for every shot needed to complete the final image.

photo by Rob Dickinson

IPANO
AllView Pro
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Our New Look

AS PROMISED in last January's Spectrum, we've given *Sky & Telescope* a makeover, which we're happy to introduce with this issue. *S&T* still has the same essential visage and voice you've known, just now with a more contemporary aspect. This publication might be 75 years old, but we've still got plenty of spring in our step.

We revamped for the usual reasons publications do so: our last punching-up occurred in 2007, and *S&T* had begun to look a bit dated, belying our cutting-edge content. Plus, we're always asking ourselves: how can we appeal to the broadest possible audience, even as we delight our dedicated readers?

Patricia Gillis-Coppola, *S&T*'s Design Director, began the redesign last spring. Pat had a trove of ideas she'd been itching to experiment with for years, and she finally got her chance. Straight into early fall, she worked hard to create our new look, even sacrificing weekends so that each 2016 issue of the magazine — which she also put together — still got done on time. She had help from Claudean Wheeler, the Art Director of *Writer's Digest* magazine (owned, like *S&T*, by F+W Media), who served as consultant and brought a fresh eye to the process. A few editors provided input as well, and we drew on suggestions received from you, our readers. But the lion's share of credit for what you see in these pages goes to Pat.

Pat (left) and Claudean at the *S&T* offices.

S&T: KELLY BEATTY

She pored over every snippet — fonts, images, boxes, backgrounds. She pondered the color palette, the architecture of pages, and the reader's navigation through the magazine. Readability of type, best use of white space, consistent appearance of graphics — all came into it.

The cover received its own transformation, naturally. Every issue's strongest headline is our own name, *Sky & Telescope*. With Claudean's help, Pat aimed to make our new title treatment eye-catching but authoritative, modern yet seasoned by experience. Its ampersand, with its implicit resemblance to an "@" symbol, offers a nod to the increasingly relevant digital landscape.

Lastly, we editors wanted to make a few editorial tweaks. Thus "Letters" has become "From Our Readers," so we can incorporate comments from our website and social media, and "Northern Hemisphere Sky" is now "Under the Stars," to highlight the poetic style of Fred Schaaf, who just celebrated 25 years writing for *S&T*. We relocated a few regular elements, such as "Sky at a Glance" (page 41), and we reintroduced a periodic calendar of major amateur events (page 83).

We hope you like what you see.

Peter

Editor in Chief

SKY&TELESCOPE
The Essential Guide to Astronomy

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

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GOTO

GOTO Gets Ready!

Since our founder Seizo Goto filmed a total solar eclipse in Japan in 1936, GOTO INC has been fascinated by eclipses. Today, as millions of Americans prepare for the 2017 eclipse, the country's planetariums are acting as important resources for their communities. Curious and eager audiences are flocking to local school and public programs to learn about moon phases, solar science, eye safety, and the history and cultural importance of eclipses. The months leading up to a total solar eclipse are perhaps astronomy's most "teachable moments."

★ : *GOTO installation theaters.*

Here are a few examples of the ways GOTO INC is helping to bring the eclipse to America:

1

Installed Model : CHRONOS II HYBRID, They are using the precise positions and motions of their GOTO CHRONOS II HYBRID's sun, moon, and planets to teach K-12 students about the eclipse. Planetarium director Paul Zeleski says, "Since we're about 97% eclipsed here, I plan to do some public outreach in Gillette with solar telescopes and some planetarium presentations to get people informed and then get them down to Casper for the main event."

2

Installed Model : CHIRON HYBRID
Planetarium director Derrick Rohl says, "Our activities build up to a 3-day Eclipse Science Festival we'll be hosting on eclipse weekend here in Music City. … and our CHIRON projector is still looking as stunning as the day we opened. Not only do we use the CHIRON HYBRID system for pre-produced content like our new "ECLIPSE: The Sun Revealed" show, but we also use the system's realtime features 363 days a year to show off the night sky in "Skies Over Nashville."

3

Installed Model : GSS-CHRONOS
(The world's first CHRONOS site) is planning for its moment in the shadow with programs director Steve Morgan says, "… include a live-narrated segment focusing on local eclipse circumstances and information.The CHRONOS is useful for teaching about moon phases and showing the motion of the Moon in its orbit. We also can run the CHRONOS to the time of the eclipse and show the position of the planets and brighter stars in the sky in relation to the eclipsed Sun's position."

GOTO "Greatest Eclipse Hits"

"GOTO's best from 80 years of eclipse chasing!"

includes:
- *-Animated map of Total Solar Eclipse 2017*
- *-Computer graphic still images and still photographs*
- *-Fulldome short clips and normal format movies;*

mechanism and geometries of eclipses, orbits, and beautiful clips of previous solar eclipses shot around the world.

Price Guide :
1K US$400
4K US$600

For more information, please contact <show-sale@goto.co.jp>

**The Price varies depending on the resolution.*
**The price is for online downloadings only. Additional fee may apply for hard drives, shipping, and handling if physical delivery is required.*

Dome Navi
<http://tinyurl.com/domenavi-eclipse2017 >

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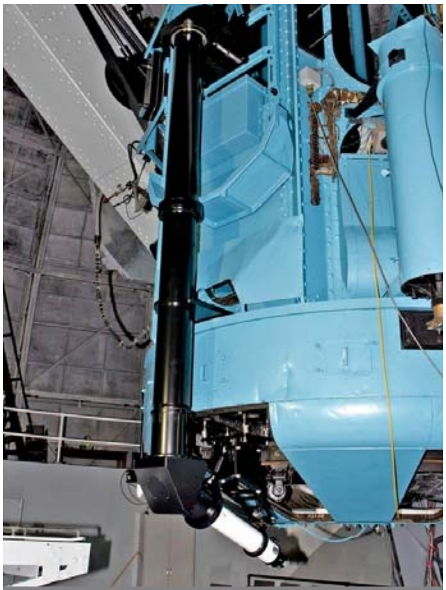
A Night on Mount Wilson

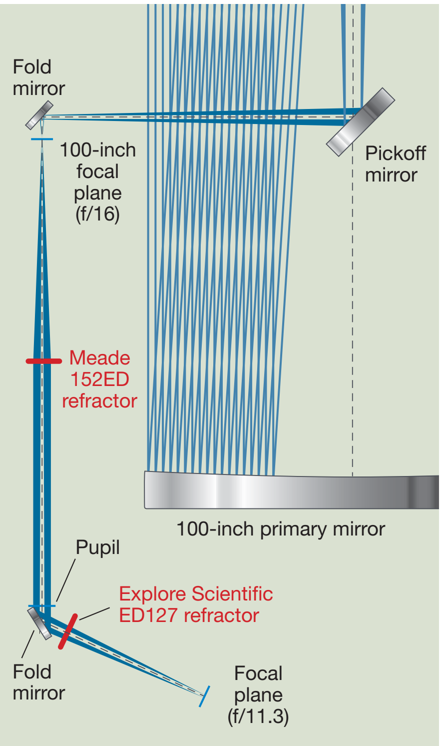
I enjoyed reading about Robert Naeye's visit to Mount Wilson's 100-inch reflector (*S&T:* Sept. 2016, p. 22). He mentions the novel relay lens system to facilitate viewing through this historic telescope. However, he didn't go into detail about its design and function. So I was curious about its optical configuration and how it converts the system from f/16 to f/11.3.

Martin Lewicki
Adelaide, South Australia

Astronomer Laszlo Sturmann replies: *As shown at right, the telescope is used in its Nasmyth configuration and the relay optics are on the outside. Think of the Meade objective as a very long-focal-length "eyepiece" that, just like any other eyepiece, forms a real image at the exit pupil of the telescope. Usually, the exit pupil of an amateur telescope is just a few millimeters across. But for the combined 100-inch telescope and Meade objective, the exit pupil is about 90 mm in diameter. If the telescope is focused to infinity, the light passing through the exit pupil is collimated. So we added a second refractor objective, from Explore Scientific, to take in that big, collimated beam and send it to a conventional eyepiece.*



The addition of a clever optical relay system, pictured above and diagrammed schematically at right, allows the famed 100-inch telescope on Mount Wilson to be used visually.



LASZLO STURMANN (2)

I had no idea that the 100-inch telescope is now available for half- and full-night rentals, much as the 60-inch has been. A full night's rental for these telescopes costs $5,000 and $1,700, respectively, but both scopes represent a huge bargain if the fee is split among members of a visiting group. I wish I lived in California!

Tom Sales
Somerset, New Jersey

It was surprising to learn that many deep-sky objects fared so poorly through Mount Wilson's famous 100-inch telescope. In fact, Naeye notes that he'd had better views of many of these with smaller-sized instruments under darker skies. This only shows that a large aperture is no remedy for light pollution.

Then there were the scope's relatively poor views of Uranus and Neptune, even though he rated the seeing at 1 to 1½ arcseconds. With its large aperture, the telescope was probably looking through a column of air that contained numerous image-distorting convection cells, each an estimated 10 to 20 cm across. In fact, it's often claimed that, when the seeing is less than ideal, smaller apertures are affected by fewer convection cells (or perhaps only one) and thus can provide a more stable image compared to that from a larger instrument.

Frank Ridolfo
Bloomfield, Connecticut

Ritchey and His Telescopes

Although it's true that the Chabot Space and Science Center in Oakland, California, once housed George Ritchey's 24-inch Newtonian-Cassegrain reflector (*S&T:* Oct. 2016, p. 66), it was returned to the Smithsonian Institution several years ago. Also, those interested in learning more about Ritchey and his relationship with George Ellery Hale should track down the definitive biography, *Pauper and Prince: Ritchey, Hale, and Big American Telescopes*. Author Donald Osterbrock beautifully and sympathetically describes Ritchey's great accomplishments while acknowledging his many personal weaknesses.

Kenneth Lum
San Carlos, California

Author Ted Rafferty replies: *In addition to Osterbrock's book, Deborah J. Mills wrote an excellent article titled "George Willis Ritchey and the Development of Celestial Photography," published in* American Scientist *in March 1966.*

The "Observer's Challenge"

In February 2009, the Las Vegas Astronomical Society started an online feature called the Observer's Challenge. LVAS member Fred Rayworth and I created this monthly forum to bring interesting galaxies, nebulae, clusters, and multiple stars to the attention of amateur astronomers.

We designed it primarily to promote visual observing, while allowing amateurs the opportunity to share their observations and work. To our surprise, it has become quite popular and includes participants in all 50 states and more than 100 foreign countries.

It's always been my opinion that every amateur needs a goal, even if it's just to get to the eyepiece on a regular basis. To that end, the Observer's Challenge has inspired me to go outside even when I would much rather have stayed inside.

Fred and I have kept at it, and this past August marked our 90th consecutive monthly report — quite an accomplishment for an amateur production. You can find and enjoy them all at **https://is.gd/observers_challenge**.

Roger Ivester
Boiling Springs, North Carolina

Moonstruck

Many thanks for "The Moon Does That to You" (*S&T:* Oct. 2016, p. 84). I can relate to Mark Mathosian's experience, as I have been involved in similar interaction with strangers.

His story also brings back the memory of another recollection that left a lasting and powerful impression on me: "The Mysterious Coney Island Telescope Lady" by Paul Johannsen (*S&T:* Jan. 1992, p. 97). That reminiscence, from the 1950s, comes awfully close to my own start in astronomy.

I have never been able to fully explain how all of this works. But no matter how many spectacular Hubble images of galaxies or incredible planetary shots by Damian Peach we see, there is something magical about the view in the eyepiece that no imager can match. And that's one reason why I have remained a strictly visual observer in this age of CCD imaging.

Vahe Sahakian
Houston, Texas

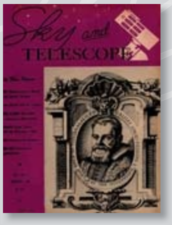
FOR THE RECORD

- The caption for a photograph of Martian sand dunes (*S&T:* Sept. 2016, p. 12) should note that the carbon dioxide ice is sublimating, not melting.
- The Little Dumbbell Nebula, Messier 76, is located in Perseus (*S&T:* Sept. 2016, p. 28).
- In the plot showing occultation chords (*S&T:* Sept. 2016, p. 49), Steve Conard's name is misspelled; also Elizabeth Warner and Holly Sheets observed from College Park, Maryland.
- In the lunar-data table (*S&T:* Oct. 2016, p. 53), last quarter occurs at 19:14 UT.

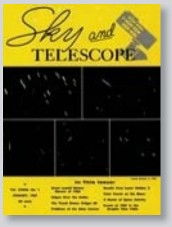
SUBMISSIONS: Write to *Sky & Telescope,* 90 Sherman St., Cambridge, MA 02140-3264, U.S.A. or email: letters@skyandtelescope.com. Please limit your comments to 250 words.

75, 50 & 25 YEARS AGO by Roger W. Sinnott

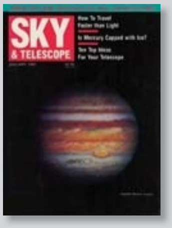
1942



1967



1992



◖ January 1942

Pulkovo Disaster "The destruction of Pulkovo Observatory, situated near Leningrad, has recently been reported [after the German army's siege of the city]. Besides numerous instruments, including a 30-inch Alvan Clark refractor, the observatory had a valuable collection of Kepler manuscripts.

"Through the work of the Struves, [Aristarkh] Belopolsky, and others, the observatory distinguished itself in many ways, giving astronomers a heritage of catalogues and contributions on star positions, double stars, spectroscopy, and other branches of astronomy. . . ."

All was not lost. The rare books, Kepler manuscripts, and 30-inch Clark objective had been safely moved off site before the Russians' assault. But the large refractor was among the equipment destroyed, and to date the lens has not been put back in service.

◖ January 1967

Leonid Storm "An intense rain of thousands upon thousands of Leonid meteors fell over the western United States for a short interval on the morning of November 17th. This brilliant display rivaled the historic Leonid showers of November 12, 1799, in Peru, and November 13, 1833, when 'stars fell on Alabama' and elsewhere in vast numbers. . . .

"'A rate of around 150,000 per hour was seen for about 20 minutes,' writes Dennis Milon of Tucson, Arizona, who with a dozen other amateurs watched from 6,850-foot Kitt Peak. . . . Jack Sulentic commented that looking directly at the radiant gave him an impression of the earth moving through space toward Leo."

Never again has such a torrent of Leonids appeared. But rates for some observers exceeded 1,000 per hour on November 18, 1999, when a concentration of debris from Comet 55P/Tempel-Tuttle, the shower's source, again looped through the inner solar system.

◖ January 1992

Exoplanet Doubts "Many stars probably have planets, but it's been an uphill battle trying to certify even one of the few good candidates found so far. . . .

"[For example, recently a] much-trumpeted planetary candidate turned up in a most unexpected place: circling around the pulsar PSR 1829 – 10, some 30,000 light-years away in Scutum. [But how] could an object with only 10 Earth masses survive the supernova explosion that presumably created the pulsar and remain in a perfectly circular orbit?. . .

"Deciding whether [one of several proposed scenarios] applies to PSR 1829 – 10 won't be easy. Thus the search for the first *confirmed* extrasolar planet goes on."

The floodgates of discovery would soon open, and today the count of confirmed planets outside our solar system exceeds 3,300. But the planet of PSR 1829 – 10 isn't one of them; its discovery claim was eventually retracted.

FROM PLANETARY TO DEEP SKY, WE HAVE EVERYTHING FOR THE ASTRONOMER ON YOUR LIST.

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Sky-Watcher USA's flagship apochromatic triplet refractor, widely considered the best value on the market, delivers unparalleled optical performance for astronomers and astrophotographers alike. Utilizing both Ohara and Schott glass elements, the Esprit series produces images that rival the performance of other refractors costing thousands of dollars more. Available in 80, 100, 120 and 150mm apertures.

Starting at just $1,649

ProED APO Doublets

Sky-Watcher's ProED doublet series utilizes a proprietary combination of matched lenses that eliminates virtually all false color to deliver optimum visual and photographic performance. Widely considered the best OTAs in their design class, ProEDs are the perfect choice for the discriminating amateur astronomer. Available in 80, 100 and 120mm apertures.

Starting at just $649

Quattro Imaging Newtonians

Our ultra-fast f/4 astrographs produce an exposure 6 times faster than the average 8-inch f/10 Schmidt Cassegrain telescope! Even pricey refractors have trouble reaching a focal ratio this fast. Available in 8-, 10- and 12-inch apertures.

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Mak-Cassegrain Compact OTAs

Our Maksutov-Cassegrain series delivers large-aperture viewing in a lightweight and portable package. This optical design has a reputation for sharp, high-contrast views, ideal for planetary, lunar and deep sky observation and imaging.

Starting at just $255

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Our Mak-Newt combines a large aperture with exceptional field correction in a compact package, making it ideal for photographers looking for a large-aperture, high-quality astrograph. In addition to its fast f/5.3 focal ratio, this OTA features a front corrector that creates a flat field free of coma and aberrations.

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AllView Multi-purpose Mount

The amazingly versatile AllView multi-purpose mount assists photographers with wide-field astrophotography, daytime panoramas, time-lapse video or simple sidereal tracking for celestial viewing with a small optical tube. Capture panoramas easier with the Easy Pano mode, create a professional-grade time-lapse with the Video Coursing mode or align in sidereal mode for astronomical viewing, all with this easy-to-use, portable mount.

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Sky-Watcher USA offers a selection of telescopes and accessories for everyone from the amateur enthusiast to the seasoned professional. We use the highest quality optics and materials to guarantee the best possible astronomical experience.

GoTo Collapsible Dobsonians

The perfect blend of tradition and innovation, Sky-Watcher's GoTo Dobsonian combines large-aperture viewing with a portable strut-tube system and computerized GoTo tracking. Featuring Sky-Watcher's legendary Syn-Scan hand controller, the GoTo Dobsonian offers astronomers an extensive catalog of over 42,000 objects with countless hours of enjoyment. Available in 8-, 10-, 12-, 14- and 16-inch apertures.

Starting at just $1,035

Collapsible Dobsonians

An innovative approach to the traditional Dobsonian, our Collapsible model takes a simple Dobsonian design and integrates a sleeve-style strut system, allowing the tube to be compacted for easy transport and storage. While truss-style Dobsonians require frequent collimation, this patented strut design enables easier transport and storing without the need to collimate before every use. Available in 8-, 10-, 12-, 14- and 16-inch apertures.

Starting at just $1,035

Traditional Dobsonians

Our Traditional Dobsonians feature the finest optical components of any Dobsonian on the market, while remaining an affordable solution for astronomers seeking large-aperture viewing. Using borosilicate mirrors with our proprietary 94% reflectivity coatings and a patented tension control handle, this is a no-frills telescope that provides advanced quality for any level of astronomer. Available in 6-, 8- and 10-inch apertures.

Starting at just $1,649

EQ6 Pro GoTo Mount

This is a beefy, 40-lb payload, computerized equatorial mount, designed for all levels of astrophotographers. The EQ Pro provides users with a high level of pointing accuracy and optical stability.

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AZ-EQ5 Hybrid Mount

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This super-steady tabletop mount is a powerful tool for astronomers, photographers and videographers alike. Capture stunning panoramic photos or smooth panning video using just about any camera or camcorder, from your DSLR to your iPhone. Included is a 90mm Mak-Cass OTA with Sky-Watcher's proprietary optics, for observatory-class viewing.

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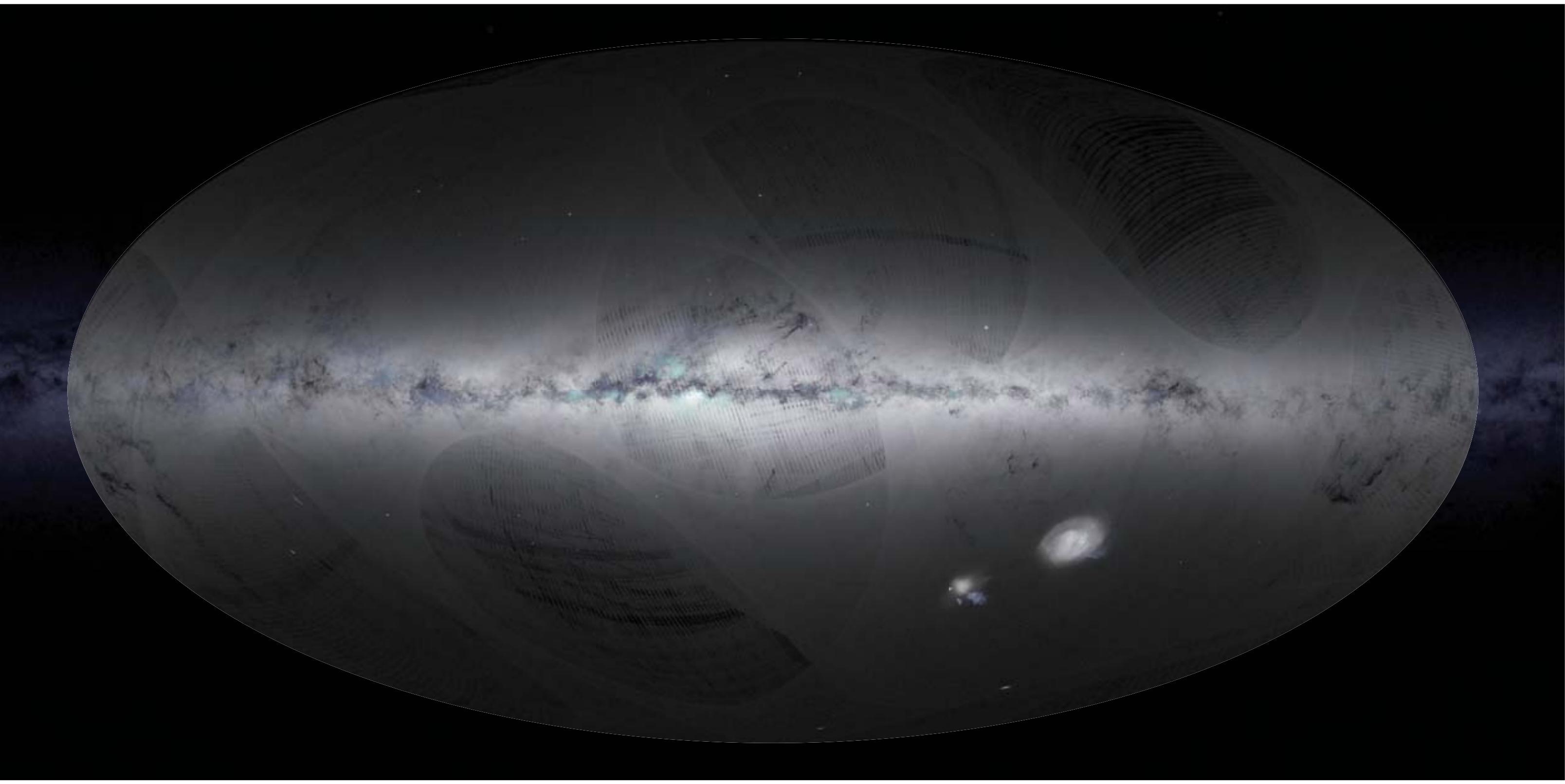

▲ This all-sky view from ESA's Gaia mission shows stars in the Milky Way and in neighboring galaxies, including the Magellanic Clouds (lower right). The map's resolution enables astronomers to study individual stars in these galaxies. Stripes are artifacts due to Gaia's scanning procedure and will disappear as more data are gathered. Background color comes from a Gaia visualization of stellar density across the sky.

ESA / GAIA / DPAC, BACKGROUND ALL-SKY: ESA / GAIA / CC BY-SA 3.0 IGO

MISSIONS

Gaia Maps a 1,000,000,000+ Stars

THE EUROPEAN Space Agency (ESA) has released the long-awaited first results from its Gaia mission, which is mapping the locations of 1.1 billion stars across the Milky Way and beyond. This first version of Gaia's atlas gives positions on the sky for those stars to a precision of less than a microarcsecond for suns as faint as magnitude 20.7. That's equivalent to pinpointing the exact location of a sand grain in San Francisco as seen from Boston. Never before have astronomers measured the locations of such a quantity of stars to such high precision.

Gaia hovers at the L_2 Lagrangian point, a gravitational "neutral zone" about 1.5 million km (1 million miles) from Earth's nightside that moves with our planet as it orbits the Sun. The mission's main goal is to create an extraordinarily precise, 3D star map. To do this, the spacecraft will monitor each star about 70 times over a five-year period as it scans the sky. It's looking for *stellar parallax*, the tiny apparent annual looping in a star's position caused by the spacecraft's moving viewpoint as it travels with Earth around the Sun.

The catalog's visual representation (above) is an all-sky map with a spatial resolution comparable to that of the Hubble Space Telescope. "It's like taking a Hubble image — just of the entire sky," explains team member Anthony Brown (Leiden University, The Netherlands).

In addition, the atlas includes measurements of 599 Cepheid stars (43 newly discovered) and 2,595 RR Lyrae stars (343 new) around the south ecliptic pole. These variable stars are vital to calculating the cosmic distance scale.

For a subset of 2 million stars, scientists have already combined Gaia data with older measurements from the Hipparcos mission to estimate distances and motions. But this first Gaia release only includes observations from the first 14 months of operations and does not include parallaxes for all 1.1 billion stars — those will come later. Scientists will issue additional, intermediate results as the mission progresses. The final batch of data is expected in 2023, about three years after the space mission has ended.

Gaia data are public, and ESA has released both the raw data and a 3D visualization software called *Gaia Sky* for those who want to explore.

■ **JAN HATTENBACH**

Further Reading:
Find weblinks to access Gaia's first data dump and other materials in the extended version of this story online: https://is.gd/gaiarelease1.

● To get astronomy news as it breaks, visit skypub.com/newsblog.

◀ FAST, seen here at its opening ceremony, is now the world's largest filled-in, single-dish radio telescope.

Chinese FAST Opens for Business

ON SEPTEMBER 25TH the Chinese Academy of Sciences announced the completion of its new Five-hundred-meter Aperture Spherical Telescope (FAST). With a dish 500 m across and an area equal to 30 soccer fields, this behemoth is now by size the largest filled-in, single-dish radio telescope in the world. A Nimitz-class aircraft carrier could easily float in the dish from bow to stern, with room to spare.

Only the 576-m diameter of Russia's RATAN-600 system is larger than FAST's. It's not all about size, though: RATAN-600's collecting surface is a ring rather than a dish, so it only has an effective area of 12,000 m^2. And FAST's *effective* aperture is only 300 m, corresponding to a collecting area of 70,000 m^2. But that's still more than twice the collecting area of Arecibo in Puerto Rico.

FAST is located in southern China in the sparsely populated Guizhou Province. Like Arecibo, the telescope sits inside a natural depression in limestone-dominated terrain. It will use the surrounding, mountainous karst features to block out radio interference, which officials have limited by relocating more than 9,000 people from the surrounding area to create a radio-free zone.

The telescope has already made its first observation and now enters an extensive commissioning phase. This is when bugs in the system manifest themselves, and rumor has it they're already cropping up. But assuming scientists overcome any hurdles, they will soon set to pursuing FAST's science goals, which include hunting for faint pulsars, mapping neutral hydrogen in distant galaxies, and searching for extraterrestrial signals.

FAST's expected resolution is 2.9 arcminutes at the key hydrogen emission line of 1420 MHz (21 cm in wavelength), compared with Arecibo's 3.4 arcminutes for the same frequency. To achieve this resolution, FAST uses actuators to push and pull on a 300-m-wide subset of panels in order to morph its spherical surface into a near-paraboloidal shape. Overall the new instrument covers a slightly smaller frequency band than its Puerto Rican counterpart: 70 MHz to 3 GHz, versus Arecibo's 47 MHz to 10 GHz.

Located at latitude 26°N, the radio telescope looks straight up, allowing Earth's rotation to "point" the dish as the sky sweeps past. As with Arecibo, FAST's receivers, suspended high above the dish, are only partially steerable. But the Chinese observatory's significantly deeper dish affords it a wider field of view: it can cover a swath of sky within 40° of its zenith, versus Arecibo's 20°.

FAST construction workers

FAST carries on the tradition of large radio telescope construction that started shortly after World War II and culminated in the Puerto Rican observatory, which since 1963 held the title of largest single, filled-in dish telescope. It's possible that FAST's record-setting dimensions will never be exceeded: future radio observatories such as ALMA and the upcoming Square Kilometer Array are "dish farms," using the interference between the radio signal collected by many dishes to assemble high-resolution images.

■ DAVID DICKINSON

SCOPES SCENE: JEFF DAI; SCOPES WORKERS: CHINESE ACADEMY OF SCIENCES

IN BRIEF

Pro-Am Team Finds First Pulsing White Dwarf

A dedicated study by amateur and professional astronomers has revealed that the long-watched variable star AR Scorpii is in fact a binary system. Reported in the September 15th *Nature*, the observations show that AR Sco comprises a cool red *M* star and a white dwarf, the latter of which generates a lighthouse-like beam of particles. The two orbit each other every 3.6 hours in a precise cosmic dance. The white dwarf lashes its companion with its energetic beam as it rotates, causing the whole system to brighten and fade dramatically every 1.97 minutes.

■ MONICA YOUNG

See page 84 for amateur and study coauthor Josch Hambsch's behind-the-scenes tale of being part of the discovery.

Osiris-REX Bound for Asteroid Bennu

On September 8th NASA's Origins, Spectral Interpretation, Resource Identification, Security, and Regolith Explorer (Osiris-REX) spacecraft launched from Cape Canaveral. Its objective is to collect a sample of at least 60 grams (and as much as 2 kg) of the Earth-crossing Apollo asteroid 101955 Bennu and bring the sample back to Earth in 2023 for study. If successful, the souvenir will represent the largest return of extraterrestrial matter since Luna 24 traveled to and from the Moon in 1976. Osiris-REX is scheduled to attempt its land grab in July 2020. It's the third mission in the New Frontiers program, after Juno and New Horizons.

■ DAVID DICKINSON

Read more at **https://is.gd/osirisrexlaunch**.

Daily Alert for Asteroid Flybys

A new e-digest from the International Astronomical Union's Minor Planet Center gives the public a head's up on asteroids passing near Earth. The alert service, called the Daily Minor Planet, sends an e-mail once a day to your inbox with information about notable near-Earth objects. It includes the time of closest approach, an orbit diagram, and other details. The digest is a public outreach initiative and isn't designed for observers; you'll need an ephemeris generator to spot these objects.

■ CAMILLE M. CARLISLE

Learn how to sign up for the daily email at **https://is.gd/dailymp**.

MISSIONS

Rosetta's Grand Finale

THE HISTORIC ROSETTA mission to explore Comet 67P/Churyumov-Gerasimenko ended in dramatic fashion on September 30th, when the spacecraft touched down on the comet's nucleus.

Rosetta accompanied Comet 67P for two years, orbiting the bilobed nucleus as it approached and survived its perihelion pass in August 2015 (*S&T:* Aug. 2014, p. 20). The spacecraft kept a good distance from the nucleus in order to protect itself from outbursts, but in its last days Rosetta spiraled in as close as 1 km from the surface.

Mission operators programmed the craft to come to rest in the Ma'at region, on the smaller of the nucleus's two lobes. Several sinkhole-style pits, measuring about 100 m wide by 50 m deep (300 by 160 ft), dot the region. Rosetta was aimed to touch down on a smooth plain between two depressions, at a velocity of about 1 mps (2.2 mph), equivalent to a slow walking pace. Instruments continued to measure gas, dust, and plasma all the way down during Rosetta's descent, and to take images like the one at right.

But even if the spacecraft survived its landing, we won't hear from it again: it's been commanded not to try to recontact Earth, says project scientist Matt Taylor (European Space Agency). "As Jim Morrison once said: 'This is the end, beautiful friend.'"

Rosetta won't be alone. On September 2nd, the team finally found the long-lost Philae lander, wedged in a dark crack about a third of the way around the smaller lobe from Rosetta. Philae bounced and disappeared after its attempted landing (*S&T:* Feb. 2015, p. 12), and its resting place shielded it from the sunlight needed to recharge its batteries and enable it to phone home.

Rosetta's data show that the comet's water ice contains three times more deuterium than water on Earth, ruling out primordial comets as the predominant source of Earth's water. But the glycine and other complex compounds discovered on Comet 67P suggest that these bodies might have delivered organic compounds to our planet.

■ **DAVID DICKINSON**

Rosetta's OSIRIS telephoto camera captured this image of Comet 67P/Churyumov-Gerasimenko on September 30, 2016, from a point 16 km (10 mi) above the surface during the spacecraft's controlled descent. The resolution is about 30 cm (12 in) per pixel.

GALAXIES

Coming in from the Void?

LIVING IN A COSMIC VOID might be responsible for two small galaxies' recent flurries of starbirth. Erik Tollerud (Space Telescope Science Institute) and colleagues used Hubble to spot the two dwarfs, Pisces A and B. They lie about 20 and 30 million light-years away, respectively, beyond the Local Group.

Pisces A and B are puny, each only a couple thousand light-years across and holding on the order of 10 million suns. The Milky Way contains approximately 100 billion stars, and its disk spans more than 100,000 light-years.

The team's observations reveal that the dwarfs lie on the edge of a nearby cosmic desert called the Local Void, one of the gaps in the cosmic web of galaxies that make the large-scale universe look like a sponge. Each dwarf also boasts a couple dozen young, blue stars. In fact, it looks like the galaxies both experienced upticks in their star production within the last 300 million years.

Dwarfs are notoriously on-again, off-again in their star formation, so the waves of starbirth might be internally triggered. But the team suspects that they're instead catalyzed by the galaxies' migration, moving from the Local Void into the strand of the cosmic web they're currently in. More gas floats around in the web's filaments than in voids, and as a galaxy entered a strand, the pressure of ramming into this ambient stuff could compress the gas inside the galaxies, triggering star formation. Indeed, several astronomers have suggested that this process could kick-start starbirth or even kill it by tearing the gas out of a galaxy (*S&T:* Feb. 2013, p. 14).

But as the team explains in the August 20th *Astrophysical Journal*, it hasn't measured the dwarfs' motions — the researchers only know the locations of Pisces A and B, not where they've been or where they're going. The idea that their star formation is being spurred by entering the web is only an extrapolation based on where the dwarfs currently lie.

■ **CAMILLE M. CARLISLE**

MISSIONS ART: ESA / NASA; MISSIONS IMAGE: ESA / ROSETTA / MPS FOR OSIRIS TEAM; GALAXIES: NASA / ESA / E. TOLLERUD (STSCI)

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Photo credit: Andrei Bacila

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MISSIONS

NASA's Juno Makes First Science Pass

ON AUGUST 27TH, Juno made the first of its 36 planned flybys of Jupiter, zooming through *perijove* just 4,200 km (2,600 miles) above the cloudtops. For comparison, geostationary satellites orbit almost nine times farther than that from Earth. No other spacecraft has come so close to the gas giant, except to plunge into its atmosphere.

Juno will probe Jupiter's composition and measure its magnetic and gravitational fields (*S&T:* July 2016, p. 18). To carry out its mission, the craft must thread the intense radiation belts surrounding the planet on successive polar passes. All instruments came through this first pass unscathed, though Juno is expected to suffer from some radiation degradation on each consecutive flyby.

The stunning, visible-light images from JunoCam (used to make the composite at left) provide scientists' first glimpse of Jupiter's north pole, which "looks like nothing we have seen or imagined," says principal investigator Scott Bolton (Southwest Research Institute, San Antonio). The poles are dappled with swirling storms and depressions, and unlike at Saturn, there's no polar hexagon.

Juno has also given researchers the first-ever view of Jupiter's southern aurorae. The observations, made at 3.3 to 3.6 microns, reveal a flurry of hydrogen ions energized by charged particles cascading in from the planet's magnetosphere. In addition, the craft made the closest recordings of Jupiter's radio outbursts.

■ **DAVID DICKINSON**

◀ A composite image of Jupiter's north pole, assembled from JunoCam images by *S&T* Equipment Editor Sean Walker.

See more images from the flyby at https://is.gd/junofirstpass.

MILKY WAY

Cloud Punches Hole in Our Galaxy

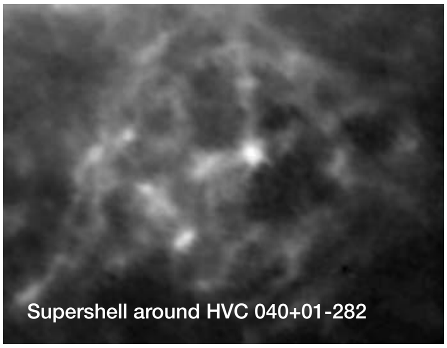
AN INTERGALACTIC CLOUD has slammed into the Milky Way Galaxy and left a big hole in its gas.

Galaxies like ours are full of gas, but it's clumpy and cavity-ridden. Among the largest cavities are *supershells*. These structures are huge bubbles in a galaxy's gas, easily 2,000 light-years wide. It takes a whole lot of energy to inflate that kind of bubble: the equivalent of at least 30 supernovae, planted like little vicious bombs at the cavity's center.

Yet oddly, most of the supershells we know of don't have aging star clusters at their centers. Instead, astronomers suspect that some of them were created by *high-velocity clouds* (HVC). These clouds shower the Milky Way from space in a steady drizzle, helping to fuel star formation. If such a cloud rammed into a galaxy, it could blast out a big bubble.

Geumsook Park (Seoul National University, South Korea) and colleagues have now found the first solid example of an HVC doing just that. As part of the I-GALFA survey with the Arecibo radio telescope, the team discovered a supershell surrounding a compact cloud called HVC 040+01-282. The shell is a whopping 3,000 light-years wide, with spoke-like structures inside it. Smack-dab in its center sits HVC 040+01-282. The team estimates in the August 20th *Astrophysical Journal Letters* that, if the cloud collided with its maximum possible velocity, it would have had more than enough energy to blow out the supershell.

■ **CAMILLE M. CARLISLE**



Supershell around HVC 040+01-282

IN BRIEF

Solar Flare Momentarily Heated Cold War

A May 1967 solar flare was nearly responsible for conflict breaking out between the United States and the Soviet Union. On May 23rd that year, all three American ballistic missile early-warning radars were simultaneously jammed. The Air Force, believing the Soviet Union was to blame, authorized aircraft with nuclear-strike capabilities to take to the skies. But space-weather forecasters realized the culprit was a powerful solar flare and convinced decision-makers to forego military action. Delores Knipp (University of Colorado, Boulder) collaborated with retired U.S. Air Force officers involved in forecasting and analyzing the storm to bring this story to light. The study appears September 5th in the journal *Space Weather*.

■ **CHRIS STUBENRAUCH**

Read more at **https:/is.gd/1967flare**.

MISSIONS: NASA / JPL / SWRI / MSSS / S. WALKER; MILKY WAY: GEUMSOOK PARK AND BON-CHUL KOO / SEOUL NATIONAL UNIVERSITY

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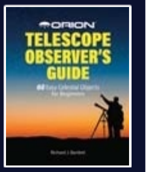

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METEORITES

An excavation crew pulls "Gancedo," estimated to weigh 30 tons, from a known meteorite strewnfield in Argentina.

Huge "Gancedo" Found in Argentina

HOLY SPUTTERING SPACE ROCKS! A team in Argentina has excavated a monster: a 30-ton chunk of iron-nickel meteorite. For comparison, the legal maximum weight for an 18-wheeler in the United States is 40 tons.

Named "Gancedo" after a nearby town, the rock was found in the heart of Campo del Cielo ("Field of Heaven" in Spanish), a meteorite strewnfield northwest of Buenos Aires whose known fragments have a total mass of more than 100 tons. A team from the local Astronomy Association of Chaco dug the huge space rock out of the ground on September 10th, and images of the find soon flooded the internet.

Gancedo fell to Earth between 4,000 and 6,000 years ago. Locals have known of the meteorites for centuries, even making iron tools from bits found in the strewnfield, which extends over an ellipse 3 km wide by 19 km long. Meteorites from here have a coarse, polycrystalline texture characteristic of iron-nickel meteorites. They are also unusually pure, consisting of 93% iron. Most of the remaining 7% is nickel.

It'll take time to weigh Gancedo more precisely, but the rock is most likely the second-largest meteorite recovered from Campo del Cielo, after the 37-ton "El Chaco" uncovered in 1980. The title of biggest space rock still safely belongs to the Hoba meteorite in Namibia, estimated to weigh more than 60 tons. It's still half buried at its discovery site.

■ **DAVID DICKINSON**

Astronomy Association of Chaco

STELLAR

Tabby's Star Gets Weirder

KIC 8462852, or Tabby's Star as it's informally known, made headlines in 2015 when Tabetha Boyajian (now Louisiana State University) announced the discovery of strange dips in the star's brightness that defied explanation (*S&T:* Feb. 2016, p. 14). The mysterious behavior even prompted speculations of an alien megastructure blocking the star's light (*S&T:* Mar. 2016, p. 16).

The controversy is now building: independent investigations suggest that the star has been fading for decades — why, no one knows.

Volunteers with the Planet Hunters citizen science project first spotted KIC 8462852's odd behavior while looking for dips in starlight created by a transiting exoplanet. Typical planetary transits reduce starlight periodically, by up to a few percent for a few hours. But this star was seen to dim irregularly for days at a time by varying amounts, even up to 20%.

Yet KIC 8462852 seems to be a normal, 12th-magnitude *F*-class star. No planet, dusty disk, or pulsations could explain the signal. The scenario that Boyajian's team settled on for publication in 2015 was a comet swarm in the midst of dissolution. But both she and others readily admitted the scenario was contrived.

Soon after, Bradley Schaefer (also Louisiana State University) sifted through the glass-plate archive at Harvard College Observatory and found that the star has faded over the past 100 years, at a rate of 0.16 magnitude per century. Heated debate ensued.

Now, Benjamin Montet (Caltech) and Joshua Simon (Observatories of the Carnegie Institution of Washington) have used Kepler observations to confirm KIC 8462852's fade — but it's dropping faster than anyone thought.

For the first three years of Kepler data, the star faded 0.3% per year, equivalent to 0.37 magnitude per century and more than double what Schaefer found. Then, for almost seven months, the star suddenly began dimming at an accelerated 2.5% per year. The sudden decline came to a halt before Kepler's initial mission ended in 2013, but it's unclear if the light curve flattened out or just returned to its previous, less extraordinary fade.

Appearing in an upcoming *Astrophysical Journal Letters*, these results support Schaefer's assertion that the star is in long-term decline, though Montet and Simon can't directly confirm the century-long trend because Kepler's observations are limited to four years. The study also puts the "comet swarm" scenario to rest.

"Honestly, I'm all out of good ideas — all of us are," Boyajian says. "We just need more data at this point!"

■ **MONICA YOUNG**

METEORITES: MINISTERIO DE GOBIERNO, JUSTICIA Y RELACIÓN CON LA COMUNIDAD (2); STELLAR: ESO / L. CALÇADA

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Mars and Our Expectations

The Red Planet has inspired a long history of brilliant mistakes.

WHILE PREPARING to give a talk recently about the impact of the New Horizons Pluto flyby, I re-read *Mars and the Mind of Man*, a 1972 book that I loved as a teenager. It arose from a panel discussion during which scientists Carl Sagan and Bruce Murray, together with science-fiction writers Ray Bradbury and Arthur C. Clarke, addressed the imminent arrival of Mariner 9 at Mars.

Previous Mars craft had been flybys, photographing only small areas. Mariner 9, our first orbiter, promised to revolutionize our understanding by laying bare the entire planet, which had for centuries been the subject of stories, fantasies, and overreaching attempts at scientific extrapolation. The book presents the transcript of the conversation, held as the craft rapidly closed in on Mars, as well as essays that each thinker wrote one year later (after Mariner 9 had thoroughly mapped the planet), reflecting on their earlier expectations and summing up what had been learned.

In the panel discussion, the sci-fi writers waxed poetic and mythical, invoking Edgar Rice Burroughs, H. G. Wells, Percival Lowell, and their own famous fictional Martian worlds. Bradbury declared: "[A]t this moment in history, it looks as if I must semi-retire to the wings . . . and hope to become part of some strange new mythology. This is probably true of many science fiction authors this week . . ."

Astronomer/exobiologist Sagan and geologist Murray were in sharp disagreement about the nature of the Red Planet. Sagan was bullish on the possibility of life, noting that Mars might have near-surface water. He described the planet as so poorly photographed prior to Mariner 9 that we might not yet have detected the equivalent of human civilization, let alone microbes or plants, if such existed.

Murray was mistrustful of Sagan's optimism. He recounted the lengthy record of wishful thinking among scientists who wanted Mars to be Earth-like and life-friendly. He clearly placed Sagan's ebullient speculations in this category. Murray pointed out that, given the pictures we had up to that point, Mars seemed much more like the cold and dead Moon than the vibrant Earth.

> Whatever we think we know about Mars today will surely not appear so correct given another 50 years of exploration.

In the essays written a year later, their disagreements are not resolved. Moreover, it is remarkable how wrong both of them still are about Mars — judged by today's knowledge. Sagan remains much more optimistic. He concedes that Mariner 9 did not find life and had definitively ruled out a human-level civilization. But he believes that the polar caps hold enough H_2O and CO_2 to intermittently give Mars an atmosphere as thick as Earth's (wrong). He expresses optimism about the upcoming 1976 Viking landers' search for life.

Murray, for his part, concludes that Mars never had a more Earth-like past but is in the process of coming to life geologically and may have an Earth-like future (wrong and wrong).

Mariner 9 played an important role in helping us achieve our current comprehension, but obviously these insights didn't come instantaneously. The fact that these two brilliant scientists, when presented with so much good new data, both so completely misinterpreted them, makes me strongly suspect that whatever we think we know about Mars today will surely not appear so correct given another 50 years of exploration.

▲ We know Mars has no Lowellian canals, but even our current understanding may change radically in time. Here, a HiRISE infrared view of a basaltic sand-filled fissure in Elysium Planitia.

MARS RECONNAISSANCE ORBITER IMAGE: NASA / JPL / UNIVERSITY OF ARIZONA

■ **DAVID GRINSPOON** is an astrobiologist at the Planetary Science Institute. Follow him on Twitter: **@DrFunkySpoon**.

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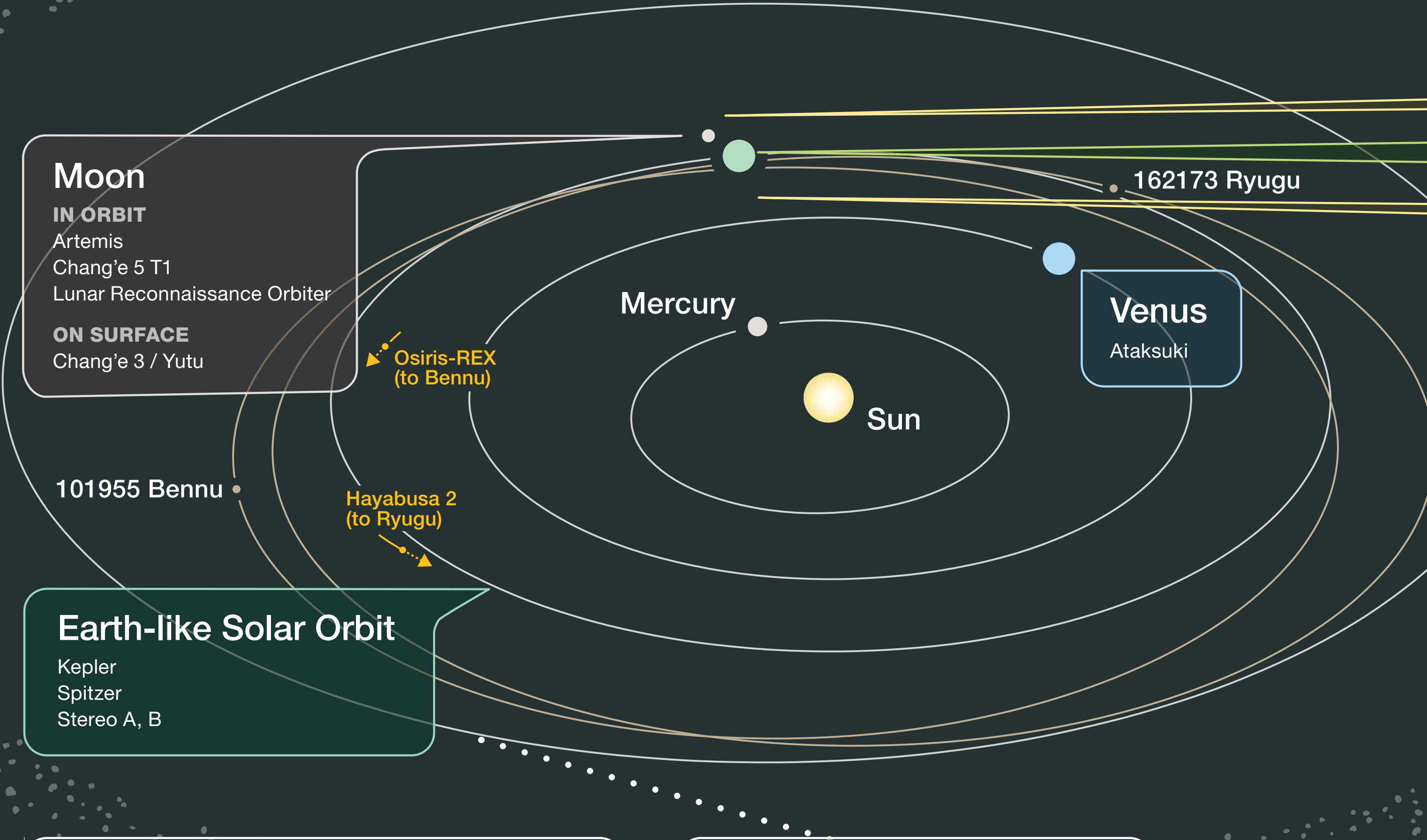
Space Missions in 2017



Moon

IN ORBIT
Artemis
Chang'e 5 T1
Lunar Reconnaissance Orbiter

ON SURFACE
Chang'e 3 / Yutu

Venus

Ataksuki

Earth-like Solar Orbit

Kepler
Spitzer
Stereo A, B

It's hard to keep track of all the space missions out there. Based on Olaf Frohn's monthly compilation (**armchairastronautics.blogspot.com**), here's our digest of active missions in 2017. Included are astrophysics, planetary, gravity, solar, space weather, and stellar projects. Planet locations are accurate for January 1st; mission statuses are current (to the best of our knowledge) as of October 2016. Those orbiting Earth are classified by primary research topic, which admittedly is sometimes subjective. Also included are planned launches and terminations for the year — but schedules often change, so treat these as mutable.

For semi-monthly updates, wavelengths covered, and other details, see Frohn's blog, also accessible via the online version of this graphic at **https://is.gd/spacemissions2017**.

—Camille M. Carlisle

Scheduled Launches

LATE 2016:
HXMT *(X-rays, Earth orbit)*

2017:
Chang'e 5 *(to Moon)*
Chandrayaan 2 *(to Moon)*
JEM-EUSO *(cosmic rays, to ISS)*
NICER *(neutron stars, to ISS)*
Spektr-RG *(X-rays, to L_2)*
TESS *(exoplanets, Earth orbit)*

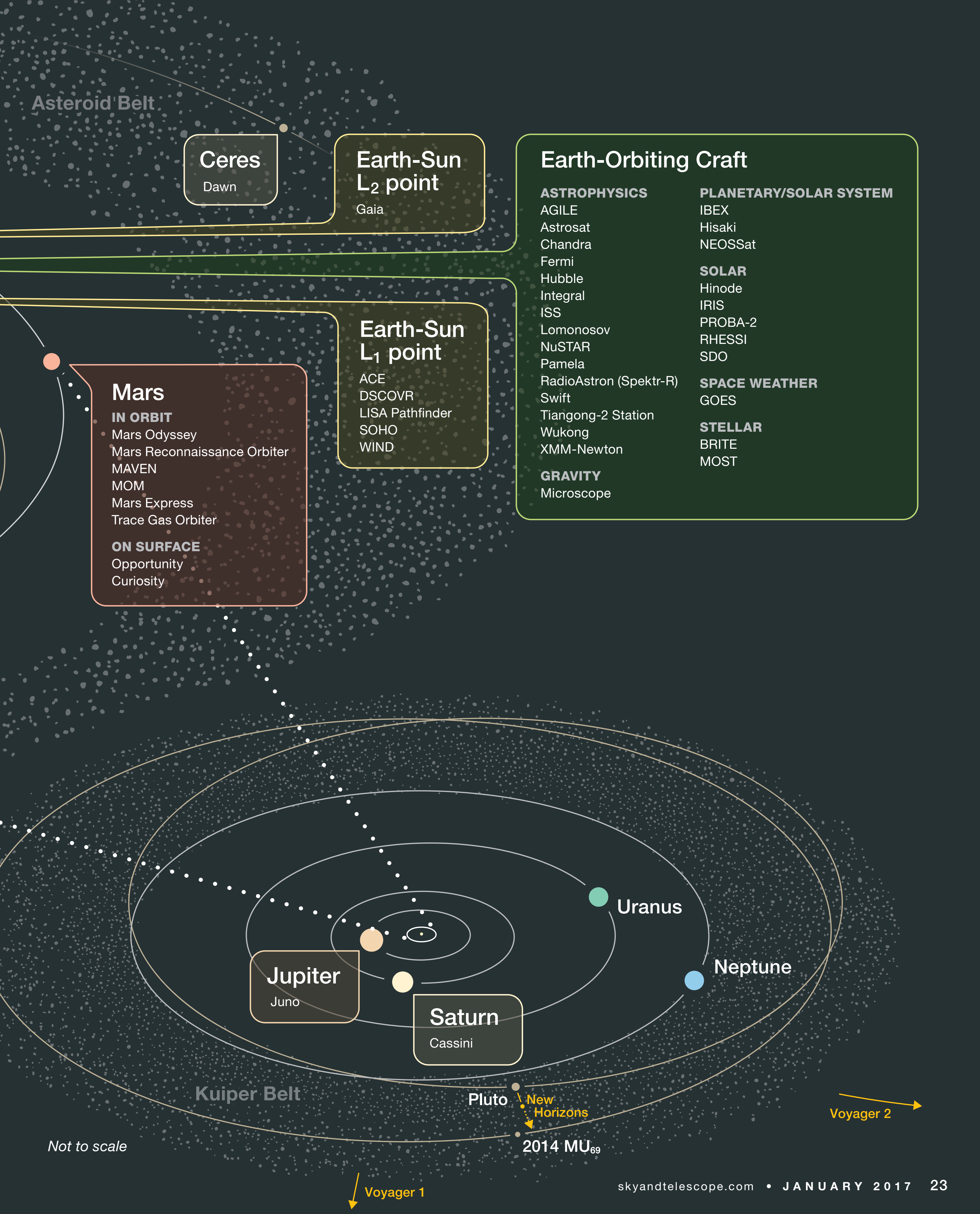
Scheduled Mission Ends

December 2016: NEOWise

June 2017: Dawn

September 2017: Cassini

S&T: GREGG DINDERMAN



Ceres

Dawn

Earth-Sun L_2 point

Gaia

Earth-Orbiting Craft

ASTROPHYSICS
AGILE
Astrosat
Chandra
Fermi
Hubble
Integral
ISS
Lomonosov
NuSTAR
Pamela
RadioAstron (Spektr-R)
Swift
Tiangong-2 Station
Wukong
XMM-Newton

GRAVITY
Microscope

PLANETARY/SOLAR SYSTEM
IBEX
Hisaki
NEOSSat

SOLAR
Hinode
IRIS
PROBA-2
RHESSI
SDO

SPACE WEATHER
GOES

STELLAR
BRITE
MOST

Earth-Sun L_1 point

ACE
DSCOVR
LISA Pathfinder
SOHO
WIND

Mars

IN ORBIT
Mars Odyssey
Mars Reconnaissance Orbiter
MAVEN
MOM
Mars Express
Trace Gas Orbiter

ON SURFACE
Opportunity
Curiosity

Jupiter

Juno

Saturn

Cassini

by Camille M. Carlisle

The *First* Black Holes

Astronomers are laboring to discover how the universe's first supermassive black holes were born.

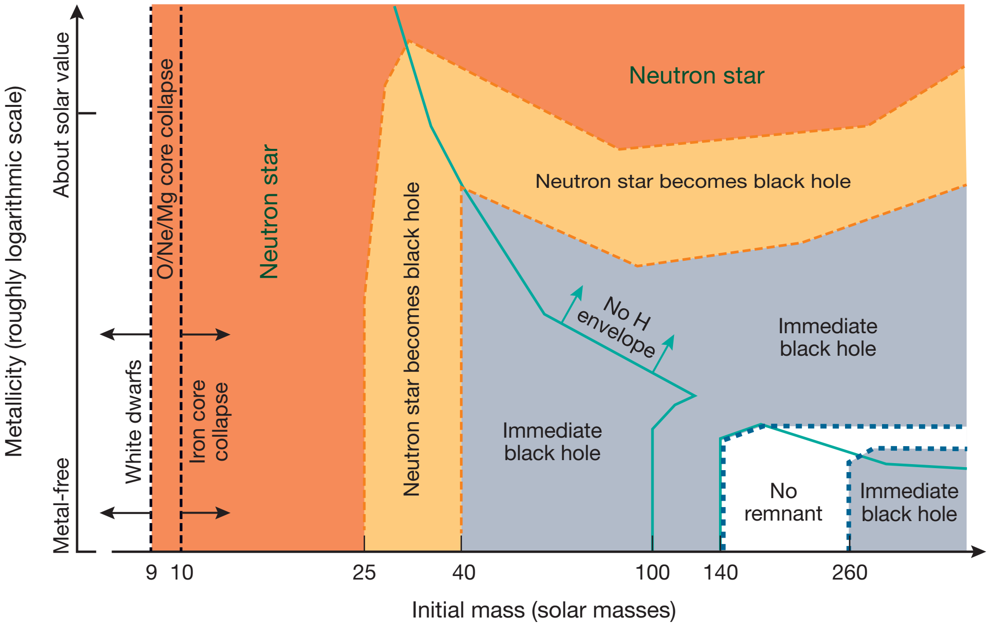
Birth Stories Matter. When I was a kid, every year on my birthday my mom would regale me with the tale of the day I took my first breath. She'd include all the gory details — and as a nurse practitioner, she could get pretty specific — to ground me in who I am by telling me how I came to be here.

Astronomers would like to do the same thing for the universe's supermassive black holes. These gargantuan spacetime potholes lurk at the center of most large galaxies. They can have the mass of millions or even billions of Suns. Like potholes, most of them go unnoticed until they throw something out of whack — say, by shredding a star or projectile-vomiting a jet of plasma.

Black holes have been around since nearly the beginning of cosmic time. Astronomers see the glow of their superheated gas shining at us from about the same time that galaxies began churning out stars with abandon. But we don't know exactly when they arrived on the scene. Their birthday matters, because how and when they formed determines how much of an impact they had on their host galaxies and the early universe at large — and that impact might have been severe.

◀ **IN THE BEGINNING (ALMOST)** This artist's concept depicts the quasar ULAS J1120+0641, powered by one of the earliest supermassive black holes detected. Astronomers see this system as it was 750 million years after the Big Bang (redshift 7.1). The black hole contains roughly 2 billion Suns' worth of mass, and scientists have long wondered how the object grew to be so big so early.

ESO / M. KORNMESSER



REMNANTS OF MASSIVE STARS When stars die, what they become next depends on their masses and how tainted their gas is with heavy elements, called metals. The most massive stars create black holes (gray regions) — except for a subset that have just the right characteristics to die in a so-called *pair-instability supernova*, which leaves no remnant. The cores of less massive and/or more metal-tainted stars become neutron stars, some of which then convert into black holes when too much material from the star's layers falls back on them and triggers runaway gravitational collapse (yellow regions). The green line separates stars that keep their outer hydrogen layer (left and lower right) from those that lose it in winds. Many of the universe's first stars should have fallen in the black hole regions of this diagram.

S&T: LEAH TISCIONE, SOURCE: HEGER ET AL. / *ASTROPHYSICAL JOURNAL* 2003

Surveys have uncovered roughly 50 *quasars*, brilliant hot-gas beacons powered by supermassive black holes, blazing only a billion years after the Big Bang. The black holes have masses of billions of Suns, comparable to the heftiest black holes we see today. To be so big so early, these titans must have grown to full size within 900 million years of the Big Bang.

But that's nonsensical. Black holes usually eat like obstinate toddlers — a little food goes down the throat, but most is left on the plate, dropped on the floor, or flung away. If the earliest objects adhered to this grazing strategy, they'd never have beefed up in time.

Still, these black holes came from *somewhere*; there's no cosmic stork. Astrophysicists have been grappling for years with the questions of how these objects were conceived and how they grew so fast. And thanks both to some high-powered simulations and to observations of dwarf galaxies, it's finally looking like the problem is not as intractable as it once seemed.

Creating Seeds

Astronomers have three main ideas for black hole genesis. The basic question boils down to whether stars stick their noses into the affair or not. For two of the theories, they do; the third circumvents them.

The first scenario starts with star clusters. Stars in clusters can sometimes bonk into each other and merge. If a cluster is compact enough, its stars could suffer runaway collisions, growing like The Blob into a single star a few hundred to a few thousand times as massive as the Sun. This superstar would then collapse into a black hole.

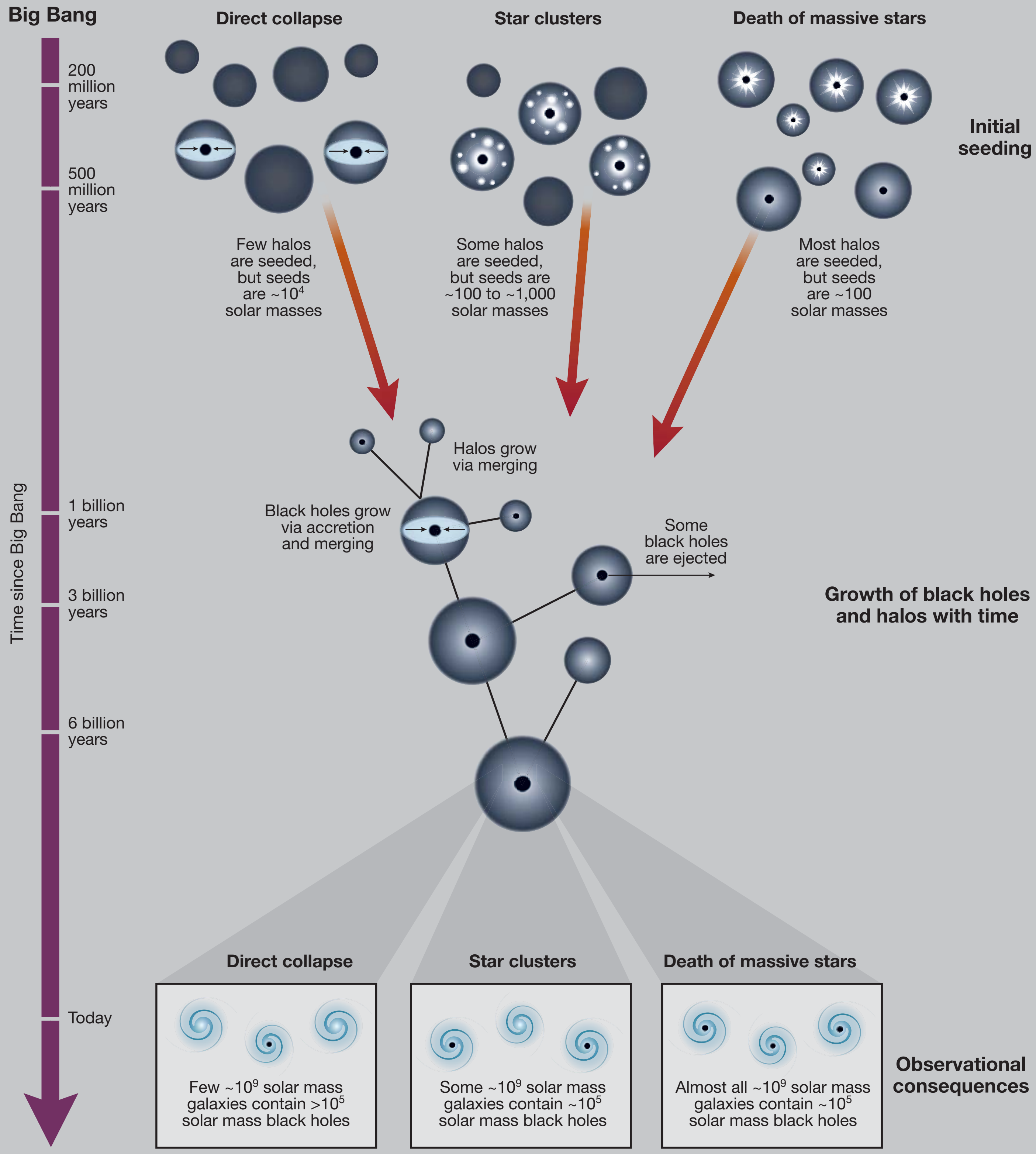
Calculations suggest that such cluster dynamics could produce black hole "seeds" of several hundred to a couple thousand solar masses. But this process is grossly inefficient, and it's hard to explain why a dense enough cluster would exist to enable this chain of events. Of the three theories, this one is the least talked about among astronomers.

The second (far more popular) star scenario is a souped-up version of "normal" black hole creation. When a single, massive star dies catastrophically, its core can collapse and become a black hole. The first generation of stars to form in the universe, called Population-III stars, would have often died this way. These stars probably weighed in at a couple hundred Suns.

The universe can't easily create stars that big anymore, because of a little thing astronomers call *metals*. In astronomers' parlance, these are all the elements heavier than helium. Stars fuse hydrogen and helium into metals, and when the stars die they spread these heavier elements into the galaxy around them.

Metals make things difficult for star growth, for two reasons. First, metals cause gas to cool faster. Cooler gas fragments into smaller star-forming clumps than warmer gas, meaning metal-rich stars will generally start smaller than metal-poor ones. Second, metals make gas more opaque. A star's light actually pushes on its outer gas layers, balancing the inward pull of gravity. If a star has a lot of heavy elements in its makeup, its gas will be less transparent. Instead of passing through the outer layers, light will shove on them, the pressure driving the layers away as massive winds. This process curtails the star's growth and exacerbates stellar weight loss.

Population-III stars didn't have this problem, because they contained no metals: there were no stars before them to pollute the gas that made them. Those that later collapsed into black holes could have retained at least half of their original mass, or about 100 solar masses (see graph above). High-end exceptions might weigh in at 10 times that. Planted at the center of a growing galaxy and fed by gas that sank there, these seeds would have then grown into supermassive black holes.



EVOLUTION OF SEED BLACK HOLES Astronomers suggest three main avenues for creating the universe's supermassive black holes: direct collapse of gas (left), runaway collisions in star clusters (center), and the death of the first, massive stars (right). The gray circles represent the dark matter halos in which each process takes place. These halos, and the protogalaxies in them, then grow through merging (center of diagram). Black holes themselves grow both by merging with each other and by accreting gas. Occasionally a merger is violent enough to kick the black hole out of the galaxy. The fraction of small galaxies that have massive black holes will depend on which of these scenarios dominated. (The Small Magellanic Cloud is 10^9 solar masses.)

S&T: LEAH TISCIONE, SOURCES: J. GREENE / *NATURE COMMUNICATIONS* 2012 & MARTA VOLONTERI

Many astronomers — and particularly those who specialize in black holes — are huge fans of this scenario. John Kormendy (University of Texas at Austin), one of the first astronomers to establish that black holes sit at the centers of most massive galaxies, describes the Population-III picture as "the only game in town."

"It's enormously natural," he says. "It's essentially inevitable that by the time the universe was half a billion years old, quite a lot of these 100-ish-solar-mass black holes would have merged, and then you've got 1,000-ish-solar-mass black holes, and that's what we need."

Not everyone agrees with Kormendy's assessment. The problem is that at these masses, the black hole seeds would need to grow continuously at their maximum feeding limit in order to become the titan quasars that existed 13 billion years ago.

This limit exists because of the same light pressure problem that curtails stars' masses. As gas falls onto a black hole, it heats up and glows. If you dump too much gas on, the glow will be so strong that the pressure of photons radiating out will actually overcome the gravity pulling in and cut the black hole's fuel line. This balance point between accretion in and radiation out is called the *Eddington limit*.

Keeping up Eddington-level growth is exceptionally hard. Not only does it mean that the galaxy must have fed its central black hole with a steady supply of gas for several hundred million years, but also that the black hole kept its mouth at the straw. That's a tall order.

Populations I, II, and III

Astronomers talk about three populations of stars, based on Walter Baade's work in the 1940s studying the Milky Way. These are:

- **Pop I:** usually young and in the galaxy's spiral disk. Metals make up about 2–4% of their total composition. Includes both the Sun and *O*- and *B*-type, bluish massive stars.
- **Pop II:** older (often 10 billion years or more), in the galaxy's bulge and halo. Metal content much lower, down to maybe a thousandth that of the Sun. Only the least massive ones survive today.
- **Pop III:** the fabled first stars. Would have formed with only hydrogen and helium (no metals). None yet conclusively detected — either they've died off or are masked by heavy-element "pollution" they've picked up over time.

Just Get to the Point

So other astronomers turn to the third scenario, direct-collapse black holes. In this scenario, warm, metal-free gas collapses under its own gravity to form a black hole of tens to hundreds of thousands of Suns. (The gas might or might not first form a supermassive star.) With masses so much greater than those created by Population-III stars, direct-collapse seeds offer an attractive alternative, explains Muhammad Latif (Paris Institute of Astrophysics).

But if growing a Pop-III seed into a titan is hard, making direct-collapse black holes can seem almost impossible.

"It's the opposite of Occam's razor," she says, sighing. "It's such a series of events to occur all at the same time that I'm like, 'Seriously?' I'm a *scientist*.'"

To make one of these objects, you need a large influx of gas. In the standard direct-collapse picture, this gas needs to stay warm (tens of thousands of kelvin) so that it doesn't fragment too early. Thus the gas must be pristine, with essentially no metals. The gas also needs to be basking in enough ultraviolet radiation to stifle the formation of molecular hydrogen, which also cools it.

Here's where things get complicated. These ultraviolet photons must come from stars. But the gas forming the black hole seed can't have been tainted by stellar-made metals. To avoid contaminating the gas but still bathe it in ultraviolet rays, the stars would need to lie in a massive protogalaxy just 10,000 light-years or so away, or less than half the span between our solar system and the Milky Way's center. Furthermore, these stars would likely be Population-II stars (which means they'd contain some metals), because such stars live longer and are more common, Latif says. So to protect the black-hole-birthing gas from the stellar winds or supernovae, either the stars' outflows must be precisely timed with the black hole's formation, or they must all aim away from where the black hole is forming.

The universe's metal enrichment did proceed patchily, and observations show that pockets of pristine gas survived even to the time that we see the titan quasars. But many astronomers have trouble swallowing the complexities of the direct-collapse scenario. Although Marta Volonteri (Paris Institute of Astrophysics) contributed to its theoretical groundwork, she's become increasingly skeptical of direct collapse in the last couple of years. "It's the opposite of Occam's razor," she says, sighing. "It's such a series of events to occur all at the same time that I'm like, 'Seriously?' I'm a *scientist*.'"

Despite her reservations, Volonteri remains agnostic. She and others recently suggested that a clump of bright, pristine gas in the protogalaxy CR7 might contain a direct-collapse black hole. Others have also found potential sources in the

CANDELS/GOODS-S survey. Astronomers are still arguing over whether any of these sources could indeed be a direct-collapse seed.

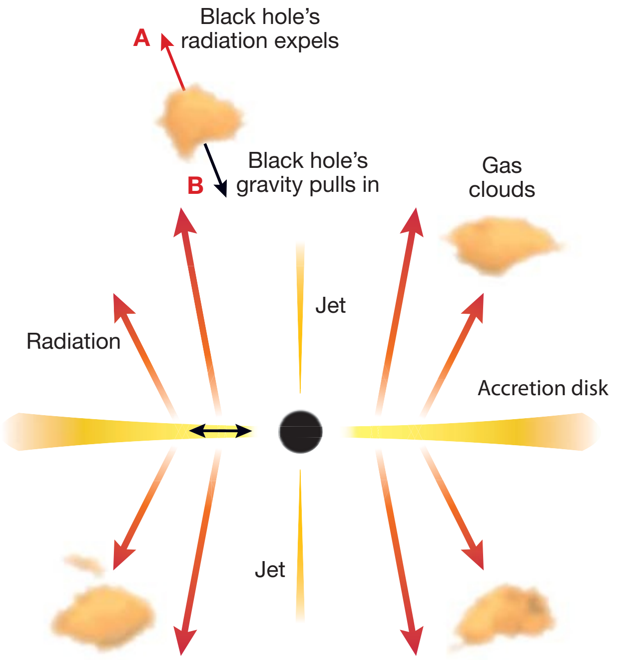
Some claim that the direct-collapse process is not as complicated as we think. Even if it is, Latif says, his team's simulations show that sufficient seeds would form to explain the titan quasars we see in the infant universe.

Overcoming Eddington

But even a 10,000-solar-mass seed is a far cry from the 2 billion solar masses of the black hole powering the quasar ULAS J1120+0641, whose light left it 12.9 billion years ago. To reach that size in less than a billion years, the black hole must have accreted gas at its Eddington limit for roughly 60% of the time if it began as a direct-collapse seed. If the seed was a stellar one of 300 solar masses, then it had to eat at the limit for *all* of those 900 million years. Either way, somehow the galaxy shoves tens of thousands to tens of millions of solar masses' worth of gas down the black hole's throat, all within a few hundred million years.

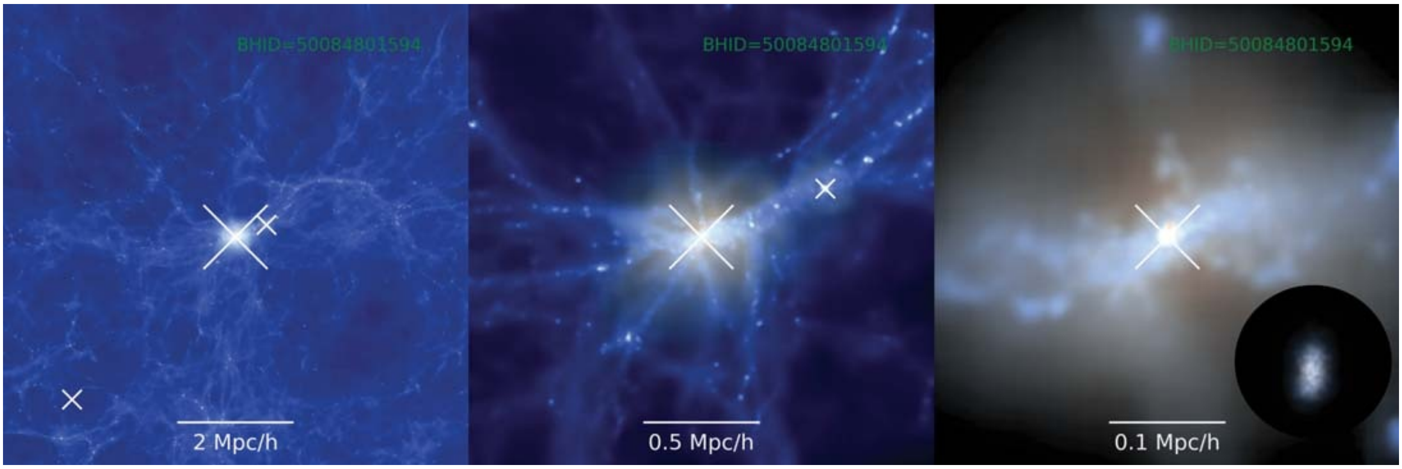
It's at this point that the accretion ceiling begins to feel more like a straitjacket than physics. "I'm not a believer in the Eddington limit," Volonteri said flatly in a recent talk at the Harvard-Smithsonian Center for Astrophysics. "If the accretion rate can be higher, then building the biggest black holes is not crazy."

But overcoming the Eddington limit is no easy task, she admits. The super-Eddington inflow of gas must trap the gas's glow well enough that the radiation doesn't launch the gas away. Nor can the black hole shoot material away in jets, unless the jets reach far enough away from it that the plasma doesn't heat the nearby accretion flow and stifle the downpour onto the hole. Galactic centers are also hotbeds of starbirth, and the stars mustn't do anything to disrupt the pipeline — no cataclysmic antics allowed. Not to mention that the violent glare from the accreting black hole can "damage" the galaxy, heating up ambient gas and preventing it from funneling into the core and feeding the beast. "Aaaah," Volonteri groans. "There are so many variables that they're driving me nuts."



▲ **SUPER-EDDINGTON ACCRETION** There are two conditions to consider when talking about whether a black hole can accrete faster than it's theoretically capable of doing. One is the balance between the gravitational pull inward and the pressure outwards, caused by the glow from the accreting black hole (red arrows). The radiation can push and shove away gas clouds (A) that would otherwise fall toward the black hole (B). The other condition is what happens inside the accretion disk itself — the disk's own glow and internal pressure work against it, limiting how much material can drain down onto the black hole (black arrow). On the other hand, when the black hole is fed at rates much higher than the theoretical limit, the disk can become so dense and thick that some of the radiation becomes trapped inside, suppressing the push on nearby gas. Regardless of the theoretical limit, the hot and powerful radiation from an accreting black hole, as well as the jets it sometimes has, would eventually stifle accretion and stymie growth by pushing or shredding the surrounding gas clouds.

▼ **SIGN OF THE TIDES** *(below)* These snapshots from the BlueTides simulation show the gas environment of one of the most massive black holes about 650 million years after the Big Bang. Hotter gas appears redder. Large crosses mark the positions of black holes, and their sizes are proportional to each hole's mass. The inset in the rightmost panel is a zoom 10 times closer than the panel it's in and shows the host galaxy.



S&T ILLUSTRATION: LEAH TISCIONE, SOURCE: MARTA VOLONTERI; SIMULATION: TIZIANA DI MATTEO ET AL. / *ARXIV.ORG* 2016

It's more natural for black holes to grow in spurts. In some recent simulations of growing protogalaxies, the black hole seemed to be "breathing," its accretion rate rising and falling as feedback from nearby exploding stars turned on and off, Volonteri says. But once the galaxy reached maybe a hundredth the Milky Way's mass, there was enough gas coming in that material built up and shoved into the black hole. Growth then took off like a rocket.

The key is to shovel enough gas into one place, says Tiziana Di Matteo (Carnegie Mellon University). For several years her team has been crafting computer simulations to explore how galaxies and black holes grow together. Their most recent simulation, BlueTides, follows the formation of galaxies and their black holes in a volume 1.3 billion light-years on a side. That's roughly 300 times larger than the largest observational survey to date of the universe in this early cosmic era. Such a sweeping simulated view enables astronomers to make testable predictions about what we should and shouldn't see in the real universe.

It's this work that has solved the mystery of how the titan quasars formed, Di Matteo declares. The problem was that previous simulations didn't have the resolution or volume coverage to probe the rarest, highest density regions of the universe. In some of these regions, the gas can plunge inward directly instead of settling into disks and draining in more slowly. In these places, "black holes can grow at their maximum rate pretty much since the time they are seeded," she explains. Such fast growth is "virtually unstoppable."

Locations where this kind of infall is possible are few and far between. "In the simulations we see hundreds of thousands of black holes — in every newly forming galaxy in the early universe," she says. "But the fast growth is induced in only a handful of regions." That's in keeping with observations, she explains: the several dozen early quasars detected are a drop in the bucket of the nearly 1 billion galaxies uncovered by surveys. Other teams' recent simulations also support this conclusion.

Delving into Dwarfs

Simulations cannot yet tell us what kind of seed was planted in these rare, dense quasar regions: Di Matteo's code plops a 50,000-solar-mass black hole into place whenever the mass of the growing galaxy surpasses about a hundredth that of the Milky Way. But given the BlueTides results, the fantastic growth rate should make the seed mass irrelevant, she says. "You can pretty much start from anything, and still end up close to what you need at a redshift of 7," she says. (A redshift of 7 corresponds to 13 billion years ago; this era is when astronomers see the enigmatically large black holes.)

Unfortunately, that means that the titan quasars tell us nothing about what type of seed they formed from. Nor do most supermassive black holes seen today. These objects have

▲ **EMPTY NEST** The Triangulum Galaxy (M33) is the third largest galaxy in the Local Group, roughly a tenth as massive as the Milky Way and Andromeda. Yet this spiral contains no supermassive black hole in its core, and astronomers aren't sure why. (There's no sign of it having been ejected.)

S&T: SEAN WALKER

grown so much over cosmic time through both accretion and mergers that they essentially suffer from amnesia: they've forgotten where they came from.

That's not true for the runts. The smallest massive black holes, and the dwarf galaxies they inhabit, have changed little since their creation. These galaxies are so small that their stars ravage them, the stellar winds and supernovae ousting the cold gas needed to feed the black hole. Thus, black holes in dwarf galaxies should be about as big today as they were when they first formed.

Amy Reines (NOAO) and others are ferreting out these dwarf supermassive black holes. So far, they've turned up more than 150 of them. Of the couple dozen that they've weighed, the smallest contains roughly 50,000 solar masses. Right now the sample is small, and observations aren't sensitive enough to detect black holes much lighter than this. But if as they keep digging astronomers find that there's a "plateau" in how low black holes go, the limit could serve as a paternity test: if the masses peter out around tens of thousands of solar masses, that would favor direct collapse; if they keep plunging past our observational reach, that would favor stellar sources.

Jenny Greene (Princeton) wants to go further: she wants a census of all galaxies, to see how often they contain big black holes. Direct-collapse seeds are harder to make than stellar ones, so if supermassive black holes are normally born through direct collapse, there should be fewer of them — they'd occupy only about 60% of galaxies whose masses are at least a billion Suns (comparable to the Small Magellanic Cloud), she estimates. If massive black holes came from stellar seeds, on the other hand, basically all galaxies of this mass would have them.

We already know of exceptions to the latter. For example, there's no sign of a central black hole in the Triangulum Galaxy (M33), the spiral satellite of the larger Andromeda Galaxy. "M33 is the whole reason we get to ask whether all galaxies have black holes," Greene says. "Because we know that, when you get to a low enough stellar mass, they don't *all* have black holes."

Based on observations, she says, the best estimate is that galaxies with more than 100 million Suns contain a black hole at least 50% of the time. "We've ruled out below 20%," she says. "So it's looking like it's not so uncommon, even at these relatively low [galaxy] masses, to host a black hole above 100,000 solar masses." But if this fraction doesn't go up with more data, it could be a strike against the Population-III scenario.

On the other hand, recent simulations by Volonteri and her colleagues warn against thinking that building black holes is ever easy. The team followed black hole formation in a wide range of galaxies but took a more individual approach than Di Matteo. For each clump of gas, the team's simulation took into account its unique conditions and calculated how massive a black hole could form there, assuming it arose from Population-III stars or stellar-cluster dynamics.


TINY SUPERMASSIVE HOLE The dwarf galaxy RGG 118 is a hundredth as massive as the Milky Way and contains one of the smallest central black holes yet detected: roughly 50,000 solar masses. The disk galaxy lies about 350 million light-years away.

SDSS

The resulting seeds spanned a wide range of masses, but most had on the order of a thousand Suns — within an order of magnitude of the teeniest known massive black hole. Plus, supernova feedback stunted black hole growth in the smallest galaxies, and stellar cities with only a tenth of the Magellanic Clouds' mass were unlikely to form a central beast. So even with a stellar seed, massive black holes might be fairly rare.

LIGO and Beyond

Dwarf galaxies are the most promising lead for answering the genesis question, but they're not the only one. Kormendy also points to gravitational wave research. "It's really interesting and a little surprising that the first binary black hole detected by LIGO didn't involve 5-solar-mass black holes," he says. "It involved 30-solar-mass black holes. I really perked up when I saw that." If gravitational wave observatories regularly turn up black holes of several tens of solar masses, that would favor Population-III seeds, he says (see sidebar below).

Future observations of the early universe may also shed some light on the matter, pushing to within a billion years of the Big Bang. NASA's proposed WFIRST spacecraft should detect 10,000 supermassive black holes this early, Di Matteo estimates. Projects such as NASA's James Webb Space Telescope and ESA's Athena X-ray observatory (both upcoming) should also be able to detect accreting black holes with millions of solar masses in this era. So it's feasible that, in the next decade, we'll be able to answer for black holes what my mother answered for me, and definitively dismiss the cosmic stork.

■ *Sky & Telescope*'s Science Editor **CAMILLE M. CARLISLE** thinks black holes are adorable.

eLISA's Gravitational Waves

◗ Slated for launch in 2035, the European space mission eLISA will "listen" for gravitational waves from merging black holes and other astrophysical phenomena. The experiment will be able to detect spacetime ripples from black holes with masses of 10,000 to 10 million solar masses from across the universe. If black holes with such masses existed, and merged, even just a few million years after the Big Bang, eLISA will find them.

INNOVATIVE ASTRONOMY GEAR by The Editors of Sky & Telescope

Hot Prod

Each year, while compiling our annual survey of products, we're constantly reminded of the high level of innovation that manufacturers bring before the astronomical community, and this year is no exception. Consider, for example, Universe2go's augmented-reality smartphone viewer (p. 34) — introducing newcomers to the night sky has never been so easy. And Primaluce-Lab's Eagle computer/control system (p. 37) significantly reduces the bulky equipment required for deep-sky imaging in the field. Other products grabbed our attention because of their superior value, their sleek design, their usefulness, or their ability to solve a problem in a unique way. As always, it's hard to pare down the list of what we'll review. But here are some of our favorites for 2017.

1 CELESTRON CGX MOUNT

Celestron celestron.com

Newly engineered from the ground up, Celestron's CGX German equatorial mount includes a host of features for visual observers and astroimagers not previously available in this price range. Built-in home and limit switches, combined with internal cabling and sophisticated control software (developed in collaboration with PlaneWave Instruments) make the CGX ideally suited for remote operation and automated data acquisition. The mount's compact design offers improved rigidity and a 55-pound (25-kg) load capacity.

- **U.S. price: $2,199**

ucts2017

2 MALLINCAM SKYRAIDER DS2.3 PLUS

MallinCam mallincam.net

Built around Sony's latest color EXmor CMOS sensor, the SkyRaider DS2.3 Plus camera offers real-time video imaging of a wide range of astronomical targets from the Sun, Moon, and planets to deep-sky objects. Fan-assisted passive cooling, which helps maintain temperature stability, coupled with on-the-fly dark-frame correction produces very low-noise images. USB 3.0 connectivity provides fast downloads for recording uncompressed video. The company states that the SkyRaider DS2.3 Plus is its most versatile camera yet made for computer use.

- **U.S. price: $899.99**

3 ORION 60-MM GUIDESCOPE

Orion Telescopes & Binoculars
oriontelescopes.com

Modern CCD autoguiders can achieve arcsecond guiding accuracy when used with this 60-mm f/4 (240-mm-focal-length) guidescope from Orion. The 1¼-inch helical focuser with 10 mm of travel also has external male T-threads that allow direct connection to many guide cameras. It comes with mounting rings and a dovetail bracket compatible with Orion quick-release finder systems as well as other mounting options. The guidescope also doubles as a straight-through finder when used with an eyepiece.

- **U.S. price: $219.99**

4 REVOLUTION IMAGER SYSTEM R2

Revolution Imager revolutionimager.com

If there's an easier way to get started with video-assisted observing, we don't know about it. The Revolution Imager System R2 has everything you need to capture and display views through your telescope. The kit includes a color CCD camera with a 1¼-inch nosepiece and remote hand control, 0.5× focal reducer, 7-inch LCD video monitor, rechargeable battery, and all cables. The setup is designed for recording solar system and brighter deep-sky objects.

- **U.S. price: $299.99**

5

MEADE ETX90 OBSERVER

Meade meade.com

In 1996 Meade set a new standard for serious, entry-level telescopes when it introduced its ETX90, and the company upped the bar three years later when Go To technology was added to the 90-mm Maksutov-Cassegrain telescope. Now this venerable instrument has been redesigned and introduced as the ETX90 Observer with AudioStar, a hand controller that provides more than 4 hours of recorded commentary on the sky's most interesting celestial sights. The optical tube is easily detached from the mount, increasing the versatility of both components. If you yearn for more aperture, there's also a brand new ETX125 Observer ($699) featuring a 127-mm Maksutov-Cassegrain telescope.

- **U.S. price: $499**

6

CELESTRON POWERTANK LITHIUM

Celestron celestron.com

Modern electronics ended the days when powering telescopes in the field meant dragging along heavy automobile batteries and bulky power converters. But even by today's standards, Celestron's PowerTank Lithium battery offers a new level of convenience and performance. Based on lithium iron phosphate (LiFePO4) chemistry, the battery has exception shelf life and up to 2,000 recharging cycles. In addition to the standard 12-VDC output, there are two USB charging ports for smartphones and tablets. And did we mention its light panel with multi-level red and white illumination?

- **U.S. price: $139.95**

7

DAYSTAR COMBO QUARK

DayStar Filters daystarfilters.com

This year's upcoming total solar eclipse on August 21st has lots of amateurs thinking about observing the Sun, especially at hydrogen-alpha wavelengths where our star puts on dramatic shows almost daily. The easy-to-use Combo Quark from DayStar Filters will turn virtually any telescope with an f/15 or slower focal ratio (either the scope's native focal ratio or one achieved by stopping down the aperture) into a high-quality hydrogen-alpha setup for visual use and photography. The unit fits 1¼-inch focusers, accepts 1¼-inch eyepieces, and is powered by an AC adapter.

- **U.S. price: $995**

8

UNIVERSE2GO PERSONAL PLANETARIUM

Universe2go universe2go.com

Coupled with your Apple or Android smartphone and a free planetarium app, this lightweight, handheld viewer offers an interactive, augmented-reality view of the night sky that lets you easily identify stars, planets, constellations, and hundreds of deep-sky objects, many of which have accompanying audio descriptions. Placed inside the viewer, your phone shows a planetarium screen overlaid onto your direct view of the sky. The screen is automatically oriented to where you are looking and updates as you sweep the sky. The website lists currently compatible smartphones.

- **U.S. price: $99**

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9 NEXDOME OBSERVATORY

Canadian Telescopes nexdome.com

Made of durable, ultraviolet-protected ABS plastic, the 8-foot-diameter NexDome can be assembled in a few hours by one person using common hand tools. The shutter extends 100°, allowing telescopes to point to the zenith. NexDome is available as the dome only, or with a variety of base assemblies and a rotation motor, including ones with up to five external storage bays.

- **Priced from $1,699**

10 QHY183C CAMERA

QHYCCD qhyccd.com

This new entry from QHYCCD piqued our interest because of its 20-megapixel Sony IMX183 color sensor. The high-sensitivity, back-illuminated CMOS detector has very small 2.4-micron pixels, making it a good match for short-focal-length telescopes. Two-stage thermoelectric cooling, a 128-megabyte internal memory buffer, and USB 3.0 connectivity for fast download times (up to 15 full-resolution frames per second) round out an impressive list for features available in a camera costing less than $1,000.

- **U.S. price: $949**

11 TAKAHASHI FSQ-130ED

Texas Nautical Repair
takahashiamerica.com

Following in the footsteps of Takahashi's legendary FSQ-106 astrograph, the larger-aperture FSQ-130ED is a 130-mm f/5 five-element, flat-field telescope, which delivers razor-sharp stars across an imaging circle 110 mm across. Three of the lens elements are made from extra-low dispersion (ED) glass for superb color correction, and the scope's 5-inch focuser is designed to handle heavy cameras and accessories. Look for our field tests of the FSQ-130ED in the coming months.

- **U.S. price: $13,150**

12 OPTIMUS EYEPIECES

Stellarvue stellarvue.com

Stellarvue's new line of ultra-wide-field eyepieces with 15 mm of eye relief is well matched to the company's high-quality, short-focus telescopes. The 3.6- and 4.7-mm eyepieces offer extraordinarily wide 110° apparent fields of view, while the 9- and 20-mm models have 100° fields. Except for the 20-mm, which has a 2-inch barrel, the eyepieces fit 1¼-inch focusers and each comes with a custom 2-inch adapter threaded for 2-inch filters. All lens elements are fully multi-coated and have blackened edges to reduce scattered light and improve image contrast.

- **U.S. price: $399 each**

13 ASTRO-PHYSICS GTOCP4

Astro-Physics astro-physics.com

The GTOCP4 control box makes state-of-the-art electronics and telescope functions available to all GTO mounts made by Astro-Physics since 1998 as well as the company's mounts going forward. While there are many updates to the electronics under the hood of the GTOCP4, users will welcome the new USB, Ethernet, and Wi-Fi connectivity now available in addition to the earlier RS-232 ports. There's also new safety-slew logic that prevents slewing errors from happening if the mount's meridian-delay feature is activated for extending the time objects are tracked across the meridian.

- **U.S. price: $1,195**

14 ATIK INFINITY VIDEO CAMERA

Atik Cameras atik-cameras.com

Our Test Report in last October's issue, page 58 explains how this new camera from Atik brings video-assisted deep-sky observing into the digital age. The Infinity's high-sensitivity Sony IC825 EXview HAD CCD II sensor, coupled with on-the-fly image-stacking software (for PCs running Windows Vista and higher), produces near real-time color views of low-surface-brightness deep-sky objects. The camera and software are easy to use, and reviewer Rod Mollise said that they have him "ready to put [his] much-loved analog cameras on the shelf."

- **U.S. price: $995**

15 EXPLORE SCIENTIFIC 92° EYEPIECES

Explore Scientific explorescientificusa.com

With 20 mm of eye relief and 92° apparent fields of view, these 12- and 17-mm eyepieces will be of special interest to observers who wear glasses and want to experience the joys of ultra-wide apparent fields. Both offer between 33% and 50% more eye relief than Explore Scientific's 100° eyepieces with 2-inch barrels. As with the company's other premium wide-field models, the 92° eyepieces are argon-purged and waterproof.

- **U.S. price: $499.99**

16 DC-3 DREAMS ACP EXPERT

DC-3 Dreams dc3.com

Astronomer's Control Panel, or ACP for short, has become the gold standard for observatory automation software (and the company's home page helps explain why — we don't have room for all the details here). ACP Expert is the most powerful version yet of this program that offers full-time observatory automation with mobile and web support for monitoring multiple systems, scheduling new observations, and downloading data. And the company's customer support is second to none.

- **U.S. price: $1,495**

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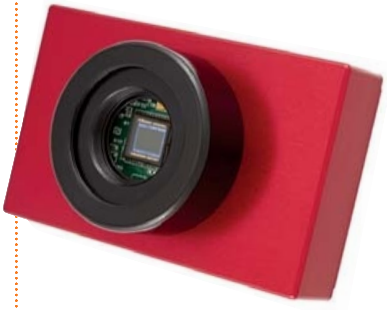

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17 QHYCCD POLEMASTER

QHYCCD qhyccd.com

This highly sensitive little camera attaches to many of today's popular equatorial mounts (check the website for the current list of available adapters) and produces a real-time 11° × 8° video image of the sky around the rotation point of the mount's polar axis. Included software for Windows PCs lets you quickly match the camera's view with the true position of the celestial pole in the Northern or Southern Hemisphere and achieve polar alignment with an accuracy of up to 30 arcseconds.

- **U.S. price: $268**

18 PRIMALUCE-LAB EAGLE

Primaluce-Lab primalucelab.com

Eagle is a small, self-contained computer/control system that mounts on your telescope and operates your mount, camera (including USB 3.0 devices), autoguider, and other accessories without the need for external wires running to a separate computer. You control it via a Wi-Fi connection to your laptop, tablet, or mobile device. There are too many details to fit here, but you can read more on the company's website and also check out the Eagle Observatory, which has even more options for controlling equipment wirelessly.

- **U.S. price: $1,299**

19 IOPTRON AZ MOUNT PRO

iOptron ioptron.com

From the company that set the modern standard for Go To altazimuth mounts comes the new AZ Mount Pro, featuring extremely simple set up and automated initialization routines. Its internal rechargeable battery can power the mount for up to 10 hours of continuous use, and a built-in Wi-Fi adapter provides wireless control with optional software. The dual dovetail (Losmandy and Vixen compatible) saddle can carry up to 33 pounds of equipment, while the retractable counterweight shaft can support an additional 10-pound telescope.

- **U.S. price: $999**

20 GLATTER PARALLIZER T-ADAPTER

Howie Glatter collimator.com

In 2012 we selected Howie Glatter's Parallizer as a Hot Product for its simple but elegant and effective method of insuring that 1¼-inch eyepieces and accessories were mounted absolutely square to a telescope's 2-inch focuser drawtube. Now this technology is incorporated in a T-thread adapter for 2-inch focusers. It will be highly useful to imagers using T-thread equipment, especially those working with fast-focal-ratio scopes and larger detectors where even a tiny misalignment of the camera can render the focus uneven across the frame.

- **U.S. price: $45**

21 S&T'S CELESTIAL GLOBE

Sky & Telescope skyandtelescope.com

What? Did you think we wouldn't have a Hot Product pick of our own? Think again. More than a year of research, planning, and testing went into the production of this 12-inch celestial globe, which features a correct-reading perspective of the heavens. Nearly 3,000 stars to magnitude 5.5, including 194 shown with their common names, and more than 200 identified deep-sky objects are plotted along with the familiar constellation patterns from our monthly center star map, constellation boundaries, the ecliptic (showing the Sun's monthly position), the Milky Way, and a coordinate grid.

- **U.S. price: $99.95**

22 L-O-A 21 3-D EYEPIECES

Denkmeier deepskybinoviewer.com

Here's a novel set of eyepieces for anyone using a binoviewer. One of the 21-mm eyepieces in this pair has been optically modified to make some stars appear offset in its field of view, rendering a 3-D effect. Rotating this modified eyepiece in its holder will shift the central object in the field from the foreground to the background. The effect is most pronounced when the field includes stars having a wide range of brightnesses, though the modified L-O-A 21 eyepiece is not meant for viewing the Moon or planets.

- **U.S. price: $599**

23 CELESTRON INSPIRE REFRACTORS

Celestron celestron.com

There are plenty of entry-level telescopes available today, but Celestron's new Inspire line of 70-, 80-, and 100-mm (pictured) refractors caught our attention for their extraordinarily well-thought-out design and execution. Their easy setup involves no small pieces that can become separated or lost in the dark, and a cleverly designed red illuminator for the accessory tray doubles as a flashlight. There's an easy-to-use red-dot finder, and for those who want to shoot pictures through the telescope, the lens cap also serves as a universal smartphone adapter.

- **Priced from $179.95**

24 ANNALS OF THE DEEP SKY

Willmann-Bell willbell.com

No, it's not déjà vu. For the second year in a row we've selected the latest volumes in Willmann-Bell's *Annals of the Deep Sky* series as Hot Products. A review of the first volumes appears in our December 2015 issue, page 65, and makes it clear how valuable we believe these celestial guides are for 21st-century observers. In addition to what's seen in a telescope eyepiece, authors Jeff Kanipe and Dennis Webb write extensively about the history, lore, and scientific background of their subjects. Coverage of the sky is broken down alphabetically by constellation, and volume 4 completes the series through Cassiopeia.

- **U.S. price: $24.95 each**

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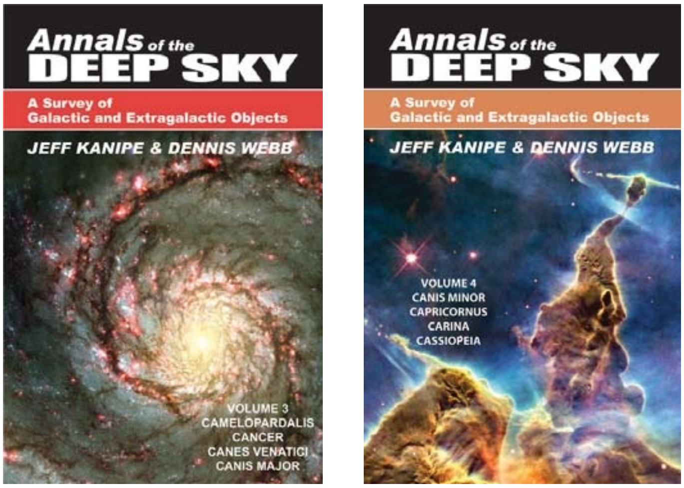

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ZWO ATMOSPHERIC DISPERSION CORRECTOR

ZWO zwoptical.com

Atmospheric dispersion smears our view of astronomical objects due to different wavelengths of light being bent by different amounts as they pass through our atmosphere. The effect is more pronounced for objects low in the sky as many northern observers know all too well from viewing Mars and Saturn last summer. Atmospheric dispersion correctors (ADC for short) based on a pair of adjustable prisms are widely used by planetary observers, but this new model from ZWO costs a fraction of ADCs available in the past. And a deal like that makes it a Hot Product in our eyes.

- **U.S. price: $128**

26

TELE VUE FONEMATE

Tele Vue Optics televue.com

Google “telescope smartphone adapter” and you’ll likely be overwhelmed by the variety of models on the market today. But the FoneMate from Tele Vue stood out for two reasons. First, there’s the easy way a smartphone (with or without a protective case) is properly positioned and held in place on the adapter. And second is how easily the assembly connects to any Dioptrx-compatible Tele Vue eyepiece (check the website for a list) already on the telescope, making it extremely simple to photograph what you’ve been observing.

- **U.S. price: $95**

27

IOPTRON SKYTRACKER PRO

iOptron ioptron.com

The SkyTracker Pro from iOptron may be small enough to fit in the palm of your hand, but it’s packed full of features and ready to mount on any solid photo tripod. The removable base has fine altitude and azimuth adjustments for achieving precise polar alignment using the polar finder scope and a smartphone app. An internal rechargeable battery offers up to 24 hours of continuous operation at solar, lunar, sidereal, or half-sidereal tracking rates, with the last one of special value to nightscape photographers shooting starry vistas above terrestrial scenes.

- **U.S. price: $399**

28

VIXEN HR PLANETARY EYEPIECES

Vixen Optics vixenoptics.com

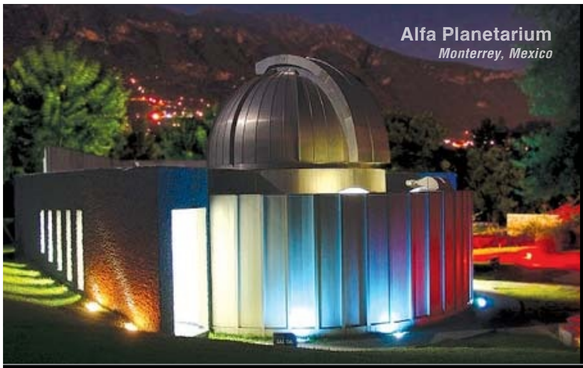
Planetary observers will be especially interested in these new eyepieces from Vixen. Their exceptionally short focal lengths of 2.6-, 2.0-, and 1.6-mm produce high magnifications with relatively short-focal-length telescopes. With only 5 lens elements arranged in 3 groups, optical coatings providing more than 99% transmission at each lens surface, and mechanical construction optimized to reduce scattered light, these eyepieces deliver superb image contrast and resolution. Each model has 10 mm of eye relief and a 42° apparent field of view.

- **U.S. price: $279 each**

Experience the 2017 Solar Eclipse in ***Beatrice, Nebraska.***

Enjoy ***2 minutes and 35 seconds of totality*** at Homestead National Monument of America or at one of our engaging viewing sites in Gage County Nebraska!

www.**EclipseBeatrice**.com



Alfa Planetarium
Monterrey, Mexico

Observa·DOME

www.observa-dome.com

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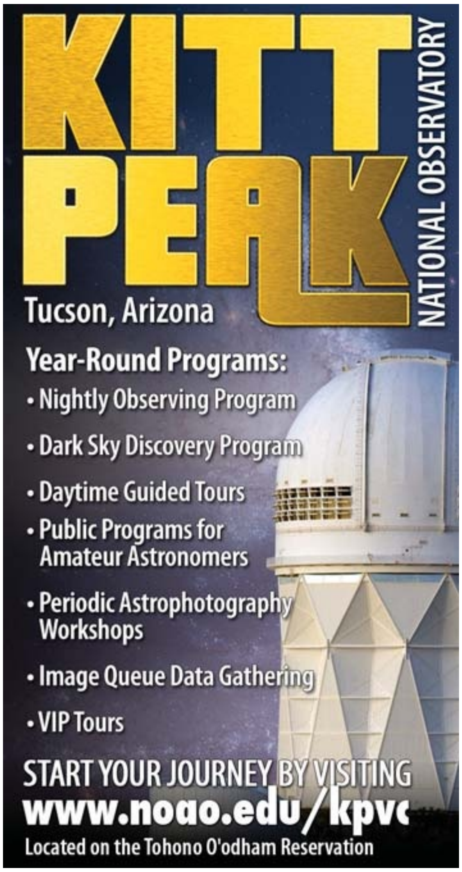

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1 **EVENING:** Find the waxing crescent Moon about 5° lower right of bright Venus in the southwest. Modest Mars shines 12° upper left of Venus.

2 **EVENING:** The Moon hangs 3–4° lower right of Mars and 5–6° upper left of Venus.

8 **DAWN:** For the next three mornings, Mercury and Saturn are 7° apart low in the southeast; bring binoculars.

8,9 **EVENING:** The waxing gibbous Moon shines upper right of Aldebaran on the 8th and lower left of it on the 9th for North America. In between, the Moon occults Aldebaran for much of Asia.

10 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 9:19 p.m. EST (6:19 p.m. PST); see page 50.

14–15 **NIGHT:** The Moon, just past full, shines near Regulus, the brightest star in Leo. Watch as the distance between them increases through the night.

19 **MORNING:** The last-quarter Moon, Jupiter, and Spica form a compact triangle. They're highest in the south before dawn.

24 **DAWN:** The thin crescent Moon slices about 3° upper left of Saturn, which gleams in the southeast.

25 **DAWN:** Binoculars will help tease out the very thin crescent Moon low in the southeast. The tiny light of Mercury sparks 5–6° below or lower left of it.

30 **NIGHT:** Algol shines at minimum brightness for roughly two hours centered at 11:04 p.m. EST (8:04 p.m. PST).

31 **DUSK:** The waxing crescent Moon, Mars, and Venus form a triangle in the west-southwest in twilight. They set around 9 p.m.

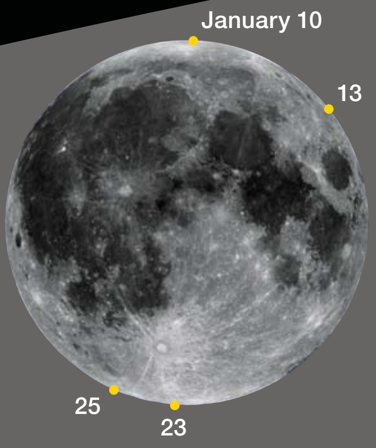
OBSERVING
January 2017

Merope, the fifth brightest star in the Pleiades cluster, is surrounded by nebulosity. NGC 1435 draws a swooping apostrophe around the star, while IC 349 hugs its southeastern flank.
◖ See more on page 60. ROBERT GENDLER

JANUARY 2017 OBSERVING

Lunar Almanac

Northern Hemisphere Sky Chart



Yellow dots indicate which part of the Moon's limb is tipped the most toward Earth by libration.

NASA / LRO

MOON PHASES

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

◐ **FIRST QUARTER**
January 5
19:47 UT

○ **FULL MOON**
January 12
11:34 UT

◑ **LAST QUARTER**
January 19
22:13 UT

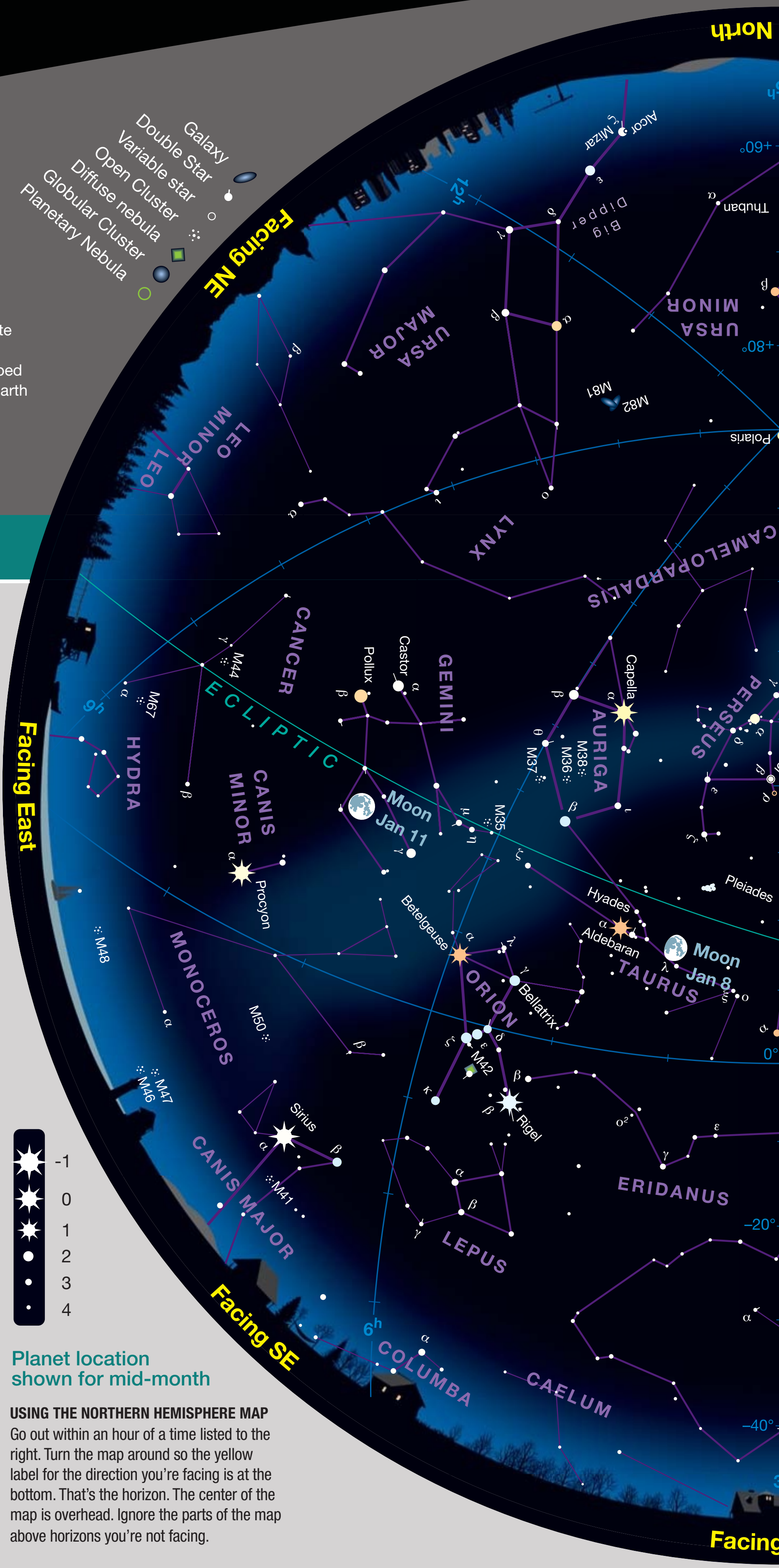
● **NEW MOON**
January 28
00:07 UT

DISTANCES

Apogee 404,914 km	January 22, 00^{h} UT diam. 29′ 31″
Perigee 363,238 km	January 10, 06^{h} UT diam. 32′ 54″

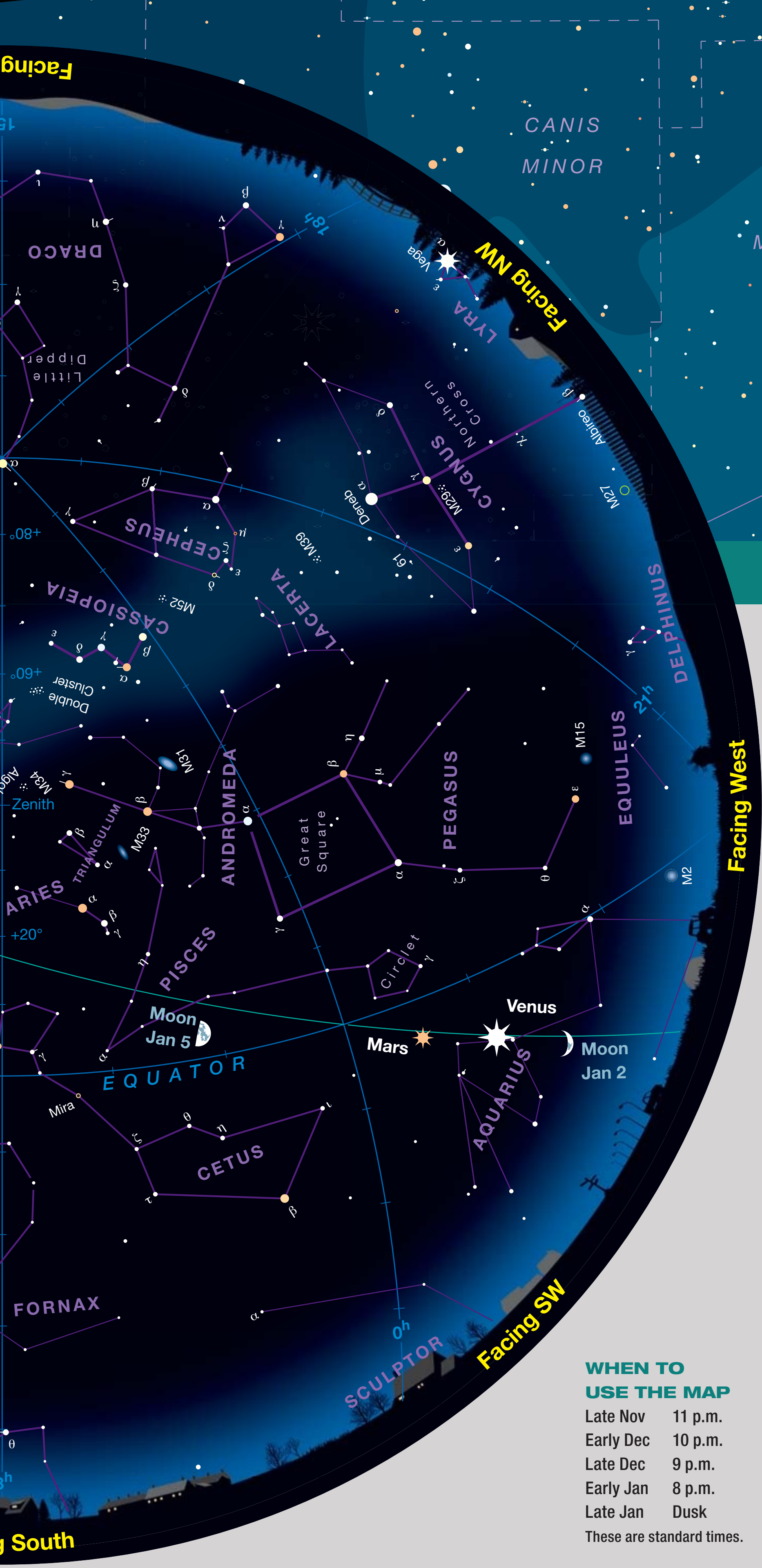
FAVORABLE LIBRATIONS

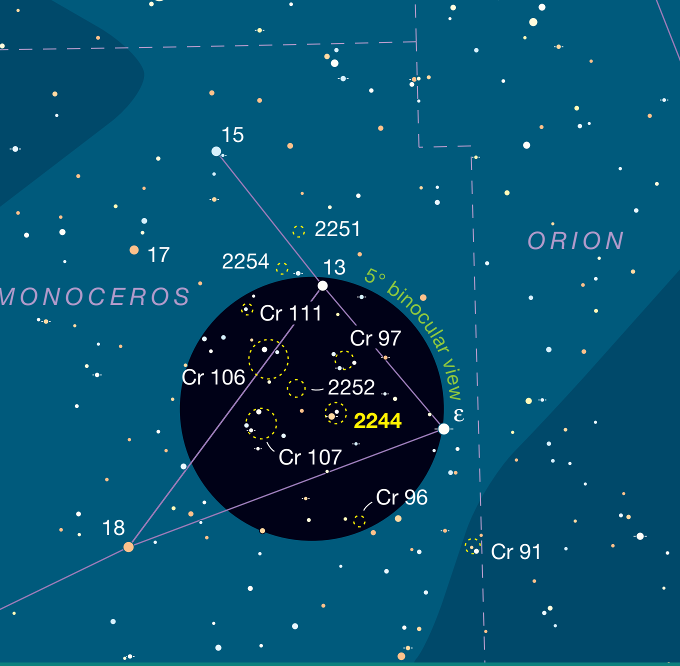
• Peary (crater)	January 10
• Gauss (crater)	January 13
• Drygalski (crater)	January 23
• Hausen (crater)	January 25



Planet location shown for mid-month

USING THE NORTHERN HEMISPHERE 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. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.





Binocular Highlight by Mathew Wedel

A Cluster of Clusters

In the 1960 TV series, Daniel Boone describes a buffalo "so big, I had to look three times to see all of it." There are starfields like that, too, those so expansive or complex that they can't be taken in all at once. One of my favorites is the area around open cluster **NGC 2244** in the northwest corner of Monoceros, the Unicorn.

This field is a little over 10° south of Gamma (γ) Geminorum, inside a triangle formed by 13 Monocerotis, 18 Mon, and Epsilon (ε) Mon. It includes the Rosette Nebula, but I'm not going to say much about that this time. Under dark skies, and with big binos, it can be a spectacular sight — but not from my driveway with 50 mm of aperture.

Instead I see a field positively spangled with open clusters. In addition to NGC 2244, three Collinder clusters are easy catches in the same area: Cr 97 lies 1° north of NGC 2244; Cr 107 stands 1.5° east; and Cr 106 completes the rectangle. All four are big and bright, between 4th and 6th magnitude. Several smaller, 7th-magnitude clusters are in the same 5° field of view: NGC 2252 in the middle of the rectangle, Cr 111 to the northeast, and Cr 96 to the southwest. You'll need very sharp eyes to pick any of those little clusters out as separate objects, but they contribute to the richness of the area. And as if that wasn't enough, most of these clusters are embedded in the Monoceros OB 2 association, a cloud of bright, young stars that extends for several degrees in all directions.

I know it's asking a lot on these cool winter evenings, but dress warm, settle in, and spend some time with this field. You may need to look a few times to see it all.

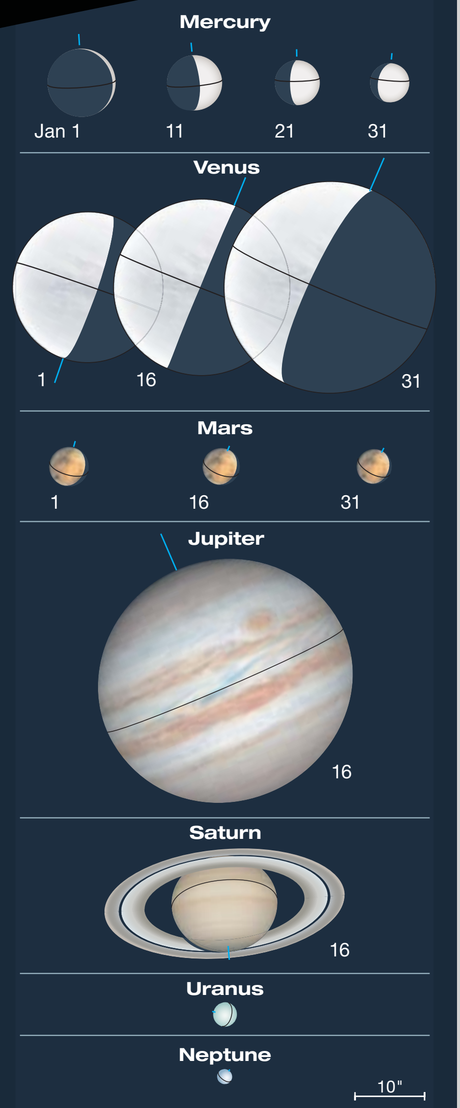
■ **MATT WEDEL** likes to kick back with his binoculars on a driveway in Claremont, California.

WHEN TO USE THE MAP

Late Nov	11 p.m.
Early Dec	10 p.m.
Late Dec	9 p.m.
Early Jan	8 p.m.
Late Jan	Dusk

These are standard times.

Planetary Almanac



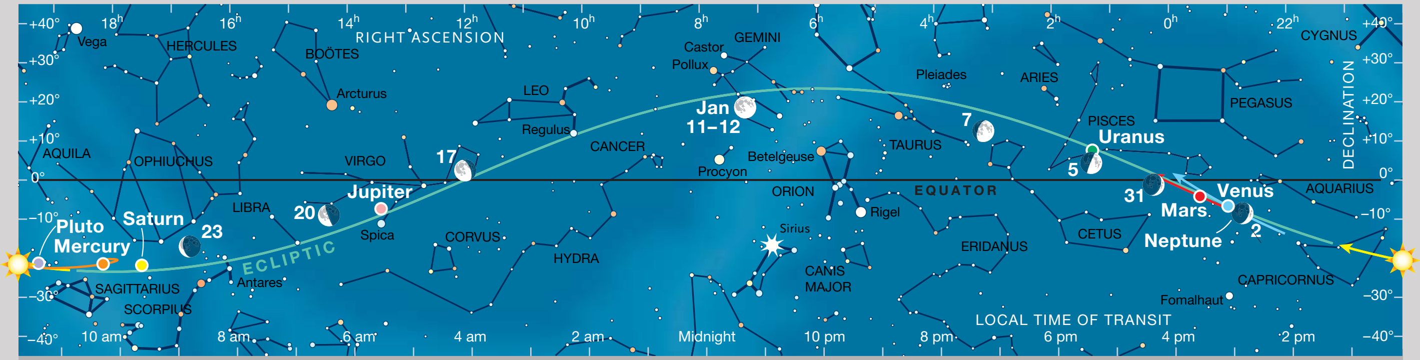
PLANET DISKS have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.

PLANET VISIBILITY: **Mercury:** Jan. 5 – Feb. 3, dawn, low southeast • **Venus:** All month, dusk and after, west • **Mars:** All month, dusk and after, west • **Jupiter:** All month, late night to dawn, east to south-southwest • **Saturn:** All month, dawn, low southeast.

January Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h\ 45.8^m$	–23° 01′	—	–26.8	32′ 32″	—	0.983
	31	$20^h\ 54.1^m$	–17° 27′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$18^h\ 13.0^m$	–20° 22′	8° Mo	+3.3	9.8″	5%	0.685
	11	$17^h\ 56.1^m$	–20° 46′	22° Mo	0.0	8.0″	41%	0.845
	21	$18^h\ 29.6^m$	–22° 10′	24° Mo	–0.2	6.5″	66%	1.038
	31	$19^h\ 23.5^m$	–22° 26′	22° Mo	–0.2	5.6″	80%	1.191
Venus	1	$21^h\ 59.9^m$	–13° 47′	47° Ev	–4.4	21.7″	57%	0.769
	11	$22^h\ 39.1^m$	–9° 14′	47° Ev	–4.5	24.0″	52%	0.695
	21	$23^h\ 14.5^m$	–4° 30′	47° Ev	–4.6	26.8″	46%	0.621
	31	$23^h\ 45.6^m$	+0° 13′	46° Ev	–4.7	30.4″	40%	0.548
Mars	1	$22^h\ 44.8^m$	–8° 54′	59° Ev	+0.9	5.7″	90%	1.640
	16	$23^h\ 26.4^m$	–4° 18′	55° Ev	+1.0	5.4″	91%	1.741
	31	$0^h\ 07.3^m$	+0° 22′	51° Ev	+1.1	5.1″	92%	1.842
Jupiter	1	$13^h\ 19.2^m$	–6° 58′	80° Mo	–1.9	35.5″	99%	5.547
	31	$13^h\ 26.6^m$	–7° 35′	108° Mo	–2.1	38.9″	99%	5.068
Saturn	1	$17^h\ 21.8^m$	–21° 52′	19° Mo	+0.5	15.2″	100%	10.970
	31	$17^h\ 35.3^m$	–22° 02′	47° Mo	+0.5	15.5″	100%	10.699
Uranus	16	$1^h\ 16.5^m$	+7° 26′	85° Ev	+5.8	3.5″	100%	20.007
Neptune	16	$22^h\ 47.0^m$	–8° 39′	44° Ev	+7.9	2.2″	100%	30.650

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.



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.

Wonders of the Year-Start Sky

Now is the time to seek new sights by night — and by day.

A new year always begins with the possibility of new sights and experiences — and therefore with the possibility of wonder. This is particularly true in the world of observational astronomy.

So let's take a look at how 2017 gets off to an especially wondrous start in the sky. Let's also explore why the familiar "year-start" sky is really a whole new beast (as the saying goes) if you look at it in new ways (or in many directions). And, finally, let's see how a small calculation about the Moon's cycle reminds us why we should appreciate not just every year, but every month, in the heavens as a thing new and wonderful.

The crescent Moon sets over ESO's Paranal Observatory in Chile.

ESO / BABAK TAFRESHI

Begins with wondrous. In our era every New Year begins at midnight with the brightest star, Sirius, on or very near the meridian — technically not a new sight but one so impressive it's always wondrous. And the opening hours of 2017 bring a sight that will be new to almost everyone: two planets hardly more than 1 arcminute apart, the closest readily observable two-planet pairing in almost 30 years (see more on the next page).

We're talking about beginnings here, but let's not forget that a little past the middle of the year there comes the awesome American coast-to-coast total eclipse of the Sun. Mark your calendars for August 21, 2017. If you're not an experienced solar observer, you can start practicing now.

Wonders of the year-start sky. In last January's edition of this column, I noted that we could start the year by going out at four different times between nightfall and midnight to experience four different "bright beginnings" in the heavens. But now let's look more closely at just one of those times — the one presented on our all-sky map at the center of the magazine.

If you look due south you see a surprising dimness. Until you reach the bright head of Cetus, the Whale, the sky in this direction is filled with the meandering of Eridanus, the River, most of which needs a really dark sky to show up well. High up, the Pleiades are approaching the meridian. But this cluster is better appreciated as a top adornment on a peerless pile of stellar brightness stacked up in another direction: the southeast.

No one direction at any hour is as splendid with stars this time of year. Sirius is low and the rest of bright Canis Major, the Big Dog, is just beginning to rear up from the southeast horizon. But directly above Sirius stands unmatchable Orion, and directly above Orion looms Taurus, the Bull, with Aldebaran, the Hyades, and Pleiades. Perseus, extending a foot to the Pleiades, poses at the zenith.

Looking east shows low Procyon under the reclining bodies of Gemini, the Twins, and the pentagon of Auriga, topped with bright Capella. The northeast sky is dim, though the bowl and part of the Big Dipper's handle are approaching it low in the north-northeast. Gazing northward reveals the Little Dipper hanging from Polaris.

A look northwest finds Vega setting, the Northern Cross of Cygnus standing upright on the horizon, and the top of the Northern Cross, Deneb, far below bright Cassiopeia. Almost the entire line from zenith to horizon in the due west is covered by the bodies of Andromeda and Pegasus, hanging straight down. And last but not least is the mostly dim southwest — this January rescued by the brilliance of Venus and Mars.

A lifetime of Moons. The new year makes us think about matters of time. One is the number of full Moons or lunations — the period from one new Moon to the next — that occur in a long human lifetime. The approximate number is 1,000, which is a generous amount, but not unlimited, especially when you consider how many cloudy nights and times of illness or preoccupation there are in our lives.

We have a limited number of lunations, a measured amount of Moons in our lives. Starting tonight, use them wisely. Use them well.

■ Contributing Editor **FRED SCHAAF** has been writing about the skies above us for more than 40 years.

The Evening Star Reigns Supreme

Venus lights the southwest in twilight, while Mars and Neptune rendezvous nearby.

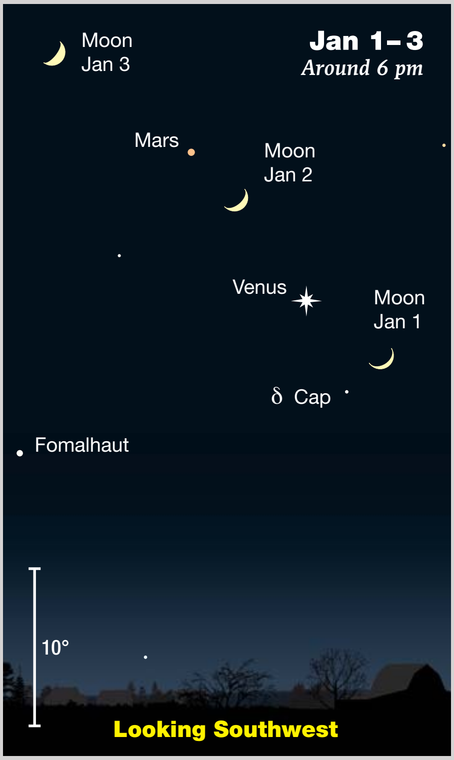
The year 2017 wastes no time in getting off to a great start. New Year's Eve brings the closest observable pairing of any two planets in almost 30 years. Mars and Neptune reach almost a minimum conjuction for observers in the Pacific, though they won't be quite so close for North America. Venus passes through greatest elongation this month, gaining altitude for observers at mid-northern latitudes as it pulls closer to much dimmer Mars. This planetary duo is well up in the southwest at nightfall and sets around mid-evening.

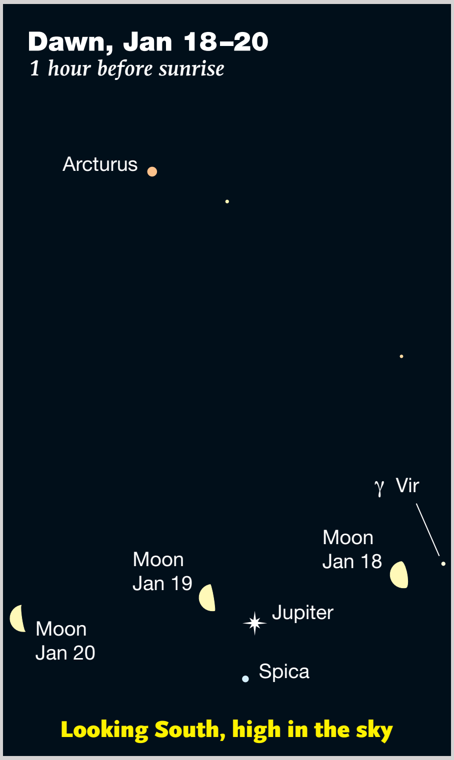
Jupiter rises around midnight and shines highest in the south by dawn. Saturn glows low in the southeast during early dawn, and to its lower left, little Mercury makes a morning appearance after the first week of the month.

DUSK & EARLY EVENING

Venus reaches a greatest elongation of 47° east of the Sun on January 12th. The resplendent planet sets about 4 hours after the Sun all month for observers around latitude 40° north.

As Venus moves north along the ecliptic, it gains height: its altitude at sunset increases from 33° to 40° during January. Its brightness improves from magnitude –4.4 to a near-maximum –4.7. In a telescope Venus's apparent diameter grows from 21″ to 30″ while its phase wanes from 58% to 40% sunlit. On which night after greatest elongation does it appear half-lit in your telescope? Look each evening, then find the midpoint between the date when it last looked a trace gibbous and the date when its terminator first appears indented.





Mars is easy to find this month, not far upper left of Venus. On the night of December 31–January 1 in North America, Mars experiences an ultra-close conjunction with 8th-magnitude **Neptune**. The two worlds appear just 68″ apart at 6:53 UT January 1st as viewed from Hawai'i and the Pacific. The pairing is already tight a few hours earlier when visible from the continental United States: they're 0.2° apart as seen just after dark from the East Coast, and 0.1° from the West Coast, with Neptune more or less above Mars. The globe of Mars at this conjunction is 5.7″ wide while Neptune's is 2.2″. Neptune is almost 20 times farther and 6 magnitudes fainter than Mars.

The brightness of Mars diminishes from magnitude +0.9 to +1.1 during January as blazing Venus chases it across Aquarius. The two planets end the month just left of the Circlet of Pisces asterism. By January 31st the gap between Venus and Mars has shrunk down to 5½°, and the two planets form a compact triangle with the month's second young crescent Moon.

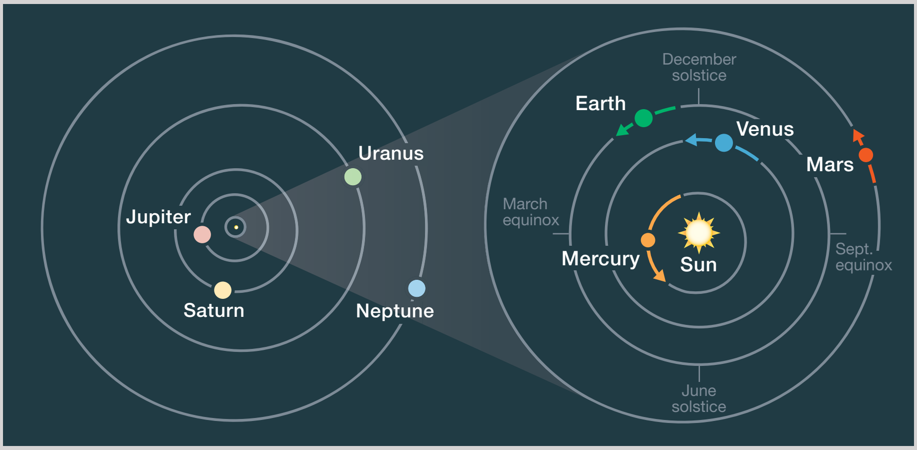
Venus, following behind Mars, passes 0.4° from Neptune on January 12th, the date of Venus's greatest elongation.

Uranus is still high in the west-southwest after nightfall. Finder charts for Uranus and Neptune are on page 50 of the October 2016 issue.

- To find out what's visible in the sky from your location, go to skypub.com/almanac.

MIDNIGHT TO DAWN

Jupiter rises in the middle of the night and is highest during or before morning twilight. The giant planet brightens from magnitude –1.9 to –2.1 during January and grows from 35″ to 39″ wide. It passes through western quadrature (90° west of the Sun) on January 12th. Jupiter shines near Spica all month — indeed, all year. The first of three Jupiter–Spica conjunctions in 2017 occurs in the early morning hours of January 20th, when the mighty world beams within 4° of the star.



ORBITS OF THE PLANETS

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

DAWN

Saturn and **Mercury** are low in the southeast at dawn this month. The ringed planet comes up about 1½ hours before the Sun on New Year's Day, about 3 hours before the Sun by the end of January. Look for Antares about 14° to Saturn's right or upper right.

Mercury becomes visible to Saturn's lower left after January 5th or so. By the 9th Mercury has brightened past the magnitude +0.5 radiance of Saturn and has closed to 7° from it. On that day, 45 minutes before sunrise, Saturn stands about 10° above the horizon with Mercury about 3° lower. Mercury never gets closer to Saturn, but begins edging away. By the time of Mercury's greatest elongation, 24° from the Sun on January 19th, 12° separates the pair.

EARTH & MOON

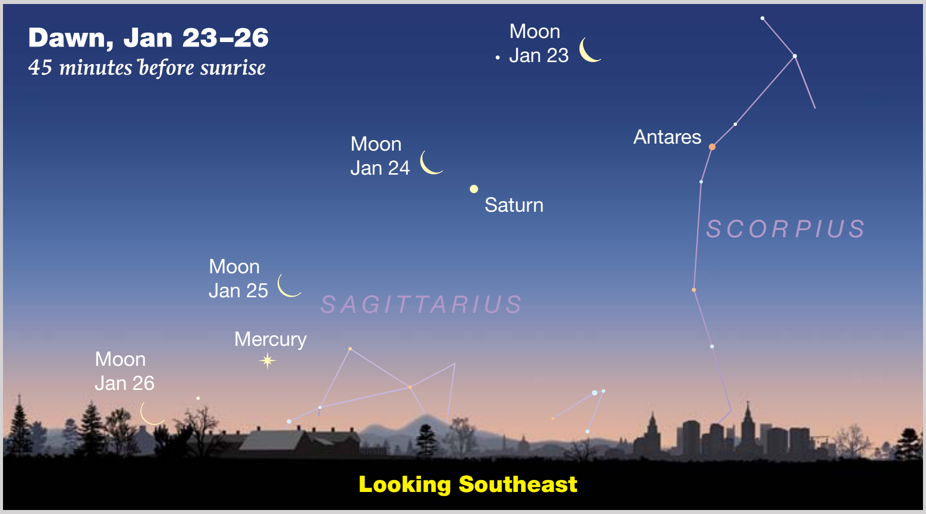
Earth is at perihelion, its closest to the Sun in space, at 14^{h} UT January 4th, when it lies 0.98331 a.u. (147,100,998 km) from the Sun.

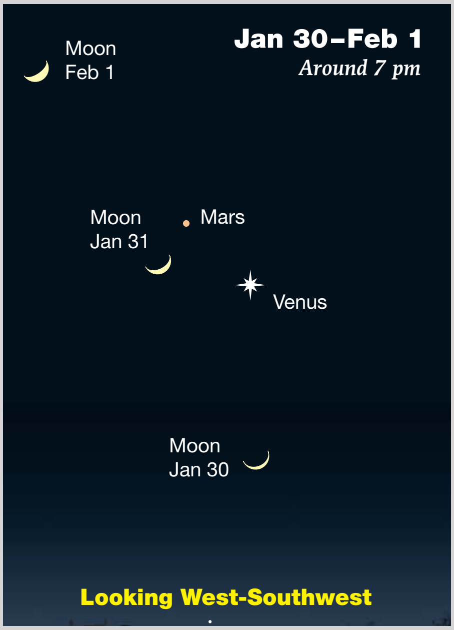
The Moon is lower right of Venus on January 1st and upper left of it on the 2nd. The Moon occults Mars and Neptune for Southeast Asia on the 3rd (local date). The waxing gibbous Moon shines upper right of Aldebaran on the 8th and lower left of it on the 9th.

At dawn on January 19th the last-quarter Moon, Jupiter, and Spica form a close triangle. The waning lunar crescent hangs about 3° upper left of Saturn at dawn on January 24th and about 6° above Mercury the next morning.

The waxing lunar crescent is well below Venus on the evening of January 30th, then closes to create a tight triangle with Venus and Mars on the 31st.

■ Contributing Editor **FRED SCHAAF** welcomes your letters and comments at **fschaaf@aol.com**.





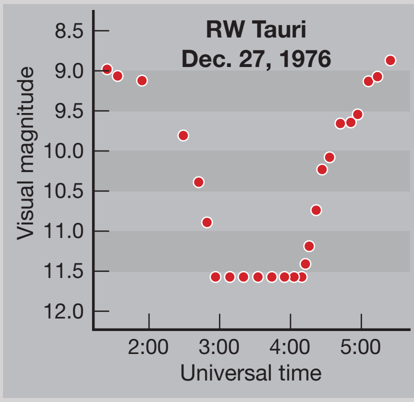
▲ These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your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

RW Tauri, an Action-Packed Eclipser

A flat-bottomed eclipsing binary star shines high near the Pleiades.

AKIRA FUJII

RW Tauri hides in plain sight near the Pleiades & Aldebaran. It's the deepest eclipsing binary known.



▲ The central 5 hours of an eclipse. Peering into a 6-inch reflector, I took extreme care in estimating RW's magnitude every 5 to 10 minutes. The effort paid off with this very clean light curve.

Well do I remember my first night with a telescopic eclipsing binary star. It was deepest December 1976. *Sky & Telescope* had published a list of upcoming eclipses predicted for RW Tauri, the most extreme eclipsing binary known. Like amateur astronomers had for generations, I read that this 8.0-magnitude B8 star fades, then positively plummets, to about magnitude 11.6. It sits there unchanged for 80 minutes, glimmering with a slight orange tint, then leaps back up to, eventually, brilliant whiteness — "brilliant" being relative, after you've been watching it sit there 1⁄25 as bright barely above the sky background in your eyepiece. Most of the show runs through its course in about five hours.

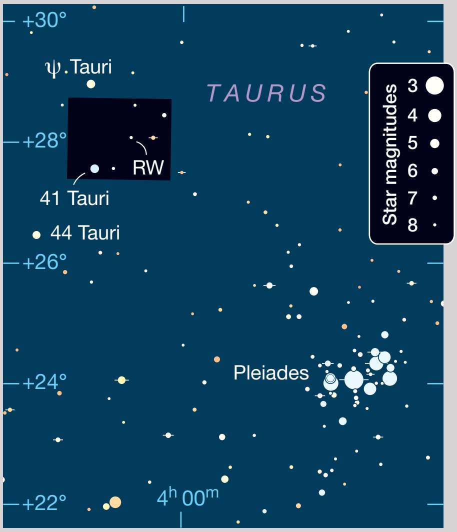
I made a night of it. In the list of predictions, I found an eclipse timed so I could follow Taurus through openings in my trees for two hours before and after the midpoint. I shoveled a space in the snow for me and my 6-inch f/8 reflector. The appointed night was clear. Every 5 or 10 minutes I made as careful an estimate as I possibly could of where RW Tauri stood with respect to the brightnesses of the comparison stars around it. I kept at it for more than four hours. As I communed so intently with this tiny point far above the silent world, its performance proved even more of an adventure than I'd hoped.

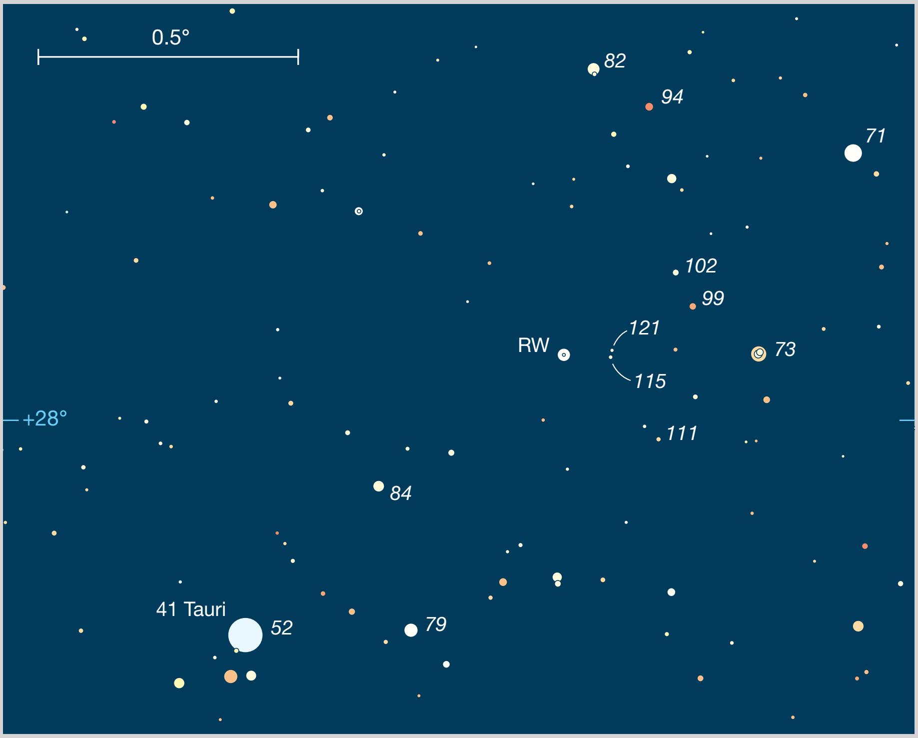
The next morning I plotted my brightness estimates on graph paper. The result was the beautiful, symmetric, flat-bottomed light curve at lower left. By folding the paper straight down the middle so the descending and rising curves aligned when I shone a light through the paper, I judged that mid-eclipse had happened at 3:32 UT.

And that was the whole point of this project. Many eclipsing binaries show slight changes in their orbital periods, for various reasons predictable and unpredictable. A period change as small as one part per million will add up over time, until the eclipses come measurably early or late to an amateur eyeballing the star through a modest telescope. Professionals and amateurs have timed eclipsing binaries for generations to create long records of what's going on.

I reported my data and timing to the Eclipsing Binary section of the American Association of Variable Star Observers. There it resides: one of about 17,000 eclipsing binary timings made by AAVSO members since 1965.

Nowadays amateurs do the job much





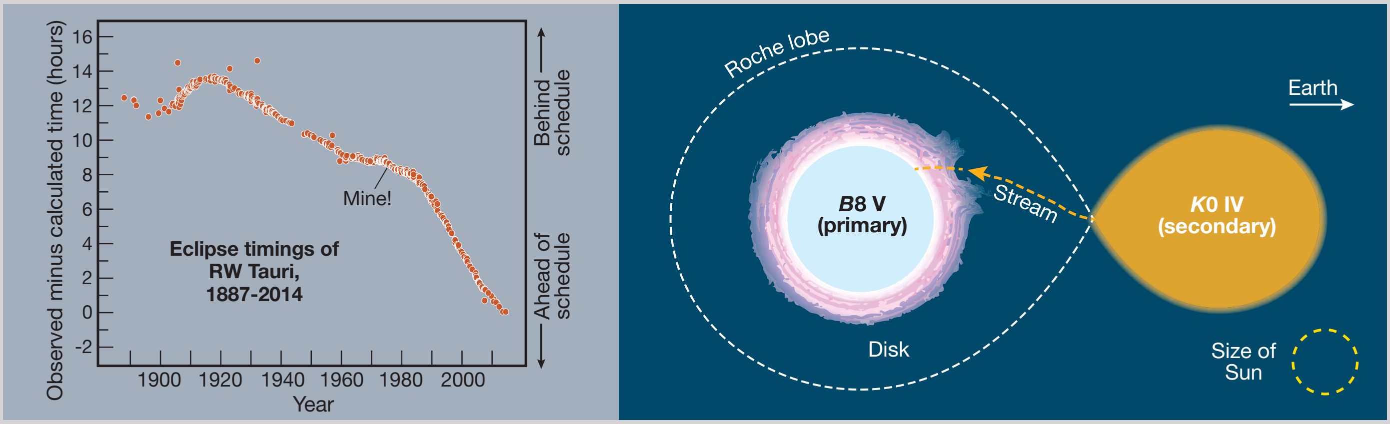
▲ Located 5° northeast of the Pleiades, RW Tauri drops 3 magnitudes — a factor of 16 in brightness — in just two hours if you get your timing right. The black box shows the area of the closeup chart at right, where comparison-star magnitudes are given to the nearest tenth with the decimal point omitted.

better, using CCD-camera photometry. This method produces timings at least 10 times more accurate thans visual ones, giving a much higher-resolution picture of the binary's behavior. The creeps and jitters in the orbital period may reveal mass loss and/or mass-swapping — both continuous and abrupt — or slow, one-way effects of stellar evolution, rotation of the line of apsides, or the orbital influence of unseen bodies.

Are you up for it? A good timing requires diligent care for about four well-chosen hours, unless you are set up for imaging and can run an automated sequence unattended. If you'd just like to look in on the height of the show near the edges of totality, when the last limb of the bright star disappears or when the first edge peeks back out, you can detect changes happening visually in just a few minutes.

Here are predicted mid-eclipse times until Taurus moves too near the Sun: **November 24,** 19:14; **27,** 13:41; **30,** 8:08. **December 3,** 2:35; **5,** 21:02; **8,** 15:30; **11,** 9:57; **14,** 4:24; **16,** 22:51; **19,** 17:19; **22,** 11:46; **25,** 6:13; **28,** 0:41; **30,** 19:08. **January 2,** 13:36; **5,** 8:03; **8,** 2:30; **10,** 20:58; **13,** 15:25; **16,** 9:53; **19,** 4:20; **21,** 22:48; **24,** 17:15; **27,** 11:43; **30,** 6:10. **February 2,** 0:38; **4,** 19:05; **7,** 13:33; **10,** 8:00; **13,** 2:28; **15,** 20:55; **18,** 15:23; **21,** 9:50; **24,** 4:18; **26,** 22:46.

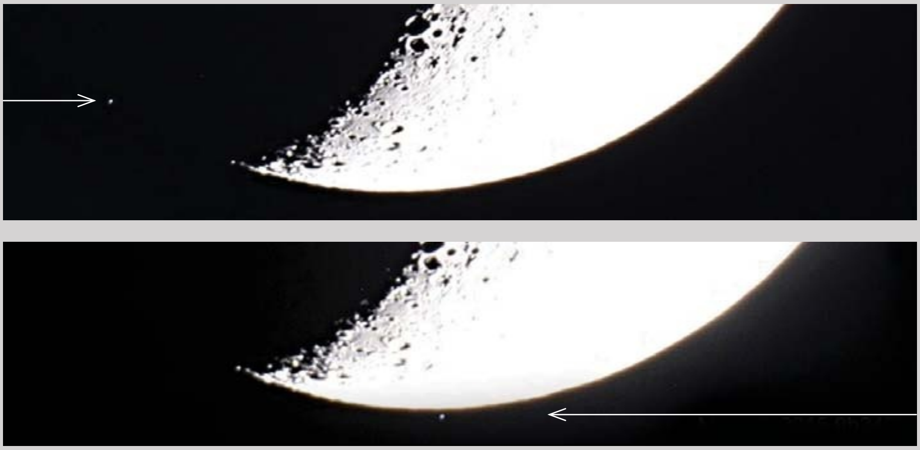
RW Tauri is about 1,000 light-years away, a distant speck indeed. Running closely north of it is a faint, slightly curving line of two stars of magnitudes 12.1 and 12.6. The line is 104″ long.



▲ The payoff. Phillip A. Reed of Kutztown University plotted all 590 known eclipse timings of RW Tauri through November 2014, including the one I made standing in the snow, as an "O minus C diagram." The *observed* time of each eclipse is compared to the *calculated* time when it should have happened if the period never changed. The difference is plotted on the vertical axis. A change in slope means a change in period. **Right:** Long studied, RW Tauri still holds secrets. The dim orange *K* star fills its surface of gravitational containment (Roche lobe) and overflows to spill an irregular stream of gas onto the hot, brilliant primary. Surrounding the primary is an intermittent ring of hydrogen, probably splashed up by the infalling stream.

S&T DIAGRAMS: LEAH TISCIONE, SOURCE: PHILLIP A. REED

Moon Occults Gamma Tauri



Lucian Gurban of Montreal was watching and photographing when the southern edge of the waxing Moon occulted Alpha Cancri, magnitude 4.2, on the evening of May 23, 2015. He used a 6-inch telescope for these before and after shots, taken 24 minutes apart.

▲**THE STAR** at the point of the Hyades V asterism, magnitude-3.9 Gamma Tauri, has a date with the waxing gibbous Moon in the early morning of January 9th for much of the northwestern U.S. and western Canada. A small scope will easily show the star disappearing behind the Moon's dark limb. Its reappearance from behind the bright limb may be lost in the glare of the sunlit moonscape.

Some disappearance times: At **Winnipeg,** 8:43 UT (2:43 a.m. CST); **Kansas City,** 8:59 UT (2:59 a.m. CST); **Denver,** 8:57 UT (1:57 a.m. MST); **Edmonton,** 8:31 UT (1:31 a.m. MST); **Vancouver,** 8:29 UT (12:29 a.m. PST). Interpolate between the UT times to estimate the time at your location. Set up early so you don't get caught short; occultations wait for no one.

The Quadrantid Meteors

THE STRONG BUT ELUSIVE Quadrantid meteor shower — elusive because its peak lasts just a few hours — should be timed for North America this year, especially the West. The richest part of the shower should be centered on 14^h UT January 3rd: 9 a.m. on that date EST, 6 a.m. PST. Dawn begins around 6 a.m. local time. There will be no Moon.

The Quadrantids' radiant is in northern Boötes between the head of Draco and the end of the Big Dipper's handle. It's up all night for watchers in the mid-northern latitudes, but like most shower radiants, it's highest in the early morning hours. This is because Earth's dawn side faces forward in our 30-km-per-second flight around the Sun. This added velocity also means the upper atmosphere hits more meteors, and hits them harder (making them brighter), than when meteors come at us from behind in the evening.

BE A METEOR COUNTER. For how to carry out a useful meteor count — no matter what the shower is or isn't doing — and report it to the International Meteor Organization, see imo.net/visual.

Jupiter High at Dawn

DECEMBER AND especially January find Jupiter shining highest as dawn begins to brighten. In a telescope it's still relatively small; during January it enlarges from 36 to 39 arcseconds wide across its equator, on its way to 44″ around opposition April 7th.

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually show at least two or three. Identify them at any date and time using the diagram at far right.

All the interactions in January between Jupiter and its satellites and their shadows are tabulated at right. Find events timed for when Jupiter will be in good view for you.

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

January 1, 7:42, 17:37; **2,** 3:33, 13:29, 23:25; **3,** 9:20, 19:16; **4,** 5:12, 15:07; **5,** 1:03, 10:59, 20:54; **6,** 6:50, 16:46; **7,** 2:41, 12:37, 22:33; **8,** 8:28, 18:24; **9,** 4:20, 14:15; **10,** 0:11, 10:07, 20:03; **11,** 5:58, 15:54; **12,** 1:50, 11:45, 21:41; **13,** 7:37, 17:32; **14,** 3:28, 13:24, 3:19; **15,** 9:15, 19:11; **16,** 5:06, 15:02; **17,** 0:58,

Minima of Algol

Dec.	UT	Jan.	UT
1	22:51	2	11:52
4	19:40	5	8:41
7	16:29	8	5:30
10	13:18	11	2:19
13	10:08	13	23:09
16	6:57	16	19:58
19	3:46	19	16:47
22	0:35	22	13:37
24	21:24	25	10:26
27	18:13	28	7:15
30	15:02	31	4:04

Algol remains near minimum brightness for about two hours. It takes several additional hours to fade and to rebrighten. These geocentric predictions are from the heliocentric elements Min. = JD 2445641.554+ 2.867324*E*, where *E* is any integer. For a comparison-star chart and more info, see **skyandtelescope.com/algol**.

10:53, 20:49; **18,** 6:45, 16:40; **19,** 2:36, 12:32, 22:27; **20,** 8:23, 18:18; **21,** 4:14, 14:10; **22,** 0:05, 10:01, 19:57; **23,** 5:52, 15:48; **24,** 1:44, 11:39, 21:35; **25,** 7:31, 17:26; **26,** 3:22, 13:18, 23:13; **27,** 9:09, 19:05; **28,** 5:00, 14:56; **29,** 0:52, 10:47, 20:43; **30,** 6:38, 16:34; **31,** 2:30, 12:25, 22:21.

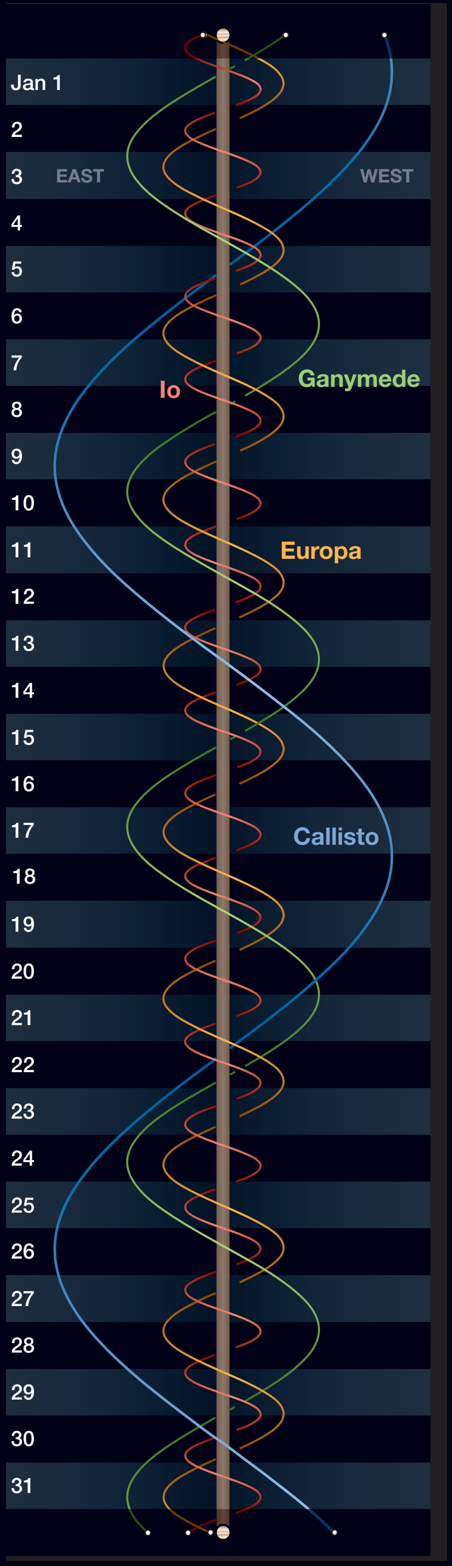
These times assume that the spot will be centered at System II longitude 254°. If the Red Spot has moved, it will transit 1⅔ minutes earlier for each degree less than that, and 1⅔ minutes later for each degree more than that. Features on Jupiter are closer to the central meridian than to the limb for 50 minutes before and after transiting.

Phenomena of Jupiter's Moons, January 2017

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard 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.

Jupiter's Moons

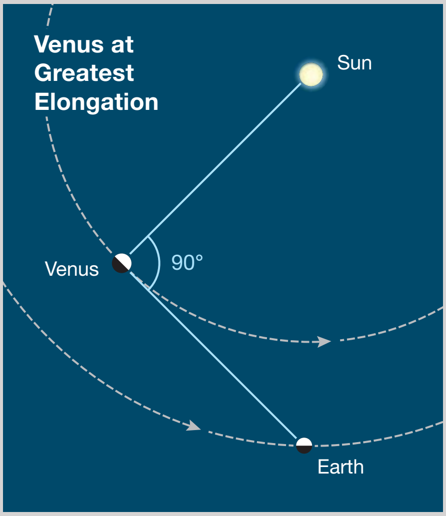


The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites'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

The Schröter Effect: A Retrospective

Thanks to tricks of light in its atmosphere, Venus isn't always quite what it seems.

▲ Johann Hieronymus Schröter in 1791. This modern painting by Heinrich Wolfgang Vogt-Vilseck is based on a rendering by George Tischbein that appears in Schröter's famous book on the Moon, *Selenotopographische Fragmente* (Volume 1).



▲ When the Sun-Venus-Earth angle is 90°, we should see the planet's disk exactly half lit. But when Venus is in the evening sky, as it will be this month, telescopically this *dichotomy* actually seems to occur several days earlier.

On January 12th, Venus reaches its greatest elongation east of the Sun, appearing brilliant and well placed for observers in the evening sky. Theoretically, as the Sun, Venus, and Earth will then form a right triangle, Venus should appear exactly 50% sunlit in a small telescope, a geometry known as *dichotomy.*

However, as first noted in 1793 by German astronomer Johann Schröter, Venus looks exactly half lit on a date that does not coincide with the theoretical one. On January 12th, for example, Venus will instead appear to have already passed the point of dichotomy, instead showing a phase that is slightly concave. At western elongations, when Venus appears in the morning sky, the effect is reversed, and the observed dichotomy occurs later than predicted.

Schröter, who died 200 years ago last August 29th, is no longer a household name, but he was once referred to as the "Herschel of Germany." William Herschel, indeed, was his inspiration. Born in Erfurt in 1745 and trained as a lawyer, Schröter had a lifelong interested in astronomy and obtained a 2.25-inch Dollond refractor in 1779.

However, not until after Herschel's discovery of Uranus in March 1781 did Schröter make a dramatic change in his life. He switched jobs to become chief magistrate of Lilienthal, a sleepy hamlet in northern Germany. His official duties must have been light, because thereafter he devoted most of his time to astronomy.

Beginning with the small Dollond refractor, which he placed in a small structure in the town hall's garden, he added new telescopes on a regular basis, including reflectors with 4- and 7-foot focal lengths built by Herschel himself — the latter an almost exact copy of the telescope used to discover Uranus.

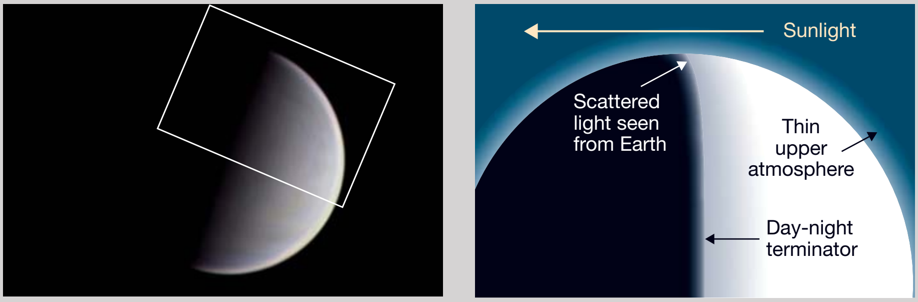
Although Schröter always will be remembered best for his pioneering observations of the Moon, Venus was actually the first object to which he devoted serious study. He searched for surface features with the Dollond refractor beginning in 1779 and for a long time reported only negative results. He wrote of his years-long quest: "I perceived neither spots, nor any other remarkable appearance, except the unusually quick decrease of light toward the boundary of illumination" — a summation with which telescopic observers of the dazzling planet ever since can commiserate.

The decrease of light seen near the terminator was, as Schröter was well aware, evidence of an atmosphere. An even more definitive demonstration came as Venus neared inferior conjunction in March 1790. Using the 7-foot reflector, he saw the planet's delicate cusps extended into thin arcs of light reaching a good way around the dark hemisphere. He concluded, correctly, that he was seeing a twilight arc, produced by the diffusion of sunlight by the planet's atmosphere. Earlier, during the transits of Venus of 1761 and 1769, observers had noted an arc or aureole around the planet and suspected that Venus had an atmosphere. Schröter had found definitive proof.

A Geometric Mismatch

Thus he'd already made significant progress in studying Venus when he discovered the discrepancy between the

VENUS IMAGE: SEAN WALKER; *SKY & TELESCOPE* ILLUSTRATIONS: LEAH TISCIONE



▲ Here's how Venus looked at greatest elongation on March 20, 2012. Note the shading near the terminator, telltale evidence for a dense atmosphere, and the fact that its disk does not appear exactly half lit. **Right:** Sunlight scatters as it passes through the upper atmosphere of Venus. As seen from Earth this scattered light is most pronounced near the planet's poles, creating a slight brightening on the night side and causing the planet's terminator to appear slightly curved.

calculated and observed times of Venus' dichotomy. In August 1793 Schröter found that the difference amounted to 8 days. Later, the famous German lunar mappers Wilhelm Beer and Johann Mädler, who were always merciless in their criticisms of Schröter's lunar work, confirmed the discrepancy in Venus' dichotomy and found that it averaged 6 days. Since then, every observer to make a serious study of the planet has confirmed the "Schröter effect."

However, the discrepancy varies. Henry McEwen, the British Astronomical Association's longtime Mercury and Venus Section recorder, observed that it was a fortnight in 1927. Another leading British amateur, M.B.B. Heath, found it to be generally only 2 days, but sometimes as much as 6 or 7 days, based on observations from 1927 to 1958.

In part owing to the wide success enjoyed by Patrick Moore's *The Planet Venus*, first published in 1956, the late 1950s and 1960s were the heyday of amateur studies of Venus and the other planets. (It was Moore, by the way, who coined the phrase "Schröter effect.") Back then Venus was a planet of mystery, and anything that could add to our knowledge of it was of value.

Estimating the time of dichotomy was thus a particularly attractive project, as it could be pursued without advanced equipment, and many amateurs of note, including John Westfall, Dale Cruikshank, William Hartmann, and Alan Binder of the Association of Lunar and Planetary Observers and Klaus Brasch and Geoffrey Gaherty of the Royal Astronomical Society of Canada, were keen students of the Schröter effect.

(Even yours truly, as an 11-year-old armed with a standard-issue, 60-mm refractor, made an estimate of the Schröter effect at Venus' eastern elongation in November 1965 and found that dichotomy occurred a week before the calculated time.)

Mariner 2's historic flyby of Venus in December 1962 revealed that this cloud-covered planet was not the kind of world expected by many astronomers. It is indeed surrounded by a dense atmosphere — but one that consists mostly of carbon dioxide. The resulting extreme greenhouse effect makes the surface hot enough to melt lead.

The Schröter effect clearly had something to do with the Venusian atmosphere. However, a quantitative model was not forthcoming until 1996, when Anthony Mallama published an elegant investigation in the *Journal of the British Astronomical Association*. He noted that the thin atmosphere above the cloud deck should scatter sunlight passing through it. The longer the light's path through this layer, the greater the scattering. So, from Earth's perspective, the brightness of this scattered light increases poleward along the terminator, thus producing the apparent concavity first noted by Schröter so long ago.

Although the Schröter effect was never more than a minor mystery and has now been fully explained, you can see this phenomenon firsthand in the days leading up to January's eastern elongation of Venus. Carefully note whether the terminator is a curve or a straight line, along with the instruments you used and seeing conditions. Such estimates, involving this simplest of simple observations, might provide information about variability in the planet's upper atmosphere.

Also, by noting this timing, you'll pay tribute to the enthusiastic, almost forgotten 18th-century observer for whom the Schröter effect is named.

▲ In another painting by Vogt-Vilseck, Schröter bows as he welcomes Prince Adolph (Duke of Cambridge and Viceroy of Hannover) to Lilienthal, Germany, in September 1800. In the background is Schröter's largest telescope, which had a 20-inch mirror and 27-foot focal length.

DIETER GERDES (2)

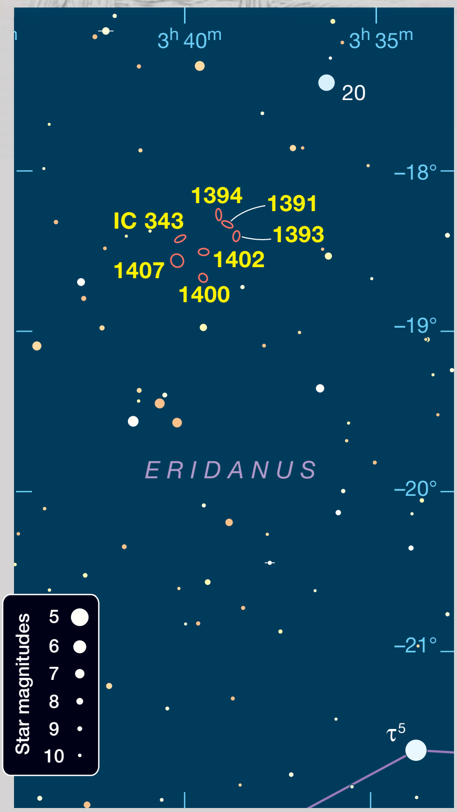
■ **WILLIAM SHEEHAN** looks forward to seeing his 32nd greatest eastern elongation of Venus from the Sun in January.

A River Full of Galaxies

Plumb the galactic depths of Eridanus this month.

▲ Dutch artist Jacob de Gheyn engraved this depiction of Eridanus for the 1600 edition of *Syntagma Arateorum (Phaenomena)* by Hugo Grotius.

DRAWING: LINDA HALL LIBRARY OF SCIENCE, ENGINEERING & TECHNOLOGY



Beneath Orion's foot Eridanus begins
His winding course, and reaches Cetus' fins.
— Aratus, Phaenomena, translated by John Lamb 1848

Across the ages, the constellation Eridanus, the River, has been portrayed with surprising variety. Arguably, its most captivating depiction appears in the beautiful edition of *Phaenomena* published in 1600 by Hugo Grotius and called *Syntagma Arateorum*. Its illustrations were inspired by an illuminated manuscript Grotius possessed, and their superb execution was carried out by engraver Jacob de Gheyn. In turn, de Gheyn's engraving style influenced Johann Bayer's magnificent pictorial atlas, *Uranometria*. In *Syntagma Arateorum*, a starry river-god personifies Eridanus, his waters spilling from an urn and swirling around him.

Although the river-god himself is bedecked with stars, the further depths of this swath of sky abound with the celestial behemoths known as galaxies. The all-sky chart at the center of this magazine shows Eridanus in the more traditional form of a flowing river of stars. The great oxbow bend in northern Eridanus crosses the chart's meridian, and within its embrace dwell a bevy of galaxies within the grasp of modest, backyard telescopes.

NGC 1407 is the brightest galaxy in the river's bend, and we find it accompanied by an entourage of smaller companions. Through my 130-mm refractor and a wide-angle eyepiece giving 23×, NGC 1407 and the 5.2-magnitude star 20 Eridani share the field of view. This round galaxy is easily visible and displays a sizable, moderately faint halo encasing a small bright center.

At 63× **NGC 1400** emerges southwest of NGC 1407 as a smaller version of its neighbor. The larger galaxy spans roughly 4′; NGC 1400 is about half that diameter. A starlike nucleus resides at the heart of each galaxy, but NGC 1407 boasts the more prominent one. At 117× diminutive **NGC 1393** joins the scene like a small child running ahead of its parents. The wee tyke is a bit difficult to see, however, so use averted vision to catch sight of it. The galaxies mark the corners of a 20′-tall right triangle.

Through my 10-inch reflector at 90×, NGC 1393 has an oval profile that's tipped north-northwest and grows brighter toward the center. Four little scraps of fluff with assorted inclinations surface in the field of view — **NGC 1402**, **IC 343**, **NGC 1391**, and **NGC 1394**. At 118× IC 343 exposes a brighter core.

Although the galaxies look as though they might be associated, they're actually sorted into two distinct groups. NGC 1407, NGC 1400, NGC 1393, and IC 343 belong to the NGC 1407 Group, some 86 million light-years distant, while the other galaxies are members of a more remote group 185 million light-years away from us.

Our next five galaxies are part of another group at a distance of about 68 million light-years. It and the NGC 1407 Group are components of a larger aggregation of about 200 galaxies, sometimes called the Eridanus Cluster.

NGC 1300 is probably the most well-known galaxy of the quintet because of its prominent bar and the impressive spiral arms that spring from each end. A striking image composed of exposures from the Hubble Space Telescope reveals a spiral swirl at the center of the bar, a feature only seen in galaxies with large

▶ The galaxy NGC 1300 sports a prominent bar at its center, out of which extend its spiral arms. Look for the bright core cloaked in an east-southeast slanting halo in your telescope's eyepiece.

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

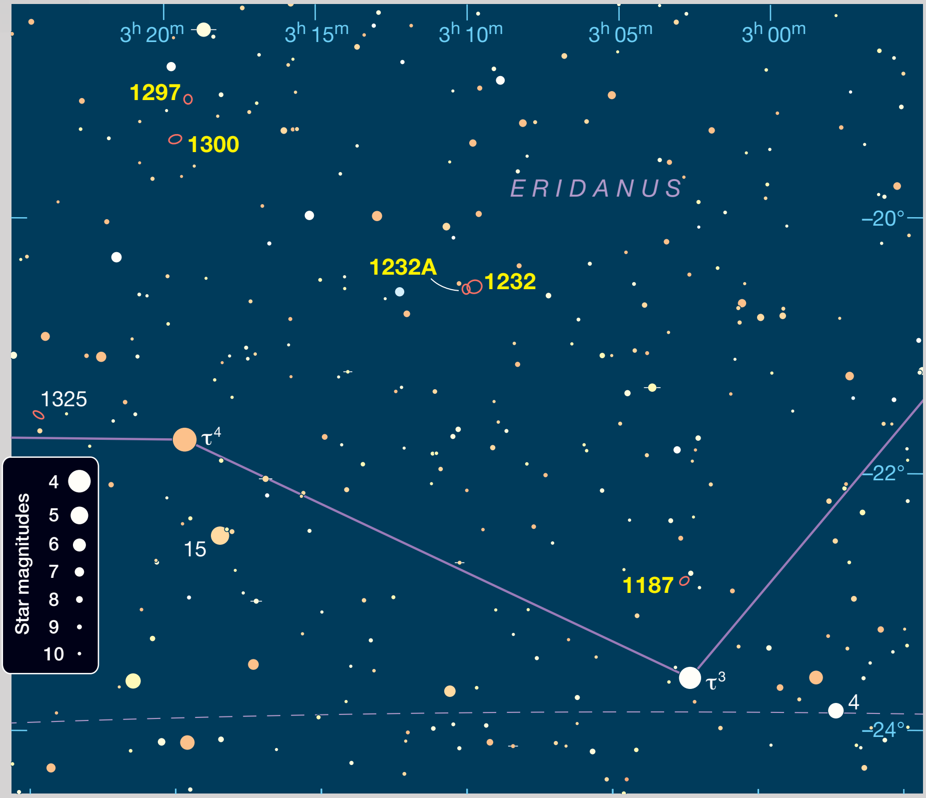
bars. It's thought that gas flows inward along the bar and then whirls into the galaxy's center.

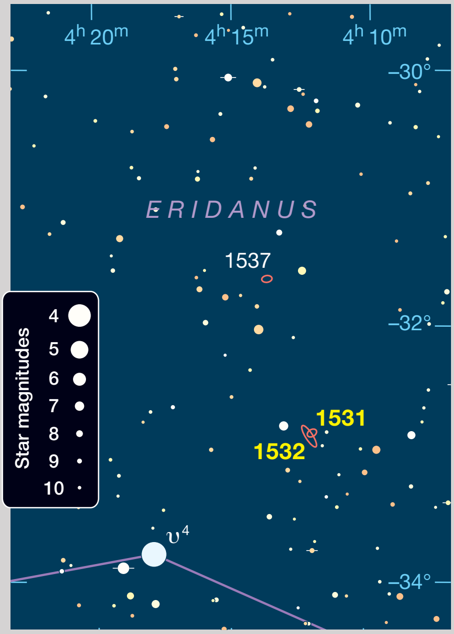
NGC 1300's structure is considerably more subtle when viewed through a telescope. Look for the galaxy 2.3° north of Tau^4 (τ^4) Eridani, accompanied by **NGC 1297** just 20′ to its north-northwest. Through the 130-mm scope at 30×, NGC 1297 presents only a small, dim spot, whereas NGC 1300 is an appreciably larger, bright, oval glow. A magnification of 74× plucks out a faint star at the northern edge of NGC 1297, and NGC 1300's halo leans east-southeast and mantles a small, bright core. On a particularly nice night at the Peach State Star Gaze in Georgia, I was able to spot NGC 1300's bar at 117×.

The 10-inch scope at 118× begins to show the true nature of NGC 1300. The galaxy's core is lens-shaped and holds a brighter point at its center. Arms unfurl counter-clockwise from the ends of the 3′-long bar. They start out relatively bright but then quickly fade. The western arm curves around to the north, fading into the general glow just before it would pass above the near end of the galactic core. The opposed arm is even shorter. NGC 1297 is slightly oval north-south, a bit more than 1′ tall, and intensifies toward the center.

Climbing 2.6° west-northwest from Tau^4 takes us to the lovely spiral galaxy **NGC 1232** and its dwarf satellite **NGC 1232A**. Although they are not currently interacting, past encounters may be responsible for the odd bends in the larger galaxy's spiral arms.

NGC 1232 is easily noticed in my 130-mm refractor at 23×. It proffers a sizable round glow with a tiny, slightly brighter core nestled in its center. At 102× the halo looks very patchy and spans about 5′. Viewed with the 10-inch scope at 220×, the galaxy's unevenly bright countenance indicates spiral arms unfolding counter-clockwise. A faint star anchors the northeastern edge of the





▶ Interacting galaxies NGC 1532 and NGC 1531 may be difficult to distinguish in your eyepiece. Use averted vision to locate the smudge of NGC 1531 on the northwestern edge of its larger companion.

ESO / IDA / DANISH 1.5M / R. GENDLER AND J.-E. OVALDSEN

halo. NGC 1232A turns up as a detached shred of mist off the larger galaxy's east-southeastern side. It sits about halfway between and south of an imaginary line between NGC 1232's center and the gold 9th-magnitude star to its east.

Our quintet's final party is **NGC 1187**, centered 46′ north of Tau^3 (τ^3) Eridani. It has fairly low surface brightness, but it's not hard to spot through the 130-mm scope at 63× as long Tau^3 is kept out of the field of view. The galaxy covers roughly 3′ × 2′, and an 8.8-magnitude star lies off the northwestern tip. Nearly aligned with the halo, a somewhat brighter, bar-like region inhabits the interior. At 117× the galaxy wears a mottled face. The fleecy appearance is quite pronounced in my 10-inch reflector at 118×, making NGC 1187 rather pretty. The galaxy grows gently brighter toward the center, and at 171× I see a slight brightness pip at its heart.

For our finale, let's swoop down to the river's next meander, which shelters the interacting galaxies **NGC 1532** and **NGC 1531**, berthed 1.5° northwest of Upsilon^4 (υ^4) Eridani. I nabbed this far-southern pair at the Winter Star Party in Florida. Even in my 105-mm refractor at 17×, NGC 1532 is a lengthy band of haze. It looks nice at 87×, about 6′ long with a brighter elongated interior. A 7th-magnitude star gleams 13′ east-northeast. NGC 1531 is visible with averted vision as a very faint smudge closely inspecting the northwestern flank of its much larger companion, but it shows up much better at 122×. This is an alluring duo when viewed through my 10-inch scope. At 118× NGC 1532's halo bridges approximately 9′. The brighter region is about 3½′ long, slightly tilted with respect to the halo, and it coffers a small, bright, round core with an almost starlike nucleus. NGC 1531's oval is ¾′ long, fairly uniform in surface brightness, and looks as if it's taking a nosedive into its companion.

Deep images show remarkable tidal tails drawn out of NGC 1532 by the encounter with its companion. Distance estimates for this striking pair have trended upward with time, from as little as 44 million-light years in the 1980s to as much as 67 million light-years during this decade.

■ **SUE FRENCH** welcomes your comments at scfrench@nycap.rr.com.

River of Galaxies

Object	Galaxy Type	Mag(v)	Size/Sep	RA	Dec.
NGC 1407	Elliptical	9.7	4.6′ × 4.3′	3^h 40.2^m	–18° 35′
NGC 1400	Lenticular	11.0	2.3′ × 2.0′	3^h 39.5^m	–18° 41′
NGC 1393	Lenticular	12.0	1.9′ × 1.3′	3^h 38.6^m	–18° 26′
NGC 1402	Barred lenticular	13.6	0.8′ × 0.6′	3^h 39.5^m	–18° 32′
IC 343	Barred lenticular	13.2	1.6′ × 0.8′	3^h 40.1^m	–18° 27′
NGC 1391	Barred lenticular	13.3	1.1′ × 0.5′	3^h 38.9^m	–18° 21′
NGC 1394	Lenticular	12.8	1.3′ × 0.4′	3^h 39.1^m	–18° 18′
NGC 1300	Barred spiral	10.4	6.2′ × 4.1′	3^h 19.7^m	–19° 25′
NGC 1297	Lenticular	11.8	2.2′ × 1.9′	3^h 19.2^m	–19° 06′
NGC 1232	Spiral	9.9	7.4′ × 6.5′	3^h 09.8^m	–20° 35′
NGC 1232A	Barred Magellanic spiral	14.6	0.9′ × 0.8′	3^h 10.0^m	–20° 36′
NGC 1187	Barred spiral	10.8	5.5′ × 4.1′	3^h 02.6^m	–22° 52′
NGC 1532	Barred spiral	9.9	12.6′ × 3.3′	4^h 12.1^m	–32° 52′
NGC 1531	Lenticular	12.5	1.3′ × 0.9′	4^h 12.0^m	–32° 51′

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

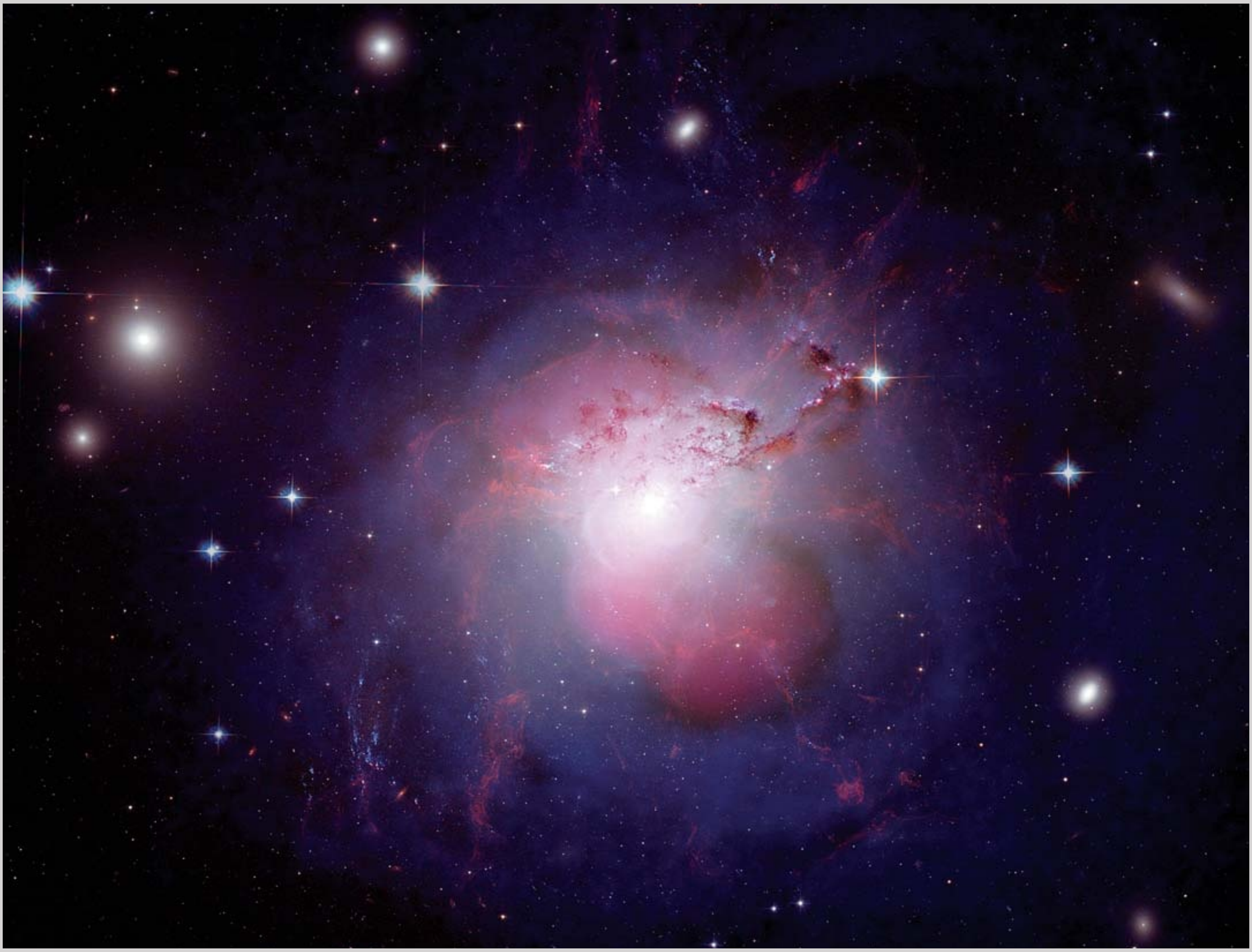
The Perseus Galaxy Cluster

Good dark adaptation is key for viewing this scattering of faint fuzzies.

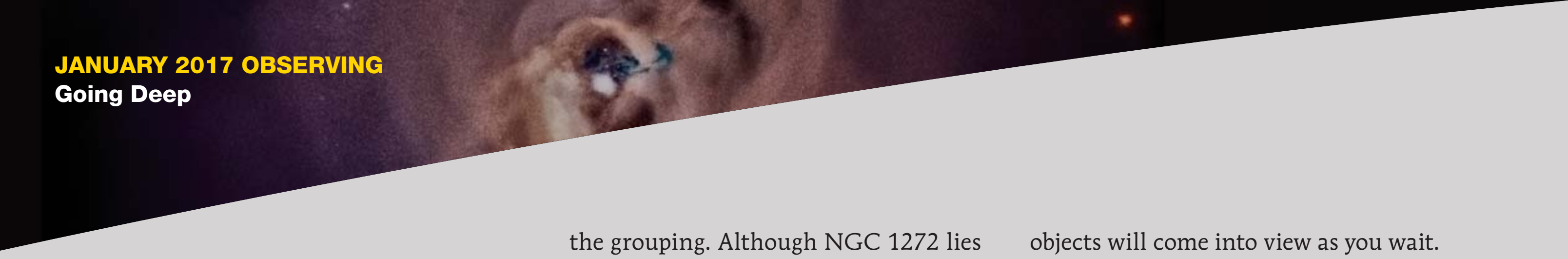
In sky lore, the hero Perseus holds the head of the Medusa, a snake-haired monster of Greek mythology. The Demon Star, Algol, represents the monster's eye. Nearby, about 2° east of brilliant Algol, lies a real monster, an active galaxy that dominates the Perseus Galaxy Cluster. If our eyes saw the sky in radio wavelengths, this galaxy would be one of the sky's brightest objects. Energetic jets streaming from an enormous black hole at its center create the object known as Perseus A, a strong radio source and X-ray emitter. The host galaxy is **NGC 1275**, a giant elliptical behemoth that's detectable in a 6-inch telescope even though it lies 240 million light-years away.

Through the mind's eye, NGC 1275 is a most intriguing object. Multi-wavelength composites using data from Hubble, Chandra, and the Very Large Array reveal an impending collision of a High Velocity System rushing at 3,000 km/second toward the supergiant galaxy that lies about 200,000 light-years

▼ Active galaxy NGC 1275 centers the Perseus Galaxy Cluster. By combining images taken in the X-ray, optical, and radio wavelengths, astronomers reveal the tremendous energy streaming from the galaxy's core. Optical data are shown in red, green, and blue, X-ray data in violet, and radio data in magenta. Dust lanes, foreground stars, and background galaxies have also been captured in the optical range.



X-RAY: NASA / CXC / IOA / A. FABIAN ET AL.; RADIO: NRAO / VLA / G. TAYLOR; OPTICAL: NASA / ESA / HUBBLE HERITAGE (STSCI / AURA) & UNIVERSITY OF CAMBRIDGE / IOA / A. FABIAN

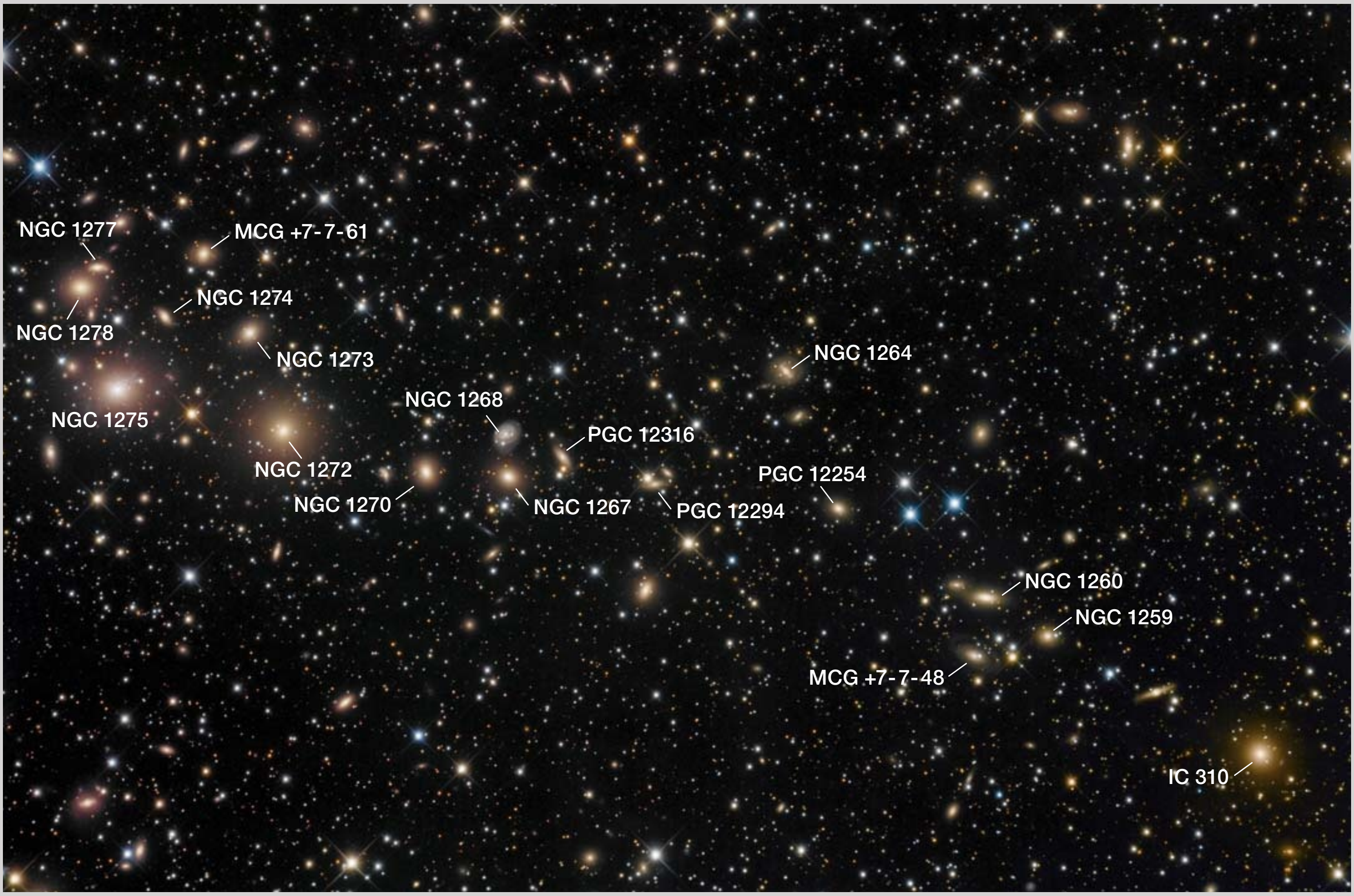


beyond it along the same line of sight. We can imagine a region of unimaginable violence with powerful jets and streamers of superheated plasma hundreds of light-years wide.

Through a telescope, NGC 1275 is the brightest galaxy in the cluster of galaxies designated Abell (ACO) 426, which, containing thousands of galaxies, is one of the most massive objects known. There are over 100 galaxies within a 1° circle centered on NGC 1275, and a patient observer with a large-aperture telescope should be able to log 30 or more. More moderate instruments can expect to detect up to a dozen. NGC 1275 and its neighbor to the west, **NGC 1272**, clearly dominate the grouping. Although NGC 1272 lies much closer to us, both appear as round ovals with much brighter cores.

To hunt galaxies in this distant cluster, you'll need a dark, transparent sky and to employ the usual best practices for detecting faint fuzzies. Meticulous dark adaptation is most important; if you use a computer as your sky atlas, allow plenty of time for your eyes to readjust after every glance at your screen, even if you use a night-vision mode. I find that a black towel draped over my head is a great help, but there's no substitute for patience. It takes several minutes for your eyes to readjust after looking at your computer screen or even reading a printed chart with a dim red flashlight. The longer you stay in near total darkness the better; fainter and fainter objects will come into view as you wait. All the other usual advice also applies: stay relaxed, stay hydrated, tap the scope to enhance detection, and avert your vision. If at all possible, take the time to memorize the field before going to the eyepiece. Many of the cluster's galaxies are just tiny spots of nebulosity that yield little more than a vague impression of detection, but several of them will eventually reveal themselves.

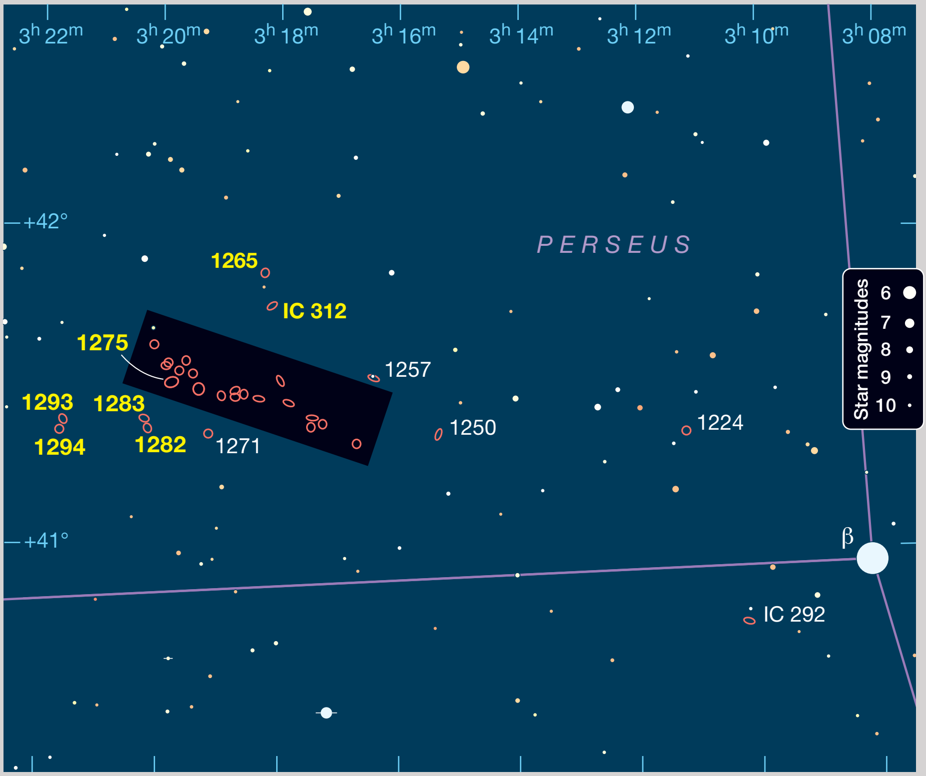
The densest clump of visible galaxies forms a house-like shape not unlike the asterism that underlies the constellation Cepheus. NGC 1272 represents the peak of the roof and NGC 1275 the southeast corner of the box-like base. A pair of galaxies occupies the northeast corner. **NGC 1278** is the larger of the two and appears round with a bright



▲ There are over 100 galaxies within a 1° circle centered on NGC 1275. This dense string of galaxies, approximately 37 arcminutes long, starts northeast of Algol and connects IC 310 in the southwest to NGC 1277 and NGC 1278 in the northeast.

BOB FRANKE, TOP BANNER (PERSEUS): CHANDRA X-RAY OBSERVATORY ACIS

● To view a table of positions and other data for galaxies in the Perseus Galaxy Cluster, visit https://is.gd/PerseusGC.



core. About 40″ northwest, its smaller neighbor **NGC 1277** is elongated east-west. It, too, sports a brighter central area but conditions must be favorable to see it as other than a uniform haze. Overall, however, the smaller galaxy appears slightly more vivid. These two aren't physically connected; NGC 1277 lies about 50 million light-years closer.

The northern corner of the galactic box contains the most difficult member of the pattern. The small, faint oval of **MCG +7-7-61** requires averted vision to detect. **NGC 1273** forms the west corner of the box. It's mostly round with a slightly brighter core. In three dimensions, this house would be very misshapen, with only NGC 1275 and NGC 1273 nearly the same distance from Earth.

Framed within the box is the most distant galaxy in the field, **NGC 1274**, but its relatively high surface brightness makes it fairly easy to detect. Look for a northeast-southwest elongation with a brighter core that becomes obvious with averted vision.

When exploring rich galaxy clusters, the observer is tempted to ignore the stars and navigate imagined shapes made of galaxies alone; *galerisms* replace the asterisms. If we back away, the house galerism takes the form of the body of a kite with a tail trailing off to the west from NGC 1272. Following the tail, we come first to **NGC 1270**. It's small and round with a brighter core. A step 2½′ to the west lands us at **NGC 1267**, paired with its neighbor to the north, **NGC 1268**. Both are faint; NGC 1267 is somewhat easier and is brighter toward its center. NGC 1268 appears more uniform. A third galaxy, much more challenging, is **PGC 12316**, which makes the apex of a westward facing triangle with the two NGCs and appears small and round. It's just barely detectable in my 30-inch Dob.

You'll need a lot of aperture to follow the tail much further. To the west is a clump of three galaxies that, with averted vision, I detected as just a single wisp of faint nebulosity. The brightest of the three is **PGC 12294**. A little easier and further west floats **PGC 12254**, an evenly illuminated oval that seemed bright by comparison.

NGC 1260, the brightest in a triangle of galaxies, lies about 6′ southwest of PGC 12254. NGC 1260 appears elongated east-west and shows a brighter core. Its neighbor to the southwest, **NGC 1259**, appears more nearly round with a brighter center. I detected the much fainter **MCG +7-7-48** with averted vision.

Before changing direction, continue another 8′ southwest to find active galaxy **IC 310**, which seems almost easy after so many eye-straining targets. It's round with a bright core.

Backtracking to PGC 12254 and turning north-northeast, you'll need averted vision to sweep up **NGC 1264**, an evenly illuminated glow. From there, it's another 14′ in the same direction to **IC 312**. Elongated northwest-southeast and evenly bright, IC 312 is a fairly easy target. Continuing north-northeast another 6′ 20″ you'll encounter the enigmatic **NGC 1265**. This galaxy either has a star superimposed on it or such a bright stellar core that it's easily mistaken for a star.

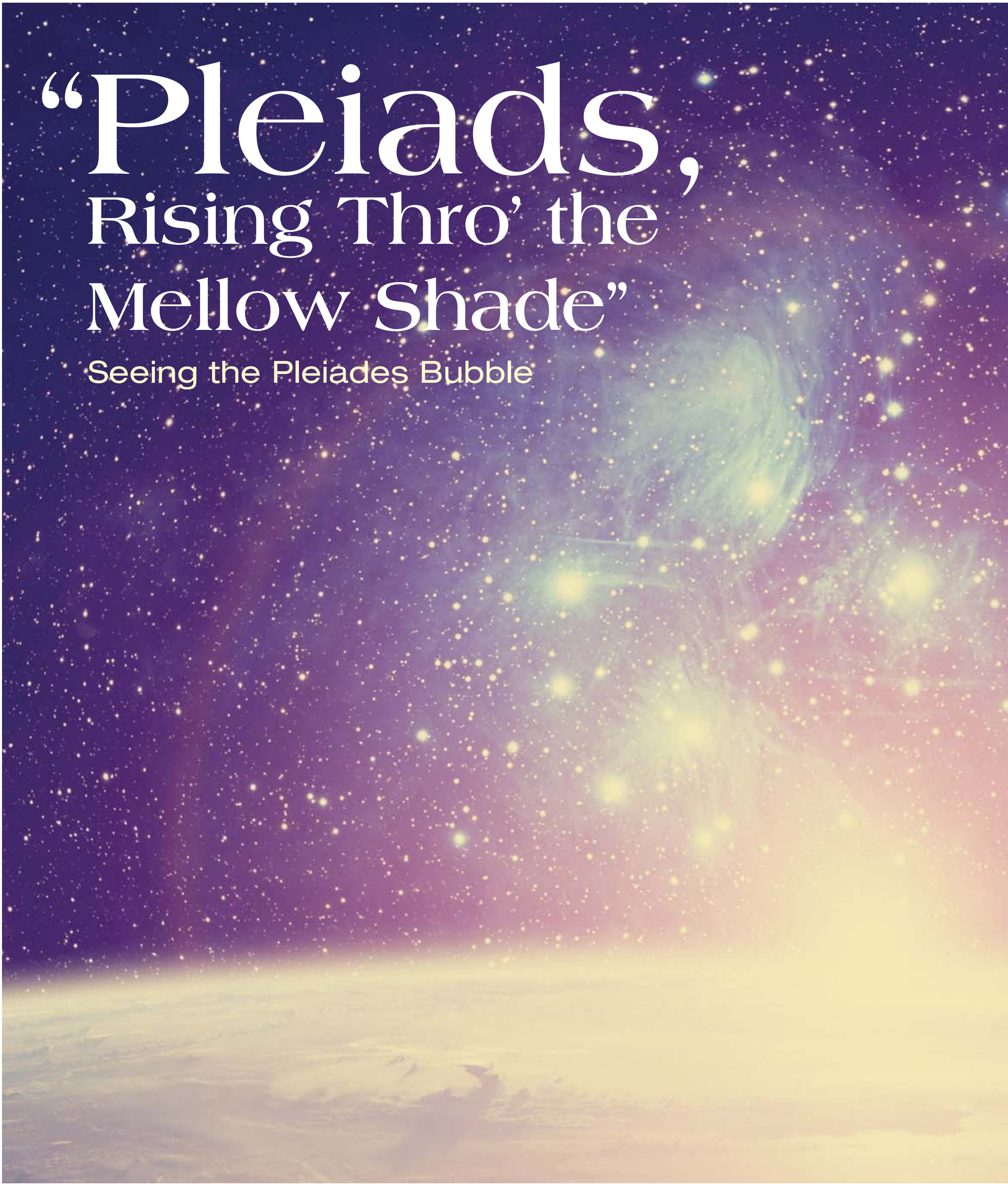
We'll end this tour with two pairs of galaxies, the first of which lies 9′ southeast of NGC 1275. **NGC 1282** and **NGC 1283** are just 2′ apart on our sky and similar in brightness. In reality, about 129 million light-years separate the two. They both have brighter cores.

Move 15½′ farther east to locate a comparable pair, **NGC 1293** and **NGC 1294**, also just 2′ apart as viewed from Earth but more than a hundred light-years apart in space. They too are similar in brightness and brighten toward their centers.

There are many more treasures in this rich field. While the vast majority of these galaxies are too faint for anything but the camera, there are several — in addition to those described here — that can be detected visually in amateur telescopes. Good hunting!

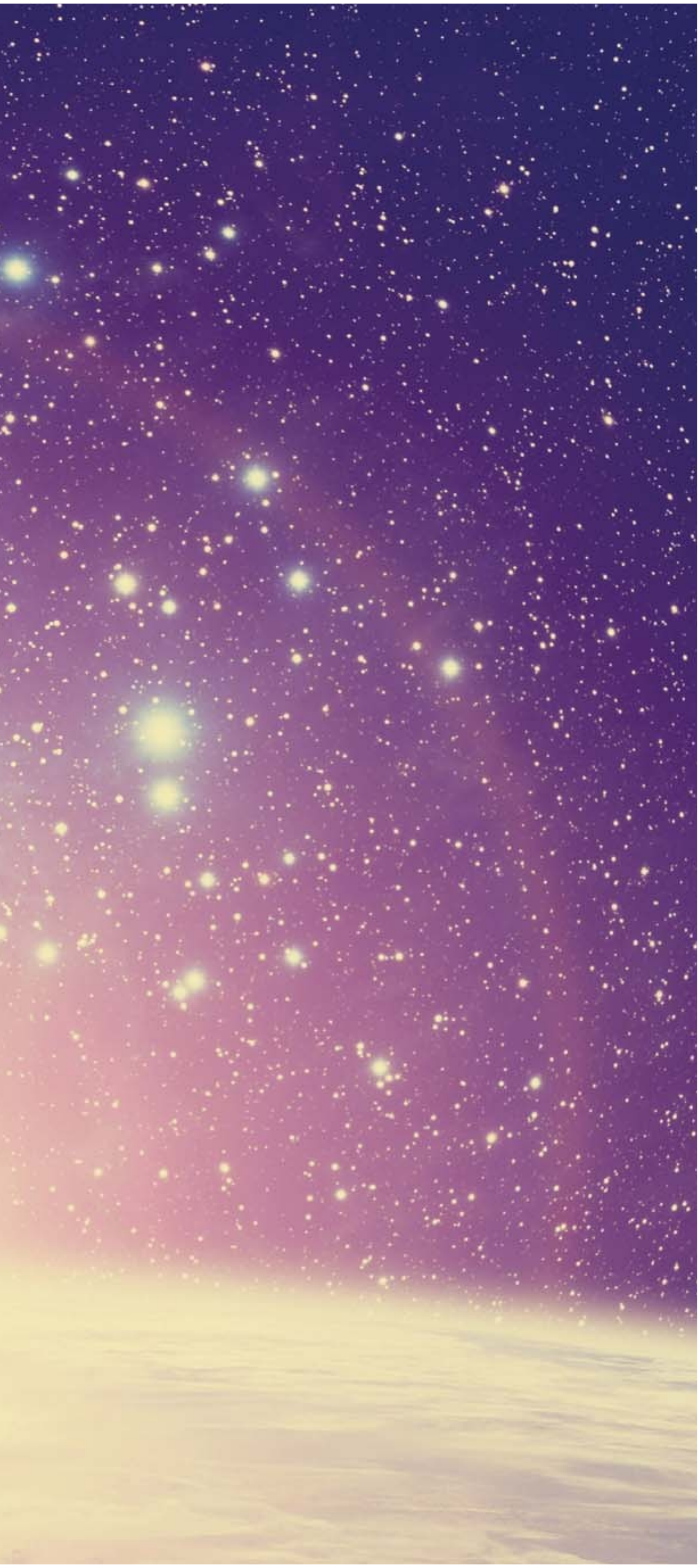
■ Contributing Editor **TED FORTE** observes from his home near Sierra Vista, Arizona. He pens a monthly astronomy column for his local newspaper, the *Sierra Vista Herald*.

by Howard Banich



“Pleiads, Rising Thro’ the Mellow Shade”

Seeing the Pleiades Bubble



ISTOCKPHOTO.COM / M-GUCCI

November 2, 1994,

was extraordinary for several reasons. About 8 inches of fresh snow had fallen in the Oregon Coast Range mountains, leaving behind an irresistibly clear sky. Driving up to the observing site after dark behind my good friend Chuck Dethloff's pickup and trailer is my first memory of this night.

The snow-covered gravel road was bordered by tall fir trees, which left only a thin, ragged slice of the night sky visible above as we slowly made our way. The headlights of our vehicles created millions of sparkles in the snow on the ground and in the trees. The sky above sparkled on its own.

The second memory is of the steady seeing. It was nearly dead-solid perfect for three hours straight, and it produced one of the sharpest views of Saturn I've ever seen. There was no waiting for the seeing to settle down, and during the entire three hours the views barely quivered. Saturn was a true wonder; Titan a tiny, sharply defined orange disk.

My third memory of that night is of my first great naked-eye view of **M45**, the Pleiades. Chuck and I both counted 13 stars thanks to the extraordinary seeing. But what I remember most about this view was not only how sharp the individual Pleiads were, but also how they made the overall cluster look larger than normal.

Just Look Up

It doesn't matter what kind of sky you have, the Pleiades are special. The bright stars of winter dominate the sky, and yet this small patch of stars packed together in an unprecedented small chunk of sky demand to be examined.

The same thing happens in a night sky illuminated by city lights. That frosty, glittering patch of Pleiads still commands attention. Under any clear sky an unaided but determined gaze at the open cluster reveals a handful of stars, maybe more, arranged in a tiny dipper shape that's caused some to wonder if they're looking at the Little Dipper. It's a logical assumption for those who don't know the constellations.

It's possible to see more than the six brightest stars even under a suburban sky. The nine brightest stars in the Pleiades range from magnitude 2.86 to 5.64. They're visible if you take the time to look. Patience will be rewarded.

Some people have seen 14 Pleiads without optical aid. The late *Sky & Telescope* columnist Walter Scott Houston's total of 18 seems to be the highest reliable naked-eye count.

Making a quick sketch is an easy way to keep track of what you've seen. Use averted vision but be careful — it can be tricky when pinpointing the exact location of the fainter stars.

▲ **DUSTY CONTEXT** The constituent stars of the Pleiades open cluster are 115 million years old so have burned through their original gas and dust. The nebulosity we see around the stars today comes from an independent cloud of interstellar dust passing through the region by chance.

JOHN DAVIS

Until recently, I'd considered binoculars the best instrument for the Pleiades. 7×50s frame the cluster with plenty of field for context and reveal dozens of stars. On a great night, the entire cluster seems a bit hazy, but to me this has always been rather subtle.

Astrometric Background

A few facts help place the Pleiades in their Milky Way context. They're approximately 444 +/– 3.9 light-years away, a number that has some controversy attached to it but is generally accepted to be the most accurate measurement to date. We'll know how accurate it is in 2020 when astronomers expect the full data set from the GAIA probe to resolve any doubt. But assuming the distance is generally correct, when we look at the Pleiades we're seeing light that started its journey just a few years before Galileo made the first telescopic drawing of them. That's a lovely thought.

The cluster's proper motion is toward southern Orion, and the stars are expected to disperse through the Milky Way in about another 250 million years due to gravitational effects between the cluster's stars and the Milky Way in general.

The Pleiades Bubble

The Pleiades is one of the most well-known objects in the sky, but well-known doesn't always mean appropriately observed. Human nature being what it is, we usually see what we expect to see, but sometimes a new perspective makes something previously unnoticed too obvious to ignore. If you've already looked at my drawings on page 64 you may be wondering about that faint nebulosity — a cloud of interstellar gas and dust passing through the cluster and illuminated by its stars — surrounding the Pleiades, and how I possibly could have seen so much of it.

Neither Chuck nor I had a short-focus telescope with us that night we went up the mountain, so looking for the Pleiades nebulosity wasn't an option. But what if I told you it was all visible at a glance through Chuck's 4-inch APO refractor and a 31-mm Nagler eyepiece at the 2016 Oregon Star Party?

Mel Bartels noticed this interstellar material (often called "Integrated Flux Nebulae" or IFN by amateur astronomers) the first time he pointed his brand-new 6-inch f/2.8 Dobsonian at the Pleiades, which also happened to be first light for his wonderful telescope. For the first time he saw the Pleiades in context, and suddenly the dusty environment was impossible *not* to see. He dubbed the nebulosity the **Pleiades Bubble**.

I saw it through his new scope at the 2014 Oregon Star Party — and it was a really cool sight. I was in the final stages of building an 8-inch f/3.3 Dob, and as soon as it was finished and I got it under a dark sky, I went looking for the Bubble. To my surprise, it didn't jump out like it had in Mel's scope. But after placing the bright stars of the cluster to one side of the field of view (FOV) I couldn't miss it.

The 2.7° true field of view (TFOV) my 8-inch produces with a Paracorr 2 and 21-mm Ethos eyepiece isn't quite large enough to frame the Bubble adequately while the cluster sits in the center of the field, making it more difficult to see. Mel's 6-inch, on the other hand, has a 4.2° TFOV with the same P2/21-mm Ethos combo, which frames the Bubble perfectly. Chuck's 4-inch f/5.5 APO refractor mentioned above produces a nearly identical 4.3° TFOV.

I put it on the 2016 Oregon Star Party advanced observing list, and the people who gave it a go were delighted.

Seeing the Classic Pleiades Nebulosity

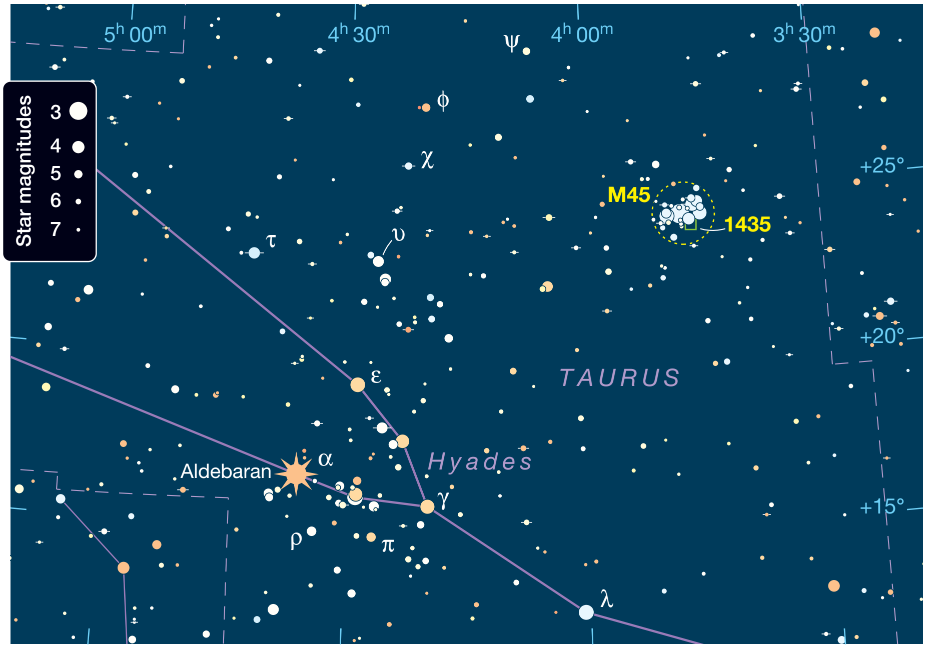
As for any faint nebulosity, you need dark and transparent skies for a successful observation. Next is a wide-field-of-view telescope. You don't need a super-wide-field telescope like Mel's to see the classic Pleiades nebulae, but you do want to use a telescope/eyepiece combination that gives at least a 1.5° TFOV to see them well. It's my guess that almost anyone with access to a dark sky and a wide-field scope will see the Bubble.

That said, the wider the field of view for a given aperture, the easier it is to see the nebulosity. A wideband filter may boost contrast a little, but a narrowband nebula filter won't help because you'll be looking at reflection nebulae. The 115 million-year-old age of the Pleiades makes them too old to have retained any of their natal nebulosity: the dust and gas associated with and highlighted by the cluster's stars is interstellar material simply passing through and being illuminated by the Pleiades. This moving material includes the Merope, Alcyone, Electra, and Maia nebulae as well.

A note of caution: the brighter Pleiads usually show a circular glow around them through a telescope, but sometimes that's just irradiation, or diffraction from dirty or damp optics. Check a nearby star of similar brightness to see if the same effect is visible — and make sure your eyepiece isn't fogged over. Chances are you'll see a glow around Merope, Maia, Alcyone, and Electra no matter what, so you're looking for a glow that's larger than you see around the comparison star you chose. The Merope Nebula, **NGC 1435**, is the brightest, so concentrate your gaze there first.

▼**CAREFUL PLACEMENT** The author used an 8-mm Plössl eyepiece with his 28-inch f/4 telescope to make this sketch of IC 349. Placing Merope just outside the field of view when the nebula was between Merope's diffraction spikes made this observation possible.

▼**STELLAR SPECTER** The ghostly streamers in this Hubble Telescope image show the effect of Merope's light on the reflection nebula IC 349. The cloud's smallest particles, slowed by the star's radiation, are left behind at the lower left of the frame while larger particles continue toward Merope's brilliant lure. The rays of light at the upper right are an optical artifact introduced by the telescope.



IC 349: NASA / HUBBLE HERITAGE TEAM (STSCI / AURA); SKETCH: HOWARD BANICH

Seeing the Bubble

Mel Bartels detected the Bubble without knowing of its existence, but Hermann Goldschmitt had already discovered it in 1863. After observing the Pleiades with a 4-inch refractor, Goldschmitt wrote: “While drawing the Pleiades I have just this moment made the discovery that they are completely surrounded on all sides by a nebula. This appearance is relatively easy to confirm, but the details demand attentiveness.”

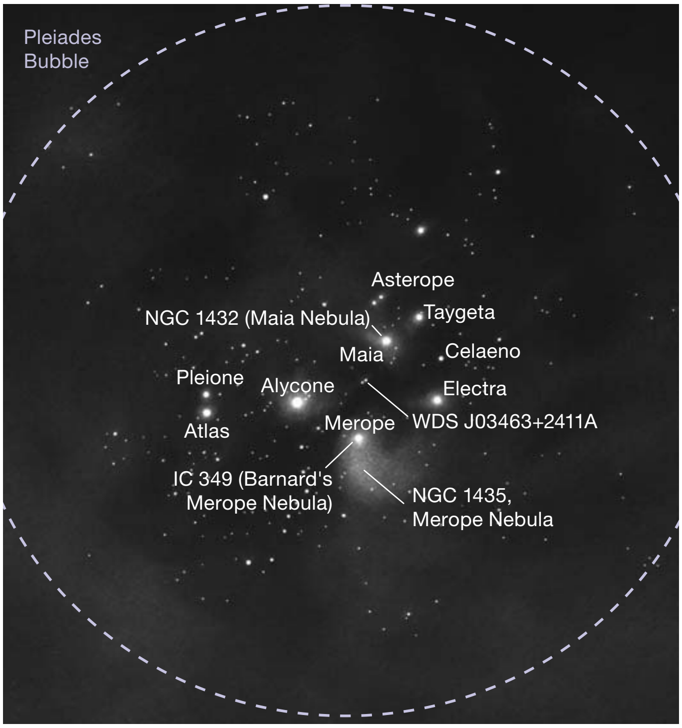
As it turns out, Mel’s unexpected observation represents at least the second rediscovery of the Bubble. Stephen Knight of East Waterford, Maine, spotted it in the mid-1980s using both 12×50 binoculars and a 6-inch reflector, as reported in Walter Scott Houston’s Deep-Sky Wonders column (*S&T:* December 1985, p. 628). Knight observed a “dimly visible dark ring that encircles the outer boundary of the diffuse nebula. It is irregular in width and darkness.” He first captured the dark ring with his 6-inch reflector and low power, and then followed it “all the way around the bright nebulosity. It appears as an area with an absence of faint background stars . . .”

Mel’s notes from 2014 are strikingly similar. “Serendipitously,” he wrote, “the first object I observed with my new widest-angle 6-inch (15-cm) f/2.8 Richest Field Telescope was the Pleiades. Because of the 4+ degree field, for the first time I could see that the Pleiades were sitting in a blackened hole surrounded by a ring of faint nebulosity.” Mel’s scope was featured recently in Telescope Workshop (*S&T:* Sept. 2014, p. 72). Since seeing the Bubble with it, he’s been observing interstellar dust and galactic cirrus (cloud-like structures at high galactic latitudes) all over the sky. Watch for his article about his observations in an upcoming issue.

But wait, there’s more

Until then, take some time to study **NGC 1435**, the Merope Nebula. Discovered by Wilhelm Tempel in 1859, it’s the brightest of the classic Pleiades nebulosity. On the very best nights, its distinctive C shape curls nearly all the way to Electra, but in average conditions I see it as a subtle, slender fan of nebulosity streaming southward of Merope.

Just north of Merope and about half way between Alcyone and Maia is a colorful double star, **WDS J03463+2411A**. The



▲▲ **COMPLETE VIEW** The drawings above were made over many nights using an 8-inch f/3.3 Newtonian. The nebulosity was even more apparent in both a 6-inch f/2.8 Newtonian and 4-inch f/5.5 refractor. The author saw the nebulosity with direct vision, but it was more plainly visible with averted vision, especially on the fainter extensions. The nine brightest stars of the Pleiades span about 7 light-years, so the entire drawing is approximately 25 light-years across.

▲ **DARK BOUNDARY** The circular outline denotes the approximate extent of the Pleiades Bubble. You may need to move the brighter stars and nebulae out of your field of view to see it.

◀ **FIRST SIGHT** Galileo Galilei was the first to observe the Pleiades through a telescope. He included a sketch of the cluster, with a total of 36 stars, in his 1610 *Sidereus nuncius*.

GALILEO SKETCH: UNIVERSITY OF OKLAHOMA HISTORY OF SCIENCE COLLECTIONS / CC BY-SA 2.0; SKETCHES: HOWARD BANICH (2)

▲ **MOUNTAIN HIGH** Deep-sky observing doesn't always require equipment. A naked-eye view of the Pleiades provides its own type of reward.

ISTOCKPHOTO.COM

component stars, both around 8th magnitude, are labeled HD 23463 and ADS 2755. HD 23463 shines with a saturated orange color, making a fine contrast to ADS 2755 and all the surrounding white-blue luminaries.

And then there's **IC 349**, often referred to as Barnard's Merope Nebula, which can be something of a challenge object. IC 349 is the brightest knot of the interstellar dust associated with the Pleiades. It's physically close to Merope and is slowly evaporating by its radiation pressure, as evidenced by the nebulous streaks in the Hubble Space Telescope image shown on page 63. Seeing this slowly dissolving nebula is a rare treat.

American astronomer E. E. Barnard discovered IC 349 visually in 1890 with the Lick 36-inch refractor. His measurements showed that IC 349 was only 36 arcseconds from Merope and 30 arcseconds in size. He observed it in a 12-inch Clark refractor using an occulting eyepiece, an observation replicated by *S&T* Contributing Editor Sue French with her 14.5-inch reflector. Her occulting eyepiece produced 212×.

A narrow field of view or occulting eyepiece is essential to block the glare of magnitude –4.17 Merope, which masks small IC 349. The narrower field of view and higher magnification of a larger scope are also essential, because the nebula is small and right next to Merope. Approach it carefully and you may be able to see this little nebula in a 12-inch.

I've studied IC 349 in 20- to 48-inch Newtonians and found a second key to a successful observation when using a reflector: make sure the nebula is placed between Merope's diffraction spikes. For my scopes, that means the Pleiades must be within an hour or so of the meridian.

Although it's fun to see IC 349 if you have a large enough scope, the real joy of the Pleiades is seeing them all at once and in context with their faintly illuminated dust bubble — glittering, as Tennyson prophetically wrote in 1835, "like a swarm of fireflies tangled in a silver braid."

■ Contributing Editor **HOWARD BANICH** lives in Portland, Oregon. Look for him and his 28-inch Newtonian telescope at the annual Oregon Star Party.

Further Reading:

A fascinating account of the entire discovery history of the Pleiades nebulae can be found in Wolfgang Steinicke's *Observing and Cataloguing Nebulae and Star Clusters, From Herschel to Dreyer's New General Catalogue* (Cambridge University Press, 2010): pp. 521–561.

- **Have you seen the Pleiades Bubble? Share your observations with Howard Banich at howard.banich@nike.com.**

STAR PARTY OF 6 MILLION by Eli Maor

1925 AN ECLIPSE LIKE NO OTHER

ISTOCKPHOTOS.COM / JAY LAZARIN

New York's Roaring Twenties eclipse cut the city in half, and not where the crowds expected.

Not often does the Moon's shadow cast its dark pall over a major population center. It's rarer still for a total solar eclipse to sweep over ten major astronomical observatories, then cut right through the world's largest city. Yet that's what happened to New York on the cold morning of January 24, 1925. As we look ahead to the total eclipse that will slash from Oregon to South Carolina this August 21st, we can look back to the last time so many Americans had such a view — remembered now by only a few in their mid-90s and up.

In anticipation of the big event, city authorities distributed pamphlets, maps, and train schedules to help area residents watch the spectacle. The New York, New Haven and Hartford Railroad Company issued an informative brochure, *Interesting Important Information On the Greatest Spectacle of the Age,* compiled by two of America's leading astronomers, Ernest W. Brown and Henry Norris Russell. It told how to watch the partial eclipse through smoked glass or dark exposed film (neither is considered safe today). It provided timetables for special rail service and reduced fares on Eclipse Day to and from locations within the track of totality, a 110-mile-wide swath. The predicted northern limit of the total eclipse went through Providence, Rhode Island, and its southern edge cut across Manhattan.

The Biggest Star Party in History

On the morning of the anticipated day, a Saturday, crowds estimated at hundreds of thousands occupied every open space of uptown Manhattan in anticipation of the celestial spectacle, set to begin just before 8 a.m. It was the largest crowd ever gathered at one location to watch a solar eclipse.

Braving a temperature of 9°F (–13°C), throngs crowded northbound subway and elevated trains, reversing the normally southbound morning rush-hour traffic. All were headed uptown above Eighty-Third Street, which astronomers had predicted to be the southern limit of totality. Many media, however, failed to report the range of uncertainty in this seemingly precise prediction.

Some spots were the most eagerly sought. “The crest of Morningside Heights was garrisoned before 8 o’clock,” reported the *New York Times* the next day. Here hundreds of tripod-mounted cameras and telescopes vied for unobstructed views both southeastward toward the Sun and westward over the Hudson River, in anticipation of catching the Moon’s approaching shadow.

It had the air of a huge street party. Parents brought their toddlers, determined that they should not miss an event the area hadn’t been seen since before Columbus and wouldn’t again for 154 more years. But the children were demanding to be taken home because their feet were freezing. The snow covering the ground didn’t help. One child was heard to ask, “Aren’t there any eclipses in the summer?”

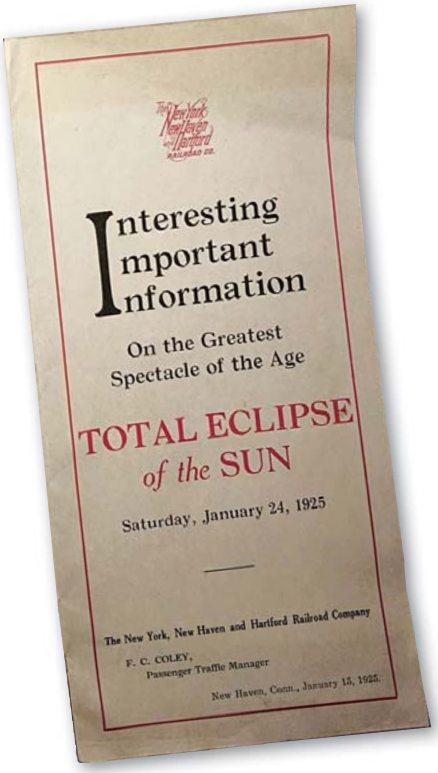
Entrepreneurs made quick profits selling pieces of smoked glass, exposed film negatives, or even just cards with a pinhole poked into them. One advertised his device with the slogan, “Save your eyes for ten cents” ($1.40 in today’s money). Yacht owners positioned themselves along the waterways around Manhattan to avoid the crowds.

New York City mayor John F. Haylan and his secretary watched from the steps of City Hall in lower Manhattan, though from here they saw only a deep partial eclipse. So did President Calvin Coolidge and his wife viewing from the rear grounds of the White House in Washington. Businesses throughout New York postponed opening. In an unprecedented move, the New York Stock Exchange (then still trading on Saturdays) delayed its opening by 45 minutes to let its members watch the event — an extraordinary nod by the world’s most iconic financial institution to a celestial event oblivious to financial matters.

A few minutes before 8 o’clock, some trained eyes thought they could detect a tiny bite encroaching on the Sun’s disk, but not everyone agreed on where exactly it was. Then the cry went out as if from an enormous choir: “There it is!” The big show had begun. But the initial excitement soon gave way to boredom, as nothing special was yet to be seen other than the slow advance of the Moon’s black silhouette over the Sun. When about a third of the Sun’s face was covered, some people noticed that the city streetlights had been turned on. They were barely visible in the still-bright sunlight but became more noticeable as the eclipse progressed, neatly outlining the city’s grid of streets and avenues. The tension among the crowds now heightened as the real show was nearing.

As the moment of totality approached, the throngs fell quiet. All eyes were trained at the Sun’s shrinking crescent, frozen toes all but forgotten. Many noticed Venus, Jupiter, and Mercury in the darkening sky. Others spotted shadow bands dancing irregularly on the ground a minute or two

▼ **DUTY STATIONS** New York Edison Company photographers prepare on a rooftop for the crucial minutes. Edison and other electric companies banded together to set up a picket line of observers across the southern limit of totality. **Right:** The New York, New Haven and Hartford Railroad issued educational pamphlets with one-day-only train schedules for eclipse chasers.



Interesting
Important
Information

On the Greatest
Spectacle of the Age

TOTAL ECLIPSE
of the SUN

Saturday, January 24, 1925

The New York, New Haven and Hartford Railroad Company

F. C. COLEY,
Passenger Traffic Manager

New Haven, Conn., January 15, 1925.

COURTESY ELI MAOR (2)

▲ **BLACK BELT** The total eclipse began at sunrise in Minnesota and raced across the Great Lakes before sweeping New York and southern New England. This map, with rail lines, appeared in the railroad pamphlet on the previous page. **Right:** Totality, shot by an unknown photographer. Film in the 1920s had a narrow dynamic range, with not much leeway between underexposure and overexposure — a problem for a subject like the solar corona with its broad range of brightnesses. The eye, with its greater dynamic range, showed much more of the corona, and in finer detail.

before totality, their visibility enhanced on the snow. The crowds watched in silent awe as the dark Moon completely blotted out the Sun, leaving the pearly corona to shine in its magical, feathery beauty. It was precisely 9:11 a.m. The Big Apple was engulfed in darkness.

Three women were reported to have fainted at the sudden onset of night. In the Bronx a lady, pointing her hand skyward, was overheard asking a man standing next to her, “Is that star Altair?” To which the man replied, “I don’t know — I’m a stranger here.” Among those who saw the eclipse were 20 prisoners waiting to be arraigned in front of the Yorkville Courthouse. At the moment of totality their patrolman scanned the sky and decided to watch the eclipse with his prisoners by his side. Police feared that pickpockets would have a field day with the rapt crowds all looking up, but the frigid temperature and the limited time in which to act must have discouraged them.

The event did not go without unfortunate mishaps. A 50-year-old man dropped dead while viewing the eclipse from a hill on the outskirts of Danbury, Connecticut. A woman was severely injured when she fell from her second-story window while watching the airship Los Angeles flying overhead on its way to observe the eclipse (more on that later).

Just north of the city, all the cadets of the United States Military Academy at West Point viewed the eclipse from the school’s grounds, deemed the center of the “black belt.” Among the spectators were a group of astronomy professors from Rutgers College. Some astronomers searched the corona with telescopes for the ever-elusive planet Vulcan, which even in 1925 some thought might orbit the Sun closer than Mercury — 10 years after Einstein’s general theory of relativity put any need for Vulcan to rest (*S&T:* Dec. 2015, p. 18).

As it happened, astronomers had not predicted very accurately either the time of the onset of totality nor the southern limit of the Moon’s shadow. Totality was about four seconds late, while the southern edge of the umbra passed between 96th and 97th Streets, thirteen blocks north of the predicted limit. Those who had confidently positioned themselves on the wrong side of the dividing line were out of luck: they saw only an extremely deep partial eclipse. The next day the *New York Times* ran a banner headline on its front page: “Eclipse Four Seconds Late Here, But A Brilliant Show; Seen from Land, Sea, And Air, It Thrills Millions; City Halts To Gaze; Scientists Now Study The Data.”

▲ **SPECTATORS** President Calvin Coolidge and his wife Grace (center couple) viewed the partial eclipse from the White House.

TOP: COURTESY ELI MAOR (2), BOTTOM: COURTESY MIKE KENTRIANAKIS / AAS / TSE1925.COM

▲ **VULCAN HUNT** Photographers and telescopic observers waited as totality approached Seagrave Observatory in Rhode Island.

Observing the Eclipse from the Air

From a scientific point of view, the New York eclipse marked several firsts. In East Hampton near the eastern end of Long Island, E. R. Hewitt of the *Scientific American* Eclipse Expedition took what were believed to be, according to the *New York Times,* the first color photographs of an eclipse. He exposed fifteen plates, four or five of them during totality.

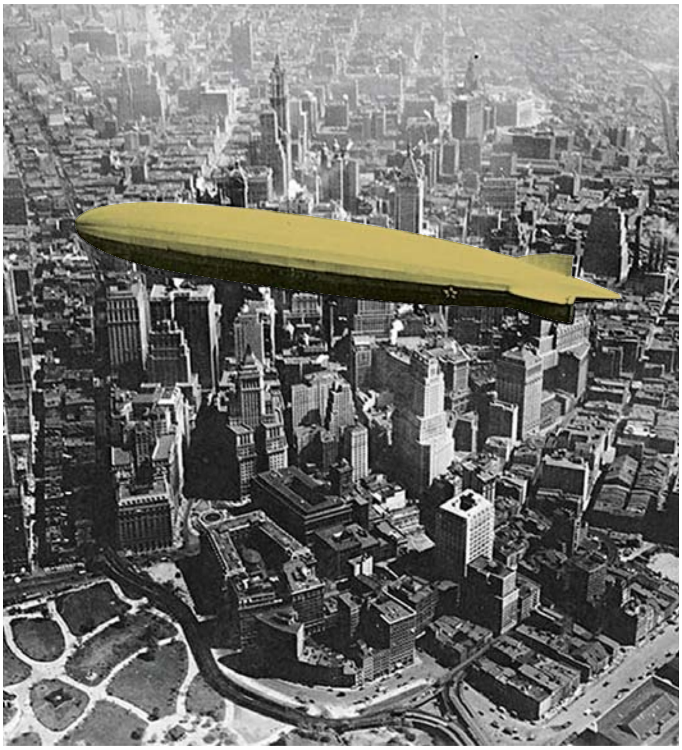
Hovering over the Atlantic about 19 miles off Long Island's Montauk Point, the giant navy dirigible Los Angeles, with 42 crew members and scientists on board, was photographing the eclipse from an altitude of 8,000 feet. Braving a bone-chilling 5°F at ground level, the cavernous airship took off from its base at Lakehurst, New Jersey, shortly after 5 a.m., assisted by a ground crew of 300 sailors and marines. It stayed aloft till 3:40 p.m. The Navy's chief photographer, A. K. Peterson, perched himself on an exposed platform outside the ship from 7:43 to 10:30 a.m., operating a long-range motion-picture camera. During the 2 minutes and 4.6 seconds of totality his nose and right cheek froze, and he was barely able to do his job; he described it as the weirdest sensation he had ever experienced. Footage from the harrowing trip of the Los Angeles — the first fully-equipped airborne astronomical observatory — can be viewed on Mike Kentrianakis's blog at **www.tse1925.com**.

The Los Angeles wasn't the only aircraft chasing the eclipse. A fleet of 25 airplanes of the Army Air Service, each carrying a pilot and an observer, took off from Mitchel Field and formed a line stretching from New Haven, Connecticut, to Greenport, Long Island, to observe the Moon's shadow as it raced over the land at a terrifying speed. In their open cockpits, braving the aircrafts' slipstream of 120 miles an hour, they snatched still- and motion-picture photographs of the eclipsed Sun. One "machine" (as airplanes were then called) was equipped with a radio transmitter, and the entire show was to be narrated live from an altitude of 10,000 feet to radio stations broadcasting from the ground. Alas, the transmitter's generator quit when the plane was already aloft, and the first-ever live podcast of an astronomical event was not to be.

When the airplanes landed back at their base, crews rushed the photographic plates and newsreel footage to developing rooms, and within 3 hours pictures of the eclipse were showing in Broadway movie theaters. One set of newsreel films was sent by air mail to the West Coast; the postage stamps affixed to the package totaled $536.14 ($7,500 today) — "the costliest package ever sent by mail in the history of the United States," reported the *New York Times.* David Todd, Emeritus Professor of Astronomy at Amherst College, debriefed the returning air crews and said, with exaggerated flair, "Astronomical science advanced a thousand years this morning."

Determining the Umbra's Edge

One of the most-reported aspects of the 1925 eclipse was the determination of the umbra's precise southern edge over Manhattan. The New York Edison Company, and seven other electric companies affiliated with the Consolidated Gas Company of New York, stationed 149 observers on rooftops along Riverside Drive overlooking the Hudson River at every street intersection from 72nd to 135th Streets. Each team comprised at least two observers: observer "A" was to watch the surface of the Hudson for the shadow approaching from the west and report whether its edge passed to the north or to the south of him. Observer "B" was to watch the Sun in



▲ **HIGH-ALTITUDE OBSERVATORY** The Navy airship Los Angeles, seen here over lower Manhattan, hosted an airborne eclipse expedition.

COURTESY MIKE KENTRIANAKIS / AAS / TSE1925.COM (2)

Section 1 "All the News That's Fit to Print"

The New York Times.

THE WEATHER
Clear and warmer today; unsettled and colder tomorrow.

Section 1

VOL. LXXIV....No. 24,473. NEW YORK, SUNDAY, JANUARY 25, 1925. FIVE CENTS

ECLIPSE FOUR SECONDS LATE HERE, BUT A BRILLIANT SHOW; SEEN FROM LAND, SEA AND AIR, IT THRILLS MILLIONS; CITY HALTS TO GAZE; SCIENTISTS NOW STUDY THE DATA

PRESIDENT URGES THE WORLD COURT AS OUR PEACE STEP

He Warns Delegates to Women's Conference Anti-War Spirit Must Be Perpetuated.

CITES CONSTRUCTIVE FORCES

Holds Intelligence of People and Community's Moral Opinion Are Greater.

WOMEN PLAN CAMPAIGN

Nine Organizations to Combine in Educational Movement—Want Peace Secretary in Government.

Wide-Bottom College Trousers Are Frowned On by Coolidge

4 SLAIN IN HERRIN; GLENN YOUNG VICTIM

Klan "Dry" Raider and "Man-Killer" Shot Down by Deputy Sheriff Thomas.

LATTER KILLED IN TURN

Six Are Wounded When Factions Renew Battle Ended by Armistice Last Fall.

CORONA DIVINELY BEAUTIFUL

Dr. Luyten, The Times Observer, Describes the Scene From Airplane.

MOON BLACK IN TOTALITY

Its Brownish Tinge and the Shadow Bands Absent Above Dense Atmosphere.

SHADOW'S SPEED TERRIFIC

Rushed on Airplane Unheralded—Perfect Observing Conditions Yield Valuable Records.

PROGRESS OF THE ECLIPSE. Moon Moves From West to East.

SUN AFFECTS RADIO, OBSERVATIONS SHOW

Short Waves From Schenectady Become Inaudible and Long Waves Steadied in Eclipse.

EXPERTS DIFFER IN VIEWS

One Sees Theories of the Influence of Light Confirmed, but Others Deny It.

THE GLORY OF THE ECLIPSE.

SKYSCRAPERS BLINK IN EMPTY STREETS

Downtown Like Sunday—Roofs Outside Totality Zone Are Crowded With Gazers.

EARLY MORN LIKE TWILIGHT

Mayor Views Spectacle From City Hall Steps—Thousands Gather at Battery Park.

MULTITUDE ON WATCH HERE

Awed by Jewel of Light Hanging From Luminous Ring.

THE MOON IS BEHIND TIME

Changes Southern Eclipse Boundary to Between 96th and 97th Streets.

CITY MIGRATES TO NORTH

Perfect Weather Allows Young and Old, Indoors and Out, to See Spectacle.

▲ **MORNING AFTER** On October 25th, the *New York Times* was full of eclipse stories. At the time, a total eclipse was not just a spectacle but a rare chance for cutting-edge discoveries regarding the Sun.

the other direction with a piece of exposed film and report whether it was completely covered by the Moon, or whether a slim crescent of brightness remained visible throughout. A few teams also took photometric readings of the ambient light. The operation was planned with military-like precision. Each observer was ordered to leave his position as soon as totality was over and report his finding to his local foreman.

▲ **TRICK SHOT** At Cornell University in Ithaca, New York, an unknown photographer took 18 exposures on the same film — 17 brief ones showing the Sun's surface, and a longer one timed to record the corona.

Planning was helped by the fact that the direction of the approaching shadow was, by a fortuitous coincidence, nearly aligned with the Manhattan street grid.

When the results were plotted on a map, they indicated that the umbra's southern edge passed between 96th and 97th Streets — a suspiciously small uncertainty of some 225 feet, considering the irregularity of the Moon's limb and the fact that the shadow was cast by an object nearly 400,000 km (250,000 miles) away.

When it was over, news reports estimated that most of the city's six million citizens watched the eclipse from the streets and parks, their homes, or the rooftops of their apartment buildings. It was the largest astrofest ever — and it was free for all to join.

New York will have to wait until the early morning of May 1, 2079, for a repeat show.

■ **ELI MAOR**, a veteran eclipse chaser, is the author of five books on the history of mathematics and astronomy. He thanks Gary Gustin of the Skokie Public Library in Skokie, Ill., for help in locating newspapers, Paul Baker for details about the New York Stock Exchange, Michael Zeiler for the newspaper above, and Luise Maor for her editorial suggestions.

TOP: COURTESY MICHAEL ZEILER, BOTTOM: COURTESY MIKE KENTRIANAKIS / AAS

Build Your Own On-Axis Guider

Eliminate a host of guiding problems with one surprisingly easy project.

WHEN I THINK OF do-it-yourself projects, I seldom think of astrophotography. Astrophotography is so exacting that it's hard to imagine anyone making photo gear in their home shop. So I was a bit flummoxed when California ATM Don Rea showed me his homemade on-axis guider. Could it really be possible?

It could. And it is. Inspired by the early work of ATM Kaz Tanaka and the commercial on-axis guider offered by Innovations Foresight, Don built a precision gadget that completely eliminates the most vexing problems with guided photography. It turns out to be surprisingly simple and reasonably low-cost.

Most astrophotographers have abandoned manual guiding through an eyepiece (the world's most boring video game) in favor of auto-guiding with a guide camera replacing the human eye and thumbs. As in the old days, that's most often done with a separate guide scope, but that still leaves a serious problem: due to differential flexure and mirror shift, the guide scope and main scope don't necessarily point in exactly the same direction in all orientations.

The solution is to aim the imaging camera and the guide camera through the same telescope. That usually means off-axis guiding, in which you guide with a star that's just out of the camera's field of view, but such stars tend to be scarce and aberrated. On-axis guiding, in which you select a guide star from within the same field you're photographing, is a more elegant solution, but how do you get light to both cameras at once?

Don Rea with his fully assembled telescope and guide setup. The imaging camera is on the bottom, with the guide camera to the right.

DON REA

Do you have a telescope or ATM observing accessory that *S&T* readers would enjoy knowing about? E-mail your projects to Jerry Oltion at j.oltion@sff.net.

The answer is to optically separate the light from the telescope into two spectral bands, using one to guide on and the other to create the photographic image you're interested in. Don's research led him to a near perfect solution: a cold mirror.

A cold mirror is not what it sounds like. Rather than being cooled like cameras often are, the mirror merely reflects "cold" wavelengths. A cold mirror reflects visible (cold) light while letting near-infrared (warm) light pass straight through. You guide off the infrared image while your imaging camera collects photons in the visible range.

The Edmund Optics #64-451 3.3-mm cold mirror proved ideal for this application. It reflects better than 95% of incoming light from ultraviolet to 700 nanometers (beyond deep red), and it passes about 95% of anything longer.

To hold the mirror and provide camera attachments, Don found that the housing of Orion's 5523 flip mirror worked perfectly. He pulled the guts out of it and mounted his cold mirror inside on brackets angled at precisely 45°. A 50-mm square mirror just fit. Behind that he mounted a smaller circular plain glass plate of the same substrate to serve as a corrector plate to remove the astigmatism in the guider image introduced by its light passing through the 45° mirror. (Without the corrector plate, the stars in the guider image would be badly distorted and guider accuracy would be

The flip mirror housing with the cold mirror and corrector plate installed.

DON REA

reduced.) The flip mirror housing has T-threads on all three ports for easy mounting of the cameras and the telescope, so all that was left was to close it up and test it out.

How does it work? Beautifully! Don reports, “It’s far easier to use than an off-axis guider. You can guide on any star that’s in the field of view of the guide camera. Additionally, the stars are about one magnitude brighter than with an off-axis guider due to the very small area of an off-axis pickoff mirror. The penalty paid for this is that the imaging camera sees about 0.4 mag less light. That’s a small price to pay for the total elimination of mechanical guiding errors. The big thing is that the setup is mechanically rock solid. Its optical performance is excellent. You can’t ask for much more from an auto-guider.”

With his fork-mounted 10-inch Meade LX200 Schmidt-Cassegrain telescope and on-axis guider, Don can guide on a 13th-magnitude star using 6-second exposures with accuracy limited mainly by the mount, not by the optics. And that’s what he needs for his intended purpose: measuring transiting exoplanet light curves. Given the ease of use and performance of this guider, Don has made this difficult work of photometry a lot easier.

■ For more information about the details of this project, contact **DON REA** at don.rea@verizon.net.

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The *ASH-DOME* pictured is 12’6” (3.8m) Model REB housing a 14” Celestron Edge telescope. The observatory is built over a research laboratory and library. It is primarily used for personal observing and astrophotography. However, the site provides school children an information introduction to astronomy with the intent to promote an interest in science. The public is invited during scheduled open houses.

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△△ NECTARIS' NEIGHBORS

Jamey Jenkins

The crater trio Theophilus, Cyrillus, and Catharina abut Mare Nectaris. Rugged Rupes Altai hugs the bottom. **DETAILS:** *D&G Optical 125-mm refractor and DMK 41AU02 CCD video camera. Stack of 62 frames.*

△STUNNING CLUSTER

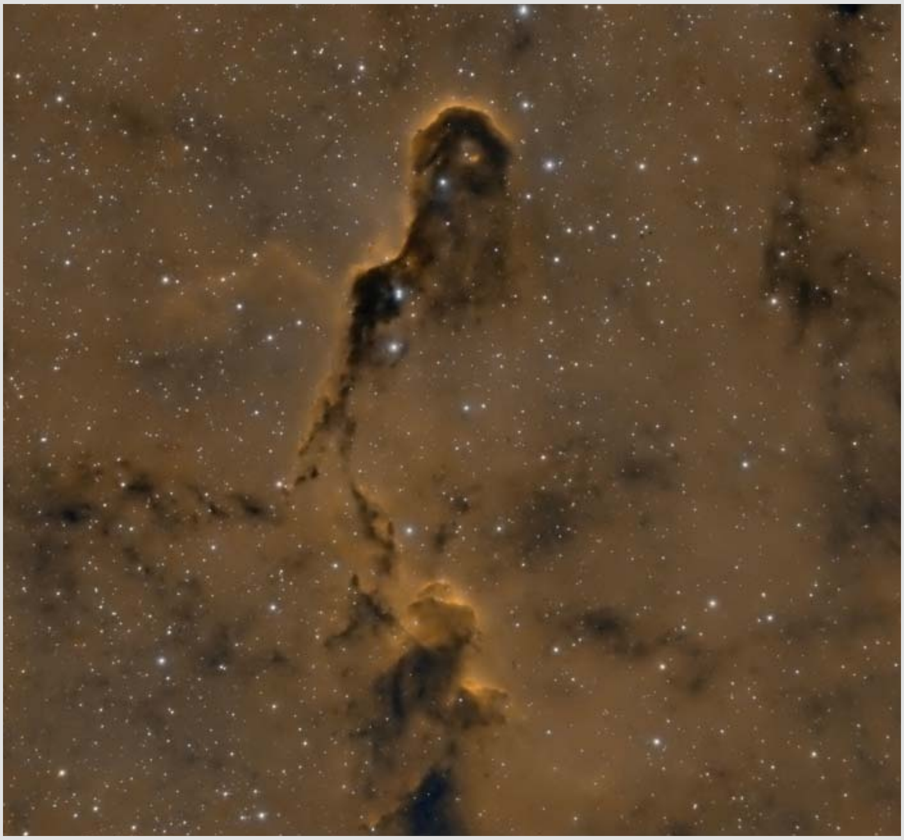
Dan Crowson

Messier 37 (NGC 2099) is the richest of three bright open clusters in Auriga. It's 4,500 light-years away. **DETAILS:** *Astro-Tech AT90DT refractor, SBIG ST-8300M CCD camera, and LRGB filters. Total exposure: 4 hours.*

◁MURKY TERRITORY

Pavel Pech

The bluish NGC 1333, at upper right, is a rare bright spot among several chocolate-hued dark nebluae. **DETAILS:** *ASA 10N astrograph, Moravian Instruments G3-11000 CCD camera, and Astrodon I-Series filters. Total exposure: 18 hours.*



◁ELEPHANT'S TRUNK NEBULA

Álvaro Ibáñez Pérez

The aptly named Elephant's Trunk is a dark, tortured thread of cosmic matter inside the much larger IC 1396 complex.

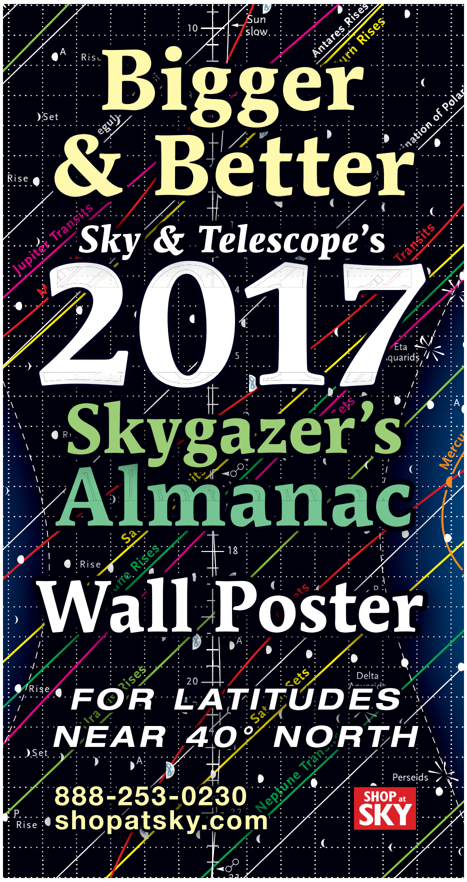
DETAILS: *Teleskop Service TS-115 apochromatic refractor, Atik 460EX CCD camera, and Baader Hα and O-III filters. Total exposure: 8.3 hours.*

▽SNAKE NEBULA

Gregg Ruppel

Also called Barnard 72, this slithering stretch of opaque cloud lies northwest of 44 Ophiuchi. To its lower right is Barnard 68, the Ink Spot.

DETAILS: *ASA 10N astrograph, SBIG STL-11000M CCD camera, and AstroDon Gen2 filters. Total exposure: 4 hours.*



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Eclipse image: Dennis di Cicco & Sean Walker

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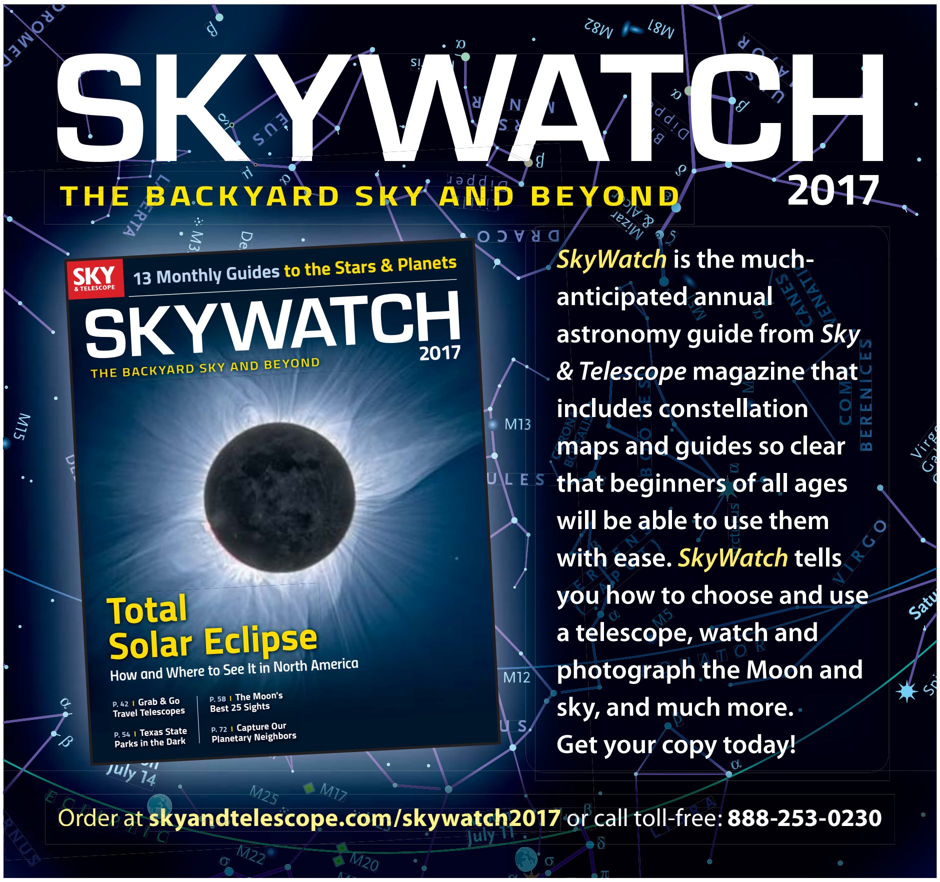

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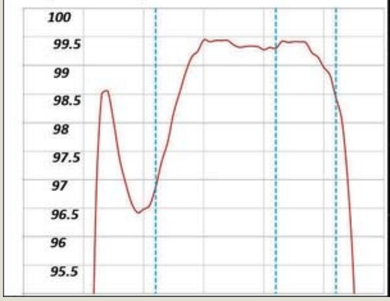

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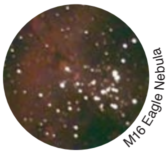

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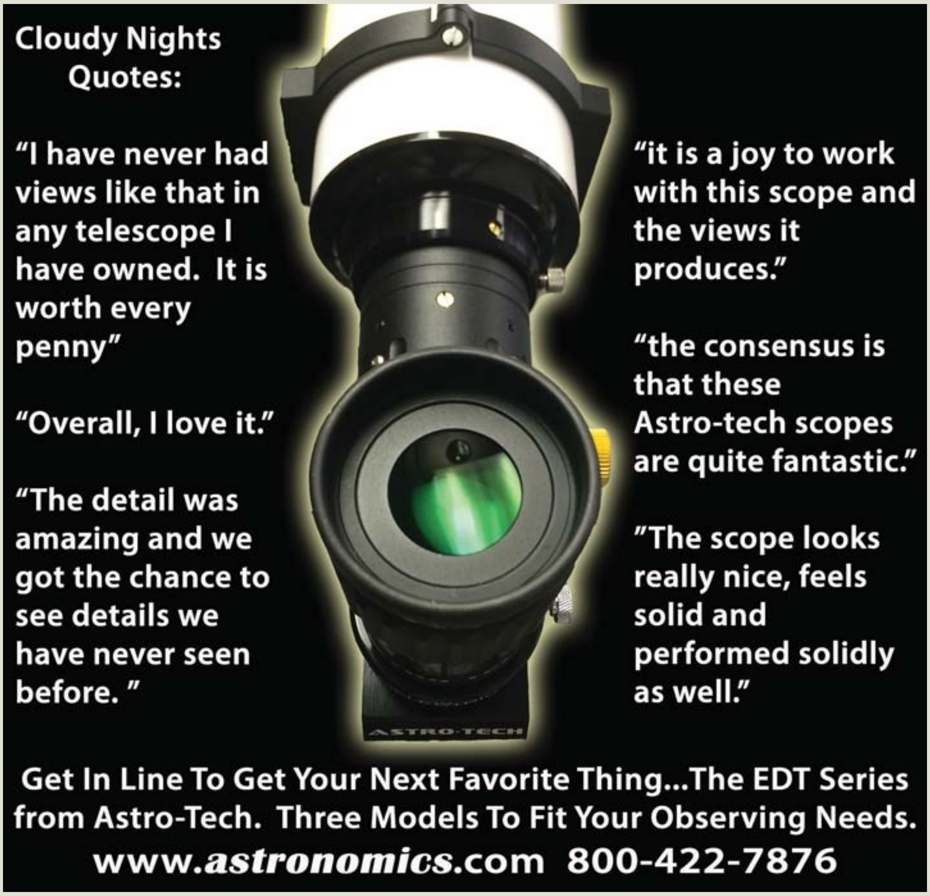

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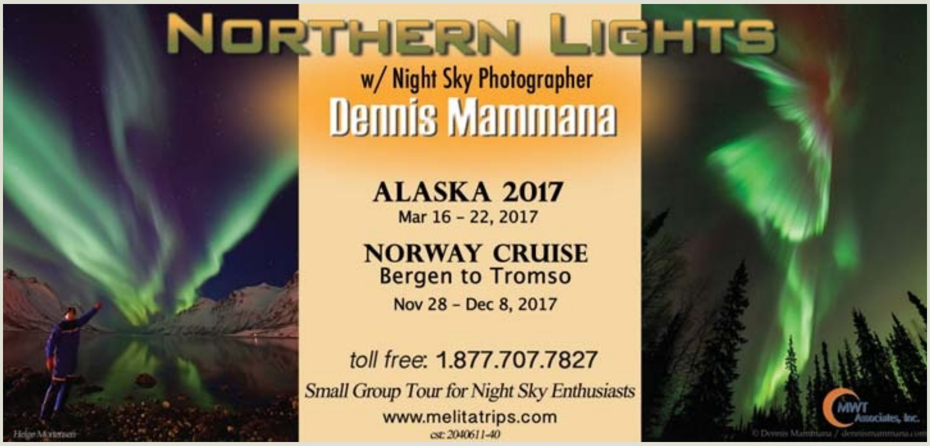

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AD INDEX

Event Calendar

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Here's the info you'll need to "save the date" for some of the top astronomical events of the year.

February 20–26
WINTER STAR PARTY
West Summerland Key, FL
scas.org/winter-star-party

April 8–9
NORTHEAST ASTRONOMY FORUM
Suffern, NY
rocklandastronomy.com/neaf.html

April 29 (also September 30)
ASTRONOMY DAY
Everywhere!
astroleague.org/al/astroday/astroday.html

May 21–28
TEXAS STAR PARTY
Fort Davis, TX
texasstarparty.org

May 25–29
RTMC ASTRONOMY EXPO
Big Bear City, CA
rtmcastronomyexpo.org

June 22–25
CHERRY SPRINGS STAR PARTY
Coudersport, PA
astrohbg.org/CSSP

June 17–24
GRAND CANYON STAR PARTY
Grand Canyon, AZ
nps.gov/grca/planyourvisit/grand-canyon-star-party.htm

June 21–25
ROCKY MOUNTAIN STAR STARE
Gardner, CO
rmss.org

June 21–25
GOLDEN STATE STAR PARTY
Bieber, CA
goldenstatestarparty.org

July 18–22
TABLE MOUNTAIN STAR PARTY
Oroville, WA
tmspa.com

July 20–23
STELLAFANE CONVENTION
Springfield, VT
stellafane.org/convention

July 20–23
STARFEST
Ayton, ON, Canada
nyaa.ca/starfest.html

July 21–25
ALMOST HEAVEN STAR PARTY
Spruce Knob, WV
ahsp.org

July 23–28
NEBRASKA STAR PARTY
Valentine, NE
nebraskastarparty.org

August 17–22
OREGON STAR PARTY
Indian Trail Spring, OR
oregonstarparty.org

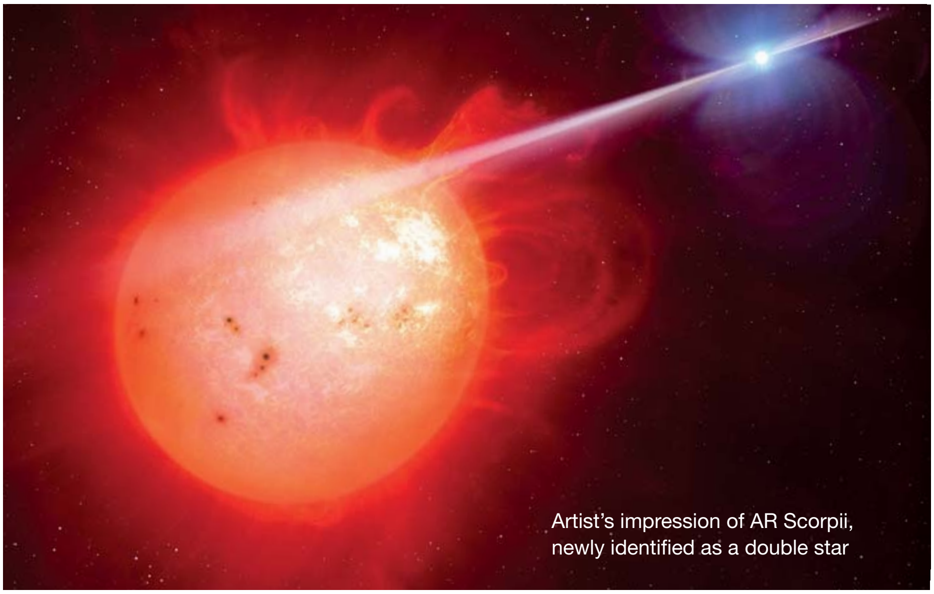
September 16–24
OKIE-TEX STAR PARTY
Kenton, OK
okie-tex.com

- For a more complete listing, visit https://is.gd/star_parties.

by Franz-Josef Hambsch

The First Pulsing White Dwarf

How amateurs helped professional astronomers make a major discovery



Artist's impression of AR Scorpii, newly identified as a double star

M. GARLICK / UNIVERSITY OF WARWICK / ESO

I'VE BEEN INTERESTED in astronomy since childhood, and I began observing with a 4.25-inch Newtonian when I was 18. About a quarter century later, I started using a CCD camera to shoot pretty pictures, some of which even became Astronomy Pictures of the Day (e.g., **https://is.gd/ZLkWgw**).

But after a few years of imaging experience, and maybe because I make a living as a scientist, I switched to observing variable stars. Nowadays, you can contribute to scientific research using digital cameras. So I joined three amateur groups in Europe that focus on variable stars: VVS (Belgium), GEOS (France), and BAV (Germany).

Among the projects I undertook when I began observing variable stars was to monitor high-amplitude Delta Scuti variables. These are short-pulsating stars for which one can observe several maxima in a single night. My contributions to this topic have resulted in several publications.

Since weather conditions in central Europe are often unfavorable, many amateurs turn to armchair astronomy. It was such a group of amateurs mining databases of automatic surveys that approached me to observe AR Scorpii, a star varying by 2 magnitudes in brightness and classified at the time as a Delta Scuti variable. The changes in brightness and the star's classification didn't match, however, and new scrutiny was needed.

The star's southern declination made it difficult to observe from central Europe. Fortunately, I had built a remote personal observatory in Chile that became operational in 2011. The weather in the Atacama Desert is marvelous, and I examined AR Sco over the course of several weeks.

I performed these observations with an Orion Optics 16-inch f/6.8 Optimized Dall Kirkham telescope and an FLI ML16803 CCD camera binned 3×3. I began a series of 60-second exposures through an Astrodon photometric *V* filter, as I thought I'd need a long exposure for a star of magnitude 14.5 to 16.5. While the results show a rather scattered light curve (see **https://is.gd/r6L08J**, third image), they confirmed the period of the brightness variations known since the 1970s.

But the light curve's shape ruled out a Delta Scuti classification.

Additional observations didn't bring us any closer to explaining the nature of this star, so we decided to seek the help of professional astronomers. My astro-buddies in Germany had already worked with the pros on previous projects, and they put us in touch with Boris Gänsicke at the University of Warwick in the UK.

Gänsicke found the object so fascinating that he convinced colleagues who had observing time at the Very Large Telescope to take a spectrum of AR Sco. With the VLT spectrum in hand, as well as a run of high-speed photometry from the William Herschel Telescope, the ball started rolling. More professional astronomers became involved, looking at AR Sco in all available passbands.

The exciting result of all this pro-am work appeared in the September 15th *Nature*. AR Sco, it turns out, is not one star but two, one of which is a white dwarf that's pulsing — the first known of its kind (see page 11).

We amateurs were delighted to contribute to work published in one of the world's premier scientific journals.

◗ The original version of this article appeared as a community news blog on **skyandtelescope.com** on August 15, 2016.

■ **FRANZ-JOSEF "JOSCH" HAMBSCH** is a nuclear physicist at the Joint Research Centre in Geel, Belgium. A list of recent astronomy papers in which Hambsch is a coauthor may be seen at **https://is.gd/dsXpmd**.

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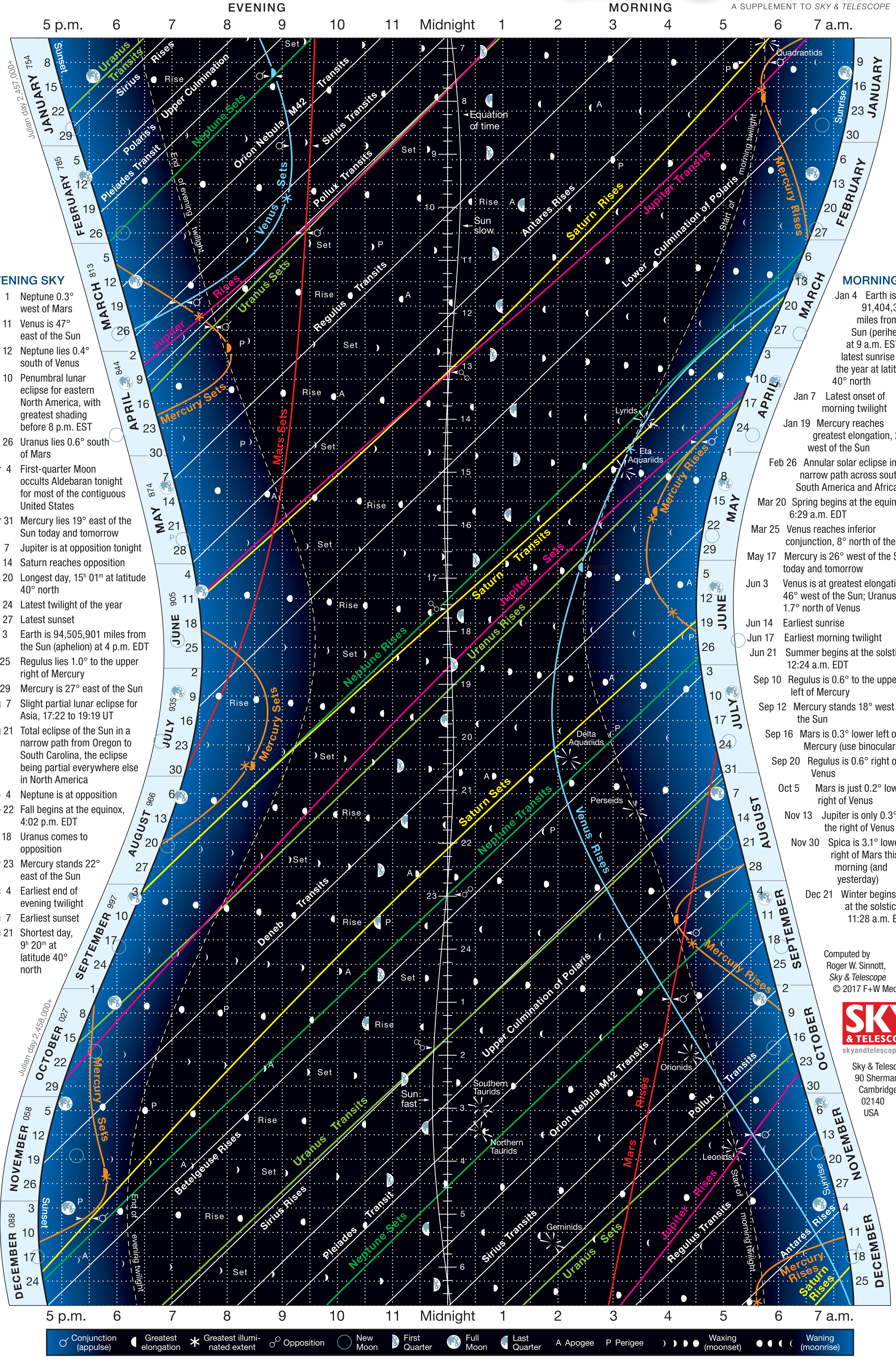
Skygazer's Almanac 40°N 2017

FOR LATITUDES NEAR 40° NORTH

A SUPPLEMENT TO *SKY & TELESCOPE*



EVENING SKY

Jan 1	Neptune 0.3° west of Mars
Jan 11	Venus is 47° east of the Sun
Jan 12	Neptune lies 0.4° south of Venus
Feb 10	Penumbral lunar eclipse for eastern North America, with greatest shading before 8 p.m. EST
Feb 26	Uranus lies 0.6° south of Mars
Mar 4	First-quarter Moon occults Aldebaran tonight for most of the contiguous United States
Mar 31	Mercury lies 19° east of the Sun today and tomorrow
Apr 7	Jupiter is at opposition tonight
Jun 14	Saturn reaches opposition
Jun 20	Longest day, 15ʰ 01ᵐ at latitude 40° north
Jun 24	Latest twilight of the year
Jun 27	Latest sunset
Jul 3	Earth is 94,505,901 miles from the Sun (aphelion) at 4 p.m. EDT
Jul 25	Regulus lies 1.0° to the upper right of Mercury
Jul 29	Mercury is 27° east of the Sun
Aug 7	Slight partial lunar eclipse for Asia, 17:22 to 19:19 UT
Aug 21	Total eclipse of the Sun in a narrow path from Oregon to South Carolina, the eclipse being partial everywhere else in North America
Sep 4	Neptune is at opposition
Sep 22	Fall begins at the equinox, 4:02 p.m. EDT
Oct 18	Uranus comes to opposition
Nov 23	Mercury stands 22° east of the Sun
Dec 4	Earliest end of evening twilight
Dec 7	Earliest sunset
Dec 21	Shortest day, 9ʰ 20ᵐ at latitude 40° north

MORNING SKY

Jan 4	Earth is 91,404,322 miles from the Sun (perihelion) at 9 a.m. EST; latest sunrise of the year at latitude 40° north
Jan 7	Latest onset of morning twilight
Jan 19	Mercury reaches greatest elongation, 24° west of the Sun
Feb 26	Annular solar eclipse in a narrow path across southern South America and Africa
Mar 20	Spring begins at the equinox, 6:29 a.m. EDT
Mar 25	Venus reaches inferior conjunction, 8° north of the Sun
May 17	Mercury is 26° west of the Sun today and tomorrow
Jun 3	Venus is at greatest elongation, 46° west of the Sun; Uranus is 1.7° north of Venus
Jun 14	Earliest sunrise
Jun 17	Earliest morning twilight
Jun 21	Summer begins at the solstice, 12:24 a.m. EDT
Sep 10	Regulus is 0.6° to the upper left of Mercury
Sep 12	Mercury stands 18° west of the Sun
Sep 16	Mars is 0.3° lower left of Mercury (use binoculars)
Sep 20	Regulus is 0.6° right of Venus
Oct 5	Mars is just 0.2° lower right of Venus
Nov 13	Jupiter is only 0.3° to the right of Venus
Nov 30	Spica is 3.1° lower right of Mars this morning (and yesterday)
Dec 21	Winter begins at the solstice, 11:28 a.m. EST

Computed by
Roger W. Sinnott,
Sky & Telescope

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Skygazer's Almanac 40°N 2017

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 2017,* 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 8, 2017.

First find "January" and "8" 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 8–9 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 8–9 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 8th occurs at 4:52 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 evening twilight ends at 6:29 p.m., the time when the Sun is 18° below the horizon and the sky is fully dark. Then at 7:39 Polaris, the North Star, reaches upper culmination. This means it stands directly above the north celestial pole (by 40′ this year), a good time to check the alignment of an equatorial telescope.

At 8:33 p.m. the Pleiades transit the meridian, meaning the famous star cluster is due south and highest in the sky. At 8:46 the brilliant planet Venus sets in the west, followed by dim Neptune at 9:06 and red-orange Mars at 9:35.

The Great Orion Nebula (Messier 42) transits at 10:21, as does the bright star Sirius at 11:30. Transits of such 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 8–9 this is $7^h 16^m$. 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 8th the Sun runs slow, transiting at 12:07 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

Giant planet Jupiter rises at 12:29 a.m. and will become better placed for telescopic viewing toward dawn.

At 4:06 a.m. 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.) Then at 4:49 a.m. Antares, a star we usually associate with a much later season, rises.

The ringed planet Saturn comes up at 5:26, and the first hint of dawn — the start of morning twilight — comes at 5:45. A few minutes later elusive Mercury rises, early enough before sunup that we should spot it later as it climbs higher. The Sun finally peeks above the horizon at 7:22 a.m. on January 9th.

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 is done for Jupiter on the night of April 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).

Mercury and *Venus* never stray far outside the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark their dates of greatest illuminated extent in square arcseconds. In the case of Venus, this is very nearly when it is at greatest brilliancy, as on the evening of February 16th.

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 early 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 754 to the date. For instance, on the evening of January 8th we have 754 + 8 = 762, so the Julian day is 2,457,762. 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.

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

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 coordinates of the Sun and planets can be found in each issue of *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.

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.

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Skygazer's Almanac 50° N 2017

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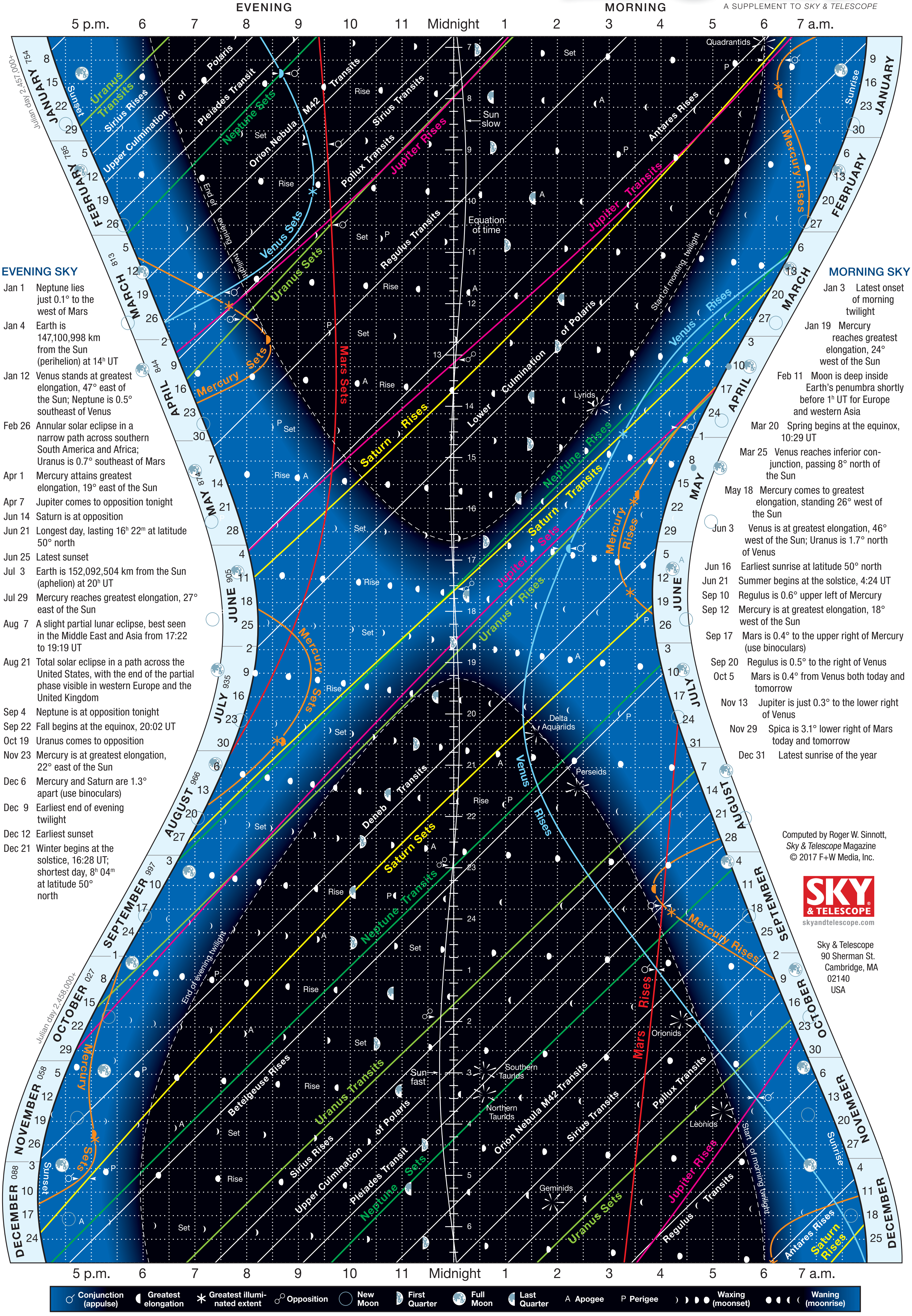


EVENING SKY

Jan 1	Neptune lies just 0.1° to the west of Mars
Jan 4	Earth is 147,100,998 km from the Sun (perihelion) at 14ʰ UT
Jan 12	Venus stands at greatest elongation, 47° east of the Sun; Neptune is 0.5° southeast of Venus
Feb 26	Annular solar eclipse in a narrow path across southern South America and Africa; Uranus is 0.7° southeast of Mars
Apr 1	Mercury attains greatest elongation, 19° east of the Sun
Apr 7	Jupiter comes to opposition tonight
Jun 14	Saturn is at opposition
Jun 21	Longest day, lasting 16ʰ 22ᵐ at latitude 50° north
Jun 25	Latest sunset
Jul 3	Earth is 152,092,504 km from the Sun (aphelion) at 20ʰ UT
Jul 29	Mercury reaches greatest elongation, 27° east of the Sun
Aug 7	A slight partial lunar eclipse, best seen in the Middle East and Asia from 17:22 to 19:19 UT
Aug 21	Total solar eclipse in a path across the United States, with the end of the partial phase visible in western Europe and the United Kingdom
Sep 4	Neptune is at opposition tonight
Sep 22	Fall begins at the equinox, 20:02 UT
Oct 19	Uranus comes to opposition
Nov 23	Mercury is at greatest elongation, 22° east of the Sun
Dec 6	Mercury and Saturn are 1.3° apart (use binoculars)
Dec 9	Earliest end of evening twilight
Dec 12	Earliest sunset
Dec 21	Winter begins at the solstice, 16:28 UT; shortest day, 8ʰ 04ᵐ at latitude 50° north

MORNING SKY

Jan 3	Latest onset of morning twilight
Jan 19	Mercury reaches greatest elongation, 24° west of the Sun
Feb 11	Moon is deep inside Earth's penumbra shortly before 1ʰ UT for Europe and western Asia
Mar 20	Spring begins at the equinox, 10:29 UT
Mar 25	Venus reaches inferior conjunction, passing 8° north of the Sun
May 18	Mercury comes to greatest elongation, standing 26° west of the Sun
Jun 3	Venus is at greatest elongation, 46° west of the Sun; Uranus is 1.7° north of Venus
Jun 16	Earliest sunrise at latitude 50° north
Jun 21	Summer begins at the solstice, 4:24 UT
Sep 10	Regulus is 0.6° upper left of Mercury
Sep 12	Mercury is at greatest elongation, 18° west of the Sun
Sep 17	Mars is 0.4° to the upper right of Mercury (use binoculars)
Sep 20	Regulus is 0.5° to the right of Venus
Oct 5	Mars is 0.4° from Venus both today and tomorrow
Nov 13	Jupiter is just 0.3° to the lower right of Venus
Nov 29	Spica is 3.1° lower right of Mars today and tomorrow
Dec 31	Latest sunrise of the year

Computed by Roger W. Sinnott,
Sky & Telescope Magazine

skyandtelescope.com

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

Skygazer's Almanac 50°N 2017

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 2017,* 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 8, 2017.

First find "January" and "8" 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 8–9 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 8–9 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 8th occurs at 4:17 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 evening twilight ends at 6:15, marking the time when the Sun is 18° below the horizon and the sky is fully dark.

At 6:52 p.m. the bright star Sirius rises. Then at 7:40 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 brilliant planet Venus, until now prominent in the west, sets at 8:32. Two minutes later the Pleiades star cluster transits the meridian, followed by the Orion Nebula, Messier 42, at 10:22. Transits of celestial landmarks tell when they are highest in the sky and remind us where the constellations are all 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 8–9 this is $7^h 15^m$. 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 8th the Sun runs slow, transiting at 12:07 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

The giant planet Jupiter rises at 12:40 a.m., a sure sign it will be well placed for telescopic study toward dawn. At 2:54 Regulus transits. Near 4:13 we see a small 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 all night up to now.) Then a star we usually associate with a later season, Antares, rises at 5:35.

The first hint of dawn — the start of morning twilight — comes at 5:59 a.m. The elusive planet Mercury rises at 6:21, early enough before sunup that we might spot it as it climbs higher. The Sun finally peeks above the eastern horizon at 7:56 a.m. on the morning of January 9th.

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening

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

and morning margins. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are marked 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 indicated there by a ☍ symbol. For instance, Jupiter reaches opposition on the night of April 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 and *Venus* never stray far outside the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark the dates when their disks in telescopes show the greatest illuminated extent in square arcseconds. In the case of Venus, this is also very nearly the date when the planet reaches greatest brilliancy, as on February 16th this year.

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 early 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 754 to the date.

Rising or Setting Corrections

	Declination (North or South)					
North Latitude	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

For instance, on the evening of January 8th we have 754 + 8 = 762, so the Julian day is 2,457,762. For European observers this number applies all night, because the next Julian day always begins at 12:00 Universal Time (noon Greenwich Mean Time).

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 order of decreasing 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 or website.

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.

Skygazer's Almanac 2017 is a supplement to
Sky & Telescope.

For reprints (item SGA17E, $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.
E-mail skyprodservice@skyandtelescope.com, or visit our online store at skyandtelescope.com.

SKY & TELESCOPE
skyandtelescope.com

Skygazer's Almanac 30°s 2017

FOR LATITUDES NEAR 30° SOUTH

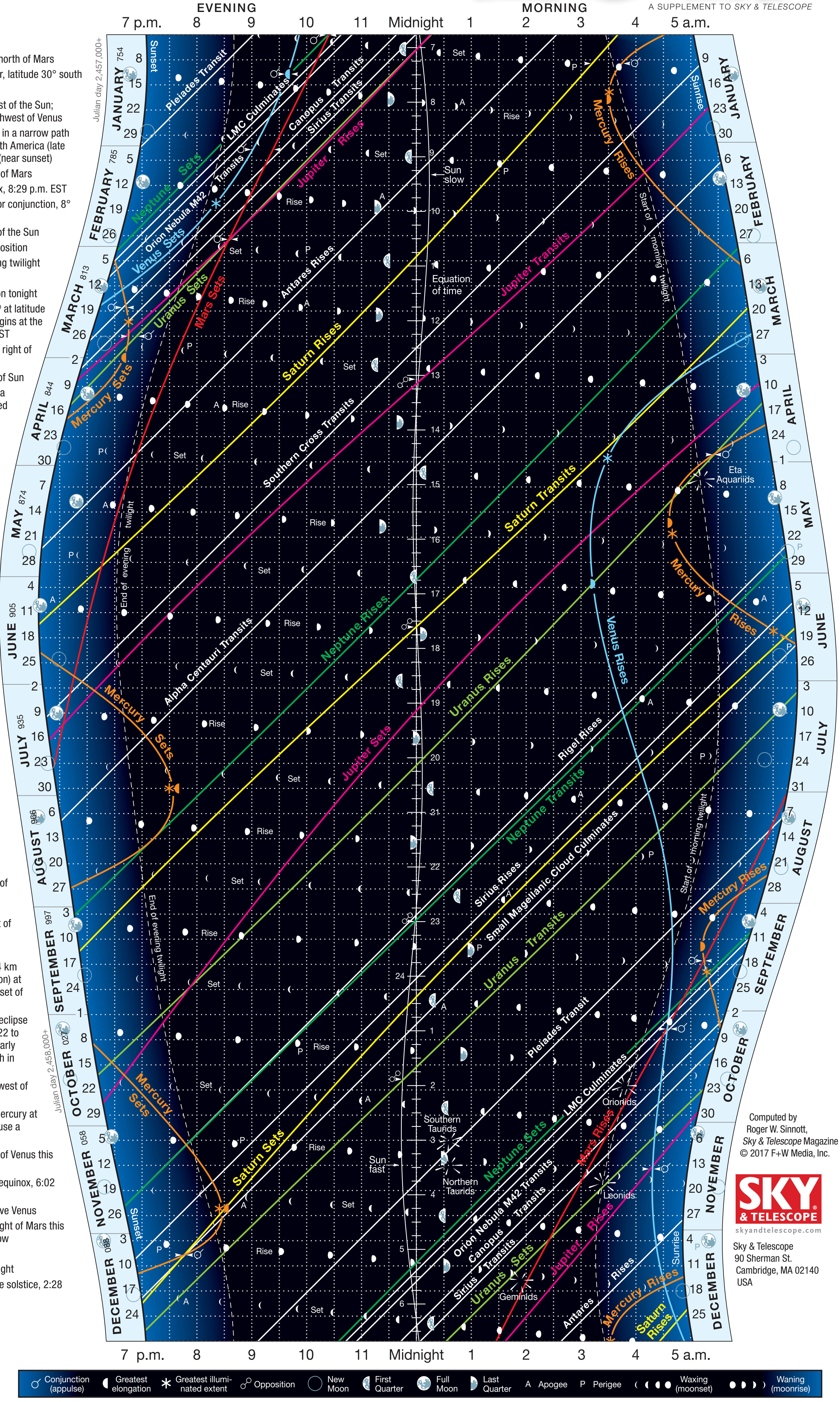
A SUPPLEMENT TO *SKY & TELESCOPE*

EVENING SKY

- Jan 1 Neptune is just 0.2° north of Mars
- Jan 4 Latest twilight of year, latitude 30° south
- Jan 9 Latest sunset
- Jan 12 Venus stands 47° east of the Sun; Neptune is 0.5° southwest of Venus
- Feb 26 Annular solar eclipse in a narrow path across southern South America (late morning) and Africa (near sunset)
- Feb 27 Uranus is 0.6° south of Mars
- Mar 20 Fall begins at equinox, 8:29 p.m. EST
- Mar 25 Venus reaches inferior conjunction, 8° north of the Sun
- Apr 1 Mercury is 19° east of the Sun
- Apr 7 Jupiter comes to opposition
- Jun 8 Earliest end of evening twilight
- Jun 10 Earliest sunset
- Jun 15 Saturn is at opposition tonight
- Jun 21 Shortest day, $10^h 13^m$ at latitude 30° south; winter begins at the solstice, 2:24 p.m. EST
- Jul 27 Regulus is 1.1° lower right of Mercury
- Jul 30 Mercury is 27° east of Sun
- Aug 21 Total solar eclipse in a path across the United States, partial in northern South America
- Sep 5 Neptune is at opposition tonight
- Sep 11 Spica is 3.1° upper left of Jupiter
- Oct 19 Uranus comes to opposition
- Nov 24 Mercury reaches its greatest elongation, 22° east of the Sun
- Dec 22 Longest day at latitude 30° south, $14^h 05^m$

MORNING SKY

- Jan 5 Earth is 147,100,998 km from the Sun (perihelion) at 12 a.m. EST
- Jan 20 Mercury reaches greatest elongation, 24° west of the Sun
- Feb 11 Moon is deep inside Earth's penumbra shortly before 1^h UT for Africa (but not Australia), and early evening (of the 10th) for South America
- May 18 Mercury is 26° west of the Sun
- Jun 4 Venus is at greatest elongation, 46° west of the Sun
- Jul 1 Latest sunrise
- Jul 4 Earth is 152,092,504 km from the Sun (aphelion) at 6 a.m. EST; latest onset of morning twilight
- Aug 8 A slight partial lunar eclipse for Australia from 3:22 to 5:19 a.m. EST, and early evening of August 7th in southern Africa
- Sep 13 Mercury stands 18° west of the Sun
- Sep 17 Mars is 0.1° above Mercury at dawn, but very low (use a telescope)
- Sep 20 Regulus is 0.6° right of Venus this morning
- Sep 23 Spring begins at the equinox, 6:02 a.m. EST
- Oct 6 Mars is just 0.2° above Venus
- Nov 30 Spica is 3.1° upper right of Mars this morning and tomorrow
- Dec 3 Earliest sunrise
- Dec 9 Earliest morning twilight
- Dec 22 Summer begins at the solstice, 2:28 a.m. EST



Computed by
Roger W. Sinnott,
Sky & Telescope Magazine

SKY & TELESCOPE
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Skygazer's Almanac 30°s 2017

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 2017,* 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 8, 2017.

First find "January" and "8" 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 8–9 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 8–9 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 8th occurs at 7:06 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 8:35 p.m. the Pleiades transit the meridian, meaning the famous star cluster is then highest in the sky. Moreover, the sky is almost fully dark, because evening twilight ends at 8:40 tonight when the Sun is 18° below the horizon.

At 9:44 p.m. the brilliant planet Venus, prominent in the western sky until now, finally sets. At 10:10 the Large Magellanic Cloud culminates (another way of saying it transits) just as Mars sets. Then the Orion Nebula (Messier 42) transits at 10:23, followed by the two brightest nighttime stars, Canopus and Sirius, at 11:11 and 11:33, respectively. Transit times of such celestial landmarks help us follow the march of constellations during the night.

The giant planet Jupiter rises at 11:50, so it will be well up toward dawn.

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 8–9 this is 7^{h} 13^{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 8th the Sun runs slow, transiting at 12:07 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

At 1:54 a.m. we see a small Moon symbol, and the legend at the chart's bottom indicates it is at gibbous phase, setting. (So we've had bright moonlight all night until now.) Then at 2:07 Antares, a star we usually associate with later seasons, climbs above the horizon. The ringed planet Saturn rises at 3:16.

The first hint of dawn — the start of morning twilight — comes at 3:34 a.m. Elusive Mercury rises soon thereafter, at 3:48, which is early enough before sunup that we might spot it when it climbs higher. The Sun finally peeks above the eastern horizon at 5:08 a.m. on the morning of January 9th.

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.

Local Mean Time Corrections

Adelaide	+16	Melbourne	+20
Brisbane	−13	Perth	+18
Canberra	+4	Sydney	−4
Cape Town	+46	Johannesburg	+8
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

Conjunctions (close pairings) of two planets are indicated by a ☌ symbol on the planets' event lines. Here, conjunctions are indicated when the planets appear closest in the sky (at appulse), not just when they have 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 April 7–8 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 and *Venus* never stray far outside the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves, and asterisks mark when their telescopic disks have the greatest illuminated extent in square arcseconds. In the case of Venus, this is also very nearly the date when it reaches greatest brilliancy, as on February 17th this year.

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 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 days in January, add 754 to the date. For instance, on January 8th we have 754 + 8 = 762, so the Julian day is 2,457,762.

Rising or Setting Corrections

	Declination (North or South)					
South Latitude	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

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.

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 order of decreasing 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 declinations of the Sun and planets are listed in *Sky & Telescope*.

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 that for the following date. Those in South America can shift it about halfway there.

Skygazer's Almanac 2017 is a supplement to *Sky & Telescope.*

For reprints (item SGA17S, $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. Send an e-mail to skyprodservice@skyandtelescope.com, or you can visit our online store at skyandtelescope.com.

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