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SKY & TELESCOPE

JULY 2015

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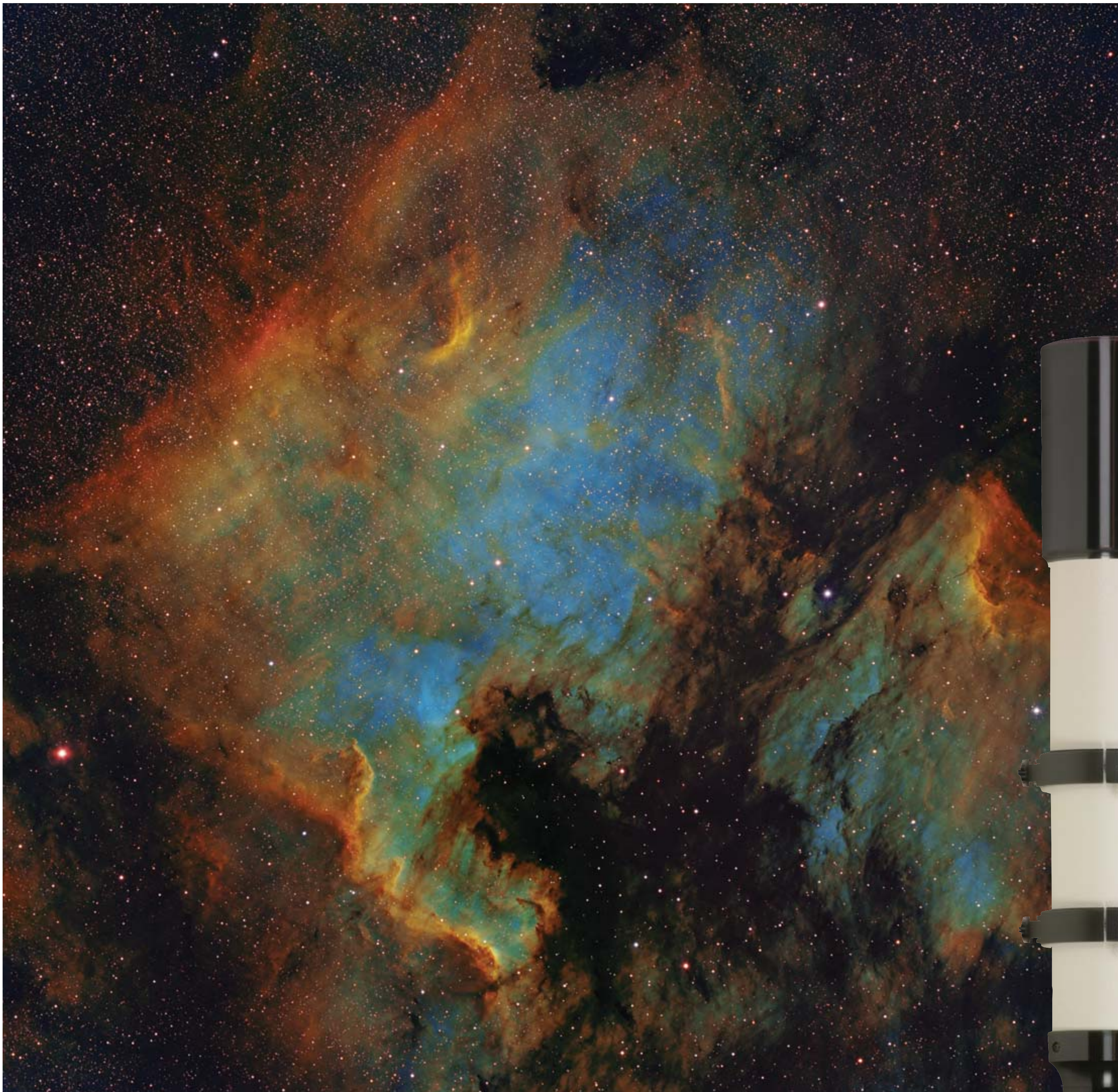
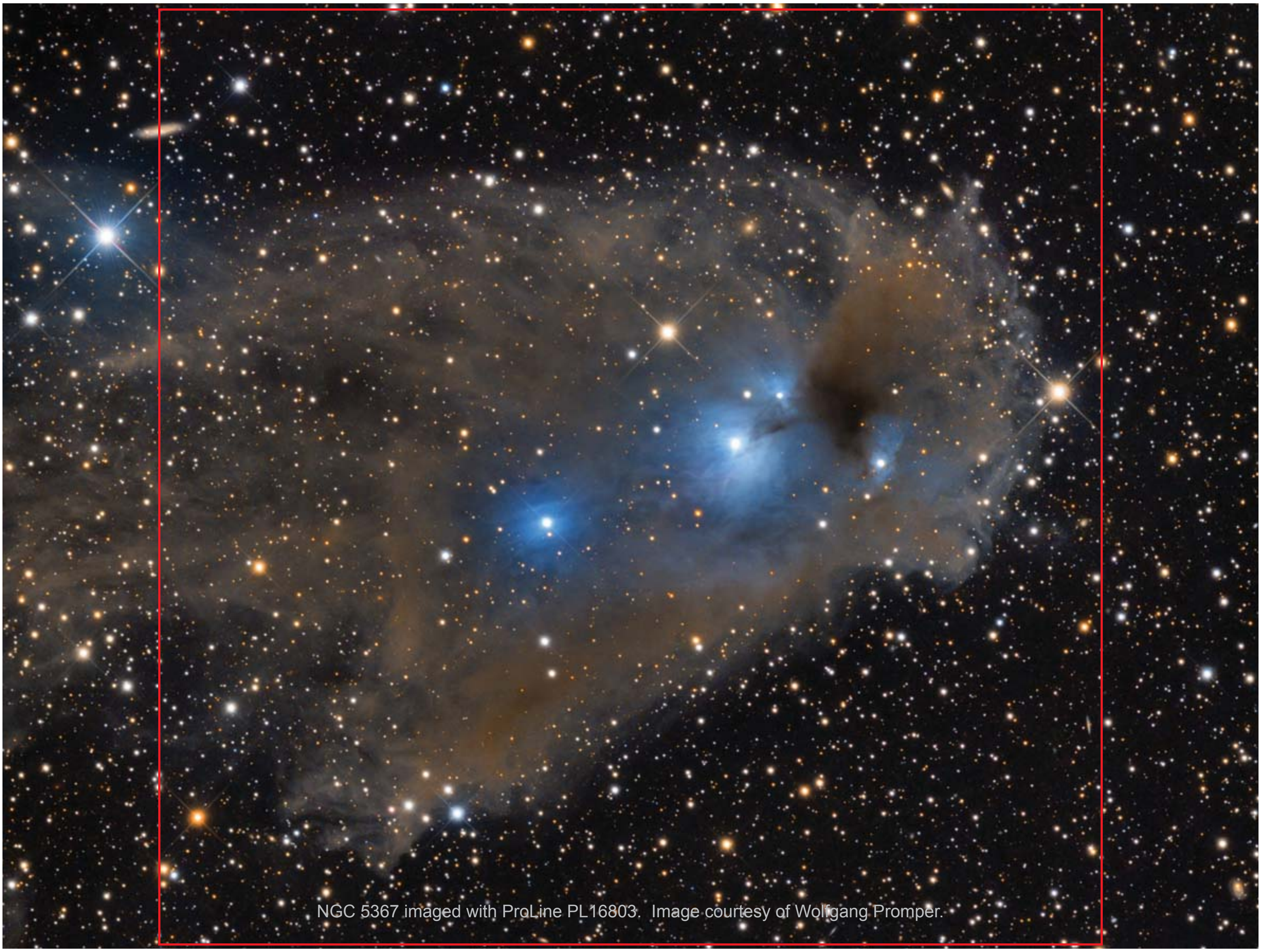


This 4.3° F.o.V. image of the North American and Pelican Nebulae was imaged by Gordon Haynes using the Tele Vue-NP127fli & FLI



NGC 5367 imaged with ProLine PL16803. Image courtesy of Wolfgang Promper.

Image above: Relative imaging area of the 50100 compared to the 16803 (red box)

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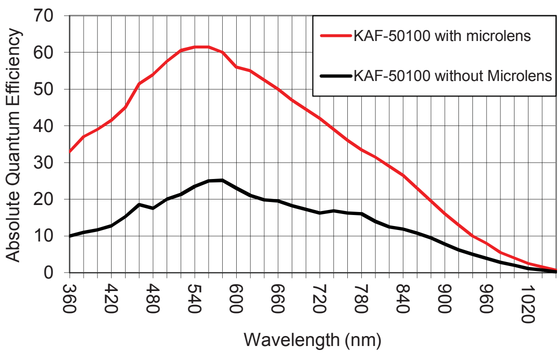

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July 2015 VOL. 130, NO. 1

On the cover: New Horizons will buzz Pluto in July, giving us our first up-close look at this frozen, chemically complex world.

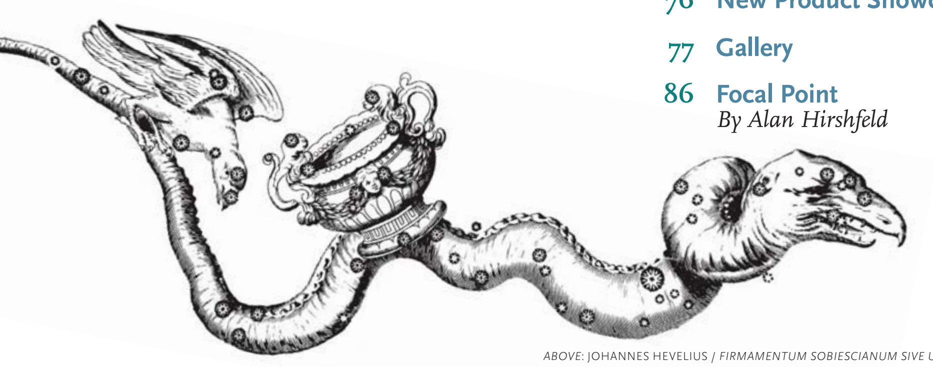
NASA / JHU APL / SWRI / STEVE GRIBBEN

FEATURES

OBSERVING JULY

S&T TEST REPORT

ALSO IN THIS ISSUE



ABOVE: JOHANNES HEVELIUS / *FIRMAMENTUM SOBIESCIANUM SIVE URANOGRAPHIA*

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July 2015 Digital Extra

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- **Prepping for Pluto**
  Look behind the scenes at preparations for the New Horizons Pluto flyby.
- **Follow Nova Sagittarii 2015 No. 2**
  Stay up-to-date with this unpredictable nova's appearance.
- **Milky Way's Ripples**
  Find out more (and see images of) the waves in our galaxy's disk.

Photo Gallery

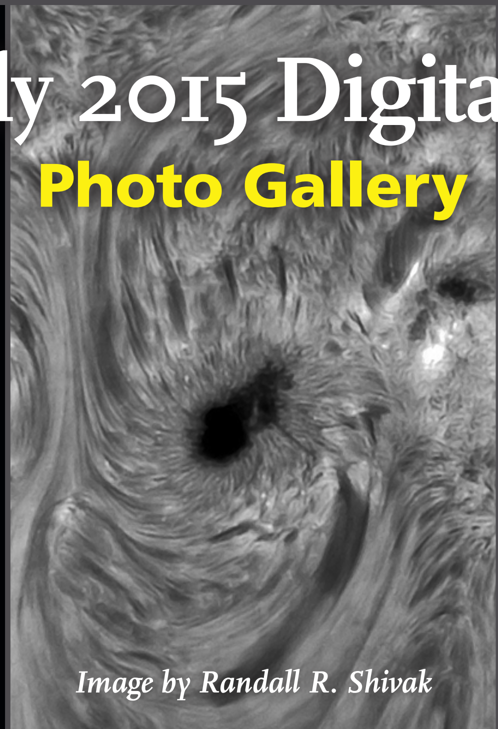

Image by Randall R. Shivak

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ONLINE PHOTO GALLERY

Eclipse chasers in icy Svalbard, Norway, lucked out with a bonus view of auroras on March 20th. Image by Kevin Morefield.

Peter Tyson
Spectrum

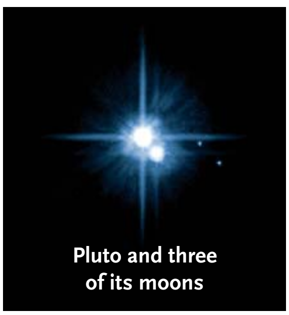
Remote Sensing

LATELY I'VE BEEN spending hours using Google Earth to explore the backcountry of Big Bend National Park in Texas. Every year or two I head out there to camp by myself in the park's 800,000 acres of rugged, silent desert — to realign my meridians, shall we say. Google Earth helps me plan targets of interest to reconnoiter.

Recently I discovered that Google had upped the resolution of its imagery of Big Bend just after my last trip in 2013. To my delight, I can now zoom down to a virtual 300 feet above the ground before the landscape begins to go out of focus. This is close enough to make out ephemeral springs, individual mesquite trees, old ranchers' walls. I can "climb" mountains or "walk" canyons I could never safely reach in person because of the steepness, the lack of water, and the often ferocious heat.

It brings a whole new meaning to armchair traveling. What's up that next arroyo? Let's just have a look. (Slide finger over iPad.) Is that a cave high on that bluff? (Spread two fingers apart to zoom in.) What's beyond that farthest ridge? (Pinch two fingers together to zoom out.) It feels like I have a drone at my bidding, ready anytime to help me indulge my passion for exploration.

It occurs to me that this is probably as close as I'll ever get to what it must feel like for Alan Stern, the principal investigator of the New Horizons mission to Pluto, and his team. They're using sophisticated technology to investigate the unknown. They're choosing targets to scrutinize once they get there. With each passing day leading up to the flyby in mid-July, they're zooming in closer and closer to their targets — Pluto and its five known moons.



Pluto and three of its moons

NASA / ESA / HUBBLE PLUTO COMPANION SEARCH TEAM

At its nearest approach on July 14th, when the spacecraft will pass within 8,000 miles of the surface, its sharpest-seeing camera will resolve surface features down to a quarter mile per pixel. That's a far cry from the resolution I see of Big Bend. But we're talking 3 billion miles away, folks, and a planet that, up close anyway, *no one has ever seen before*.

My personal proxy for planetary exploration — Google Earth at Big Bend — is fun for me. But it pales next to what Stern and his colleagues have at *their* fingertips with New Horizons. Happily for the rest of us, they will be sharing what they find every step of the way.

If you haven't seen them already, check out the monthly blog posts on New Horizons that Stern is writing through August for the *S&T* website. And throw yourself into the particulars of the mission with Emily Lakdawalla's cover story on page 20. Both will help you prepare for what promises to be quite a show. ✦

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Here at the geographic South Pole, we have the biggest site for astrophysics in Antarctica. We've got the South Pole Telescope, IceCube Neutrino Observatory, BICEP3 (which followed BICEP1 and BICEP2), and the SPUD/Keck Array.

What we *don't* have is a subscription to *Sky & Telescope* — with recent budget cuts, all our magazine subscriptions got canceled. Therefore, last year I wrote to *S&T* and asked for some old issues. (Since we only get mail from November through February, when the station is accessible from the outside world, even old magazines are new to us.)

As the photo shows (taken when the ambient temperature was −65°F), they've arrived. Thanks so much!

Robert Schwarz
South Pole Station, Antarctica

ROBERT SCHWARZ

Astronomers at Amundsen–Scott South Pole Station can now catch up on celestial happenings with back issues of *Sky & Telescope*.

Seeing Red

Here's a minor issue regarding the "Phenomena of Jupiter's Moons" printed in most issues — at least that's what I remember it being called (I'm composing this comment in the dark while simultaneously viewing the magazine with a red headlamp on). This section's title and dates are printed in red, and when viewed with the headlamp they become invisible! I don't typically consider dark-adapting before taking on Jupiter, but I do often check this tabulation during the night before Jupiter comes up. Seen with just the red light from my headlamp, the listing can be quite baffling.

I wear out every monthly issue from use because you have such a great magazine, but would you consider fixing those "invisible" labels?

Riley Friedrich
West Springfield, Massachusetts

Editor's note: *Great feedback! Jupiter in July is sinking into the sunset, but when we resume the table we'll adjust the color to be more readable under red light.*

Musings on Gravitational Lensing

I enjoyed Govert Schilling's article "Hubble Goes the Distance" (*S&T:* Jan. 2015, p. 20). It did raise a few questions in my mind, though. I can understand how a large cluster of galaxies such as Abell 2744 can act as a gravitational lens, albeit a very crude, irregular lens (as I might grind!). Such a lens would have many individual focal points that, I assume, result in the arcs, lines, and "blobs" highlighted on page 23. So how could such an imperfect lens magnify or brighten a distant galaxy behind it? The light of a distant galaxy would be focused in many places because of the different ray paths. Also, it seems to me that the distant, lensed galaxy might appear *dimmer* than it actually is because its light is spread out over a larger area (for example, as pictured on page 26). Finally, is it possible to deconstruct the ray paths somehow to obtain a clearer picture of the distant galaxy?

Philip Petersen
League City, Texas

Govert Schilling responds: *The distant background source/galaxy is indeed "magnified" over a larger (sometimes smaller) area on the sky as seen from Earth due to an intervening gravitational lens. However, in the process the source's "surface brightness" is conserved — the number of photons seen per square arcsecond of sky does not change. So if the source is magnified by some factor* M*, then its flux becomes* M *times greater (that is, we see more total light coming from it) but not* M *times brighter per unit of angular area. Any point of the source has exactly the same surface brightness before and after lensing.*

Regarding your second question about deconstructing the ray paths, indeed observers have been doing this for several decades, leading to increased resolution of the lensed source. One complication is that, in general,

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the magnification varies across the lensed images, leading to a varying resolution of the source. However, this effect is quantifiable from the model of the gravitational lens.

Giant Telescopes

Robert Zimmerman's update on the progress of the next big scopes (*S&T:* Jan. 2015, p. 60) took me back to my youth, when I learned about the flawed and successful castings of the primary-mirror blank for Palomar's 5-meter Hale telescope. Back then *Life* magazine and various newspapers, as well as *S&T,* had frequent updates on the progress of that scope. These days *S&T* is about the only source of any news on such projects, aside from googling the projects' websites.

Terry Herlihy
Chicago, Illinois

In Zimmerman's discussion of Keck Observatory, he states that its interferometer was not fully operational and that the 1.8-m outrigger telescopes were necessary to properly combine the images from the two 10-m telescopes. While it's correct that the outriggers were never installed, the interferometer mode combining Keck's twin 10-m telescopes was operational for years. The astronomical community used this capability to explore many areas of astrophysics, among them active galactic nuclei and disks around young stars.

NASA's primary goal in developing and operating the Keck Interferometer was the characterization of faint dust disks around nearby main-sequence stars. Only after this goal had been accomplished did the agency withdraw the funding that led to the closure of this powerful scientific tool.

Rachel Akeson
Deputy Director
NASA Exoplanet Science Institute
Pasadena, California

Peter Wizinowich
Optical Systems Manager
W. M. Keck Observatory
Mauna Kea, Hawai'i

Editor's note: *The intent was to point out that, while the interferometer was successful, it did not become a primary research tool because the 10-m reflectors were more valuable when used individually. In retrospect, this distinction would have been clearer by using the phrase "not operational full-time" instead of "not fully operational."*

For the Record

- *April issue, page 65: SOFIA's operations contract is with Universities Space Research Association (USRA), not Association of Universities for Research in Astronomy (AURA).*
- *May issue, page 21: Most of Harvard College Observatory's photographic plates are 8 by 10 inches (not 8 by 14 inches) in size.*
- *May issue, page 30: Claudius Ptolemy championed a geocentric (not heliocentric) model of the solar system.*
- *May issue, page 40: In the graph of light sensitivity versus wavelength, the black curve represents human circadian sensitivity to light, not our eyes' scotopic (dark-adapted) response, which peaks at 507 nm.*

75, 50 & 25 Years Ago

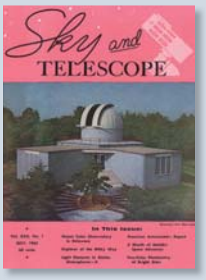
Roger W. Sinnott

July 1940

The Magical Schmidt "This peculiar hybrid telescope, half reflector, half refractor, will cover a region of the sky 20 degrees in diameter, the stars appearing in all parts of the photograph as nice round dots. . . . With a focal ratio [of] f/1 . . . , nebulae can be photographed in about 1/10 of the time required by the fastest astronomical lenses and mirrors previously available. . . . To date, about 20 Schmidt cameras have been completed, two thirds of them in the United States. For the most part, they have been made by courageous, patient, amateur telescope makers. . . .

"What kind of work is being done with Schmidt cameras? Dr. Fritz Zwicky . . . has used the 18-inch Schmidt on Mt. Palomar with notable success to discover supernovae . . . ."

Charles H. Smiley (Brown University) was explaining Bernhard Schmidt's great 1931 invention. In those days the Schmidt camera was just as exciting for astronomical imaging as the CCD would be in the 1990s.

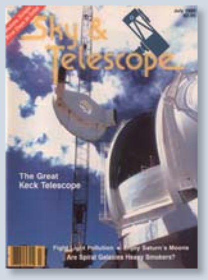


July 1965

Star Colors "Astronomers have long agreed on the need for more accurate apparent magnitudes of the naked-eye stars. But . . . until fairly recently the best available data were still the visual measurements made some 70 years ago at Harvard and Potsdam observatories. . . . Furthermore, astronomers felt a growing need for measurements of star colors as well as brightnesses. . . .

"Beginning on page 25, we present photoelectric measurements of more than 1,300 bright stars in five broad wavelength bands — U, B, V, R, and I. The stars selected are those brighter than 5.0 on the Harvard visual system. The catalogue is complete to this limit for all of the sky north of declination –30°. . . ."

Braulio Iriarte, Harold L. Johnson, and two colleagues told how they made their "Arizona-Tonantzintla Catalogue." S&T's *editors deemed this observational effort enough of a milestone that they published the entire list and offered it as a reprint for years thereafter.*



July 1990

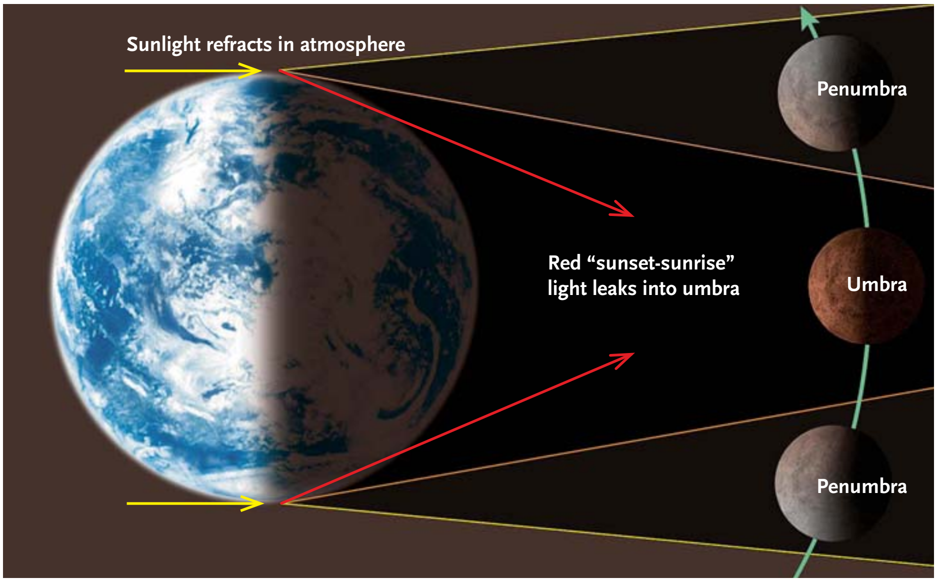
No KBOs? "As astronomers understand it, comets originate in the Oort cloud, a halo of trillions of comet nuclei enveloping the solar system out to a distance of 2 light-years. . . . Theorists now suspect there also exists a closer reservoir of comets — the so-called Kuiper belt — a ring of bodies that may begin just beyond the orbit of Neptune. . . .

"An attempt to photograph possible Kuiper-belt comets has come up empty. Harold F. Levison (U. S. Naval Observatory) and Martin J. Duncan (Queen's University, Ontario, Canada) . . . hope to receive observing time for a more sensitive search using the 4-meter reflector at Kitt Peak National Observatory. This would allow them to detect Chiron-size bodies (about 180 km) out to 60 a.u. . . ."

Other teams soon joined the effort, with stunning success. Today 1,650 various categories of Kuiper Belt or trans-Neptunian objects are known, the largest being Pluto and Eris.

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

ECLIPSES | Not-Quite-Total Lunar Eclipse?



A little sunlight refracts through our atmosphere and into Earth's umbra, coloring the lunar disk during totality. The atmosphere also makes the umbra appear 1% to 2% larger than it should be. (Not to scale.)

An intriguing eclipse of the Moon on April 4th (*S&T:* Apr. 2015, p. 50) delighted observers from western North America to Australia and the Far East. What makes it intriguing is whether this was a "barely total" eclipse, as had been almost universally predicted — or "barely partial," with a hair-thin rim of sunlit lunar surface remaining just outside the umbra of Earth's shadow. Many observing reports received by *Sky & Telescope* suggest it was the latter. But the most detailed mathematical analysis suggests that it was probably just barely total.

The core issue is that our atmosphere enlarges Earth's shadow by a not-quite-exact amount. The U.S. Naval Observatory, which routinely adds 2% to the umbra's "geometric" radius to account for this effect, predicted 12.2 minutes of totality for April's eclipse. The French national almanac office and eclipse guru Fred Espenak instead use the "Danjon method," and both predicted just 4.7 minutes of totality. However, Chicago amateur Curt Renz points out that neither method includes Earth's oblateness, which is about 0.3%. This tiny shortfall in our planet's polar radius, normally insignificant, becomes a factor in such a borderline case.

Eclipse specialist David Herald conducted a full analysis that includes both oblateness and the best new information about the size of the umbra from a massive study of lunar eclipse crater timings he recently undertook with Roger Sinnott (*S&T:* June 2015, p. 28). Herald concludes that April's lunar eclipse had a magnitude (a measure of its completeness) of 1.002. In other words, by the numbers, it was total by just one part in 500, putting the theoretical edge of the umbra beyond the limb of the Moon by a mere 4.6 arcseconds at maximum eclipse. But the result remains uncertain, because Herald and Sinnott find that the atmosphere's effective eclipsing layer can differ in thickness by a few kilometers for reasons unknown.

■ **J. KELLY BEATTY & ALAN MACROBERT**

GALAXIES | New Dwarfs near Milky Way

Two teams of astronomers went panning for gold in the Southern Hemisphere sky — and both struck it rich. Between the two, the teams discovered nine candidate dwarf galaxies near the Milky Way. Future observations will determine whether these are really dwarf galaxies or merely globular clusters.

The teams both used data from the Dark Energy Survey, an optical and near-infrared project at Cerro Tololo Inter-American Observatory in Chile. Combing through the first year of images taken by the Dark Energy Camera, a team led by Keith Bechtol (University of Chicago) found eight clusters of stars well outside the boundaries of the Milky Way; the second team, led by Sergey Koposov (University of Cambridge, UK), found the same eight dwarf candidates, plus one more near a gap in the detector.

The dwarf candidates range in size from 120 to 1,300 light-years across. The nearest, Reticulum 2 at a distance of almost 100,000 light-years, is the strongest candidate. Even though it's small (200 light-years across), it's elongated, so it's less likely to be a globular cluster posing as a dwarf galaxy. The second most-likely dwarf galaxy, Eridanus 2, is also stretched out and lies the farthest away at a whopping distance of 1.2 million light-years.

Astronomers will need to measure the total mass of each object to determine whether they are all really dwarf galaxies. Unlike in globular clusters, most of the mass in galaxies resides in dark matter. The teams will collect spectra and measure the stars' velocities and bulk motions to determine their hosts' mass and whether these clusters of stars are moving as satellites of the Milky Way or not.

■ **MONICA YOUNG**

MARS | MAVEN Spots Dust Cloud, Aurora

NASA's bat-winged MAVEN spacecraft has detected dust high in the Red Planet's atmosphere and auroras across its northern hemisphere, team members announced in March at the Lunar and Planetary Science Conference.

MAVEN found the dust indirectly, by what grains do to the spacecraft when they strike it, explains mission principal investigator Bruce Jakosky (University of Colorado, Boulder). When a speedy dust mote hits hard enough to vaporize and ionize its bits, the aftermath affects the spacecraft's electrical potential and creates a milliseconds-long signature that the Langmuir Probe and Waves (LPW) instrument detects.

LPW has "seen" the dust since turning on last fall. But LPW doesn't encounter it everywhere. MAVEN's orbit precesses around Mars, meaning that over time the spacecraft's closest point to the surface moves around the planet. LPW detected dust near local dawn and dusk, but not at night. "That's an important clue, but we haven't yet figured out how to interpret it," Jakosky says.

The dust is generally concentrated between 150 and 500 kilometers (90 and 300 miles) above the surface; it also occasionally shows up as high as 1,000 km. It's hard to explain how dust would get to this part of the atmosphere. Raising it up from far below doesn't make sense, physics-wise. Off-planet alternatives include dust from Mars's two moons, Phobos and Deimos, or dust carried by the solar wind. It might also be comet debris the planet picks up along its orbit, although it seems unrelated to Comet Siding Spring, which brushed past Mars in October.

The low point of MAVEN's orbit has now swept around to the planet's dayside. If LPW detects dust during local daytime, too, that will help scientists narrow in on where the dust is coming from.

MAVEN's second discovery, the aurora, looks different from its counterpart on Earth. On our planet, auroras happen when the solar wind pours charged particles down the magnetic-field highways near the poles and into the atmosphere. But Mars doesn't have a global magnetic field; instead, it has *remanent fields*, ghost fields locked into the surface when molten, magnetizable rocks solidified during the brief era that the planet did have a global field, more than 4 billion years ago.

The European Mars Express orbiter detected an aurora in the southern hemisphere in 2005, where these magnetic anomalies exist. MAVEN has now seen an aurora across much of the northern hemisphere, too. The northern aurora persisted for five days. MAVEN didn't observe the whole hemisphere simultaneously — only a region about the size of Africa — so the team doesn't know for sure that the aurora covered the whole northern nightside, but it's likely.

The aurora might have spread so far because there are essentially no magnetic fields in the northern hemisphere: with nothing to channel the energetic particles, they just dump into the atmosphere. The team will need further observations to confirm this scenario.

The electrons that created the northern aurora dove deep into Mars's atmosphere, 50 to 100 km above the surface. That's deeper than those spotted in the south, which made it to 120 km or so. The northern electrons penetrated so much deeper because of their high energies: tens of thousands of electron volts, ten times higher than the ones that triggered the southern aurora. They seem to have come from a solar temper tantrum that happened around that time.

■ **CAMILLE M. CARLISLE**

IN BRIEF

Magnetosphere Mission Launches. With the goal of better understanding Earth's space weather environment, NASA's Magnetospheric Multiscale (MMS) mission launched on March 12th from Cape Canaveral. MMS is a quartet of four, 3.5-meter-wide (11-foot-wide) octagons each decked out with 11 instruments. With a nominal 2-year mission, the quartet will fly 10 km (6.2 miles) apart from one another in a tetrahedron formation, with positions accurate to 100 meters. The mission aims to provide a high-resolution, 3D view of magnetic reconnection in Earth's magnetosphere, with measurements taken 100 times faster than before. Reconnection is essentially a magnetic explosion, the rapid-fire splicing of magnetic field lines that releases in energy the equivalent of billions of megatons of TNT. When Earth's field lines reconnect, they can hurl charged particles into our atmosphere, spurring auroras. Reconnection is also the process by which the Sun unleashes massive flares and that causes so-called *sawtooth crashes*, an active topic of investigation for plasma physicists trying to harness nuclear fusion in the lab. Find videos explaining reconnection and the mission at http://is.gd/mmslaunch.

■ **CAMILLE M. CARLISLE**

NASA Selects Asteroid Mission Concept. NASA has opted to retrieve a boulder from an asteroid for its Asteroid Redirect Mission (*S&T*: Oct. 2014, p. 16), tentatively slated to launch December 2020. The boulder will be up to 4 meters wide and brought back to lunar orbit for two astronauts to have a look-see mid-decade. Sans launch vehicle, the total mission cost is $1.25 billion. This cost is slightly more than that of Option A (bagging a small asteroid and toting it home). But the boulder option provides more time to assess the asteroid during approach, more targets (such as boulders) to pick from, and multiple opportunities for the actual pickup. The mission will also develop capabilities for human space exploration and defense, including the *gravity tractor technique*, in which the spacecraft will attempt to redirect the asteroid's orbit with its own gravitational influence.

■ **MONICA YOUNG**

MILKY WAY | Cepheids Map Galaxy & Beyond

Astronomers are using a famous class of pulsating star to map out hidden reaches of the Milky Way.

Classical Cepheid variables are aging, massive stars trying to avoid gravitational collapse. Having run out of hydrogen to fuse in their cores, they struggle to burn shells of helium instead, puffing up and deflating at a rate directly tied to their intrinsic luminosity.

In a study last year, Michael Feast (University of Cape Town, South Africa) and colleagues found five "classical" Cepheids in the outer reaches of the Milky Way's disk, between 42,000 and 72,000 light-years from the galaxy's center. Since classical Cepheids are massive and young, they typically appear in spiral arms. Feast's team suggested that these Cepheids lie in an outer arm of molecular gas, which would have to flare to account for the Cepheids' spread above and below the galactic plane.

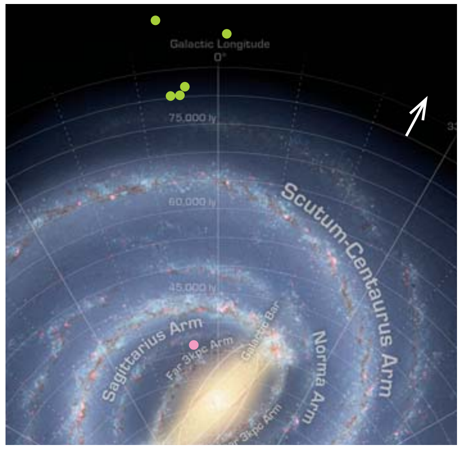
Two recent studies build off these results. In the first, István Dékány (Millennium Institute of Astrophysics, Chile) and colleagues announced the discovery of two Cepheids 37,000 light-years from Earth and 11,000 light-years from our galaxy's center. The pair is remarkably tight, separated by only 3 light-years, and both are between 45 million and 51 million years old, the team reports in the January 20th *Astrophysical Journal Letters*.

These Cepheids were likely born in the same (as-yet unseen) star cluster in the "Far 3-kiloparsec Arm," a spiral arm thought to encircle the far side of the galaxy's star-packed bulge. The team will need deeper observations to confirm.

Another study appearing in *Astrophysical Journal Letters* reports the detection of four other Cepheids in data from the VISTA Variables in Vía Láctea (VVV) survey, being undertaken at Paranal Observatory in Chile.

But the pulsing stars found by Sukanya Chakrabarti (Rochester Institute of Technology) and colleagues appear to be almost 300,000 light-years from the Sun — far beyond the Milky Way's disk, which is roughly 100,000 light-years across.

Six years ago, Chakrabarti predicted the existence of a dwarf galaxy at this location, to explain why the outer part of the Milky Way's gas disk looks perturbed. She and Leo Blitz (University of California, Berkeley) ran simulations that showed a dwarf 1⁄100 the Milky Way's mass could have passed through our galaxy and created ripples. The dwarf would have escaped detection until now because it's dim and lies right behind the galactic plane from our perspective.



NASA / JPL-CALTECH

Three studies detected Cepheids in and around the Milky Way: Dékány *et al.* (pink), Chakrabarti *et al.* (arrow, since they lie far off the galactic disk), and Feast *et al.* (green). Distances are measured from Earth (below bulge, not shown).

It's still possible that the variables Chakrabarti's team detected are a dimmer, rarer type of Cepheid. If so, they're only 160,000 light-years away and don't match the dwarf galaxy's predicted location. Spectroscopy would cinch the matter, but it will be a challenge for these faint stars. If the team can get radial velocity observations, it can see whether the clump of Cepheids moves together and in the way predicted for the dwarf's passage through the Milky Way.

■ MONICA YOUNG

IN BRIEF

Milky Way Has Ripples. Astronomers have detected four undulations in our galaxy's disk. Previous observations had revealed clumps in the density of stars at the disk's outermost edge, part of two structures now called the Monoceros Ring and, beyond it, the Triangulum Andromeda Stream. But a second look at Sloan Digital Sky Survey (SDSS) observations suggests that the disk actually has four ripples, with two more lying between us and the Monoceros Ring. The closest is about 6,000 light-years out from the Sun, with each subsequent structure lying roughly 6,000 light-years beyond the previous one. The lumps vary between being above and below the disk, like the ripples in corrugated cardboard. There also appears to be a vertical ripple in the disk, Yan Xu (National Astronomical Observatories of China) and colleagues report in the March 10th *Astrophysical Journal*. The two types of ripples look like the waves a dwarf galaxy would create if it passed through the Milky Way's disk, according to computer simulations by various teams. More info at http://is.gd/mwripples.

■ CAMILLE M. CARLISLE

Stars Have Out-of-plane Experience. The Milky Way Galaxy is a thin spiral, with 85% of its stars in a disk only 3,000 light-years thick. A fatter, sparser disk of older stars extends up to 16,000 light-years above and below the galactic plane. Young stars generally only occupy the thin disk. But two newly discovered clusters of stars, still embedded in their natal clouds of dust and gas, are floating 16,000 light-years above the pancake-shaped disk, Denilso Camargo (Military School of Porto Alegre, Brazil) and colleagues report in the April 1st *Monthly Notices of the Royal Astronomical Society*. The star clusters themselves are only 2 million years old. The cloud containing them crossed the thin disk between 45 and 50 million years ago, an event that likely caused the clouds to condense and form stars. The clusters will cross the disk again in another 50 million years.

■ MONICA YOUNG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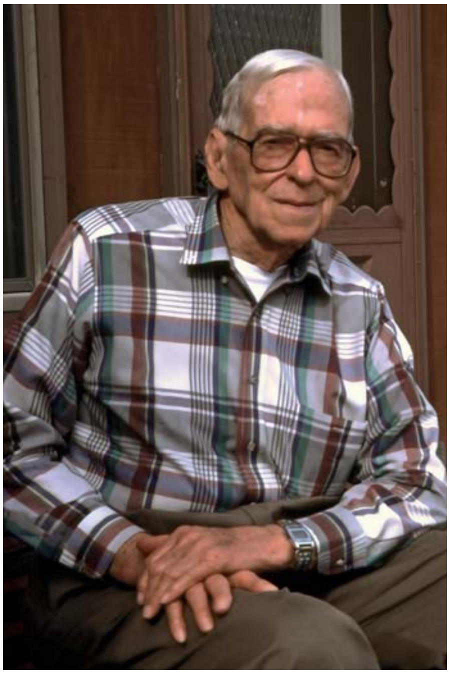
OBIT | Walter H. Haas (1917–2015)

With Walter Haas's passing April 6th, amateur astronomy lost a pioneer who excelled both as an individual observer and as an organizer. He died at age 85 of natural causes in Las Cruces, New Mexico, where he had lived for decades.


S&T: DENNIS DI CICCO

Walter Haas relaxes at a gathering of amateur observers in 2000.

Haas showed an early interest in astronomy that blossomed after spending a summer assisting the renowned planetary observer William H. Pickering. At a time when professional astronomers held little regard for amateur observers beyond their meteor and variable-star reports, Haas changed the paradigm. He became well known as a meticulous and objective observer. Then, on March 1, 1947, while teaching mathematics at New Mexico State University, Haas dispatched a self-produced six-page newsletter titled *The Strolling Astronomer*. It was subtitled "Association of Lunar and Planetary Observers" (which he thereby created) and branded with "Volume 1, Number 1."

The breadth and influence of ALPO flourished under Haas's leadership. Within six years, the association boasted 350 members worldwide. More critically, the heightened visibility of amateur lunar and planetary observations paved the way for enduring professional-amateur collaborations. Haas retired as ALPO's executive director in 1985 but continued to serve on its board. He also kept observing with his trusty 12½-inch Newtonian reflector until being sidelined by a broken hip in 2004.

■ **J. KELLY BEATTY**

NOVAE | Naked-eye Nova in the Teapot

On March 15th, amateur nova hunter John Seach in Australia spotted a new 6th-magnitude star shining in the Sagittarius Teapot in images from his DSLR patrol camera. Amateurs worldwide watched before dawn in the following week as the nova climbed to about magnitude 4.4. That made it the brightest nova in Sagittarius since at least 1898, and the brightest anywhere in the sky since Nova Centauri 2013 peaked at 3.3.

"Nova Sagittarii 2015 No. 2" displayed the normal spectrum of an iron-rich classical nova. But it didn't act normal. It quickly dropped back to 6th magnitude, then surged twice in the next month to magnitude 4.5 to 5. If it's a "slow nova," as seems likely, it may not truly peak until this summer at possibly 3rd magnitude. That would disrupt the Teapot's appearance! See for yourself; get charts, more information, and links to an up-to-date light curve at **http://is.gd/sagnova20152**.

■ **ALAN MACROBERT**

IN BRIEF

Monster Black Hole in Early Universe. Astronomers have discovered one of the brightest quasars in the early universe: SDSS J0100+2802, powered by a supermassive black hole of 12 or 13 billion solar masses. Xue-Bing Wu (Peking University, China) and colleagues found the quasar in an extensive survey of quasars in the early universe and report the detection in the February 26th *Nature*. The quasar has a redshift of 6.3, meaning that its light left it 12.8 billion years ago. J0100+2802 is one of a handful of billion-solar-mass black holes seen in the universe's first few hundred million years. To have grown so large so fast, the black hole must have been stuffing itself with gas at close to its maximum accretion rate for most of its existence — but the outward push of radiation from the gas being swallowed should have cut off the black hole's accretion after 10 million to 100 million years. J0100+2802 thus highlights an outstanding mystery in astrophysics: how did supermassive black holes grow to be so large so fast?

■ **CAMILLE M. CARLISLE**

Hubble Spots a Lensed Supernova. For the first time, astronomers watched as a supernova's light bent around a massive galaxy on its way to Earth. Line up two objects just right, one in front of the other, and the gravity from the foreground object splits light from the background one into four separate, magnified images. Until now, such *Einstein crosses* have always involved background quasars. But Patrick Kelly (University of California, Berkeley) and colleagues report in the March 6th *Science* that they've finally seen a supernova cross. Additional observations after the paper's publication show that three of the four images have brightened over about a month and a half in the supernova's time frame; the fourth image remains too faint to accurately monitor changes. The gradual increase suggests that the supernova is the death of a massive star throwing off its outer layers. Although astronomers hope that they can use the event to measure cosmic expansion, that would require knowing to within 1% how the density changes across the cluster in which the lensing galaxy sits (an ugly problem) *and* measuring the difference in the four images' arrival times to at least 5% precision. ✦

■ **MONICA YOUNG**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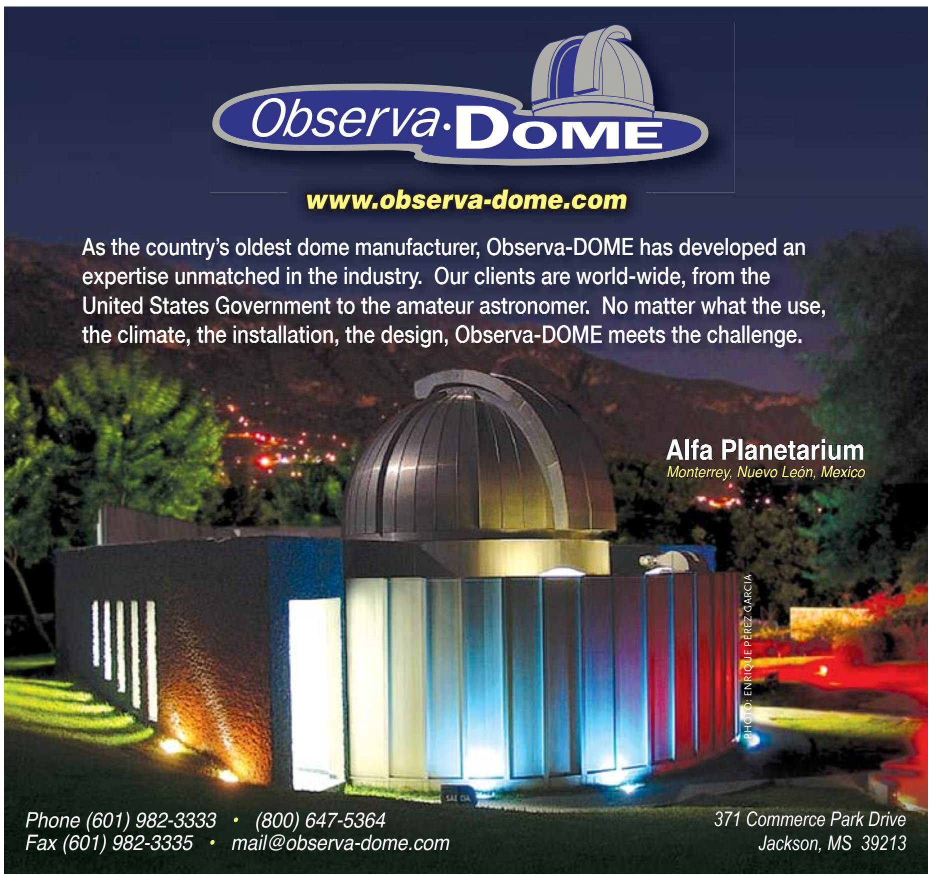
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Pluto at Last

After a 9½-year flight, NASA's New Horizons spacecraft is making a long-awaited visit to Pluto and its moons.

Emily Lakdawalla

Beyond any planet that's ever been explored before lies the frozen "Third Zone" of the solar system: the Kuiper Belt. It's dark, cold, and sluggish, a place so remote that its small, icy inhabitants take hundreds of years to complete a single orbit of the distant, dim Sun. We've only seen a handful of Kuiper Belt objects from Earth — and none of those as anything more than vague smudges. But after nearly a decade of interplanetary travel, NASA's New Horizons spacecraft is about to change the status quo. Now we're about to see, up close, the region's most famous member: Pluto.

New Horizons is not the first spacecraft to traverse this region of space, but it will be the first to study any of its denizens. The spacecraft follows a trail blazed by four others — twin pairs of Pioneers and Voyagers — that are well on their way to escaping our solar system entirely. Yet New Horizons is "less" in every way than its predecessors: a smaller vehicle, smaller data volume, smaller instrument package, and a price tag only 40% that of the Voyager mission.

NASA

FAST START Propelled by an Atlas V rocket, New Horizons left Earth on January 19, 2006, and attained 58,537 km (36,373 miles) per hour — so fast that the spacecraft reached the Moon's orbit only 9 hours after its launch.

Nor will it be the first craft to study a dwarf planet. That distinction goes to Dawn, which started orbiting asteroid 1 Ceres in March and has settled in for a year-long mission there (*S&T:* Apr. 2015, p. 20).

For New Horizons, orbiting Pluto will be impossible — like the Pioneers and Voyagers, New Horizons is a flyby mission. At 11:50 Universal Time on July 14, 2015, it will zip past Pluto at nearly 14 kilometers (8.6 miles) per second, never to return. And although it will gather observations throughout most of 2015, all of its highest-priority reconnaissance is squeezed into a 48-hour period around closest approach. How much can such a constrained spacecraft accomplish in only two days of work? Will it be worth the 9½-year wait?

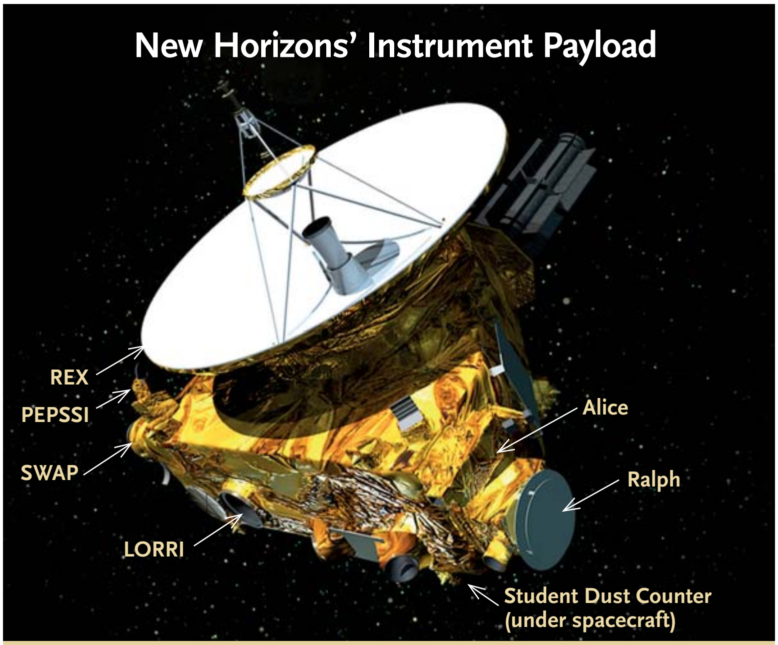
A Challenging Assignment

The mission's highest-priority goals are to map the global geology of Pluto and its moon Charon, to determine their surface composition, and to study Pluto's wispy atmosphere. The target system's configuration presents several challenges that make New Horizons' task harder than it might otherwise be. For one thing, Pluto's spin axis is tilted sideways, much like that of Uranus. So, just as Voyager 2 saw only half of the planet

LONG TIME COMING No one knows what NASA's New Horizons spacecraft will find when it views Pluto and its moons up close for the first time, but the July 14th flyby is certain to be exciting.

S&T: CASEY REED

New Horizons' Instrument Payload



NASA / JHU-APL

Ralph MVIC (Multicolor Visible Imaging Camera): Combines medium-resolution panchromatic imager and moderate-resolution color imaging through blue, red, methane, and near-infrared filters.

Ralph LEISA (Linear Etalon Imaging Spectral Array): Near-infrared imaging and spectroscopy; will provide composition and thermal maps.

Alice: Ultraviolet imaging spectrometer; will analyze composition, structure, and escape rate of Pluto's atmosphere and will look for an atmosphere around Charon.

REX (Radio Science Experiment): Uses radio transmissions passing near limbs of Pluto and Charon to measure atmospheric pressure and temperature; also serves as a passive radiometer for studies of surface properties. Careful tracking of Doppler shifts during radio transmissions will refine the masses of Pluto and Charon.

LORRI (Long Range Reconnaissance Imager): Telescopic panchromatic camera with 2.63-m focal length; will obtain images at long distances, search for rings and moonlets, record Pluto's farside, and provide high-resolution geologic data on the hemisphere in sunlight.

SWAP (Solar Wind Around Pluto): Solar wind and plasma spectrometer; will measure the escape rate of atmospheric gases and observe Pluto's interaction with the solar wind.

PEPSSI (Pluto Energetic Particle Spectrometer Science Investigation): Hockey-puck-size time-of-flight mass spectrometer; will measure the composition and density of ions escaping from Pluto's atmosphere.

SDC (Venetia Burney Student Dust Counter): Built and operated by students at University of Colorado; measures interplanetary dust that strikes New Horizons during its long voyage.

during its 1986 flyby of Uranus, New Horizons will stare at one of Pluto's poles throughout approach, with only foreshortened views of the southern hemisphere. The south pole will be hidden in winter darkness.

Pluto and Charon are locked in a mutual spin-orbit resonance with each other and rotate very slowly, only once in 6.4 days. We'll only see one hemisphere of each world sunlit as the spacecraft races past them. The opposite hemispheres will be well lit 3.2 days earlier, when New Horizons is still millions of kilometers away and only barely able to discern detail on their surfaces.

Nor will the spacecraft get a chance to pass close by all of Pluto's other moons. When New Horizons was being designed and built, Pluto had only one known moon: Charon. Then, a year before launch, Hubble Space Telescope photos revealed two smaller siblings orbiting farther out: Nix and Hydra. The discovery of Kerberos (between Nix and Hydra) followed in 2011, and Styx (inside the orbit of Nix) in 2012. The science team has prioritized a single one, Nix, for detailed study; the rest will be relegated to distant views.

The smaller moons have presented a problem to mission planners since their discovery. All five moons experience micrometeoroid impacts relatively often, and the little ones lack sufficient gravity to hang on to the dust raised by each strike. This dust might form tenuous rings that share the little moons' orbits or, potentially, have spread beyond them. As the count of Pluto's companions swelled from one to five, mission planners confronted the terrifying possibility that New Horizons might smash into a sand-grain-size particle just as it crossed the moons' shared orbital plane — and be lost — before it had a chance to return its precious data.

Fortunately, careful analysis revealed that the location in the Pluto system most likely to be dust-free is along Charon's orbit — and this location in the moons' orbital plane is exactly the spot where New Horizons had already been targeted to traverse through the system. Charon probably sweeps that portion of space clean of dust with every revolution around Pluto.

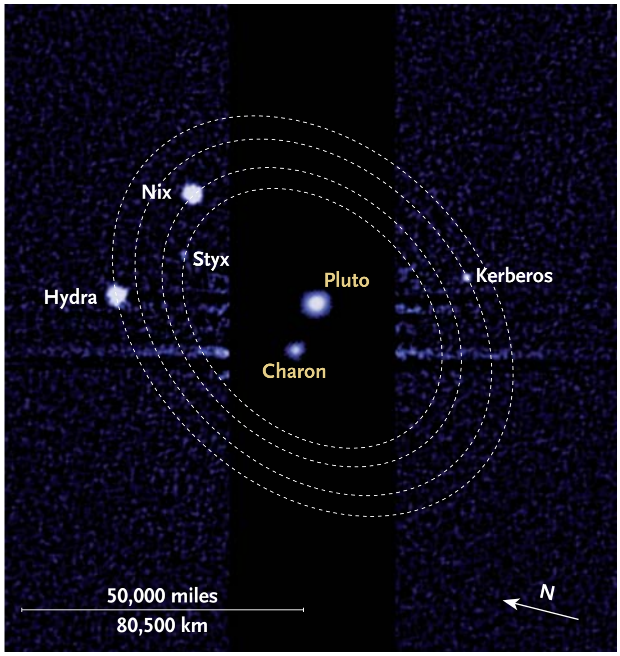
Nonetheless, the spacecraft will conduct deep imaging surveys for dust rings as it approaches Pluto, just to be sure. If needed, the team could redirect New Horizons to an alternate trajectory that would be almost certainly safe, but the scientific cost of switching to a different flyby path would be high.

Approach Science

New Horizons has seven science instruments, which are described at left. PEPSSI (short for Pluto Energetic Particle Spectrometer Science Investigation) and SWAP (Solar Wind Around Pluto) are devices that measure energetic particles. Together with the Student Dust Counter (SDC), which — surprise! — counts hits from interplanetary dust particles, they have been gathering data throughout the cruise since leaving Earth. At Pluto, PEPSSI and SWAP will observe how the solar wind interacts with the molecules that stray off the top of Pluto's tenuous atmosphere.

Meanwhile, the Alice and Ralph spectrometers and Long Range Reconnaissance Imager (LORRI) camera will study Pluto's family from afar, even though they'll generate most of their high-priority data within the day before and after closest approach. Ralph is not a single instrument but instead a set of color and panchromatic cameras married with a near-infrared spectrometer, tasked with creating detailed surface-composition maps of Pluto and its moons. Alice will concentrate on analyzing Pluto's atmosphere. (You might recall that these were the names of main characters on *The Honeymooners* sitcom in the 1950s.) LORRI is the highest-resolution camera ever flown beyond Mars. Able to discern details just 1 arcsecond across, it spotted tiny Nix and Hydra circling Pluto from 200 million km away.

All of the mission's targets are very small compared to the worlds we've visited in the outer solar system before. For much of New Horizons' approach, LORRI recorded Pluto and its moons as little more than dancing dots, and it won't have improved upon Hubble's imaging until May. In fact, the entire Pluto system out to Hydra will fit comfortably within LORRI's field of view until June 25th, just three weeks before the flyby.

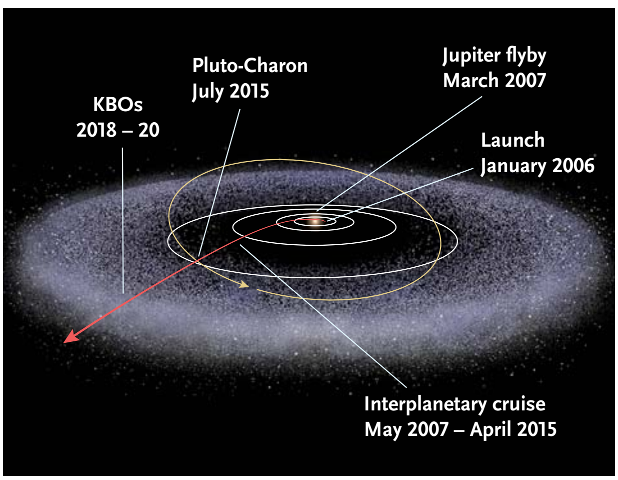


NASA / ESA / M. BUIE

FAMILY PORTRAIT A composite of images taken in 2012 by the Hubble Space Telescope shows Pluto's five known moons. Note how their highly inclined orbits create a "bull's eye" pattern as seen from the Earth-Sun perspective. (The brightness of Pluto and Charon has been reduced by a mask; faint horizontal stripes are imaging artifacts.)

Throughout this period, New Horizons will send observations to Earth as rapidly as possible. But it's nearly 32 astronomical units (4.7 billion km) away, so these transmissions take about 4½ hours to get here. The long distance also attenuates the craft's radio signal, slowing the telemetry stream to 1 kilobit per second most of the time. At this rate, it takes about 50 minutes to transmit a single LORRI image to Earth.

Both the main antenna and the instruments are fixed to the spacecraft body, so New Horizons can't point at a target and transmit at the same time. (PEPSSI and SWAP are less sensitive to a given orientation, so they can continue gathering data while the spacecraft talks with Earth.) Throughout most of the approach, the mission plans call for alternating periods of remote-sensing observations and data transmission. This ensures that all the necessary optical navigational data reach Earth within a few days of acquisition.



NASA

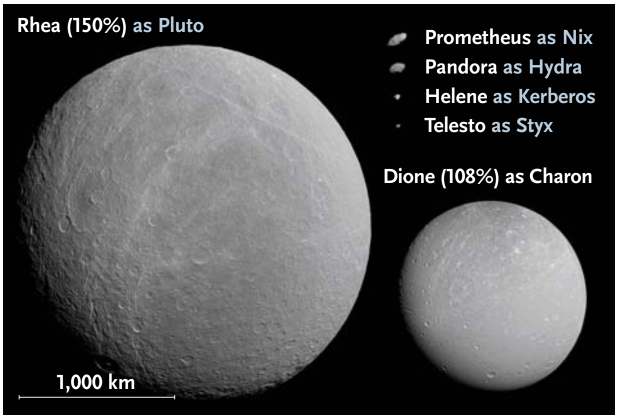
GETTING TO PLUTO New Horizons has traveled 4½ billion miles over 9½ years to reach the Pluto system. Along the way it got a speed boost from flying past Jupiter at close range.

New Horizons will empty its memory banks for the last time before the encounter in a two-week-long data dump from May 15th to 27th, during which no imaging will occur. Then new observations will be transmitted as they're obtained — even though the spacecraft will collect data faster than they can be relayed to Earth.

From Astronomy to Geology

The first set of images unambiguously better than Hubble's will not be taken until May 28th, when Pluto will span something more than eight LORRI pixels. Views of Pluto and Charon will continue to improve throughout June, though their surface features won't yet be readily discernible. We know Pluto is covered with patches of brighter and darker material; in June, we'll see those splotches rotate with Pluto's slow spin. Some of these might turn out to be clouds. Charon is comparatively gray and might appear featureless.

We recently saw, as Dawn approached Ceres, a dwarf planet morph from a smudgy disk into a world with rec-



NASA / JPL / SPACE SCIENCE INST. / E. LAKDAWALLA

DIVERSE TARGETS Assorted moons of Saturn serve as proxies to show the range of sizes of Pluto and its five moons. Nix is only about 100 km across, Styx no more than 25 km. Only Pluto, Charon, and Nix will be seen in detail during July's flyby.

ognizable geology. This transition happened once Dawn's camera recorded 200 pixels across Ceres's disk. For Pluto, this same threshold won't occur until July 12th, just two days before New Horizons' closest approach.

It's impossible to know when Pluto's true face will become evident. Its high-contrast surface should provide interesting views even from far away, but bright and dark patches could make it difficult to tell impact craters from surface coatings. At some point during the approach, Pluto will transition from a world seen only fuzzily to one that has mappable, nameable features.

Mission scientists hope this transition happens by July 7th, a week before the encounter. At that point the disk will only appear about 50 pixels across. Pluto's slow rotation means July 11th is the last day the spacecraft will see some regions in sunlight.

To mitigate the possible loss of New Horizons and all that high-priority science data, the last two days of the approach include four "fail-safe" radio transmissions. The spacecraft will sacrifice time that it might have used for observations close to Pluto in order to send home a tiny, carefully selected sampling of data from each of its science instruments. Back on Earth, anxious mission scientists will receive just a few images that resolve Pluto and its moons as geological worlds before the craft crosses the system's potentially hazardous orbital plane.

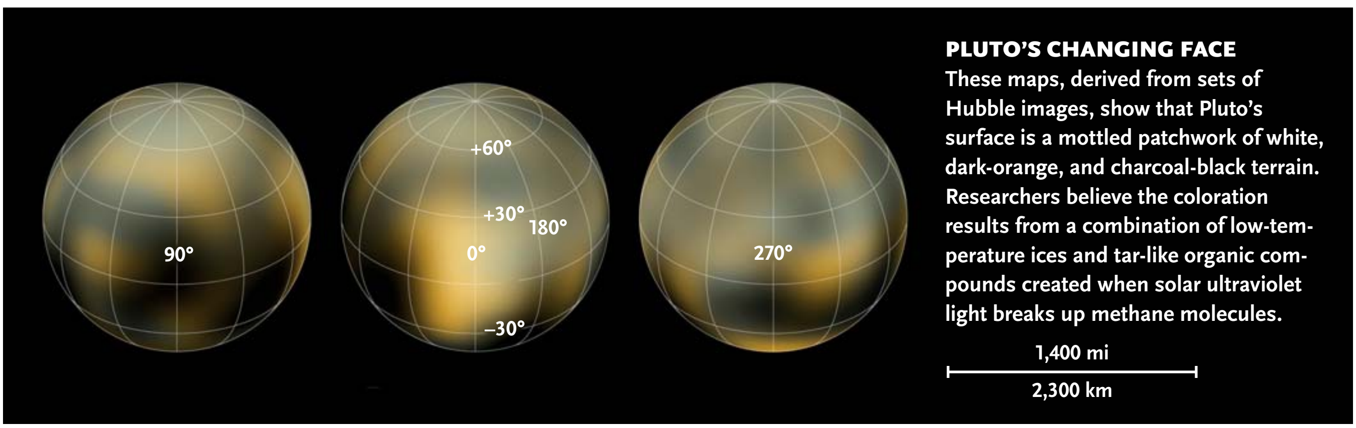
The Long Silence

The 48 hours around closest approach are so precious that the observing plan for that period has been set in stone since 2009. New Horizons has even rehearsed every turn and instrument operation of the sequence, gathering data on empty space in a dress rehearsal of July's command performance.

Any radio communications near this window would come at a cost of priceless time for science. Therefore, New Horizons will be mostly out of contact with Earth during the flyby's most critical period, called Near Encounter Phase. It begins with the spacecraft 1.2 million km from Pluto. Atmospheric scientists believe this is a bit beyond the maximum distance at which PEPSSI and SWAP might detect the shock front along which the solar wind collides with Pluto's escaping atmosphere. Once inside this boundary, PEPSSI and SWAP will directly sample gases and ions that originate from the dwarf planet's atmosphere.

The spacecraft will twist and scan, pointing at Pluto, Charon, Nix, and Hydra in turn. It will map the reflected and thermal radiation coming from their surfaces while searching for undiscovered moonlets and rings. Its spectrometers and particle instruments will also sweep the space into which Pluto's atmosphere might be escaping. The plan is internally redundant so that, if any one instrument fails, New Horizons' highest-priority scientific goals can still be achieved with data from other instruments.

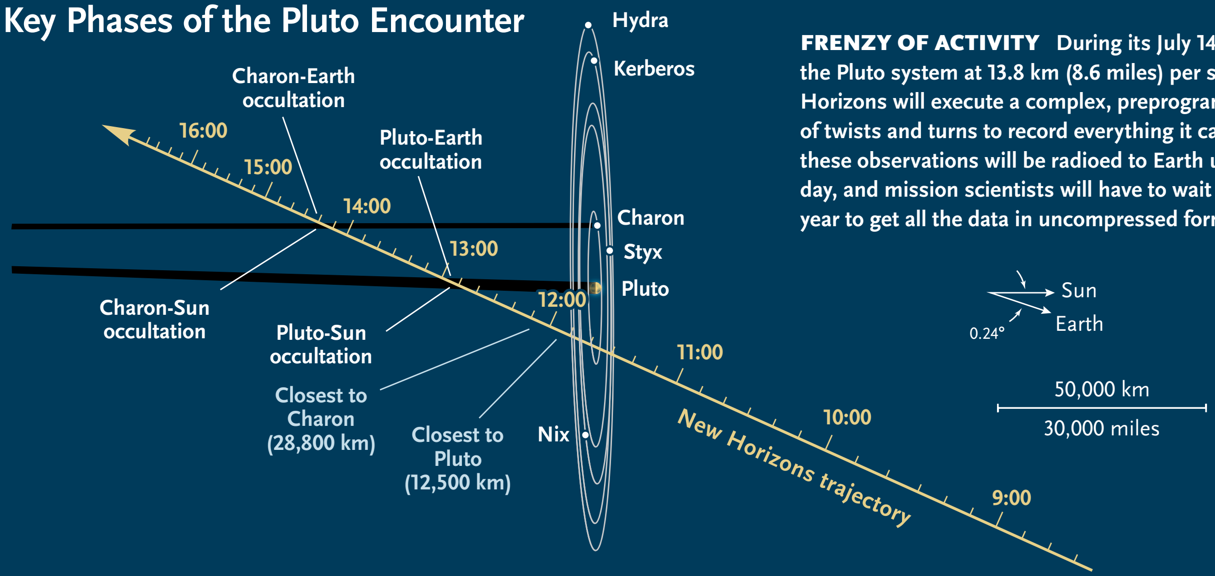
New Horizons will briefly turn toward Earth one last time before closest approach, transmitting a final image of Pluto, its globe still fitting easily inside LORRI's field of view. This transmission will end at 3:15 UT on Tuesday, July 14th. Then we'll have to endure 22 long hours of silence as the spacecraft gyrates through its busy obser-



NASA / ESA / M. BUIE

PLUTO'S CHANGING FACE These maps, derived from sets of Hubble images, show that Pluto's surface is a mottled patchwork of white, dark-orange, and charcoal-black terrain. Researchers believe the coloration results from a combination of low-temperature ices and tar-like organic compounds created when solar ultraviolet light breaks up methane molecules.

Key Phases of the Pluto Encounter



FRENZY OF ACTIVITY During its July 14th pass through the Pluto system at 13.8 km (8.6 miles) per second, New Horizons will execute a complex, preprogramed sequence of twists and turns to record everything it can. None of these observations will be radioed to Earth until the next day, and mission scientists will have to wait more than a full year to get all the data in uncompressed form.

S&T: GREGG DINDERMAN, SOURCE: NASA

Encounter phase	Dates	Starting range	LORRI's resolution	Major activities
Approach Phase 1	Jan. 6 – April 4	226×10^6 km	1,000 km/pixel	LORRI shoots images for optical navigation; SWAP, PEPSSI, and SDC measure environment unaffected by Pluto.
Approach Phase 2	April 4 - June 23	121×10^6 km	May 28: 281 km/px	Previous activities continue; Ralph (MVIC) and LORRI map Pluto to look for surface changes; LORRI searches for moonlets and rings.
Approach Phase 3	June 23 – July 13	26×10^6 km	July 1: 79 km/px July 12: 13 km/px	Previous activities continue; Ralph (LEISA) and Alice map atmosphere and look for variability; LORRI and Ralph (MVIC) map surface geology and search for hazes and clouds.
Near Encounter Phase	July 13–15	1.2×10^6 km	July 13: 4 km/px July 14: 0.4 km/px	High-resolution imaging; measurement of escaping atmosphere; REX and Alice record radio and solar occultations.
Departure Phase 1	July 15 – Aug. 4	1.2×10^6 km	July 15: 4 km/px	LORRI and Ralph (MVIC) image crescents and search for rings; SWAP and PEPSSI study magnetotail and pickup ions through one solar rotation; REX measures nightside temperatures.
Departure Phase 2	Aug. 4 – Oct. 22	24×10^6 km	(no imaging)	SWAP, PEPSSI, and SDC activities continue.
Departure Phase 3	Oct. 22 – Jan. 1, 2016	119×10^6 km	(no imaging)	SWAP, PEPSSI, and SDC activities continue.

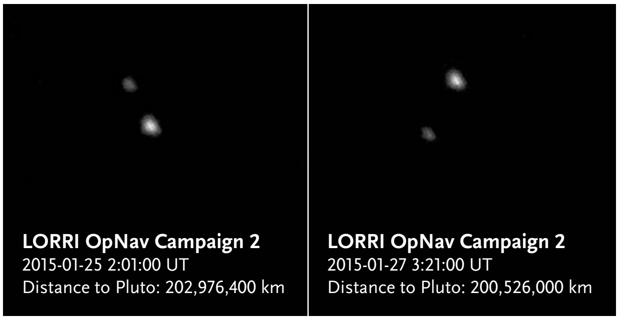
vational schedule. As Pluto and Charon grow in apparent size, the spacecraft must begin shooting mosaics of overlapping images to cover their globes.

About 4 hours before closest approach, four of the Deep Space Network's giant radio dishes will begin to broadcast a pure, unmodulated signal toward Pluto that will race across space toward the retreating spacecraft. Closest approach happens at 11:50 UT, when New Horizons will pass 12,500 km from Pluto's surface. Fourteen minutes later the spacecraft comes its closest to Charon, which will be almost exactly opposite Pluto from New Horizons, 28,800 km away.

New Horizons will continue imaging as it begins to speed away from Pluto. LORRI will look toward its limb, potentially photographing haze layers floating high above Pluto's surface. By this time, the radio beam from Earth will have caught up with the spacecraft, which will record it as the signal strength begins to fade while passing through Pluto's atmosphere.

An hour after the flyby, the faint light of the Sun will briefly go out as New Horizons enters Pluto's shadow; a minute later, Pluto will block Earth as well. About 1½ hours later, New Horizons will experience a similar pair of occultations at Charon.

These radio occultations will enable scientists to sensitively probe the structure of Pluto's atmosphere and Charon's (if one exists). The Alice spectrometer will also watch the Sun wink out behind both bodies,



NASA / JHU-APL / SWRI

VIEW FROM AFAR New Horizons' LORRI telephoto camera recorded Pluto and dimmer Charon on January 25th and 27th from a distance of more than 200 million km. Flight planners use images like these to refine the objects' positions and to tweak the spacecraft's trajectory as needed.

measuring atmospheric composition from its effect on the solar spectrum. In between the Pluto and Charon occultations, the spacecraft will spin, allowing PEPSSI and SWAP to sensitively map the ions and neutral atoms streaming down Pluto's magnetotail (if it has one).

Nearly 9 hours after the flyby, New Horizons will take the briefest pause from its frenzied observations to radio a few precious packets of engineering data about its health. This "phone home" will take 4 hours 23 minutes to reach its apprehensive observers back on Earth, arriving — we hope! — at 1:09 UT on July 15th, confirming that the spacecraft survived the encounter and is continuing to operate normally.

But it'll be no time for New Horizons to rest. Following the flyby, as it rapidly recedes from Pluto, New Horizons will see Pluto and all its moons with the Sun positioned nearly behind them. This will yield pretty crescents in photos but also provide hints about the structure of the objects' surfaces from the way they scatter the high-angle light toward the spacecraft's cameras. New Horizons will also attempt an imaging feat: looking down on the nightside of Pluto, it will try to record regions not seen at high resolution in daylight, by using sunlight that has reflected first off Charon and then onto Pluto's darkened landscape.

The Near Encounter Phase ends a day after the flyby and transitions to the Departure Phase. New Horizons will use its cameras to study the system for only one full Pluto day (6.4 Earth days) following the close approach, seeing Pluto and all its moons as skinny crescents. Facing toward the Sun, New Horizons will continue its search for the dusty rings that might be generated from micrometeorite impacts onto the small moons. Meanwhile, PEPSSI, SWAP, and SDC will gather data for at least a month after the flyby, corresponding to one rotation of the distant Sun.

What Will We See — and When?

All these observations will fill the spacecraft's onboard memory to bursting. In all, it will take about 18 months to transmit the full, uncompressed data set back to Earth. Naturally, the mission scientists (and we!) want to get results as soon as possible. So through July 20th, New Horizons will return a carefully selected 1% of all the near-encounter science data, including 14 LORRI and two Ralph images of Pluto, Charon, Nix, and Hydra.

After that, the image pipeline will go dry for about two months. New Horizons will continue to transmit data in real time from PEPSSI, SWAP, and SDC. But before sending back any more images, the spacecraft will first transmit housekeeping data on all those frames, building a "library catalog" back on Earth that is

NASA / JPL / J. FOUST

The Long Road to Pluto

When New Horizons whizzes past Pluto this July, it will have been 9½ years since the spacecraft left Cape Canaveral, Florida. Yet that span pales in comparison to the 16 years it took to get a Pluto mission on the launch pad in the first place. Starting in 1990, five Pluto vehicles were proposed and cancelled before New Horizons got a green light from NASA in late 2001. Building a spacecraft is hard — but often the political hurdles are harder.

The first three Pluto proposals varied wildly in cost and complexity. "Pluto 350" was named after its mass in kilograms. That gave way to a two-ton behemoth based on the Saturn-bound Cassini spacecraft. The third concept, "Pluto Fast Flyby" (PFF), called for a pair of lightweight probes launched a year apart.

The Pluto Fast Flyby team poses with a mockup of their proposed spacecraft in 1992.

ready to receive the full-resolution pictures themselves.

On September 14th, New Horizons will begin transmitting the entire science data set, or at least the portion of it that can be digitally compressed. Only then will we really begin to unpack the visual riches from this historic encounter. Even with the use of strong compression algorithms to make the image files smaller, it will take two months to download every image. With that done, around November 16th, New Horizons will start again from the beginning, re-transmitting everything *without* compression. It will likely take another year, until November 2016, for the spacecraft to send all of its results across the 5 billion km separating it from Earth.

But waiting is nothing new for the New Horizons science team. It took decades to get a mission to Pluto approved and launched (as detailed below) and nearly another decade for the spacecraft to race outward from Earth to Pluto. A wait of another year for the full return of the science data is manageable. Besides, the lengthy data trickle will keep New Horizons in the news for years after the flyby, as we gain new insights on Pluto, Charon, Styx, Nix, Kerberos, and Hydra — and perhaps moons we haven't even discovered yet.

"We will be living in a year of discovery-suspense," comments deputy project scientist Kimberly Ennico (NASA Ames Research Center). "We are carrying modern instruments to 32 a.u. — megapixel cameras and thousand-pixel spectrometers. That means a lot of data, and also a lot of science and discovery."

Moreover, New Horizons' tour does not end at the Pluto system. Late in 2015, the spacecraft will fire its main engine to bend its path toward a newly discovered Kuiper Belt object, something much smaller than Pluto, setting up a flyby in late 2018 or early 2019. And, if we're lucky, continued ground-based searches will yield a second dim, distant object to explore beyond that. So New Horizons will give us our first views of at least seven worlds beyond Neptune, carrying on the tradition of discovery established by the Pioneers and the Voyagers. ✦

*An S&T contributing editor since 2010, Emily Lakdawalla blogs daily about solar-system science and space exploration for The Planetary Society (**planetary.org/blogs**). She thanks Kimberly Ennico for assistance with this article.*

NASA / JHU-APL

PLUTO-BOUND EXPERIMENT Technicians install the SWAP (Solar Wind Around Pluto) instrument, one of seven science packages carried by the New Horizons spacecraft.

More than half the cost of PFF was wrapped up in its beefy Titan launch vehicles. Alan Stern, who went on to lead the New Horizons effort, was so determined to get PFF off the ground and on to Pluto that he went shopping for cheaper rockets in Russia.

But the mission stalled following the loss of NASA's Mars Observer in 1993. In the meantime, astronomers were discovering additional icy worlds beyond Neptune's orbit, confirming the existence of the Kuiper Belt. Pluto, it seemed, was no longer a planetary outlier but instead just one example of an entirely new class of objects on the fringe of our planetary system.

This revelation led to a multiple-target concept called Pluto Express, which soon morphed into Pluto Kuiper Express. But when NASA canceled the mission in 2000, a groundswell of scientists, citizens, and advocacy groups pushed back. The space agency relented, accepting a new round of Pluto proposals in 2001 and selecting New Horizons later that year.

For behind-the-scenes views of preparations for New Horizons, visit http://is.gd/PlutoFlyby).

More funding skirmishes ensued — along with a frantic search for enough plutonium for the craft's fission-powered electrical generators. But when a comprehensive 2003 study by the National Academy of Sciences named Pluto a top priority for planetary exploration over the next 10 years, the future of New Horizons was secure. Humanity would finally get its first up-close look at Pluto.

For Alan Stern, the 26-year slog to get the first science results from Pluto is an important and cautionary tale for scientists with their own ambitious plans. "You have to really want it and be prepared to fight for it," he says. "There are many more good ideas than there is money to go around."

— Jason Davis

***Jason Davis** is a digital editor for The Planetary Society. He covers the society's science and technology projects.*

Cosmology Primer

Planck Upholds Standard Cosmology

The latest analysis of the universe's oldest light provides an exquisite look at the cosmos.

Camille M. Carlisle

I spent the end of 2014 squirming. For months I'd been waiting for the release of the full-mission data from the European Space Agency's Planck spacecraft. Planck launched in 2009 to study the cosmic microwave background (CMB), the relict radiation from the universe's birth. It's the latest advance in a field fairly young by astronomical standards: 50 years ago this month, Bell Labs' Arno Penzias and Robert Wilson published their landmark detection of the CMB.

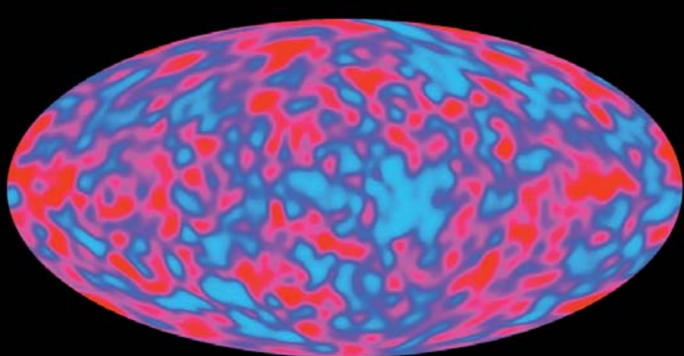
The 1965 paper, "A Measurement of Excess Antenna Temperature at 4080 Mc/s" in the *Astrophysical Journal*, is less than two pages long. Only two paragraphs talk about the "unaccounted-for antenna temperature" Penzias and Wilson had stumbled upon, and the authors politely leave suggestions for its origin to a companion article by Robert Dicke and others at Princeton. (The Princeton folks, who had been hunting for the CMB, had the good grace to accept they'd been scooped.)

Since then, CMB studies have revolutionized our understanding of the cosmos, giving birth to an era of *precision cosmology*. Many of us today recognize the splotchy maps, the pattern they record spawned by density fluctuations in the universe's earliest moment. The CMB might seem esoteric, but it has big implications: the density fluctuations also served as seeds for the growth of cosmic structure, the sprawling web of galaxy clusters in which nearly all matter resides. From dark matter and cosmic expansion to when galaxies first set the universe alight, the remnant radiation touches a boggling number of areas in astronomy. Understanding why the CMB looks the way it does thus helps us understand the entire universe.

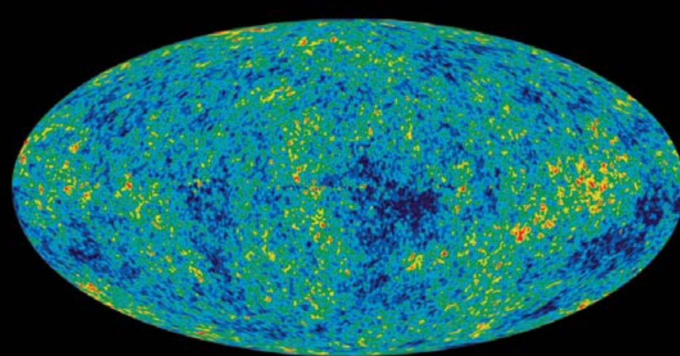
Hence my squirming.

Planck observed in nine frequencies spanning 30 to 857 GHz, mapping the CMB's temperature in all nine frequencies and its polarization in seven, before shutting down on schedule in 2013. The team released the tem-

COBE



WMAP



perature observations from the mission's first 15 months that same year (*S&T*: June 2013, p. 10). These data were mostly in beautiful agreement with the standard picture of cosmology astronomers have developed.

Since then, the team has been working feverishly to analyze the full, four-year data set. This past December, members presented those data at a conference in Ferrara, Italy, and the team released most of the 28 official analysis papers in February. (A few stragglers were still in the wings in March.) The results provide a wow-worthy view of the universe and of how precision cosmology works, although if you're like me, you'll need some help to see how this psychedelic picture comes together — and maybe some ibuprofen when we're done.

How Astronomers Find the Universe in the CMB

At first glance, CMB maps look like toddler finger-paintings — colorful, but enigmatic. It's not intuitive how cosmologists derive things from them like the universe's age.

Yet they do. They start with the splotchy CMB pattern. Then they make some assumptions about what kind of universe they're dealing with. In astrospeak, they assume the *standard lambda-CDM model*, the cosmological framework astronomers currently use. This framework includes

1. a particular solution to the general relativistic equations of gravity, including an anti-gravity force called the cosmological constant, or *lambda* (what's now called dark energy);
2. an expanding universe that looks basically the same on large scales;
3. an early period of stupendous expansion called inflation;
4. quantum fluctuations that seeded today's large-scale matter distribution (those density fluctuations I mentioned earlier); and
5. the existence of a type of matter that responds to gravity but not to electrical or magnetic forces (generally called dark matter).

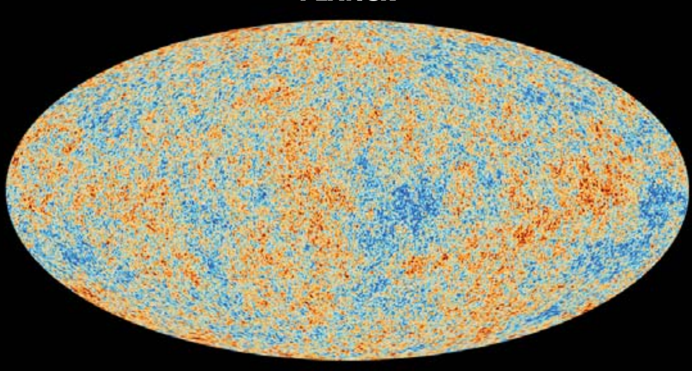
From there, they start tweaking the specific values of different parameters, like a dressmaker tucking and letting out a dress pattern until it fits. They could even chuck any assumption that proves to be wrong. Eventually, they find the pattern that most successfully fits the CMB.

The amazing thing is, this method works. It works *really well*. That's because back when the universe's contents cooled down enough to stop being plasma and release the CMB's photons (about 370,000 years after the Big Bang), the universe was simple, says team member Charles Lawrence (JPL) — basically a hot, bland soup of particles and dark matter, with no chemical reactions going on. So scientists can actually figure out the exact physical setup that would create the CMB we observe.

Six Numbers Tell All

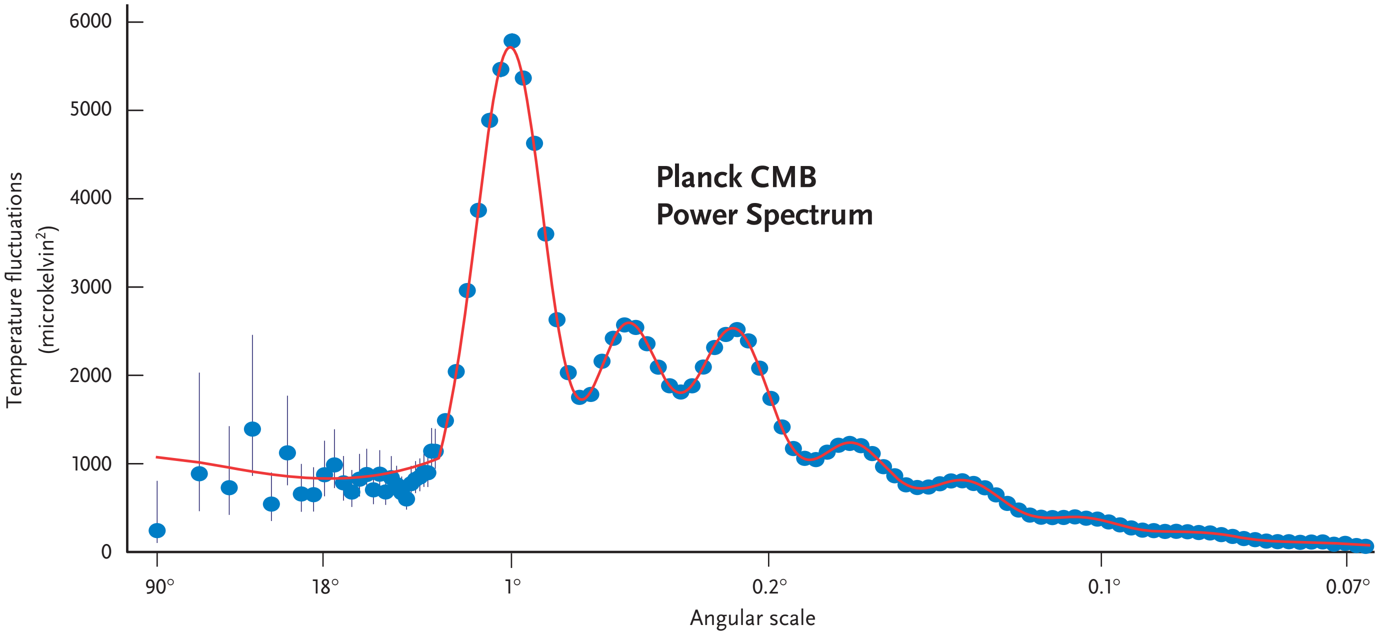
Planck's 2015 release upholds that of 2013, with only slight changes. The results still overwhelmingly favor an early universe defined by only six parameters:

1. The density of baryonic matter (a.k.a. normal matter, like you and me) in the universe's first few minutes;
2. The density of cold dark matter at that same time;
3. How far sound waves traveled from the end of inflation to when the CMB photons were released;
4. The fraction of CMB photons that have scattered off "free-floating" electrons and protons over the universe's history. These particles were set free by radiation from stars and quasars ionizing the neutral hydrogen filling the cosmos. This number is directly related to when the first galaxies had pumped out enough stars to set the universe aglow;
5. The strength of the initial density fluctuations on a scale of about 65 million light-years at the end of inflation. Fun fact: Planck's value of parameter #5 says that, after inflation, the density of matter varied only 0.000000002 across 65 million light-years; and
6. How the strength of the density fluctuations at the end of inflation changes depending on how big a patch of sky you look at.



OUR VIEW OF THE CMB One of our first detailed views of the CMB's temperature spots came from the Cosmic Background Explorer (COBE), launched in 1989. The Wilkinson Microwave Anisotropy Probe (WMAP) followed in 2001, and Planck in 2009. The COBE map here has an angular resolution of 10°, WMAP's is about 15′, and Planck's is 5′.

COBE: NASA; WMAP: NASA / WMAP SCIENCE TEAM; PLANCK: ESA / PLANCK COLLABORATION



MORE THAN JUST WIGGLES This graph is the CMB's *power spectrum*. It plots the magnitude of temperature variations (vertical) at different angular scales (horizontal, approximate). The red line is the standard cosmological model, the blue dots are Planck data. Once cosmologists confirm that the standard model is a good match to the real universe, they can use the power spectrum to determine the cosmological parameters — an easier task than fitting directly to the map. The spectrum reveals that temperature variations are strongest on a scale of about 1°. Although there's a tiny dip around 10°, at the moment there's no strong evidence that it requires a physical explanation. S&T: GREGG DINDERMAN, SOURCE: PLANCK COLLABORATION

From these parameters, the team can calculate just about anything you please, such as the universe's age. The exact values depend on which data subsets scientists include in the calculations — and there are reasons for not always using the kitchen sink. In this article, I've chosen to use the version highlighted in the team's overview paper, which includes information from all the temperature and some low-frequency polarization measurements. It also accounts for the slight blurring in the splotchy pattern created when CMB photons pass massive cosmic structures and are bent slightly from their straight-shot paths by gravity.

Of all the numbers that come out of the results, here are three worth remembering:

- Age of universe: 13.799 +/- 0.038 billion years (note: that means we know the age of the universe to within 38 million years)
- Fraction of universe's content that is dark energy: 69.2 +/- 1.2%
- Universe's expansion rate: 67.8 +/- 0.9 km/s/megaparsec (a parsec is 3.26 light-years)

The universe's expansion rate, called the Hubble parameter or Hubble constant, not only sets the time scale for cosmic expansion but also the scale for the universe's size and age. When Planck's 2013 results came out, the fact that the team derived a rate below 70 km/s/Mpc caught attention. Its predecessor, NASA's Wilkinson Microwave Anisotropy Probe (WMAP), had also found a lower value, in conflict with the 73-and-change value calculated using supernovae. The Planck value is a forward-looking extrapolation, a prediction of how fast the universe "should be" expanding today, given what we see in the early universe, explains Planck team member Martin White (University of California, Berkeley). So if it's different from what we actually see, that's "a sharp test of our understanding and could potentially indicate new physics, new constituents of the universe, or show we don't understand as much as we think we do," he says.

But several other measurements have now also pushed the Hubble parameter down, so a lower expansion rate might be here to stay. On the other hand, not *all* measurements have. If astronomers can directly measure a precise expansion rate for today's universe that's clearly higher than Planck's value, then it would be strong evidence that there's something missing from our cosmology.

Of Stars and Galaxies

The latest Planck data say some interesting things about the universe. One neat result is that the *era of reionization* — basically, when the universe's galaxies really started lighting up with stars — is later than estimated using data from WMAP. WMAP had favored reionization at a redshift of 10.6 (440 million years after the Big Bang), but Planck pegs it at 8.8 (560 million years after the Big Bang).

"For many cosmologists, I would say that it is a relief," says David Spergel (Princeton), who worked on the WMAP team.

The problem was that astronomers studying early star formation had a hard time explaining the earlier start time from WMAP. Astronomers think the universe's first stars formed about 100 million years after the Big Bang; the first black holes came soon after. Both stars and black holes madly gobbling down gas emit light. But the era of reionization happened when there were so many photons flying around that much of the plain old hydrogen atoms filling the universe lost their electrons and got ionized. (Because everything started out ionized at the universe's birth — no atoms formed until things cooled down 370,000 years in — this is the second time things are ionized, hence "reionization.") And with the earlier WMAP date, there just shouldn't have been enough photons around to break up the hydrogen.

Planck's result makes things better, although not perfect. "We're still kind of short of photons," says Marta Volonteri (Institut d'Astrophysique de Paris), "but with some extrapolations and optimistic assumptions, it seems that galaxies may provide enough photons."

There also remains the strange problem of the missing galaxy clusters (*S&T*: May 2014, p. 10). The Planck team finds a certain lumpiness in the CMB, which should match up with the lumps in the distribution of matter in the universe. This distribution manifests as cosmic structure, which is made up of galaxy clusters. But Planck predicts about 2.5 times more clusters than are actually observed. This could be due to error in the estimates from either side, or due to new physics.

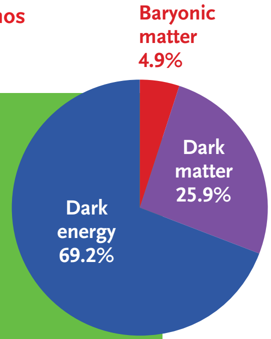
Cosmic Inflation and Whatnot

Then there are the implications for inflation. No. 6 in the list of parameters (how the strength of the density fluctuations changes with angular scale on the sky) is called n_s or the *scalar spectral index*. It's important because it describes the state of affairs at the end of inflation, and the fluctuations it measures are the ones that started sound waves sloshing in the universe's primordial plasma, ultimately leading to the CMB we see. Planck finds a value of 0.968, which means that the strength of the fluctuations is slightly larger on larger scales — a tilt predicted by most inflation models. This offset has a slight effect on galaxies' formation rate over time, Spergel says.

For polarization, there's still no sign of primordial B-modes, the swirly polarization patterns that would be the signal from spacetime ripples triggered by cosmic inflation. These *gravitational waves* would have various wavelengths, and some waves would be stronger than others, meaning that, like with the CMB's fluctuations, their strength changes depending on how big a patch of sky you look at. Focusing on a scale of 65 million light-years (for convention's sake), the Planck team calculated an upper limit for the ratio of the gravitational waves' strength to the strength of the run-of-the-mill density fluctuations of 0.11. Combining that with the joint analysis done with the BICEP2/Keck Array team (*S&T*: May 2015, p. 12) gives 0.09. In other words, the gravitational waves' strength must be less than 9% that of the regular fluctuations.

On their own, these numbers sound like jargon. What matters is that they home in on some of the simpler types of inflation. (By one count, there are four dozen inflation models out there.) These simpler types involve an inflation generated by the decay of a single energy field, a field that decreased slowly compared to the universe's expansion rate — although, given that the

Find all the Planck papers at www.cosmos.esa.int/web/planck/publications.

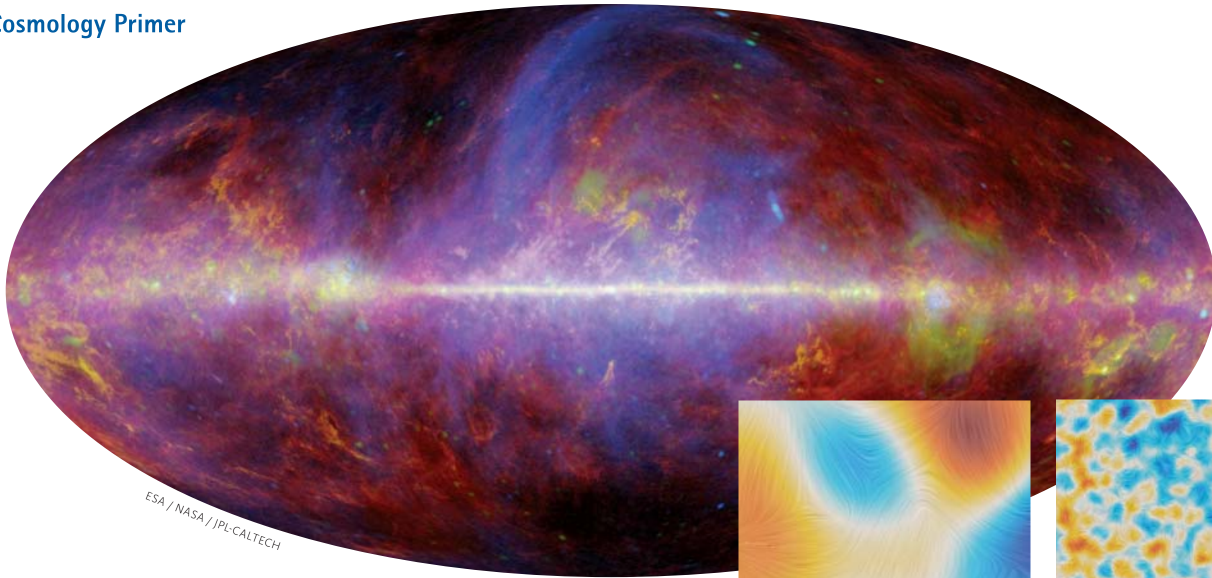


The Cosmic Pie

The latest Planck results suggest the universe breaks down to 69.2% dark energy, 25.9% dark matter, and 4.9% baryonic matter. But the exact values of these fractions can change by several tenths of a percentage point, depending on the data subsets used and assumptions made — for example, the six different combinations the Planck team lists in its cosmological parameters analysis give a range for dark energy from 68.4% to 69.4%. The values in this article are taken from the team's overview paper and use a combination of temperature, low-frequency polarization, and gravitational lensing data.

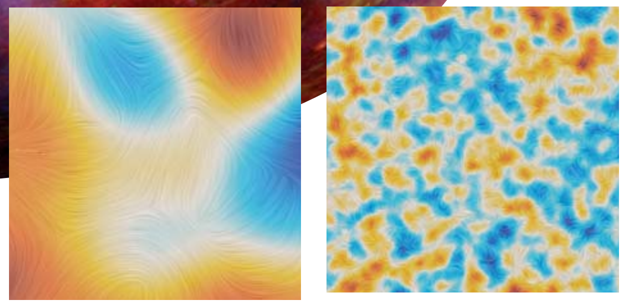
COSMIC EXPANSION

The units for the universe's expansion rate, kilometers per second per megaparsec (km/s/Mpc) can be confusing. They mean that, the more distant the galaxy, the faster it's receding from us. Think of the universe like a loaf of raisin bread baking in the oven. If a "unit" of dough always doubles in size in 10 minutes, then in 10 minutes, two raisins that began 2 units apart will be 4 units apart, but two raisins that were 4 units apart will now be 8 units apart. In other words, because the expansion rate of the dough is the same throughout the loaf, raisins move apart from one another at a speed that's proportional to the distance between them. That's what the units of the Hubble constant (km/s/Mpc) mean: a galaxy is moving away from us at a speed that's proportional to its distance.



ESA / NASA / JPL-CALTECH

DUSTY VIEW To study the CMB, cosmologists must first peel away all the "foreground" emission from the Milky Way — a herculean task, as apparent from this false-color composite. The most widespread feature is dust's thermal glow (red). Also shown are synchrotron radiation from high-energy electrons corkscrewing through the galaxy's magnetic field (blue); carbon monoxide gas (orange), a tracer for the molecular hydrogen from which new stars form; and emission from hot, ionized gas near massive stars (green). As expected, the last two are concentrated in the galaxy's disk, where star formation is ongoing.



ESA / PLANCK COLLABORATION (2)

POLARIZATION OF THE CMB A small fraction of the CMB is polarized, meaning the light vibrates in a preferred direction. The photons became polarized in their final encounter with electrons in the primordial plasma soup, before the universe cooled enough for radiation to travel freely. Thus, the CMB's polarization contains information about the distribution of matter in the early universe, and its pattern follows that of the tiny fluctuations observed in the CMB's temperature. In these maps, colors represent temperature differences, while texture indicates the direction of the polarized light. The all-sky map on the top of p. 28 is filtered to mostly show the signal detected on a scale of 5° (as is the left patch above) on the sky, but Planck detected fluctuations on smaller angular scales as well (right, same patch at 20′).

observable universe expanded at least 5 billion trillion times in 10 nano-nano-nano-nanoseconds, that's not that slow. The energy scale implied for inflation is less than 2×10^{16} gigaelectron volts, on par with the level expected for the merger of the strong, weak, and electromagnetic forces into one, called the Grand Unified Theory. Physicists think these forces were united in the first mini-moment of the universe, then broke apart. Their breakup might somehow be connected to inflation.

These are only selections from the cosmology results. Planck also amassed tons of information on "foreground" stuff, such as the dusty Milky Way in which our solar system twirls, but the team is focusing on the core cosmological science and leaving much of the astrophysics to others. Astronomers have already been playing with Planck's data, and there's a focus meeting at the International Astronomical Union conference in August devoted to exploring uses for the mission's results. The team will release a final data set in a year, with improved calibration and other fine-tuning. Then they will essentially bow aside and leave the riches for the world's astronomers to explore. ✦

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*Every time she writes about cosmology, Science Editor **Camille M. Carlisle** feels like she's knocking her head against a wall, hoping the debris will lodge in her brain. The original version of this article appeared as a news blog on **www.skyandtelescope.com** on February 10, 2015.*

Other Notable Results

In the discussion of what dark matter is, one idea is that it's its own antiparticle; thus, if two dark particles collide, they'll go *poof*. Planck scientists don't need dark matter annihilation to make sense of the CMB, although interpreting what that means for dark matter depends on the properties we assume dark matter has.

A delightful consequence of having to clean Planck's data of other stuff in the universe is all the insight gained about that intervening stuff. As CMB photons pass through cosmic structure, the matter acts as a gravitational lens, bending the light's path. The resulting zigzag paths slightly blur the CMB's pattern. Because Planck's observations are so precise, the team had to take this gravitational blurring into account. As a result, they created a detailed map of all the matter the photons passed from 370,000 years after the Big Bang until now.

Celestial Frontispieces of the Golden Age

Nick Kanas

Astronomy-themed art and allegory reached an early peak as illustrators sought to outdo one another.

HYDRA, Crater, and Corvus as drawn by Johannes Hevelius in his 1687 star atlas *Firmamentum Sobiescianum sive Uranographia*. Hevelius drew his charts mirror-reversed as if on a celestial globe. Above, the constellations are reversed again to match the stars as seen from the ground.

ABOVE: JOHANNES HEVELIUS / *FIRMAMENTUM SOBIESCIANUM SIVE URANOGRAPHIA*

The first Golden Age of sky mapping happened in Europe from 1600 to 1800. Advances in the arts of printing, engraving, and terrestrial mapping, and widening audiences of educated readers in the Renaissance and Enlightenment, brought forth grand books both scholarly and popular on the wonders of the heavens. Especially prominent were the sky atlases of the "Big Four" celestial cartographers: Johann Bayer, Johannes Hevelius, John Flamsteed, and Johann Bode, in order of date.

Baroque styles were in vogue during much of this time, and engravers competed to show off their artistry. So book illustrations were often replete with acanthus leaves, scrolls, ribbons, banners, and playful angelic *putti* winging among clouds. These added artistry and allegory to the scientific content of a star atlas or other astronomical work — and sometimes, hidden messages.

In particular, great time and effort often went into the frontispiece facing the title page of a book, especially Bibles and scholarly works. Among other things, an impressive frontispiece signaled quality and erudition in the contents. Many were hand-colored during or after publication to enhance a book's beauty and value.

An example introduces the great *Uranometria* atlas of Johann Bayer (1572–1625), a lawyer in Augsburg, Bavaria, who had a passion for astronomy. Published in 1603, it was the first atlas of the

BAYER, *URANOMETRIA*, 1661 EDITION

At the top of this stage-set for Bayer's breakthrough star atlas are figures representing the Sun holding a lyre, Eternity holding a quill pen and mastering two lions, and the Moon: the goddess Diana the huntress, sleeping with bow, arrows, and hunting dog. At their feet is written, in mixed Greek and Latin, "Let no one who is unlearned in geometry approach eternity."

Framing the title banner are Atlas (left) and Hercules, standing on pedestals labeled "To Atlas, earliest teacher of astronomy" and "To Hercules, earliest student of astronomy." Atlas is looking toward his pupil and pointing to an astrolabe. Hercules, wearing his lion skin as a cap, cape, and loincloth, does duty holding up a celestial sphere, relieving Atlas of the burden. At bottom center, under a Capricorn pointing with his forefoot, is a view of the city of Augsburg where the atlas was printed. Beneath that is the printer's mark. This colored version is slightly degraded from the precision-crafted, black-and-white engravings in earlier editions.


ΟΥΔΕΙΣ ΕΙΣΙΤΩ
ΑΓΕΩΜΕΤΡΗΤΟΣ
AETERNITATI.
IOANNIS BAYERI
RHAINANI I.C.
VRANO-
METRIA,
OMNIVM ASTERISMORVM
CONTINENS SCHEMATA,
NOVA METHODO
DELINEATA,
AEREIS LAMINIS EXPRESSA.
VLMÆ
SVMPTIBVS IOHANNIS GÖRLINI.
M.DC.LXI
ATLANTI
VETVSTISS.
ASTRONOM.
MAGISTRO.
HERCVLI
VETVSTISS.
ASTRONOM.
DISCIPVLO.

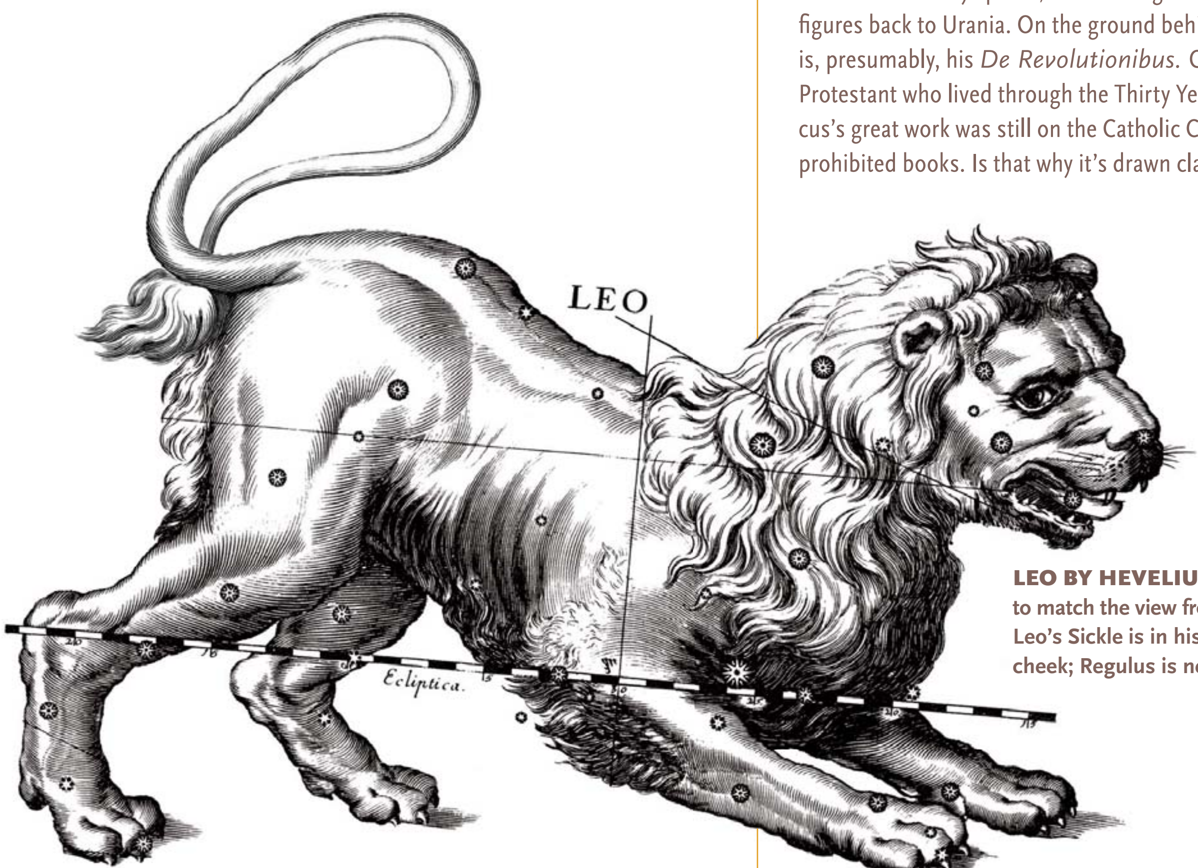
celestial Golden Age and the best the world had ever seen. Its 51 star maps, finely engraved on copper plates, include 48 featuring each of the classical Greek constellations. They depict allegorical drawings of the constellation figures (widely reprinted today for their attractiveness) and have an accompanying star catalog. The stars themselves were plotted with unprecedented accuracy, based on the measurements of Tycho Brahe. Their ecliptic coordinates could be read from the pages with high accuracy by placing a straightedge across the page between the scales around the borders. The charts also introduced lowercase Greek letters for stars in each constellation; astronomers have used them ever since. On page 40 is Bayer's Andromeda; on the previous page is the colored frontispiece from *Uranometria*'s 1661 edition.

Striving to outdo that page is the stunning frontispiece from Andreas Cellarius' *Atlas Coelestis, seu Harmonia Macrocosmica,* first published in 1660. Cellarius (ca. 1596–1665) was born in Germany but later settled in Holland, where he became rector of the Latin School at Hoorn. He wrote several books and poems but is best known for his sky atlas, perhaps the most gorgeously illustrated ever. In addition to discussing a number of astronomical topics, the book includes 29 double-page plates, lavishly decorated in Baroque style, illustrating differing cosmological systems and providing maps of the heavens. It became very popular, being reprinted in 1661 and 1666 and then reissued without its Latin text by the Amsterdam publishers Gerard Valk and Petrus Schenk.

CELLARIUS, *HARMONIA MACROCOSMICA,* 1708
Flanking the title banner, two *putti* hold a zodiacal ring illuminated by a central Sun, with the off-center Earth attached to the zodiac. Two others use cross-staffs to measure angular separations in Libra and Virgo on the actual zodiacal band overhead.

At center below, on a balcony overlooking a classical garden behind her, sits Urania, the Muse of Astronomy. She holds an armillary sphere: a type of analog computer used by astronomers and astrologers to figure out positions. She is surrounded by, clockwise from left, Tycho Brahe the star measurer, holding a compass to a celestial sphere; Claudius Ptolemy with, presumably, his great book the *Almagest;* al-Battani (Albategnius) of Raqqa, Syria, mathematician and a refiner of Ptolemy's work during the golden age of Arabian science; and becrowned King Alfonso the Wise of 13th-century Spain, a patron of astronomy incongruously holding a Sun-centered model of the solar system.

Next is the Dutch astronomer Johan Philip Lansberg, an important early supporter of Copernicus. He points with a long lecturer's stick to the Earth attached to the zodiac ring around the Sun; that device is closely copied from the frontispiece of Lansberg's own, much earlier *Tabulae motuum coelestium perpetuae* (1632). Rounding out the dignitaries is dark-robed Copernicus himself, writing as he measures a second armillary sphere, thus closing the circle of seven figures back to Urania. On the ground behind Copernicus is, presumably, his *De Revolutionibus.* Cellarius was a Protestant who lived through the Thirty Year's War; Copernicus's great work was still on the Catholic Church's index of prohibited books. Is that why it's drawn clasped shut?



LEO BY HEVELIUS, de-reversed to match the view from the ground. Leo's Sickle is in his mane and cheek; Regulus is near his heart.

THE NICK AND CAROLYNN KANAS COLLECTION

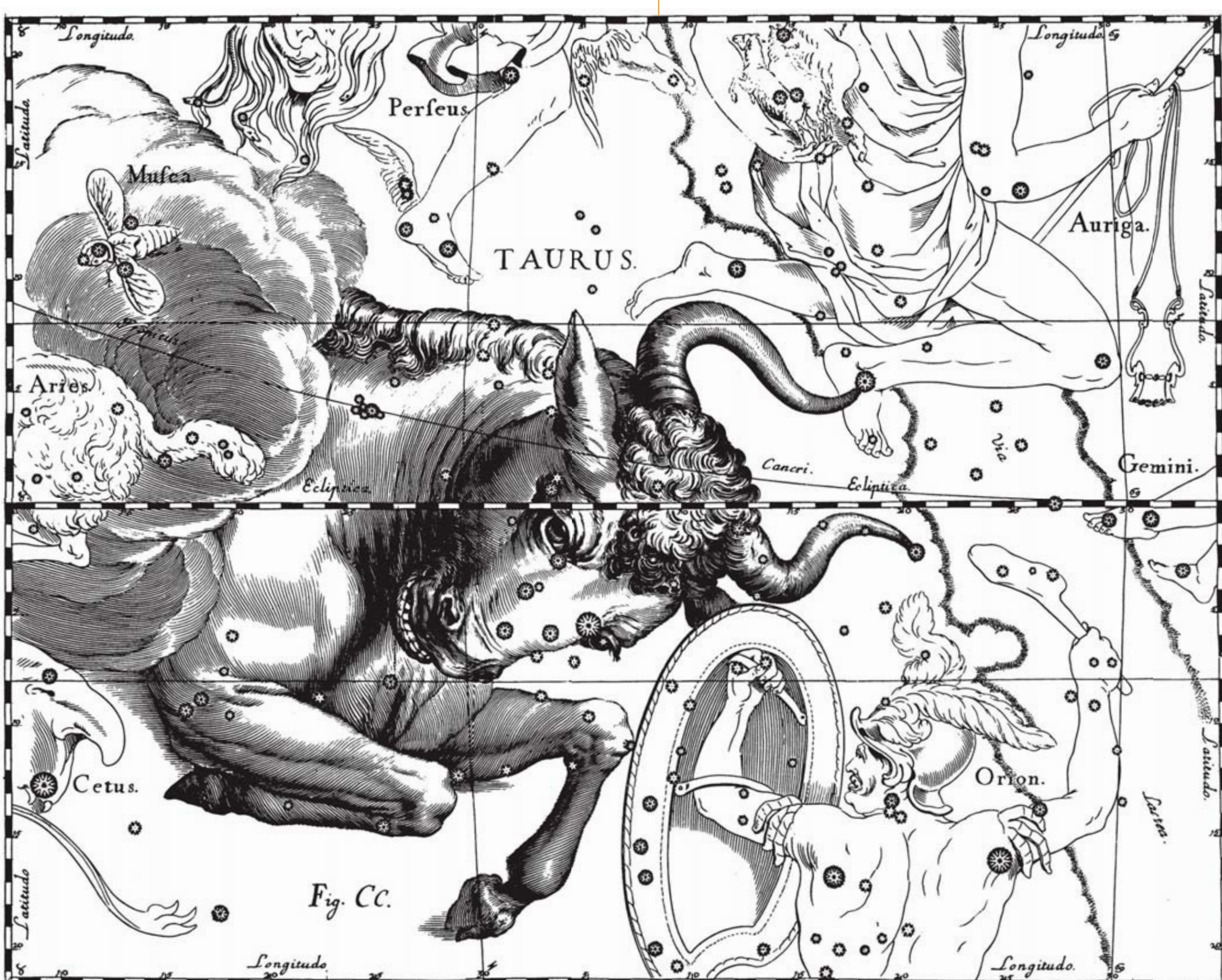
The frontispiece of their 1708 edition is on the previous page; it's identical to the original except for the acknowledgement *Apud G. Valk et P. Schenk* engraved below the title at the top.

Another fine frontispiece comes from *Selenographia,* the first reasonably accurate Moon atlas, by Johannes Hevelius (1611–1687). He was the son of a Polish brewer and property owner who became interested in astronomy as a student and used the family's wealth to obtain astronomical instruments and set up his own observatory. Published in 1647, *Selenographia* included informative text, three large plates of the full Moon, and a series of smaller images showing the lunar phases day by day. Its frontispiece is at right.

Just four years later, Giambattista Riccioli (1598–1671) in Italy published an even better lunar map in his massive *Almagestum Novum*. We still use nearly all of its names for lunar seas and craters, systematically bestowed as told in the May *Sky & Telescope,* page 26. That article showed the central part of the book's frontispiece. It portrays the starry Muse of Astronomy weighing the Copernican and Tychonic models of the solar system in a balance before a many-eyed observer holding a telescope. Tycho's

HEVELIUS, *SELENOGRAPHIA,* 1647
At the top, Contemplatio rides an eagle skyward with telescope in hand, beneath a well-mapped Moon and a Sun carrying sunspots across its face as it rotates. Two *putti* hold a banner referencing Isaiah 26: "Lift up your eyes on high, and behold who hath created these things...." Presenting the title scroll are Ibn al-Haytham (Alhazen), who stands on the pedestal of Reason marked by a skullcap, and Galileo (with telescope), who stands on the pedestal of the Senses marked by an eye. The lengthier, printed title page suggests that the atlas unites these two principles to resolve all sorts of astronomical, optical, and physical questions.

TAURUS BY HEVELIUS **Johannes Hevelius is remembered not just for his *Selenographia* but for his star atlas, *Firmamentum Sobiescianum sive Uranographia*. He engraved the plates himself, outdoing Bayer's *Uranometria* for intricate artistry. His style of portraying the sky mirror-reversed as if on a celestial globe was already out of fashion by his time. One of Taurus's eyes is placed at Aldebaran. The Pleiades are on his neck.**



JOHANNES HEVELIUS, *FIRMAMENTUM SOBIESCIANUM SIVE URANOGRAPHIA* / U. S. NAVAL OBSERVATORY

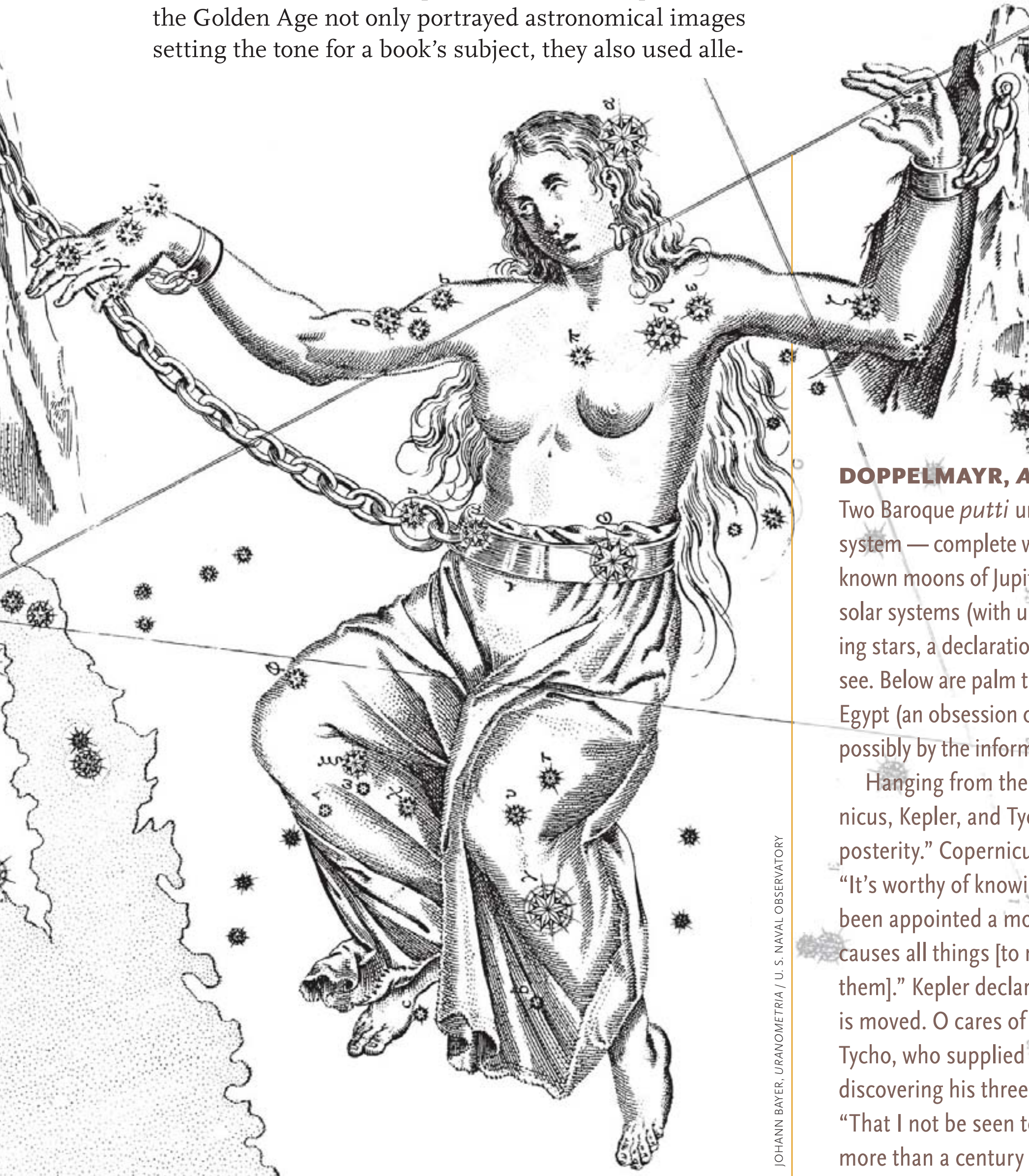

Contemplatio
Attollite in sublime oculos vestros, et videte quis creaverit ista
Esai. 40.
IOHANNIS HEVELII,
SELENOGRAPHIA:
sive,
LVNÆ DESCRIPTIO;
tam macularum
quam motuum diversorum
aliarumq omnium vicissitudinum,
Phasiumq Lunarium,
telescopii ope,
deprehensarum,
delineatione accuratâ,
atq locupleti
rerum Coelestium,
auctario exornata:
prodiit,
GEDANI.
Anno à Christo nato, 1647.
Autoris sumtibus,
Typis Hünefeldianis.
ALHASEN.
RATIONE.
GALILÆVS.
SENSV.

Earth-centered model wins the judgment. But despite this up-front declaration of orthodoxy, Riccioli (a Jesuit priest in Italy soon after the Galileo affair) seems to have secretly signaled, in his Moon map, that he favored the Copernicans instead.

Another grand frontispiece introduces Doppelmayr's *Atlas Coelestis*. Johann Doppelmayr (1677–1750) taught mathematics at a gymnasium (secondary school) in Nuremberg and wrote on a number of scientific topics, including astronomy and cartography. He collaborated with the famous Homann map-publishing firm to create beautiful and accurate astronomical and cosmological prints and charts. Many of these were collected in 1742 and issued as the *Atlas Coelestis,* which consisted of 30 plates dealing with such topics as the different solar-system models, planetary motions, and the surface of the Moon. Its dramatic frontispiece is shown at right.

As seen in these examples, celestial frontispieces of the Golden Age not only portrayed astronomical images setting the tone for a book's subject, they also used allegory to transmit messages and vivid pagan, Christian, and Islamic imagery to link past and present. They consistently emphasized the timelessness and vastness of the cosmos and the antiquity of astronomical inquiry, along with the promise of modernity in the pages to follow. Mythological characters and real astronomers were prominently featured, along with tools of the astronomical trade, to emphasize the book's scholarship. The results were engaging and informative artworks that, even as their elaborate symbolism has often grown obscure, retain their appeal today. ✦

Nick Kanas, M.D., *is a professor emeritus in psychiatry at the University of California, San Francisco. A collector of antiquarian star maps for over 30 years, he authored* Star Maps: History, Artistry, and Cartography *(2007; second edition 2012) and* Solar System Maps: From Antiquity to the Space Age *(2014). He is a longstanding member of the San Francisco Amateur Astronomers.*



JOHANN BAYER, *URANOMETRIA* / U.S. NAVAL OBSERVATORY

ANDROMEDA BY BAYER **Like the other constellations in the *Uranometria*, Andromeda is carefully drawn to place her body parts correctly near stars classically named for them. But Bayer also introduced a new star-naming system: lowercase Greek letters. He sometimes named the brightest star in a constellation Alpha, then added letters in alphabetical order more or less from a figure's head to feet for stars of middling brightness, then did so again for fainter stars. When the 24 Greek letters ran out he used Roman ones, but these have mostly fallen out of favor.**

DOPPELMAYR, *ATLAS COELESTIS,* 1742
Two Baroque *putti* unveil a grand banner with a diagram of our solar system — complete with shadow-casting planets, a comet, and the four known moons of Jupiter and five of Saturn. Surrounding this are other solar systems (with up to eight planets!) conjectured to circle the shining stars, a declaration that there is more to God's universe than we can see. Below are palm trees and two sphinxes suggesting the wisdom of Egypt (an obsession of the times), and a celestial globe being unveiled, possibly by the information in this book.

Hanging from the palm trees are placards behind Ptolemy, Copernicus, Kepler, and Tycho. Says Ptolemy, "All was done for the good of posterity." Copernicus quotes from Seneca on whether Earth rotates: "It's worthy of knowing what state of things we're in: whether we have been appointed a most stable or most rapid dwelling; whether God causes all things [to move] around us, or causes us [to move beneath them]." Kepler declares, "All is changed, the Sun stands and the Earth is moved. O cares of men! O how much emptiness there is in things!" Tycho, who supplied the meticulous observations that Kepler used in discovering his three laws of planetary motion, looks to him and sighs "That I not be seen to have lived in vain." It's a triumphant answer, more than a century later, to his deathbed lament that he might be.


Claud. Ptolemæus.
Nic. Copernicus.
Omnia mutantur, stat sol et terra movetur. O curas hominum! ô quantum est in rebus inane!
Ioh. Keplerus.
Ne frustra vixisse videar.
Tycho Brahe.
ATLAS COELESTIS
studio et labore
IOH. GABRIELIS DOPPELMAIERI. Math. P.P.
impensis
Heredum Homannianorum
Noribergæ. A. MDCCXLII.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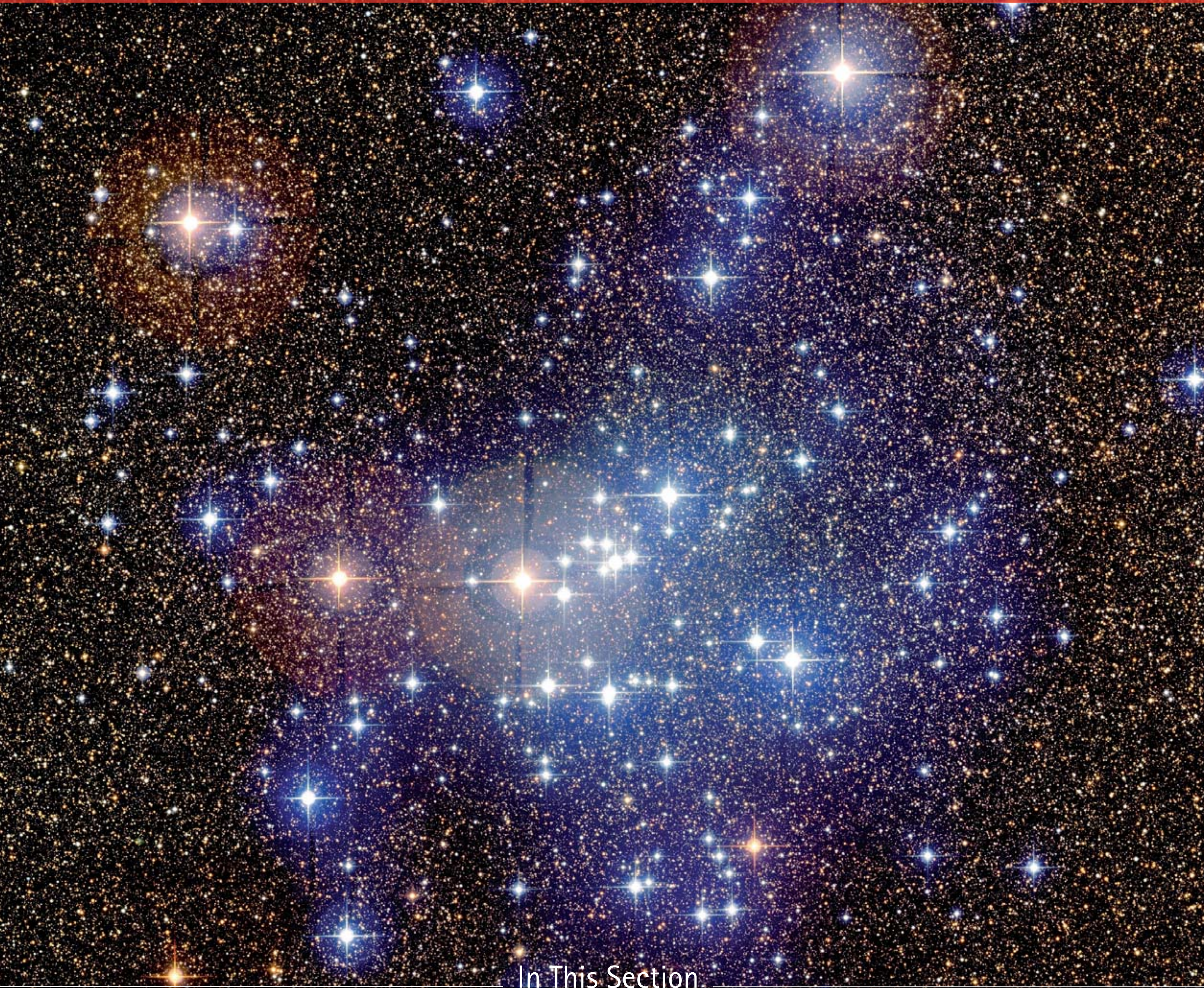


In This Section

PHOTOGRAPH: CFHT / COELUM – J.-C. CUILLANDRE & G. ANSELMI
Open cluster M25 was discovered c. 1745 by Philippe Loys de Chéseaux, see p. 58.

OBSERVING

Sky at a Glance

JULY 2015

1 **EVENING:** Venus and Jupiter begin July still spectacularly close, low in the western sky. Watch them slowly move apart during the month.

12 **MORNING:** The thin curve of the waning crescent Moon pulls within 5° of Aldebaran. Observers in Japan, northeast Siberia, and the far north of North America will see the Moon occult the orange giant star.

14 **EVENING:** Venus has been moving closer to much-fainter Regulus in the past two weeks. It makes its closest approach on this date, blazing just 2° or 3° from the first-magnitude star.

18 **DUSK:** Look west just after sunset to spot Venus and the waxing crescent Moon within 2° of each other. As the sky darkens, Regulus will appear a few degrees above the pair. The flame of Jupiter will be visible to the right.

22, 23 **EVENING:** The first-quarter Moon is about 7° to the right of Spica on the 22nd and a similar distance upper left of it on the 23rd.

25 **NIGHT:** Ceres reaches opposition; see p. 50.

NIGHT: The waxing gibbous Moon is just a few degrees from the shining disk of Saturn in Libra.

30 **NIGHT:** The modest, long-lasting Delta Aquariid meteor shower peaks around this date. Higher rates are seen from southerly latitudes. The bright Moon will hamper viewing.

31 **MORNING:** The Moon reaches full for the second time this month; sometimes this event is known as a "Blue Moon."

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

	◄SUNSET	MIDNIGHT	SUNRISE►
Mercury		Visible through July 13	NE
Venus	W		
Mars		Hidden in the Sun's glare all month	
Jupiter	W	Visible through August 5	
Saturn	S	SW	

Moon Phases

Last Qtr	July 8	4:24 p.m. EDT
First Qtr	July 24	12:04 a.m. EDT
Full	July 1	10:20 p.m. EDT
New	July 15	9:24 p.m. EDT
Full	July 31	6:43 a.m. EDT

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

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.

When

Late May	2 a.m.*
Early June	1 a.m.*
Late June	Midnight*
Early July	11 p.m.*
Late July	Dusk

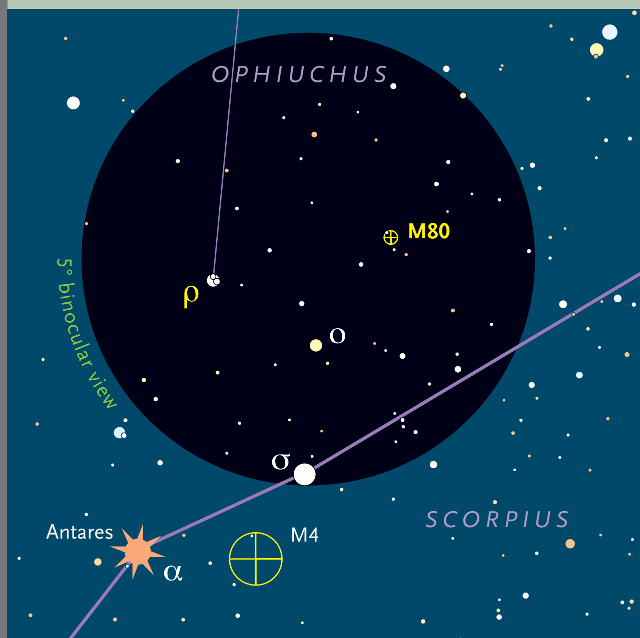
*Daylight-saving time.

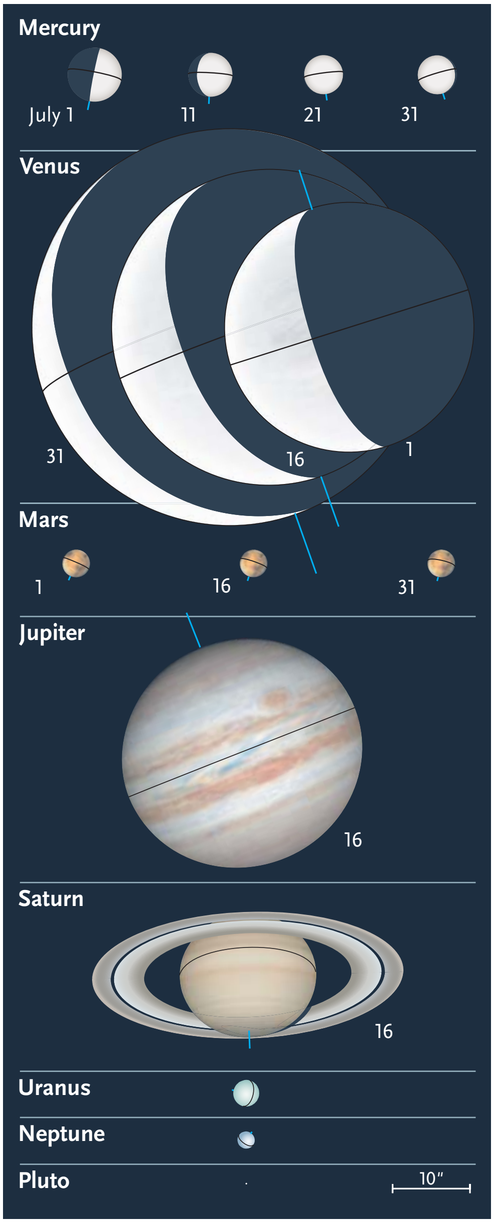
A Triple and a Globular

An observing friend of mine has a particular fondness for what he calls "pizza objects." These are celestial two-for-one deals — a pairing of targets lying in the same field of view. Two objects for the effort of finding one. And if they're different from each other, so much the better — variety is the spice of life! So in his honor, let's enjoy a two-for-one binocular field northwest of Antares that gives us an easy triple star and a much more challenging globular cluster.

The triple star is **Rho (ρ) Ophiuchi**. It might just be the most famous star you've never seen. In long-exposure photographs of the region, Rho is surrounded by a colorful fog of nebulosity. Indeed, the Rho Ophiuchi Nebula is so well-known that few seem aware that Rho is also a striking binocular triple. It comprises a 5th-magnitude primary with an equidistant duo of 7th-magnitude companions forming a tidy triangle. I can easily see all three component stars in 7×35s.

Half a binocular field west of Rho, we find our bonus object, globular cluster **M80**. Most globulars are tricky at the low magnifications of typical binoculars, but M80 is doubly difficult because it's so small. What you're hunting for is something that looks like a slightly out-of-focus 7.3-magnitude star. Even in my 15×45 image-stabilized binoculars, M80 doesn't exactly jump out of the field. Fortunately, it's the brightest point of light in that spot. It also serves as the westernmost tip of a triangle that includes Rho Ophiuchi and Omicron (ο) Scorpii. M80 is one of those binocular targets that's not difficult to see but is a challenge to identify. ✦



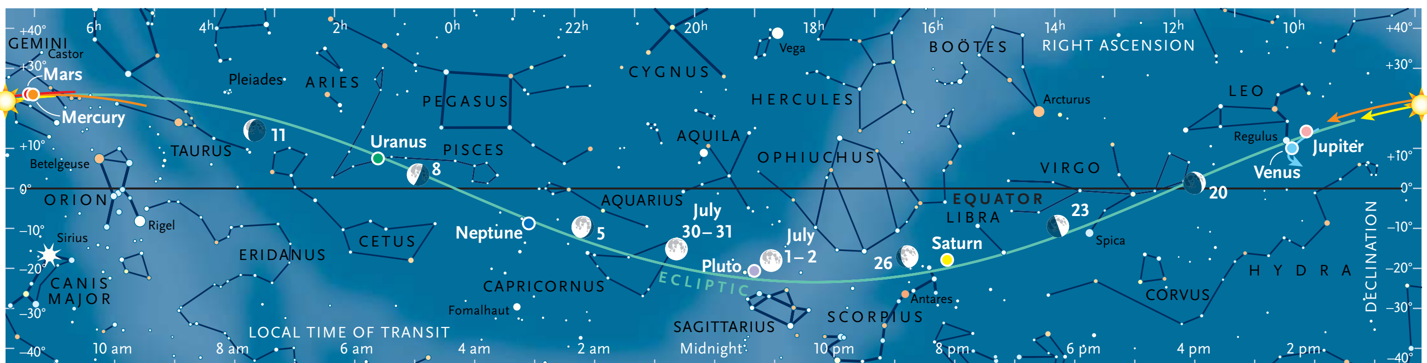


Sun and Planets, July 2015

	July	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$6^h\ 37.7^m$	+23° 09′	—	–26.8	31′ 28″	—	1.017
	31	$8^h\ 38.8^m$	+18° 27′	—	–26.8	31′ 31″	—	1.015
Mercury	1	$5^h\ 06.9^m$	+20° 35′	21° Mo	–0.2	7.0″	52%	0.963
	11	$6^h\ 16.8^m$	+23° 09′	14° Mo	–1.0	5.7″	81%	1.179
	21	$7^h\ 46.4^m$	+22° 34′	4° Mo	–2.0	5.1″	99%	1.321
	31	$9^h\ 12.8^m$	+17° 58′	8° Ev	–1.3	5.0″	96%	1.334
Venus	1	$9^h\ 35.0^m$	+14° 58′	43° Ev	–4.6	32.3″	34%	0.516
	11	$9^h\ 55.5^m$	+11° 41′	39° Ev	–4.7	37.7″	26%	0.442
	21	$10^h\ 05.1^m$	+8° 48′	33° Ev	–4.7	44.3″	17%	0.377
	31	$10^h\ 01.1^m$	+6° 49′	23° Ev	–4.5	51.4″	8%	0.324
Mars	1	$6^h\ 18.0^m$	+24° 07′	5° Mo	+1.6	3.6″	100%	2.584
	16	$7^h\ 01.6^m$	+23° 33′	9° Mo	+1.6	3.6″	100%	2.586
	31	$7^h\ 44.0^m$	+22° 15′	13° Mo	+1.7	3.6″	99%	2.576
Jupiter	1	$9^h\ 36.1^m$	+15° 12′	43° Ev	–1.8	32.4″	100%	6.076
	31	$9^h\ 59.4^m$	+13° 12′	20° Ev	–1.7	31.2″	100%	6.324
Saturn	1	$15^h\ 48.5^m$	–17° 51′	140° Ev	+0.2	18.1″	100%	9.183
	31	$15^h\ 45.1^m$	–17° 47′	111° Ev	+0.4	17.3″	100%	9.584
Uranus	16	$1^h\ 15.7^m$	+7° 19′	93° Mo	+5.8	3.5″	100%	19.916
Neptune	16	$22^h\ 44.7^m$	–8° 49′	134° Mo	+7.8	2.3″	100%	29.253
Pluto	16	$18^h\ 59.1^m$	–20° 46′	171° Ev	+14.1	0.1″	100%	31.906

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

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



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

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

Fred Schaaf

Storm Clouds and Star Clouds

Make the sky part of your annual summer vacation.

Thirty-three years ago this month of July, I took a travel vacation I'll never forget.

The part of this vacation I spent in North Dakota went from just before full Moon to new Moon. Those two weeks found me seeing: the most spectacular auroral displays of my life; the longest total lunar eclipse in U.S. history; the longest, strongest "volcanic twilights" in perhaps about 70 years; my closest funnel cloud; my longest-lasting sunsets, earthshadows, and Belts of Venus; my strongest airglow bands; my closest, farthest, and longest-after-sunset rainbows. And much more.

Some of these sights are ones that you might not be lucky enough to have happening in any particular two weeks no matter where you are. But it's really quite astonishing how much of what a person sees is a function of how often he or she looks and the desire and awareness he or she has of the sky. A travel vacation can give a person more looks at the sky and a fresh, seeking state of mind that will bring amazing visions.

Supercell thunderstorm near Glasgow, Montana

SEAN R. HEAVEY

Changes in Latitude and Attitude. My trip in the summer of 1982 took me only about 8° of latitude farther north of my home location. Yet this was enough to make noticeable — and inspiring — differences in my views of stars and other phenomena. While observing the long lunar eclipse and looking for the Northern Lights, I was startled to see a zero-magnitude star low in the north. It was Capella, best known as a winter star — but at latitude 48° north also the great low northern star of summer nights. Another star whose altitude was very noticeably changed — lowered — was Antares. On one of the nights when Northern Lights covered the sky all the way to the south horizon, the red of Antares was intensified by the surrounding green aurora. And the star appeared even lower — right above the brink of our apparent horizon — because a friend and I were observing from a shallow little dell.

Bikes to Storm and Stellar Beauty. My friend was working as a field meteorologist that summer, manning a weather radar in a Winnebago and advising pilots when they should seed storm clouds to try to convert crop-destroying hail to rain. Although the town we stayed in had less than a thousand people and its nearest neighboring town, no bigger, was about 14 miles away, we rode bikes out of town into the even darker country for better views when auroras fired up. We also biked out of town to come within about a mile of a (weak, not-very-threatening) funnel cloud.

Then there were the nights of storms and stars when I biked up to the weather radar on the ridge outside of town. On one of these occasions, I observed a distant supercell thunderstorm that generated "crawlers" of side-propagating lightning many miles long — yet left visible directly adjacent to it a richness of 6th-magnitude stars and splendid Scutum Star Cloud.

The Most Distant Sights and Sound. I've seen objects in the telescope billions of light-years away. But the most distant sound I've ever heard came on the night before the long eclipse.

I was lying on the ground with a handheld camera to photograph the Moon, attempting to catch part of a cloud-corona as it formed around the Moon in the blow-off from a supercell storm. With the weather radar in the Winnebago, we were able to determine that we likely heard the first thunder from that storm when the lightning was 50 miles away. When the thunderstorm finally arrived, it rocked the RV with wind that the anemometer measured at more than 70 mph.

An Astro-Vacationer's Travel Advice. Many of us find the time and money to take a vacation trip during the summer. If you do, I urge you to make the sky a part of your itinerary. ✦

Summer Sensations

Venus, Jupiter, and Saturn grace the evening, Mars and Mercury the dawn.

After finally having their majestic closest pairing on the final day of June, Venus and Jupiter continue to nearly match motions and stay surprisingly close together in July. They set sooner after the Sun each night, becoming troublesomely low for observers by month's end. But they also move closer to Regulus, and on July 18th the three have an astounding compact gathering with the crescent Moon.

Saturn is in the south at nightfall this month, and Mercury is still visible low in the dawn until about mid-month.

DUSK

Venus and **Jupiter**, 0.3° apart on the American evening of June 30th, are separated by only 0.6° on July 1st. They start the month setting about 2 hours and 20 minutes after the Sun, but end it with Venus setting about 30 minutes — and Jupiter almost an hour — after the Sun.

The planetary pair shares the last of its 8 days within 2° of each other on July 4th. By then dazzling Venus is only about 7° lower right of Regulus in Leo, which is only half a percent as bright. Venus then marches closer to Regulus, spending July 11th to 18th within 3° of the star. During this time Venus shines at magnitude –4.7, the planet's maximum brightness for the current apparition.

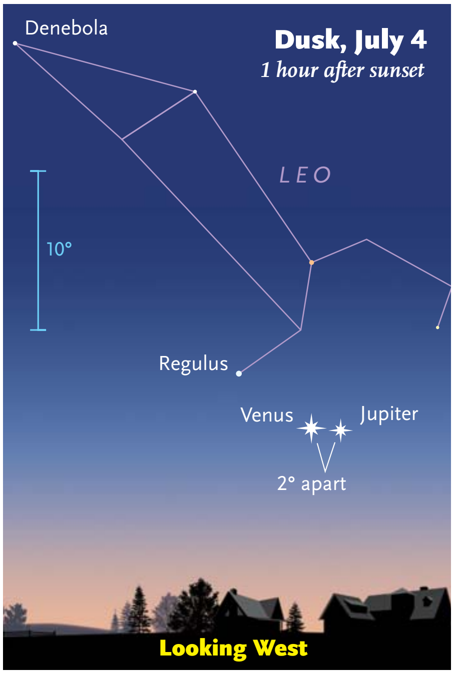
On the American evening of July 18th, the thin crescent Moon glows only about 1½° from Venus, while the Moon, Venus, Jupiter, and Regulus all fit within a 7° circle. The glorious grouping stands about 10° to 12° above the western horizon 1 hour after sunset, depending on your latitude; bring binoculars.

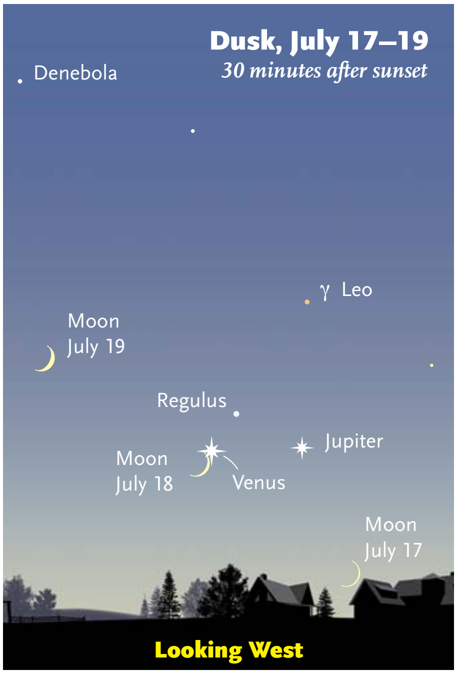
Venus, rounding the near arc of its orbit to us, begins retrograde (westward) motion with respect to the stars on July 23rd. Since it loops south, its next conjunction with Jupiter on July 31st finds it 6° south of the gas giant.

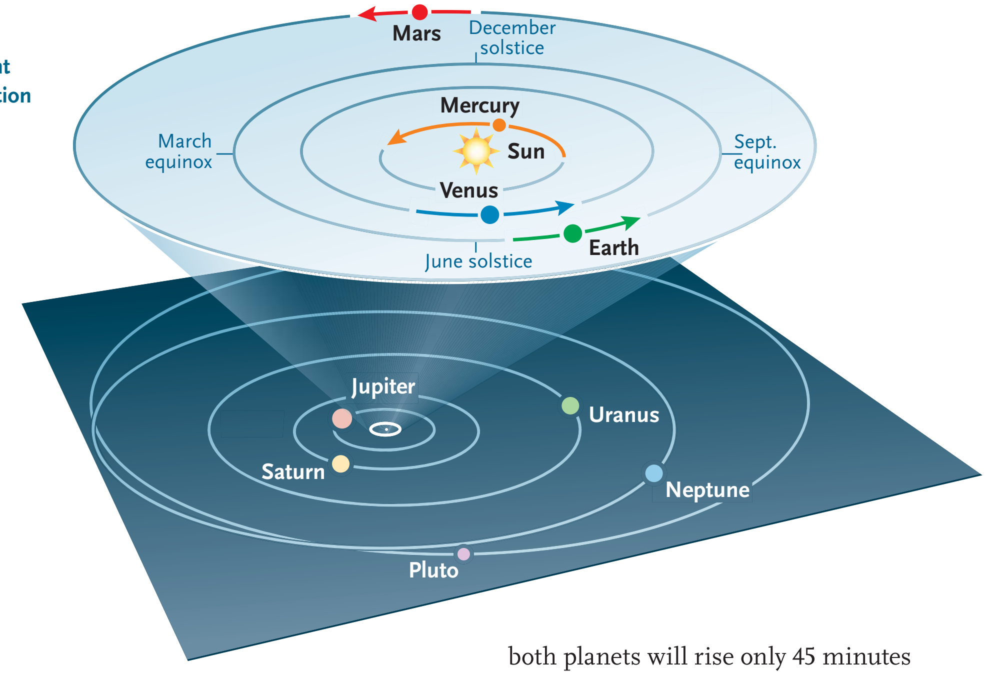
Jupiter dims from magnitude –1.8 to –1.7 during July, and its equatorial diameter appears little more than 30″ wide. Venus, nearing Earth but turning ever more of its night side toward us, is fascinating in the telescope (and binoculars) this month. Starting July about 33% lit and 33″ wide, by the 18th the crescent Venus is 19% lit and 43″ wide; on July 24th it appears 13% lit and 47″ wide; on August 1st, 7% lit and 53″ wide.

UNTIL AFTER MIDNIGHT

This month **Saturn** is well-placed for observation in the south at nightfall, languishing in easternmost Libra, some 5° west of the fine telescopic double star Beta Scorpii. The ringed world dims from magnitude +0.2 to +0.4 over the course of July and appears a bit smaller by the end of the month. The rings remain a magnificent telescopic sight, however, displaying a 24° tilt.







ORBITS OF THE PLANETS

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

DUSK TO DAWN

Pluto reaches opposition on July 6th and is highest in the middle of night. This is one of the most appropriate months ever to (try to) observe this challenging 14th-magnitude speck, as NASA's New Horizons spacecraft is due to give us our first close-up look at the dwarf planet as it flies by on July 14th; see p. 20 of this issue. This summer, Pluto lies near Xi^1 (ξ^1) and Xi^2 (ξ^2) Sagittarii, stars in the bowl of the Teaspoon of Sagittarius. A detailed finder chart for Pluto appears on p. 52.

Ceres comes to opposition on July 25th, when its magnitude +7.5 light can be found between the southern part of Sagittarius and Capricornus; see the finder chart on p. 50. Ceres has its own visitor, the Dawn spacecraft, which went into permanent orbit around that dwarf planet in March of this year.

Neptune rises a few hours after sunset and **Uranus** around midnight, but neither planet is very high until the approach of dawn.

DAWN

Mercury was at the highest of its current morning apparition on June 30th for viewers around latitude 40° north, when it was rising about 75 minutes before the Sun. On the American morning of July 16th, **Mars** is only 0.1° north of Mercury, but the conjunction will be exceedingly difficult to see low in the bright dawn; both planets will rise only 45 minutes before sunup, and though Mercury shines at magnitude –1.5, Mars is a feeble +1.6.

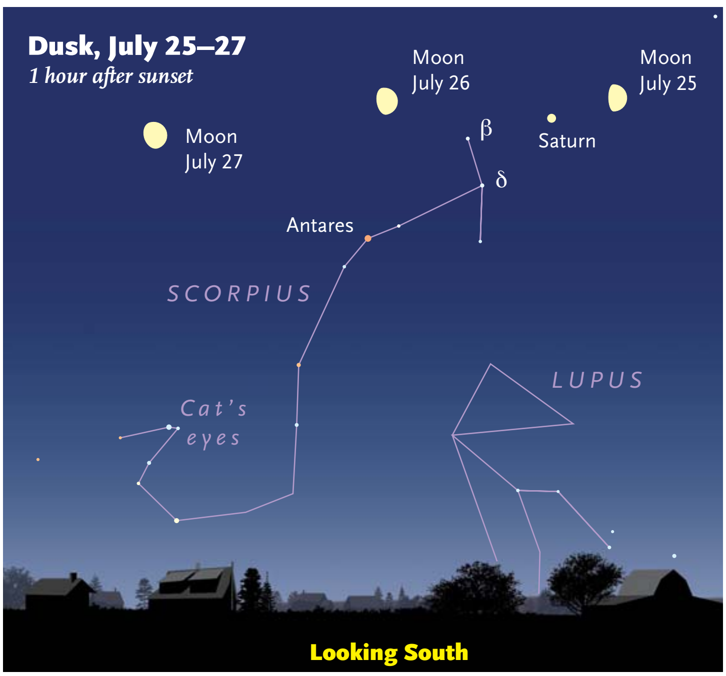
Mercury plunges through superior conjunction with the Sun on July 23rd.

EARTH AND MOON

Earth is at aphelion, its farthest from the Sun in space, at 3:41 p.m. EDT on July 6th. At that time our planet lies 94,506,507 miles from the Sun, measured center to center.

The **Moon** is full for the first of two times this month at 10:20 p.m. EDT on July 1st. The waning lunar crescent floats in the Hyades star cluster at dawn on July 12th, just a few degrees upper right of Aldebaran. Mark your calendar for the American evening of July 18th, when the waxing crescent Moon joins Venus, Jupiter, and Regulus in the stunning tight gathering described above.

The waxing gibbous Moon is only modestly close to and upper right of Saturn on the evening of July 25th; it's much farther left of Saturn the next night. The Moon is full once more at 6:43 a.m. EDT on July 31st. The second full Moon of a calendar month is sometimes called a "Blue Moon" — not to be mistaken for the far more interesting and truly rare Blue Moon that appears blue due to dust particles in the Earth's atmosphere. ✦



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.

It's Dwarf-Planet Summer

As Dawn and New Horizons watch Ceres and Pluto, you can too.

This is revelation time for the first dwarf planets we've ever seen close up. Dwarf planets are the class of bodies that the International Astronomical Union defined in 2006 as being too large and round to be just "asteroids," but too small and gravitationally uninfluential to count as full "planets." Since March, NASA's Dawn spacecraft has been orbiting Ceres, by far the largest main-belt asteroid. Dawn is working its way down to lower altitudes and in August will begin a mapping project from 1,480 kilometers (920 miles) above the surface. Dawn should reach its lowest planned orbit in late November, at an altitude of about 375 km.

And on July 14th, NASA's New Horizons probe will fly by mysterious Pluto and its five moons as described beginning on page 20.

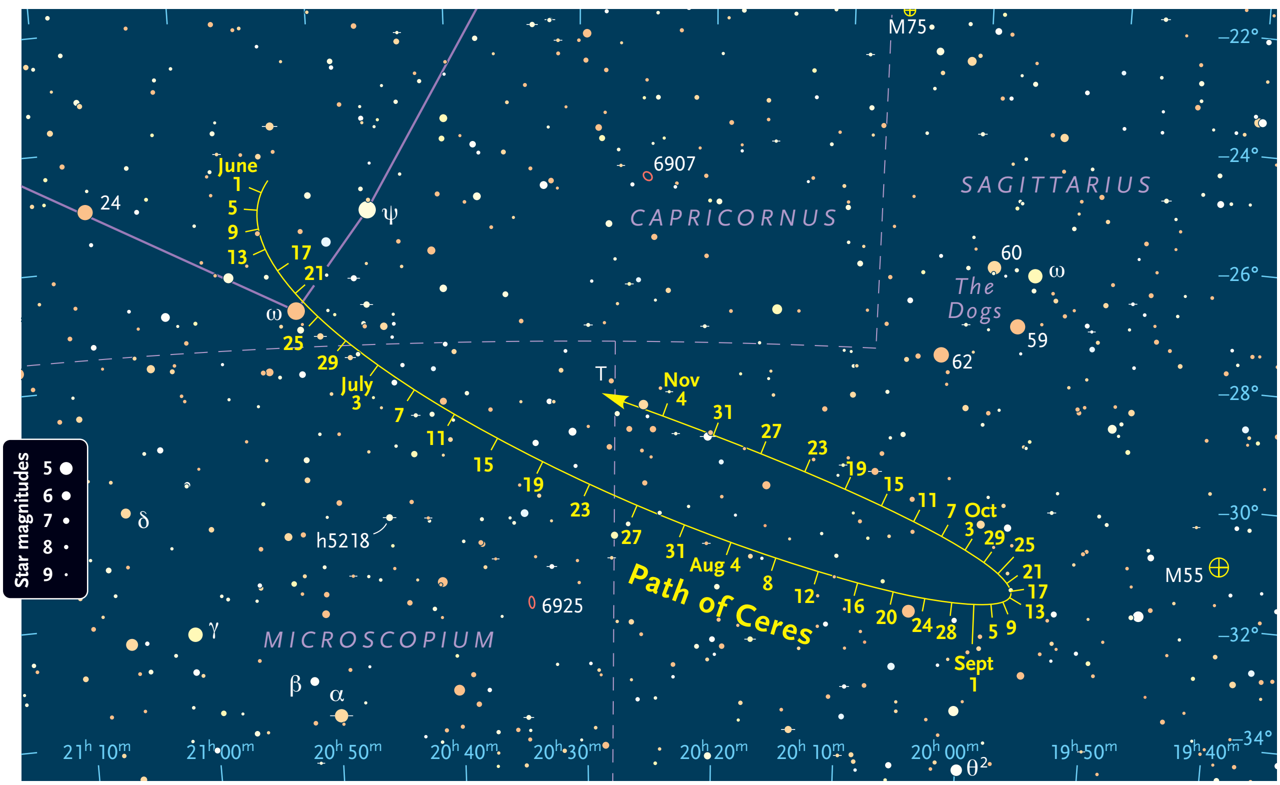
Never before have we seen any dwarf planet as more than a pinpoint or vague little blur.

For backyard astronomers, Ceres and Pluto are worlds apart. Ceres can be spotted with good binoculars from June through August, and it's an easy pinpoint in a 3-inch scope. Pluto will challenge skilled deep-sky hunters using 12-inch and larger scopes under dark skies. Both objects are in or near Sagittarius, highest in the south late at night. They're about 25° apart.

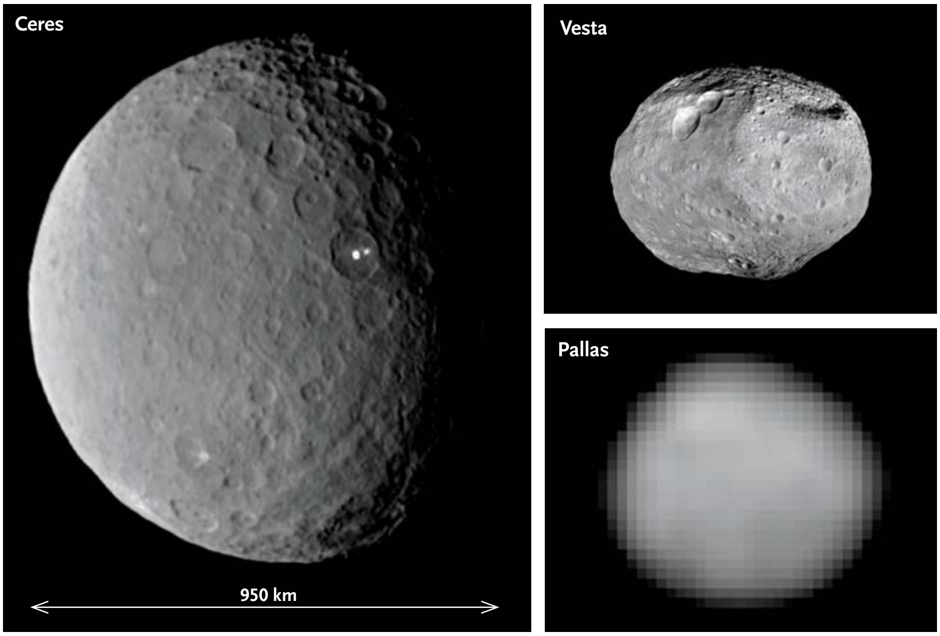
Ceres for Everyone

The first-discovered asteroid, 1 Ceres, has twice the diameter of the next-largest two, as illustrated at right. It's the only object in the asteroid belt that rises to dwarf-planet status. By itself, it accounts for about a third of the entire asteroid belt's mass.

This season finds Ceres swinging from the southern



Looping among southern constellations, Ceres remains brighter all summer than the faintest stars (magnitude 9.0) plotted here. The ticks on its path every four days mark 0:00 Universal Time on the dates indicated. Opposition is on July 25th, near the middle of the retrograde loop.



CERES, VESTA: NASA / JPL / UCLA / MPS / DLR / IDA. PALLAS: NASA / STSCI

The three largest asteroids to scale. Ceres is twice the size of the two runner-ups, 2 Pallas and 4 Vesta, so it has enough mass for its gravity to pull it into a rounder shape. Dawn took the Ceres image on February 19th from a distance of 46,000 km; much better pictures have since come down. Dawn took images for the full-Vesta montage during its mission there from July 2011 to September 2012. Our best views of Pallas were taken by the Hubble Space Telescope in September 2007.

tip of the Capricornus star pattern down through little-known Microscopium and into easternmost Sagittarius. That's not as daunting for northerners as it sounds. If you can see the whole Sagittarius Teapot, you have a low enough southern view for Ceres. Observing it will be a late-night project; Ceres is highest just before dawn on June 1st, around 4 a.m. daylight-saving time on July 1st, 1 a.m. on August 1st, and 10 p.m. by September 1st.

Ceres comes to opposition on July 25th this year. Expect it to brighten from magnitude 8.4 on June 1st to 7.9 on July 1st. It will remain at 7.5 for the second half of July, then fade from 7.6 on August 1st to 8.2 on September 1st and 8.7 at the beginning of October.

On the finder chart at left, put a dot on its path for the date and time you plan to go out and look. Stars are plotted to magnitude 9.0.

Ceres is not the brightest asteroid (lighter-colored 4 Vesta claims that prize around its oppositions), but Ceres was the first discovered, in 1801. That means we've known about it for two and a half times as long as we've known Pluto.

And rather like Pluto, it was discovered somewhat by accident — even though in each case, a pack of astronomers already thought they sniffed its scent and were hot on its trail.

In 1772, Johann Elert Bode suggested that a small planet remained undiscovered between Mars and Jupiter. He based this guess on the very wide gap between those two planets, which broke the otherwise fairly smooth progression in the spacing of planets outward from the Sun. This spacing came to be called "Bode's Law."

Picking up on this idea in 1800, the Hungarian astronomer and journal editor Franz Xaver von Zach organized an international team of 24 astronomers to track down Bode's fugitive planet. They nicknamed themselves the "Celestial Police." One of them was Giuseppe Piazzi in Palermo, Sicily. But before Piazzi received the letter inviting him to join the hunt, he happened to notice an uncataloged star near another star whose position he was measuring. The newcomer proved to be moving. At first Piazzi thought it was a comet. In fact, the "missing planet" had turned itself in before the police could catch it (see *S&T:* March 1988, p. 271).

Piazzi named it Ceres for the Roman goddess of grain (think "cereal"), a patron goddess of Sicily. The element cerium, discovered two years later, was named for Ceres the asteroid — something telescope makers can remember while polishing mirrors with cerium oxide.

Pluto in the Depths

At magnitude 14.1, Pluto is not for the light-polluted or for users of telescopes smaller than 12 inches. Opinions may differ on that, but Pluto has been fading over the years as it creeps farther away from both Sun and Earth. (It was magnitude 13.6 in the years around its 1989 perihelion.) Moreover, Pluto has been moving southward almost since its discovery in 1930. Both trends will continue to worsen slightly year by year.

At least Pluto hunters in 2015 have a good starting point: Pluto is at the bowl of the naked-eye Teaspoon of Sagittarius. The chart on the next two pages shows stars to magnitude 14.5. For easier use with a dim red flashlight at the telescope, you may want to photocopy and blow up the field around Pluto's position.

The ticks again mark 0:00 Universal Time. Once you've pinpointed Pluto's exact location in your eyepiece, switch to your highest power and use your best averted vision. Don't give up easily; glimpsing it will probably take time. It's a good idea to check back the next night to confirm that the thing you saw (or thought you saw) has moved.

Like Ceres, Pluto was discovered a couple of decades after it was predicted and not in the way expected.

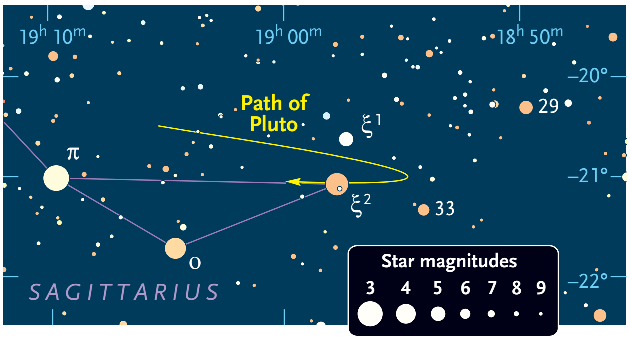
Neptune had famously been discovered in 1846 by way of its slight gravitational influence on Uranus. In 1906 Percival Lowell, the founder of Lowell Observatory in Arizona, launched a hunt for a ninth planet beyond Neptune based on apparent hints that Neptune too was being perturbed by a planet farther out. Lowell and his staff found nothing by the time of his death in 1916. After a long hiatus, Lowell Observatory resumed the search in 1929 by hiring the young Clyde Tombaugh to take photographic plates with a 13-inch astrograph and blink-compare them for moving objects. He hit on Pluto, then in Gemini, the following year.

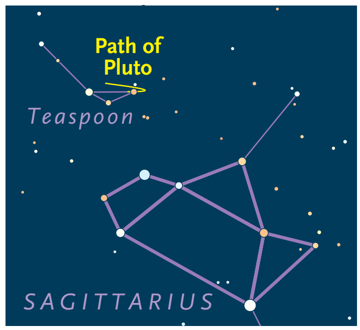
The discovery made international headlines, and the observatory received more than 1,000 suggestions for what to name the new planet. The winning name, after the Greek god of the underworld, came from 11-year-old Venetia Burney in Oxford, England, who had a fascination for classical mythology.

Pluto the dog entered Disney comics later that year.

But astronomers quickly realized that Pluto was much too faint, and thus presumably too small, to affect Neptune. Was it actually large but fantastically dark black? Was it mirror-polished like a ball bearing, showing only a tiny specular reflection of the Sun? Was it small but made of something incredibly dense, partway to white-dwarf matter?

In reality, the claims of tiny perturbations in Neptune's orbit turned out to have been mistaken. The whole hunt was a wild goose chase — with, as so often happens, a serendipitous result. ✦

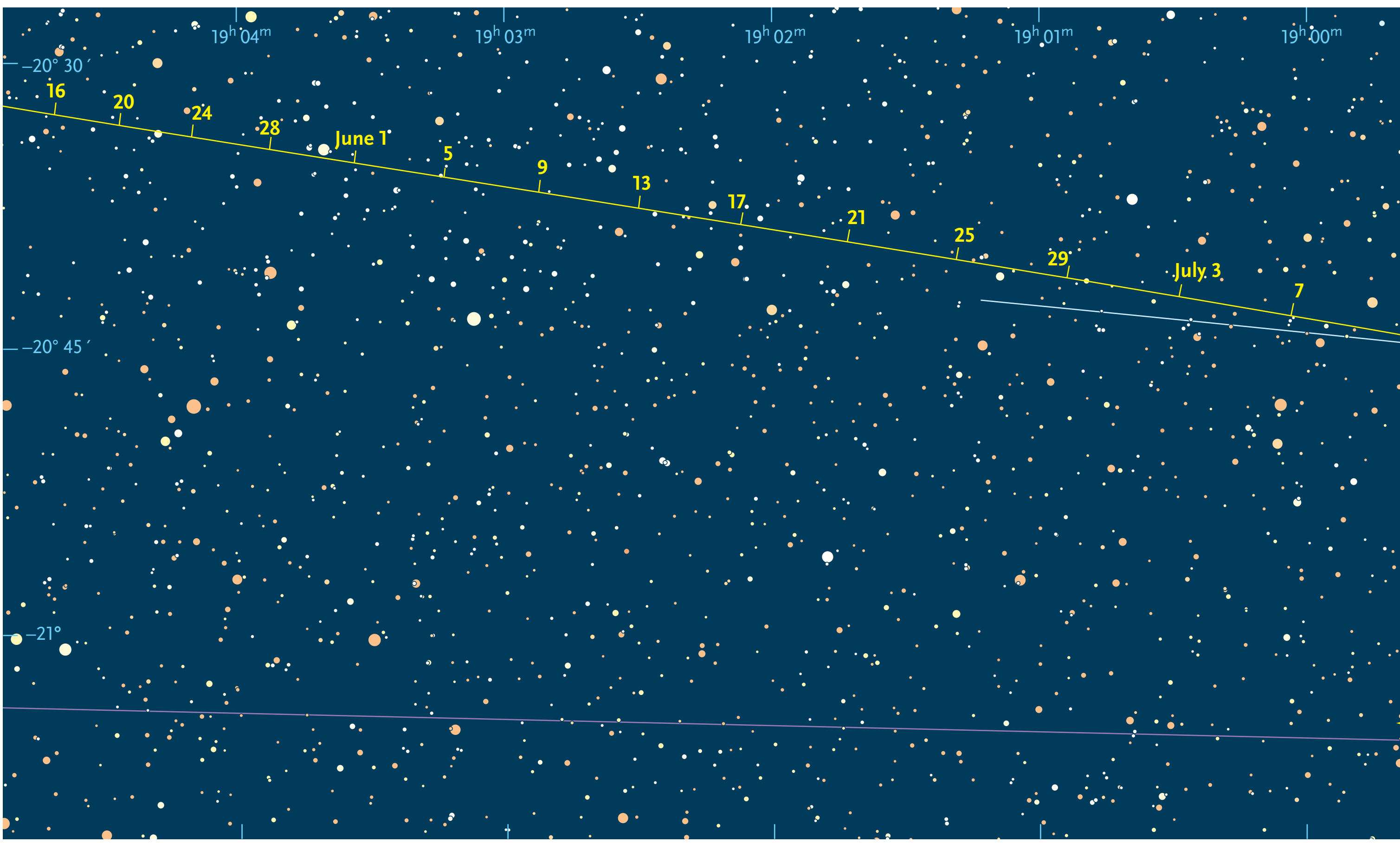




KEEP UP WITH THE CLOSE-UPS

Follow news from Ceres at the Dawn mission site, **dawn.jpl.nasa.gov**.

Follow New Horizons' approach to and flyby of Pluto at **pluto.jhuapl.edu**.



Two Dwarf Planets Compared

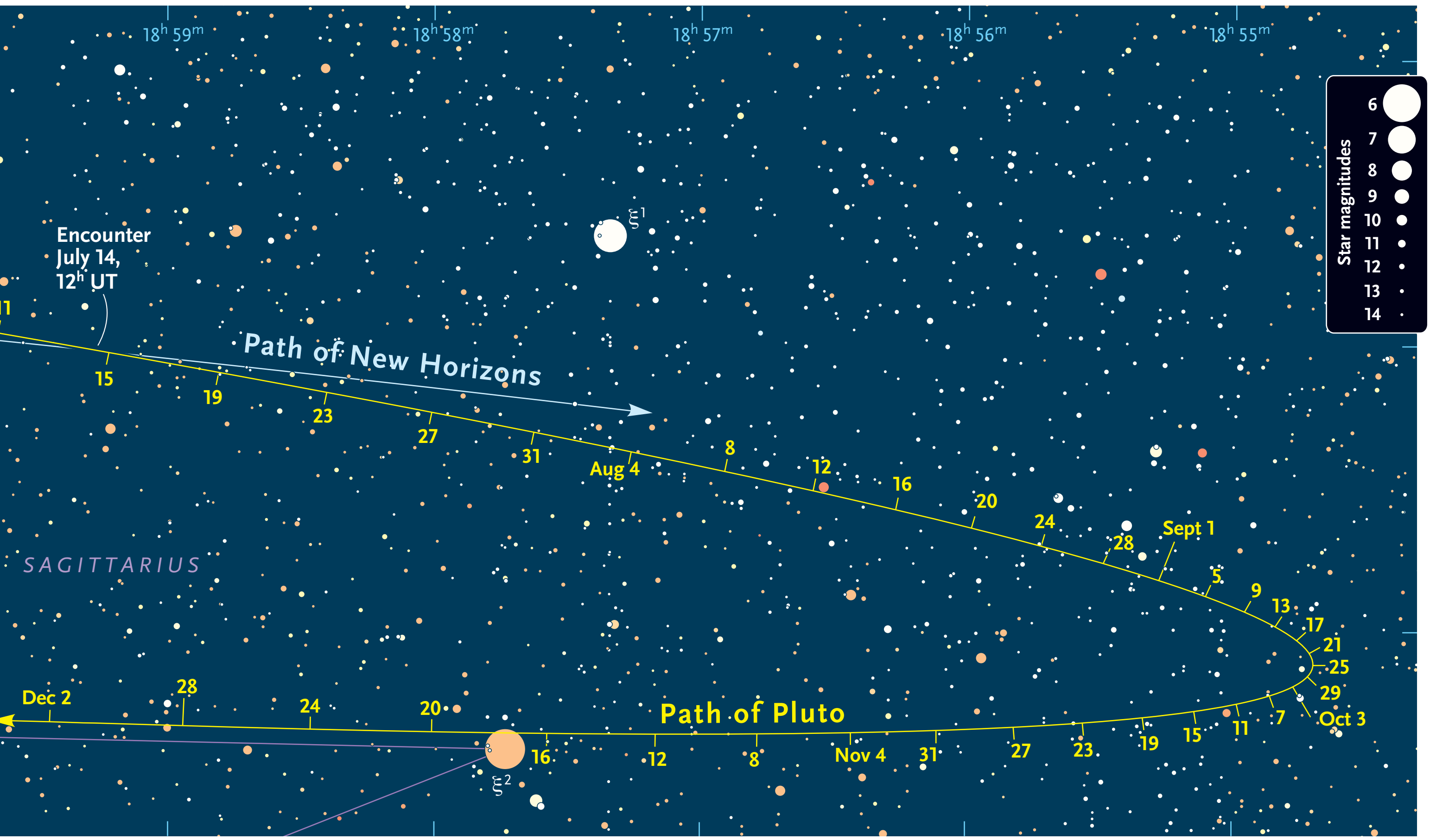
	Ceres	Pluto
Diameter	950 km	2,390 km
Density	2.1 gm/cm³	1.8 gm/cm³
Surface gravity	0.03 g	0.07 g
Albedo (mean)	0.09	~0.55
Color	Dark gray, dark brown	Brown-black, orange-tan, white
Surface composition	Rock	Nitrogen ice, other ices
Bulk composition	Rock, water ice	Rock, water ice
Rotation period	0.3781 day	6.3872 days
Temp. (daytime mean)	168 K	50 K
Known natural satellites	0	5
Discovery	January 1, 1801	February 18, 1930
Discoverer	Giuseppe Piazzi	Clyde Tombaugh
Minor-planet number	1	134340
Magnitude July 1st	7.9	14.1

Asteroid Occultations

On the evening of July 16–17, an 8.3-magnitude star near the Sagittarius Teaspoon (and Pluto) will be occulted for up to 4 seconds by 12th-magnitude 679 Pax. The occultation will happen along a narrow track from northern Idaho through northern California. The star will be low in the southeast.

On the evening of July 21st, a 10.6-magnitude red star in easternmost Virgo will be occulted by 15th-magnitude 856 Backlunda for up to 4 seconds along a narrow track from the Dakotas through Arkansas to southern Mississippi or possibly New Orleans. The star will be fairly high in the southwestern sky.

For track maps with time predictions, finder charts for the stars, and predictions of other asteroid occultations worldwide, see **asteroidoccultation.com/IndexAll.htm**. For more about timing asteroid occultations and where to report, see **asteroidoccultation.com/observations**. For human advice and help, join the discussion group at **groups.yahoo.com/neo/groups/IOTAoccultations**.



A Polar Expedition to Saturn

Why is the ringed planet crowned by a distinct hexagonal cloud pattern?

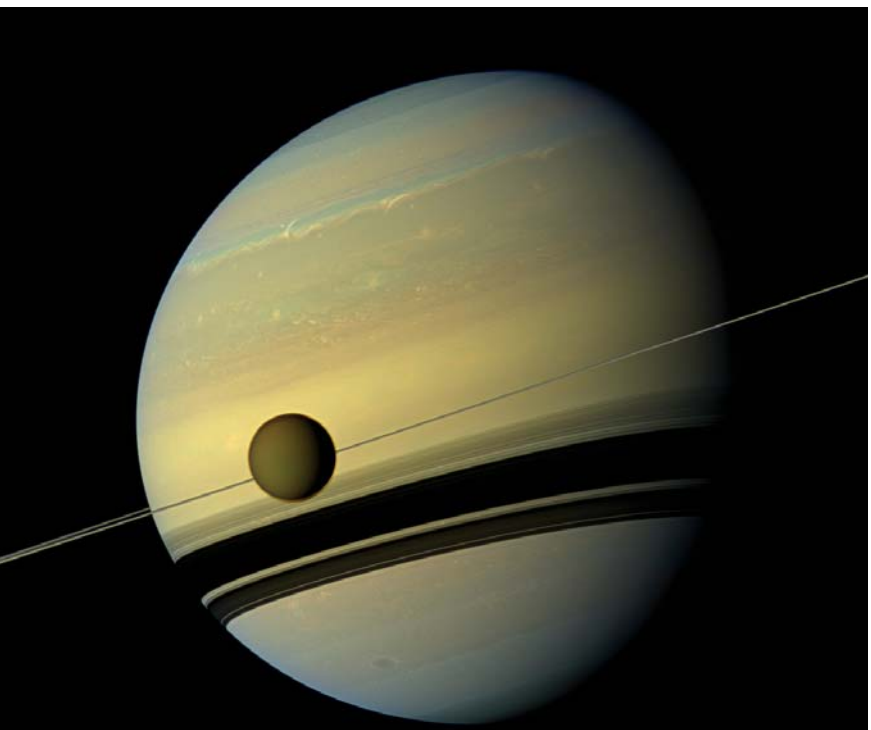
Saturn's rotational axis is tilted by almost 27° to the plane of its orbit, giving the ringed planet a full array of seasons. While seasons on Earth last only 3 months, Saturn's endure for more than 7 years, owing to its 29½-year-long orbital period.

Northern summer solstice on Saturn will occur in May 2017, when the planet's north pole and the northern face of its rings will be tipped toward the Sun — and toward Earth — to their maximum extent. While the increasingly apparent opening of the rings is undoubtedly the principal attraction, this favorable viewing geometry also affords an opportunity to observe colorful features at high northern latitudes on the planet's globe.

Saturn displays alternating dusky belts and bright zones that resemble those of Jupiter but are comparatively muted in contrast and bland in appearance. In many respects, Saturn's atmosphere is similar in structure and composition to Jupiter's, with a deck of water clouds at the bottom, ammonium hydrosulfide (NH_4SH) clouds in the middle, and a deck of frozen ammonia (NH_3) clouds at the top — the one we see — discolored by traces of nitrogen, sulfur, and phosphorous compounds. The upper troposphere, which lies above this layered sandwich, consists of colorless hydrogen and helium with a trace of methane (CH_4) and a murky haze of photochemical smog.

NASA / JPL / SPACE SCIENCE INSTITUTE (2)

Although seen distinctly at visual wavelengths, Saturn's enigmatic north-polar hexagon was even more striking when recorded in near-infrared light by Cassini in 2013. This feature, first discovered in Voyager images, is twice Earth's diameter in size. The day-night terminator is at upper left.



In this 2012 Cassini image, the giant moon Titan looms in front of Saturn, whose north temperate latitudes are becoming less blue as summer approaches and its southern ones more so as they edge toward winter.

Two factors account for the dramatic difference in the appearance of these two gas giants. Clouds form deeper down at the cooler temperatures that prevail at Saturn's greater distance from the Sun. This thermal effect is greatly reinforced by the planet's weaker gravity. (Although only slightly smaller in diameter than Jupiter, Saturn is only 30% as massive.) Jupiter's atmosphere is pulled much more powerfully toward the center of the planet, so the pressure gradient in the Jovian atmosphere is almost three times steeper.

Viewing Saturn's cloud deck through the planet's hazy, distended upper troposphere washes out details and subdues the saturation of colors. Saturn's dark belts appear pale greyish brown rather than the reddish sepia characteristic of Jupiter's belts, while the ringed planet's tropical and temperate zones feature a delicate palette of straw yellow, butterscotch, and saffron hues.

Saturn's dusky polar regions, however, often display assorted cooler colors reminiscent of the frigid ice giants Uranus and Neptune. Ranging from olive green to teal, aquamarine, and azure blue, they can be detected by a keen-eyed observer through a telescope of only 6 to 8 inches in aperture. Yellow (Wratten 12 or 15), orange (Wratten 21), and red (Wratten 23A or 25) filters greatly enhance this distinction.

As long ago as 1806 William Herschel noted that Saturn's poles appear to darken as they slowly tilt sunward. Decades of observations amassed by the British Astronomical Association's Saturn Section show a close correlation between solar altitude and the darkness of the polar regions, suggesting that Saturn's atmosphere responds quickly to the increasing input of sunlight.

The Sun's intensity at Saturn is only 1⁄90 of that on Earth, and the ringed planet radiates about twice as much internal heat as it receives from the Sun. So warming temperatures are not responsible for intensifying the polar colors. Instead, the greenish and bluish hues are widely attributed to Rayleigh scattering by hydrocarbon aerosols produced by solar ultraviolet radiation and charged particles, augmented by the selective absorption of light from the red end of the spectrum by methane. But the chemistry of Saturn's polar hazes is surprisingly complex — for example, polarimetry data suggest that the haze particles are shaped like microscopic grape clusters — and in truth the exact cause for the distinct hues remains uncertain.

A Curious Aspect

Saturn's colorful northern polar region is the site of a persistent hexagonal cloud feature centered at latitude 76° north. Curiously, it has no counterpart at the planet's south pole. First noticed in 1988 on old Voyager spacecraft images, it was still present and seemingly unaltered when the Cassini spacecraft imaged Saturn's north pole in 2006. The Voyager images revealed that clouds along the hexagon are propelled by fierce jet-stream winds that exceed 400 kilometers per hour.

Physicists at the University of Oxford recently recreated the appearance of this mysterious feature by placing a cylinder of water on a slowly spinning table to simulate Saturn's atmosphere spinning with the planet's rotation. Inside this vessel they placed a small ring that rotated more rapidly than the cylinder to mimic an atmospheric jet stream. The researchers used fluorescent green dye to make the currents visible. They soon noticed that the greater the difference in rotation rate, the less circular the turbulent boundary became. Stable vortices of similar size formed on the slower, outer side of the fluid interface, and these interacted with each other to space themselves out evenly around the perimeter. By varying the rate at which the inner ring spun, the investigators were able to generate a variety of polygons, but a hexagonal form was the most common and stable. You can watch a video of the simulation at **http://is.gd/saturn_hexagon**.

DAMIAN PEACH

Thanks to the favorable tilt of Saturn's north pole toward Earth, amateur astrophotographers are getting a good look at the planet's polar hexagon for the first time since its discovery in 1988.

Is that what's happening on Saturn? Perhaps, though Cassini has not observed any differential rotation between the hexagon's interior and exterior. Also, why is there no comparable feature surrounding the planet's south pole?

In any case, the north-polar hexagon is huge, spanning 25,000 km (twice Earth's diameter), and it subtends more than 3 arcseconds for earthbound observers — four times the apparent diameter of Titan, Saturn's largest satellite. Although well-equipped webcam imagers are routinely capturing stunning images of this feature, discerning its straight-sided outline poses a challenging test for visual observers. But don't let that dissuade you from trying. Saturn reached opposition in late May, so now is an excellent time to see the ringed planet at its best — hexagon or no. ✦

The Moon • July 2015

Phases

- **FULL MOON** July 2, 2:20 UT
- **LAST QUARTER** July 8, 20:24 UT
- **NEW MOON** July 16, 1:24 UT
- **FIRST QUARTER** July 24, 4:04 UT
- **FULL MOON** July 31, 10:43 UT

NASA / LRO

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

Librations

Bailly (crater)	July 4
Plutarch (crater)	July 18
Cabeus (crater)	July 26
Montes Rook	July 31

Distances

Perigee 228,101 miles	July 5, 19h UT diam. 32′ 7″
Apogee 251,553 miles	July 21, 11h UT diam. 29′ 14″

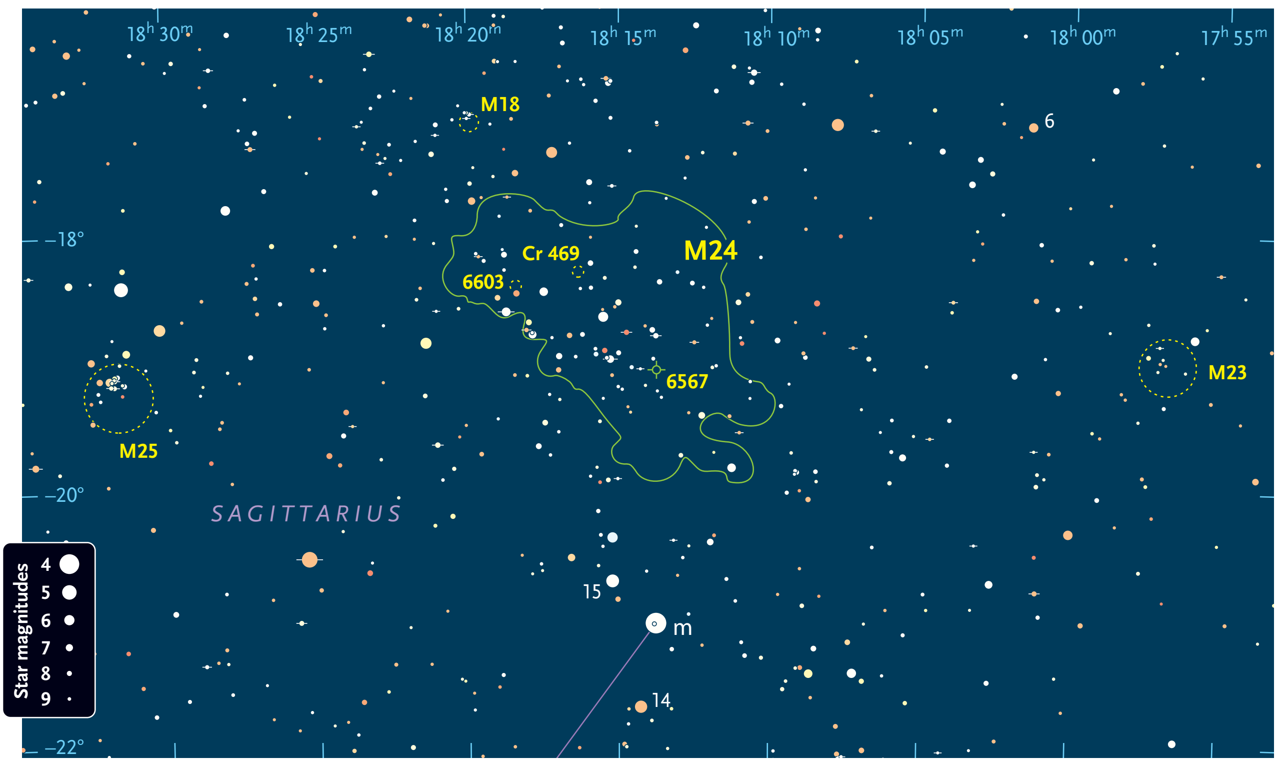
Small Sagittarius Star Cloud

The Sagittarius Milky Way is host to dark nebulae and open clusters.

On moonless nights away from the glow of outdoor lighting, the misty fall of the Milky Way tumbles down to the horizon through Sagittarius. Its gossamer glow is fashioned from remote swarms of innumerable stars, and the silvery splendor of their intermingled light shows us the plane of the disk-shaped, spiral galaxy we live in. The Sagittarius Milky Way is interlaced with dark rifts. For the most part, the stars that lie along this section of the Milky Way, as well as the dark clouds that decorate it, lie within the Sagittarius-Carina Arm of our galaxy. This is the next spiral arm inward from ours, and it blocks the view beyond. Within the dark rift, however, a gap allows us to peer deeper into the galaxy. The stars that shine through this hole make up **Messier 24**, the Small Sagittarius Star Cloud.

Messier 24 is sometimes called Delle Caustiche, a name attributed to the 19th-century Italian astronomer Angelo Secchi. However, Secchi made it clear in his 1877 book *Le Stelle* that he was only describing a small part of M24. He writes of a little cloud, less than half the Moon's apparent diameter, made up of a multitude of separate groups of tiny stars. Two of these groups are charted as seen through a 9.6-inch telescope. The first is labeled "Gruppo delle Caustiche" (Group of Caustics), because its diminutive stars are arrayed in arcs that resemble caustic curves. Secchi describes the second group, close south of the first, as a circular collection of beautiful starlets arranged in several rays diverging from its brightest star. Its chart is labeled "Gruppo a raggera" (Sunburst Group). He refers to yet another section, next to the Sunburst, as a magnificent system of crossed arcs, the middle strewn with faint stars too numerous to count.

Indeed, one can't help but point a telescope anywhere within the 2° × 1° oblong of M24 without being struck by the richness and variety of the star fields. Through my 130-mm refractor with a wide-angle eyepiece at 23×, M24 spans most of the field of view. Its best-known features are the dark nebulae **Barnard 92** and **Barnard 93**, seen in projection against the cloud like dusky eyes in a fuzzy face. B92 is a nearly north-south ink spot covering about



13½′ × 8′. B93 is an 8′ ×3′ band with a less pronounced extension bending southward from its southwestern end. This eye seems to be winking. **Collinder 469** is a little knot of stars just a few arcminutes off the extension's end. A very long and distinctive line of faint stars sweeps east-northeast to west-southwest across M24. The star chain skims north of B92 and B93, and it has a northward bump between them.

The open cluster **NGC 6603** is a nicely obvious patch of haze flecked with a few superimposed stars. It's perched near a red-orange star, which is the middle star in the northern arm of a 20′ V of 7th- and 8th-magnitude stars. The middle star in the southern arm of the V is the double **SHJ 264** (S,h 264). Its whitish components are well separated, with the 7.6-magnitude companion 17″ northeast of its 6.9-magnitude primary. The pair's designation tells us that it's the 264th entry in James South's and John Herschel's multiple star catalog of 1824.

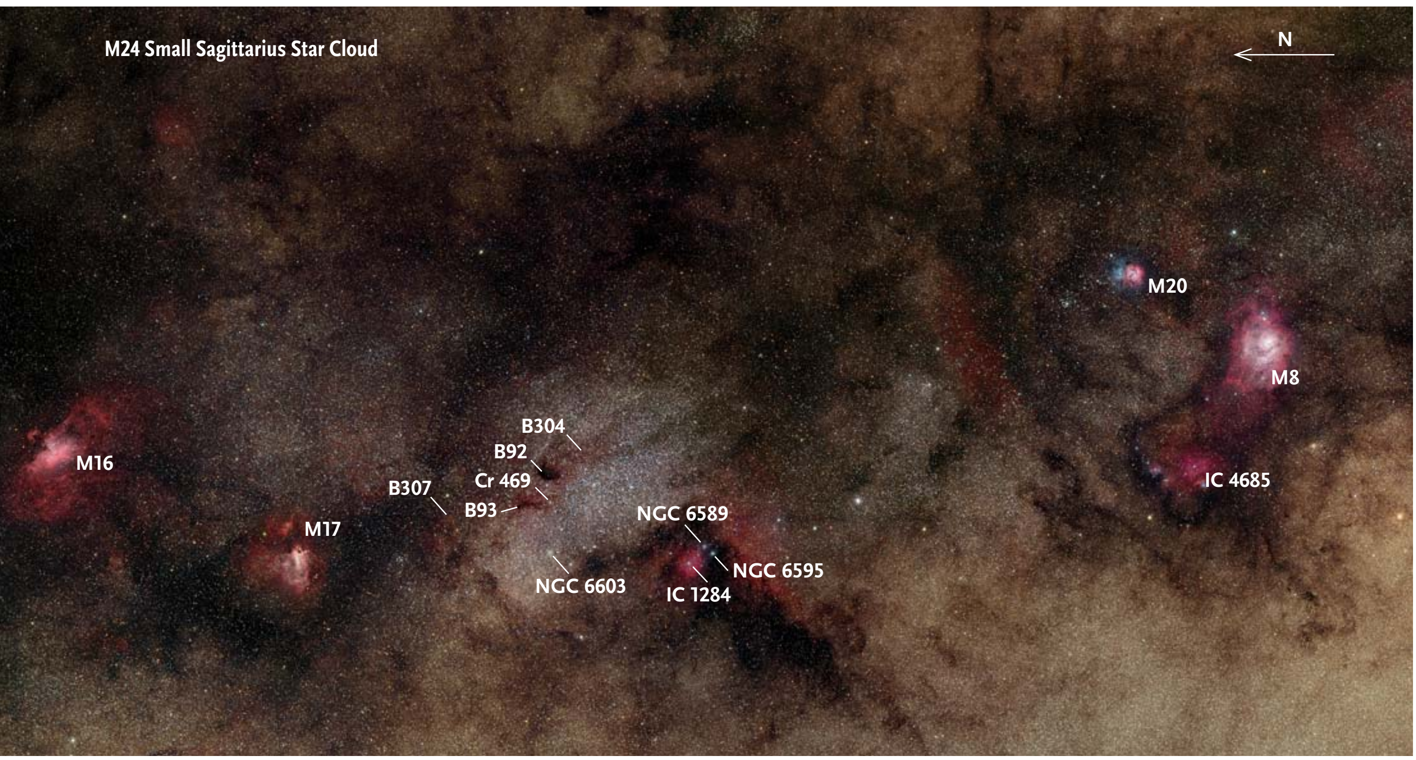
Although I can't fit all of M24 in the field of view at 63×, it's amazing how much more obvious and intricate the dark nebulae are at this magnification. A fairly conspicuous thread runs east-northeast from B93, leading to a large area of patchy darkness that contains **Barnard 307**. Much dark nebulosity spreads west from B92, and a long, forked patch (**Barnard 304**) reaches southwest. Collinder 469 and NGC 6603 share a field of view. Cr 469 shows six stars that form a capital A pointing northeast, while pretty NGC 6603 is a granular patch of mist. At 117×, Cr 469 displays 11 stars in a group whose longest dimension is about 3¼′. A bit larger but much more crowded, NGC 6603 is sprinkled with many faint to very faint stars over haze. It sports a prominent southeast-northwest band of stars that cuts across the cluster's center.

NGC 6603 is wonderfully transformed by the 10-inch scope. At 213×, it's a beautiful cluster of myriad diamond-dust stars, with little unresolved haze remaining.

You might think that M24 would be a terrible place to look for a petite planetary nebula, but I was surprised to find **NGC 6567** reasonably easy to spot through my 130-mm scope. At 37× it appears bluish and minuscule, but most definitely not stellar. A magnification of 117× reveals a tiny blue-grey disk that's fairly bright. A dim star sits just off the nebula's eastern side. At 205× the nebula seems to have a brighter center.

Through my 10-inch reflector at 115×, NGC 6567 presents a strikingly blue-green disk that I judge to be about 9″ across.

A few other star groups from Charles Messier's famous 18th-century catalog keep M24 company. Its nearest neighbor on the sky is the open cluster **Messier 18**, which hovers over (north of) the star cloud's northeastern end. My 130-mm refractor at 48× shows 15 moderately bright to faint stars, most arranged in a cute shape resembling a slightly mangled hairpin. At 91× I



JASON JENNINGS

M18 as viewed by Jeremy Perez through his 6-inch Newtonian reflector at 48x magnification.

count 24 stars loosely scattered across approximately 7½′.

Two richer star clusters bracket M24. To the west we find **Messier 23**, which blossoms into a populous collection of 9th- to 12th-magnitude stars when seen through my 130-mm scope at 37×. The cluster spans about ½° and boasts about 90 stars strung in glittering chains meandering through the group. Pushing the scope east from M24 brings me to **Messier 25**, a lovely cluster of 70 mixed bright and faint stars prettily displayed in sprays and gently curving lines. The four brightest stars shine gold, and there's an adorable little D of seven faint stars at the group's heart. The nice double star 3′ south of the D is **Burnham 966 CD** (β966 or BU 966), with a yellow primary whose companion rests 11″ to its south. Altogether, the stars form a vaguely rectangular gathering that's about 40′ long, tipped a bit east of north.

The Small Sagittarius Star Cloud plumbs our galaxy to considerable depth. Its stars spread from about 10,000 to 15,000 light-years away from us. This would include stars from the Scutum-Centaurus Arm, the major spiral arm between us and the galactic center. M24 may also include stars within a minor spiral arm farther inward, the Norma Arm. Thus, M24 is not a true physical object, but merely a pile-up of stars along our line of sight.

At a distance of 12,000 light-years, NGC 6603 is actually within the bounds of the Star Cloud. It's difficult to tell where NGC 6567 fits into the scene. As is often the case with planetary nebula, even recent distance estimates are widely varied — in this case from 5,500 to 12,000 light-years. The other objects are in the foreground, and we simply see them projected against M24. Collinder 469 is about 4,800 light-years distant, while the dark nebulae are roughly 700 light-years away from us.

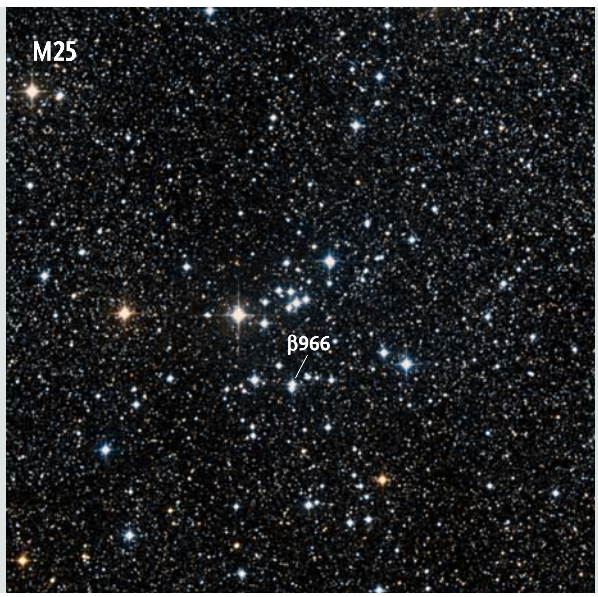
Most Messier objects are also listed in the 1888 *New General Catalogue of Nebulae and Clusters of Stars* (NGC), but neither M24 nor M25 is among them. They were added to the 1908 supplement to the NGC, known as the *Second Index Catalogue of Nebulae and Clusters of Stars* (IC). In the catalog, IC 4715 (M24) is described as a most extremely large cloud of stars and nebulae and IC 4725 (M25) as a cluster, pretty compressed. We can just call them beautiful. ✦

Select Objects from the Small Sagittarius Star Cloud

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Messier 24	Star cloud	2.5	2° × 1°	$18^h 16.8^m$	–18° 33′
NGC 6567	Planetary Nebula	11.0	12″	$18^h 13.8^m$	–19° 05′
Messier 18	Open cluster	6.9	7.2′	$18^h 20.0^m$	–17° 06′
Messier 23	Open cluster	5.5	29′	$17^h 57.1^m$	–18° 59′
Messier 25	Open cluster	4.6	32′	$18^h 31.8^m$	–19° 07′

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.

***Right*: The double star Burnham 966 CD (β966) lies 3′ south of the D-shaped figure resting at the heart of open star cluster M25.**



POSS-I / STSCI / NATIONAL GEOGRAPHIC SOCIETY / CALTECH/ POSS-II / PALOMAR OBSERVATORY

Ken Hewitt-White

A Deep Field in Draco

These faint galaxies will test your observing skills in different ways.

EARLY SUMMER, NIGHTFALL. The sky is pristine. Using chart 22 of the *Uranometria 2000.0* (2nd ed.), I plot a path to a couple of attractive edge-on galaxies 1.4° apart in southern Draco. I see that the big edge-ons aren't alone. A dozen smaller galaxies scattered around them populate a square of sky measuring 2° on a side — a doable "deep field" for my 17.5-inch f/4.5 Dobsonian. Naturally, I decide to go for all 14 fuzzies.

My box of galaxies rests on the Draco-Boötes border, four-fifths of the way from 2nd-magnitude Eta (η) Ursae Majoris (Alkaid) to 3rd-magnitude Iota (ι) Draconis (Edasich). From the 5th-magnitude star HD 134190, I push northeast into the target area and locate three 8th-magnitude stars forming a ¼°-long east-west arc. The westernmost star, HD 135295, is at the exact center of the 2° × 2° field and becomes the starting point for my exploration. Join me as I work through four 1° quadrants, employing magnifications ranging between approximately 200× and 300×.

ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA

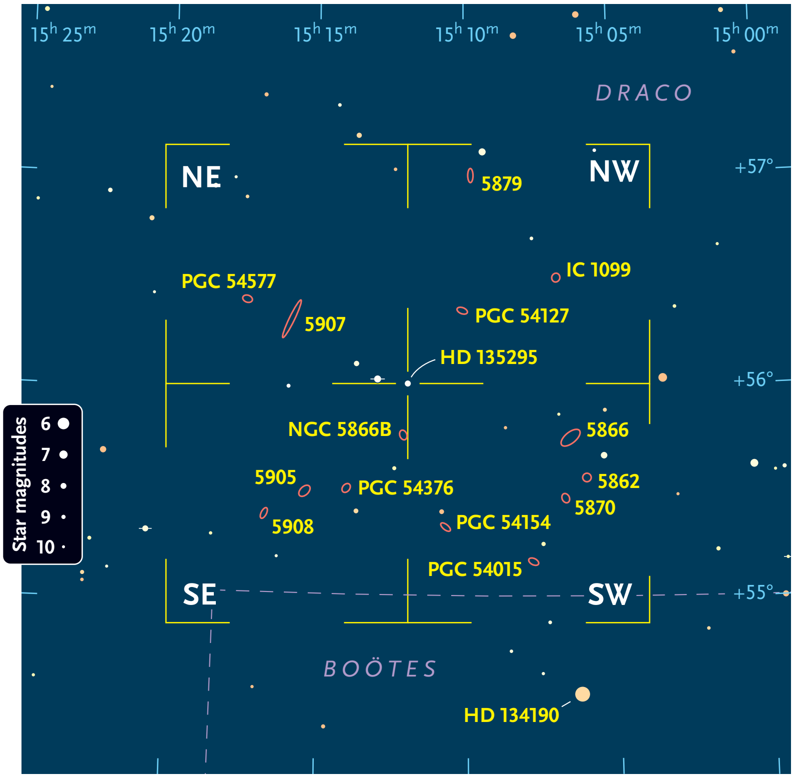
The face-on orientation of NGC 5908 *(lower right)* reveals the bar that centers the nearly symmetrical arms of the spiral galaxy. The luminous central bulge, partially cloaked by a lane of dust, is the most obvious feature of NGC 5905, a spiral galaxy seen edge-on from our vantage point on Earth *(upper left)*.

Southwest Quadrant

From HD 135295, I sweep toward an 8th-magnitude star almost 1° west-southwest. Only 11′ shy of that marker is the brightest blob in the box: 9.9-magnitude **NGC 5866**. As Sue French reported in her "Deep-Sky Wonders" column (*S&T:* July 2013, p. 56), some observers consider this galaxy a perfect fit for the missing Messier object, M102. Others disagree. Either way, NGC 5866 is a fine edge-on specimen in a starry setting. In addition to the above-mentioned 8th-magnitude marker, a 9th-magnitude star lies 13′ northwest (our edge-on points to it), a 10th-magnitude star is 7′ north, a star of 11th magnitude is visible just north of the galaxy's northwest tip, and another of 12th magnitude flickers southwest of center.

With its bulging middle and tapered ends, NGC 5866 is a fuzzy flying saucer canted on a northwest-southeast angle. At 222×, the southeast half fades away smoothly while the northwest half seems patchy. The blotchiness is due to a few faint stars, visible in images, superimposed along the galaxy's northwest portion. My scope actually reveals one, at the tip. That aside, I agree with Sue that NGC 5866's most enchanting feature is the "dusky thread following the long axis of the spindle's broad, central bulge." Upping to 285×, I can barely see the razor-thin dust lane exactly bisecting the galaxy's luminous core.

From NGC 5866, I nudge southward to **NGC 5862**, which is minute and dim. **NGC 5870**, 8′ to the southeast, is fainter but larger, oval, and accompanied by a 12.0-magnitude star 1′ east. Next, I shift further southeast, beyond an 8.9-magnitude star, to **PGC 54015**. It's small, marginally elongated, and of higher contrast than



the previous two galaxies. A 12.6-magnitude star shines 1′ southwest. An eastward hop nets **PGC 54154** plus an 8.6-magnitude star less than 5′ north. Despite the star's glare, this diffuse cloud appears noticeably elongated.

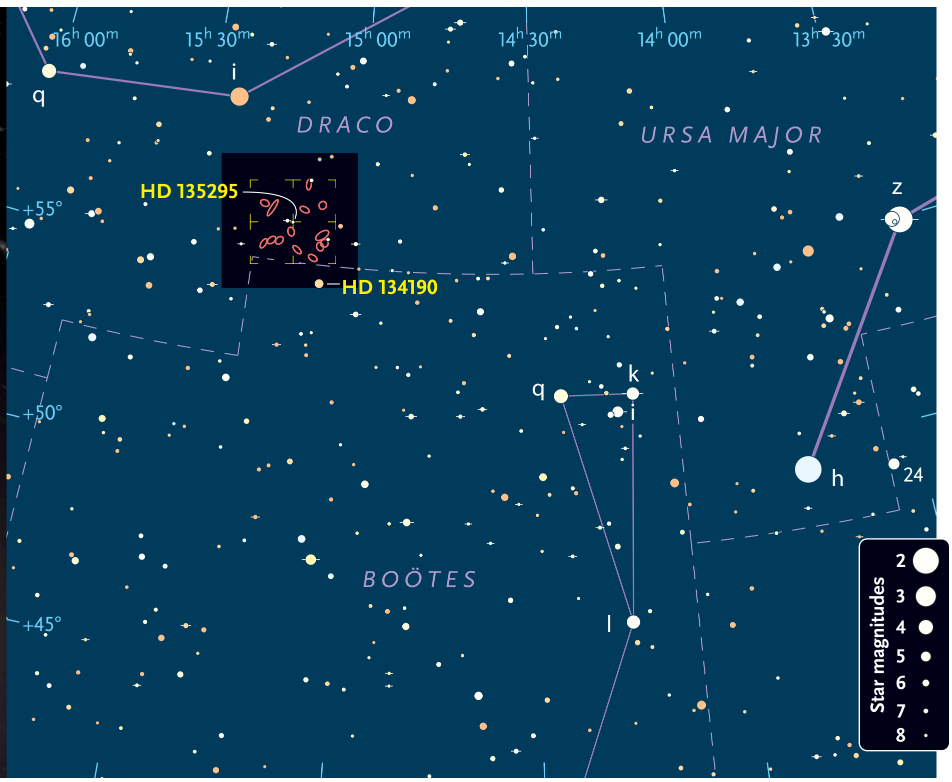
Southeast Quadrant

I return to my stellar starting point, HD 135295, then drop southward to **NGC 5866B** (it's directly east of NGC 5866). This spiral galaxy is larger than the previous four studies, but its surface brightness is extremely low. After patient staring I'm satisfied with a faint, formless mist. Emboldened, I search for tiny **PGC 54376** south-southeast of NGC 5866B, but without success. I'm disappointed — but better things lie ahead.

A tad eastward, in the middle of the quadrant, is a pair of relatively luminous galaxies, just 13′ apart. The westerly one, **NGC 5905**, is a barred spiral that I perceive as a moderately large, oval fuzz with a brightly concentrated center. The elongated mass is oriented approximately north-south, with two dim stars flanking the south end. Concentrating on that end at 300×, my averted vision traces a spiral arm curling westward, then northward. I try for the opposing arm but with no luck. My consolation prize is a petite binary star, **Wirtz 13** (magnitudes 11.1, 11.5; separation 9″), that lies a few arcminutes southeast of the galaxy.

Below: A Hubble Space Telescope image reveals the cerise central bulge and cerulean line of stars parallel to the dust lane of edge-on galaxy NGC 5866.

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



*Canadian observer **Ken Hewitt-White** does much of his deep-sky observing atop the 6,000-foot summit of Mt. Kobau in the southern interior of British Columbia.*

The other member of the pair is **NGC 5908**. This edge-on spiral is smaller than its neighbor but sports a higher surface brightness. The narrow (4:1) spindle aims northwestward at an 11th-magnitude star. I stare intently. The result is tapered ends, a moderately large central bulge, a pinpoint nucleus, and — during instants of steady seeing at 300× — a hairline dust lane immediately west of the nucleus. That the dust lane doesn't overlay the nucleus means the disk is tilted slightly. My perception is that the western edge of NGC 5908 is sharply defined by the dark lane, while the eastern side is more diffuse.

Northeast Quadrant

Returning again to my starting point, I follow the short arc of three stars roughly its own length northeastward to the second-brightest galaxy in the box: 10.3-magnitude **NGC 5907**. A member of the "superthin" galaxy club (*S&T:* May 2011, p. 62), this alluring edge-on spiral boasts an axial (length-to-width) ratio of 10:1. That's flat. "With such a long slim profile," wrote Sue French in 2013, "NGC 5907 has won the nicknames Splinter Galaxy and Knife-Edge Galaxy." For my money, NGC 5907 is the best flat galaxy in the northern heavens.

Sloping north-northwest to south-southeast, the Splinter exhibits no discernible central bulge. The galaxy's disk is just marginally thicker towards the middle, where any small bulge is hidden in the haze. However, I do see an oblong core and a nucleus, and at 285× I get glimpses of a dark strand spanning the core, southwest of the nucleus. Like NGC 5908, this slender specimen isn't precisely edge-on. Images of NGC 5907 show lots of dust spread along its western flank. But the effect is not the same as in NGC 5908. In my scope, the Splinter's west rim appears a bit fuzzy. It's the east flank that's sharp — like a knife-edge!

There's only one other galaxy in this quadrant. From the Splinter, I hike north-northeast to an 11.3-magnitude star, then slant eastward to the rather underwhelming **PGC 54577**. Thanks to its favorable surface brightness, the wee wisp isn't difficult to spot. That said, PGC 54577 is what I expected it to be: a smudge!

Northwest Quadrant

I retreat to NGC 5907, then head west to another smudge — except it's more interesting than that. The spiral galaxy **PGC 54127** is certainly dim, but a 12.8-magnitude star seemingly contacts its southeast edge. At 222×, my averted vision produces a "comet" whose stubby fantail (the galaxy) is issuing from a gleaming nucleus (the star). This ersatz comet is helpful, too, for it points me west-northwestward to my next target, **IC 1099**. This face-on spiral is larger but awfully dim and featureless.

My final maneuver involves backtracking to the "comet galaxy" then going north to **NGC 5879**. This 14th item straddles the northern border of my Draco deep field, less than 8′ southeast of a 7.4-magnitude star. NGC 5879 is much more prominent than its neighbors in the northwest quadrant. The edge-on spiral is a 4:1 north-south ellipse with a bright, condensed middle and a distinct nucleus. When I bump up to 300× and place the distracting 7th-magnitude star outside the field of view, NGC 5879 sprouts finely tapered ends.

Tapered ends . . . threads of dust . . . even hints of spiral structure. Most of the galaxies in my informal survey yield subtle but satisfying detail. My observing mantra is simple: don't ignore the dim stuff — sometimes it can surprise you. ✦

A Field of Galaxies in Draco

Object	Mag(v)	Surface Brightness	Size/Sep	RA	Dec.	Chart 22 *Uranometria*
SW Quadrant						
NGC 5866	9.9	12.9	6.4′ × 2.9′	15^h 06.5^m	+55° 46′	
NGC 5862	14.8	13.1	0.5′ × 0.5′	15^h 06.1^m	+55° 34′	
NGC 5870	13.9	13.8	1.2′ × 0.9′	15^h 06.6^m	+55° 29′	
PGC 54015	13.8	13.5	1.2′ × 0.7′	15^h 07.8^m	+55° 11′	UGC 9737
PGC 54154	14.2	13.4	1.8′ × 0.3′	15^h 10.7^m	+55° 21′	UGC 9759
SE Quadrant						
NGC 5866B	14.2	15.8	2.7′ × 1.9′	15^h 12.1^m	+55° 47′	
PGC 54376*	15.5	15.3	1.1′ × 0.8′	15^h 14.0^m	+55° 32′	MCG +09-25-37
NGC 5905	11.7	14.1	4.0′ × 2.6′	15^h 15.4^m	+55° 31′	
NGC 5908	11.8	13.1	3.2′ × 1.2′	15^h 16.7^m	+55° 25′	
NE Quadrant						
NGC 5907	10.3	13.3	12.6′ × 1.4′	15^h 15.9^m	+56° 20′	
PGC 54577	14.3	13.0	0.7′ × 0.5′	15^h 17.4^m	+56° 25′	MCG +10-22-10
NW Quadrant						
PGC 54127	14.9	13.9	0.9′ × 0.5′	15^h 10.1^m	+56° 22′	MCG +09-25-29
IC 1099	14.0	14.2	1.2′ × 1.1′	15^h 06.9^m	+56° 31′	
NGC 5879	11.6	13.3	4.2′ × 1.3′	15^h 09.8^m	+57° 00′	

*not visible on the night observations were made

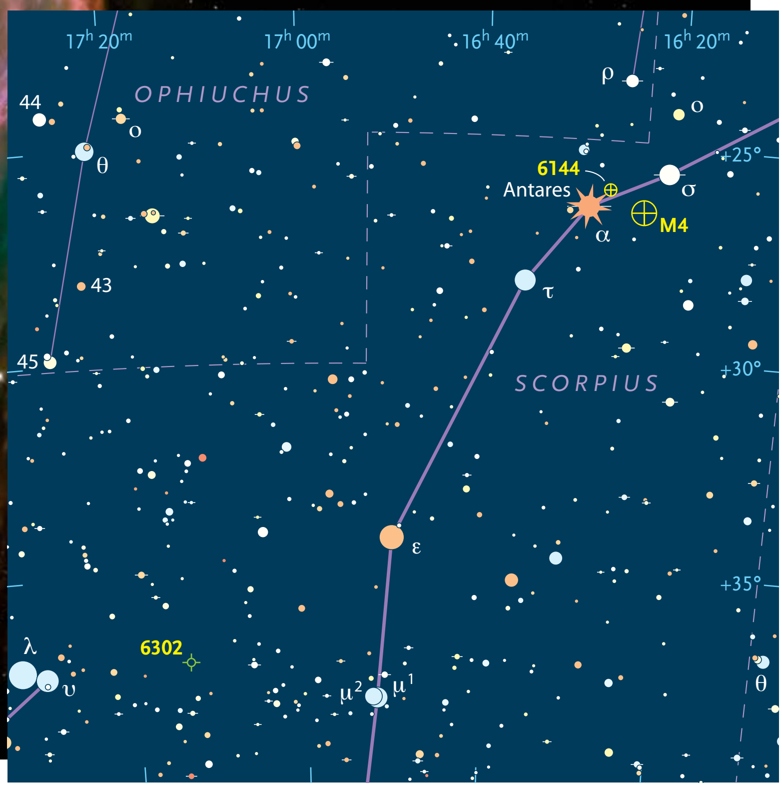
Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

The Backyard Sky: SUMMER

Stretch your observing skills to spot these seasonal sensations.

THE BUG NEBULA The nebulosity of NGC 6302 stretches for more than 2 light-years, or about half the distance from the Sun to the nearest star, Proxima Centauri.

NASA / ESA / HUBBLE SM4 ERO TEAM



Rod Mollise

Fellow amateur astronomers who tell you the summer sky is impossible to enjoy from your backyard are wrong. It *is* more difficult to get good looks at summertime deep-sky objects due to the season's haze and humidity, which tend to amplify light pollution. Nevertheless, there are still plenty of star clusters and nebulae to observe and plenty of details to be seen in them. To experience the wonders of summer, however, you have to go out and look at them.

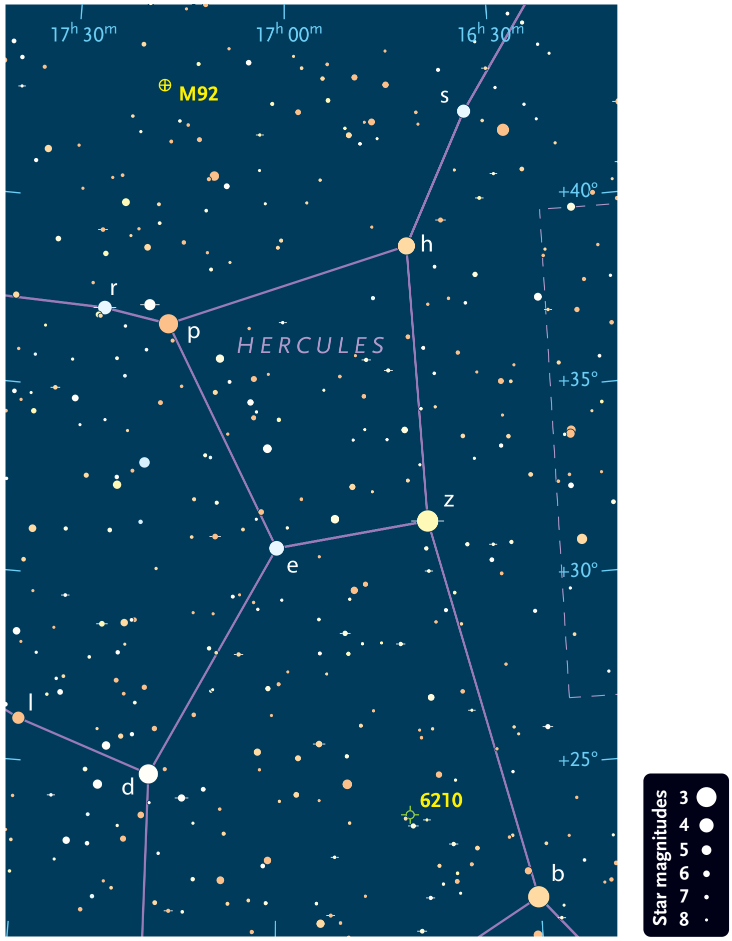
I've often said the surest way to be proven wrong in amateur astronomy is to say a particular observation is "impossible." Certainly, there are objects that are difficult or even impossible from the backyard, but don't just take somebody's word for it. Get out and search for some of the less-observed wonders for yourself.

Let's begin tonight's sky tour with a visit to Scorpius. The Bug Nebula, **NGC 6302**, located in the Scorpion's tail area, is supposedly a waste of time for most Northern Hemisphere observers because of its far southern declination. In addition, the magnitude value often given for the Bug is a forbidding 12.8. Finally, it's a little on the large side for a planetary nebula, 1.2′ long, which spreads out its light. Surprise! Despite these "facts," the Bug stands out amazingly well in the eyepiece even when close to the horizon. I suspect its magnitude may actually be more like 9 or 10.

What you'll see of the Bug when you've pinned it down not far from the Scorpion's stinger stars depends on the quality of your particular sky, but NGC 6302 is interesting from my average backyard. In my 4-inch f/10 refractor at 150×, the Bug shows a strongly elongated patch of nebulosity with a brighter core. The view in my 12-inch Dobsonian reflector is better, with the Bug looking like an ant, with streamers of nebulosity at either end forming "legs" and "mandibles." I've tried various nebula filters, including an O III, on the Bug, but none seem to make a huge difference.

The Scorpion doesn't hold as many bright and spectacular deep-sky objects as neighboring Sagittarius, but there are still treats here, including the loose globular star cluster **M4** (NGC 6121), the Cat's Eye Cluster. My mission is to point out the less-visited backyard deep-sky wonders, so why am I taking you to a bread-and-butter object? Because many amateurs, and not just novices, don't realize there's a bonus globular here.

The Cat's Eye is beautiful. This loose cluster is a standout because of a line of stars across its core that looks like the iris of a cat's eye. What is *really* cool, though, is that just 57′ to the northeast is another glob, **NGC 6144**, with a 9.0 magnitude and 7.4′ diameter. Like M4, this less-known cluster is on the loose side. It won't be easy in a small scope under bright skies, but it's doable. You'll probably need high power to make



ESA / NASA

SOME 300,000 STARS M92 shines at magnitude 6.5, making it one of the brightest globular clusters in the Milky Way.

NGC 6144 pop out. At 200× in my 8-inch f/10 Schmidt-Cassegrain telescope, the cluster is a small, soft, round glow that occasionally gives up a star or two. For best results, keep Antares, 38′ southeast, out of the field.

Hercules is the constellation that spells "summer" for me, and Messier 13, the Great Globular Star Cluster, is undoubtedly Herc's premiere deep-sky object. Tonight we'll bypass it for another globular, one most of us haven't looked at quite as many times. Conventional wisdom says that if not for nearby M13, **M92** (NGC 6341) would be considered a showpiece. Again, what everybody "knows" isn't quite right. It *is* good, but not *that* good.

Shining at magnitude 6.5 and appearing 14.0′ across, M92 is a middle-of-the-road cluster. That doesn't mean it isn't worthy of your frequent attention, though. At a magnification of 150× with the 4-inch refractor, it easily gives up a nice sprinkling of stars. The core of this Shapley–Sawyer Class IV cluster (medium-concentrated core) looks almost square, and the area around it is populated by numerous stars, a few of which hold steady with direct vision but most of which wink in and out.

Beyond M13 and M92, most of Hercules' objects are dim and difficult; it's not uncommon to hear fellow deep-sky observers opine that there's *nothing* to see beyond the two globular clusters. Not true. The evening's next target, **NGC 6210**, known as the Turtle Nebula, swims in the southern part of Hercules. This planetary nebula can be difficult, but not because it's dim; the nebula has a relatively bright magnitude of 8.8. The problem is its size. Appearing only 20″ across, its diameter is less than half of Jupiter's average, and it looks like a star in smaller telescopes.

How do you catch the Turtle? I've found that even at

ESA / HUBBLE & NASA

STELLAR STRETCH A Hubble image of M10 reveals the globular cluster's core, which measures some 13 light-years across.

low power this planetary's pale green color is obvious. The easiest way to be sure you're looking at the Turtle and not an anonymous field star, though, is to crank up the magnification to 150× – 200×. At that power, the nebula's oval disk should be discernible. Higher magnification is always a good thing in a light-polluted backyard anyway, since it helps spread out the background sky glow.

At high powers in larger scopes, streamers of nebulosity may be seen around the periphery of NGC 6210's elongated disk, looking a little like a turtle's head and

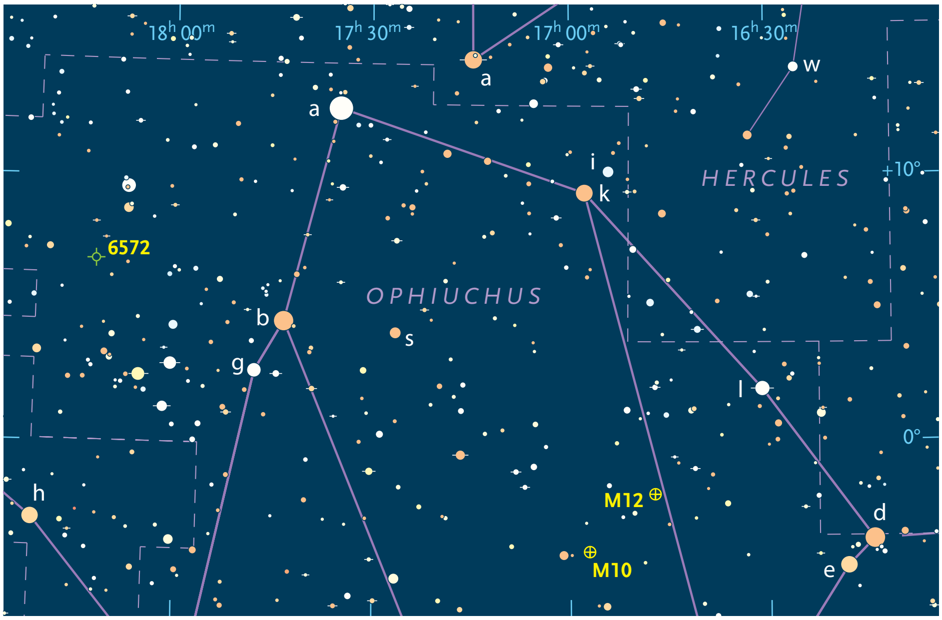
NGC 6888 The visually elusive nebulosity was heightened with a 60-cm Hypergraph in primary focus with a Hα filter in this image from the Skinakas Observatory in Crete.

VOLKER WENDEL / STEFAN BINNEWIES / JOSEF PÖPSEL

Deep-Sky Summer

Object	Con	Type	Mag(v)	Size/Sep	RA	Dec.
NGC 6302	Sco	Planetary nebula	9.6	83″ × 24″	17^h 13.8^m	–37° 06′
M4	Sco	Globular cluster	5.4	36′	16^h 23.6^m	–26° 32′
NGC 6144	Sco	Globular cluster	9.0	7.4′	16^h 27.2^m	–26° 01′
M92	Her	Globular cluster	6.5	14′	17^h 17.1^m	+43° 08′
NGC 6210	Her	Planetary nebula	8.8	48″ × 8″	16^h 44.5^m	+23° 48′
M10	Oph	Globular cluster	6.6	20′	16^h 57.2^m	–04° 06′
M12	Oph	Globular cluster	6.1	16′	16^h 47.3^m	–01° 57′
NGC 6572	Oph	Planetary nebula	8.1	16″ × 13″	18^h 12.1^m	+06° 51′
NGC 6888	Cyg	Wolf-Rayet shell	—	20′ × 10′	20^h 12.1^m	+38° 21′

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.



HEAD OF HERCULES
The author's sketch of the globular cluster M92 shows the nice sprinkling of stars revealed by a 5-inch Maksutov Cassegrain at 150×.

feet. I've never seen even a hint of these features from my backyard with my 12-inch, however.

In the 1970s, when I was asked "What's your sign?" I'd reply, "Ophiuchus," which generated puzzled looks. The name of that constellation still does today, even among some amateur astronomers. If you want to delve deeply into the backyard sky, you've got to get off the path and become familiar with constellations like huge, house-shaped Ophiuchus, southeast of Hercules.

You'll be glad you learned Ophiuchus; he's a wonderland for a deep-sky observer. His most prominent of many good objects are our next targets, **M10** (NGC 6254) and **M12** (NGC 6218), often referred to as "the Twin Globulars," since they supposedly look exactly alike. Once more, common knowledge is wrong. They are twins in the sense that they are close together (3 degrees and 16 arcminutes apart), but they look *nothing* alike.

M12 is the brighter and smaller of the two but can be disappointing in scopes smaller than 6 inches. This magnitude-6.1, 16′-diameter cluster is loose and under poor conditions is just a ghostly glow with a few stars popping in and out. Averted vision (looking away from the object instead of directly at it) helps some, but using a 6-inch or larger scope and waiting for the cluster to rise to at least 30° of altitude will aid your view the most.

M10 is larger (20′ in diameter) and dimmer (magnitude 6.6) than its neighbor but looks better in the eyepiece. It's more concentrated but not so tight as to make resolving stars difficult. In my 6-inch Newtonian reflector, I can easily pick out a few suns here, even with direct vision. In the 12-inch Dobsonian, M10 is a wonder, showing plenty of tiny stars and really "looking like a globular."

Yet another incorrect assumption I hear glibly tossed around at astronomy clubs is that few deep-sky objects show color. It's true you'll rarely see the reds and pinks of emission nebulae, but many planetary nebulae display surprisingly vivid colors. Some will even display a hint of blue or green in compromised backyard skies.

NGC 6572, the Blue Racquetball Planetary Nebula in Ophiuchus, looks more green than blue from my back-forty, but I always see at least a hint of color in this magnitude-8.1 fuzzball. The only problem is that it's small, with a roughly 15″ diameter. As with the Turtle, if you use plenty of magnification, at least 200× on a night of steady seeing, the eyepiece should reveal a small disk.

Are you up for a backyard challenge? Something to work on all summer long? Let's end with one. Thirty years ago, I'd have said Cygnus's **NGC 6888**, the beautiful Crescent Nebula, would be impossible from the backyard. Today, however, nebula filters prove me wrong.

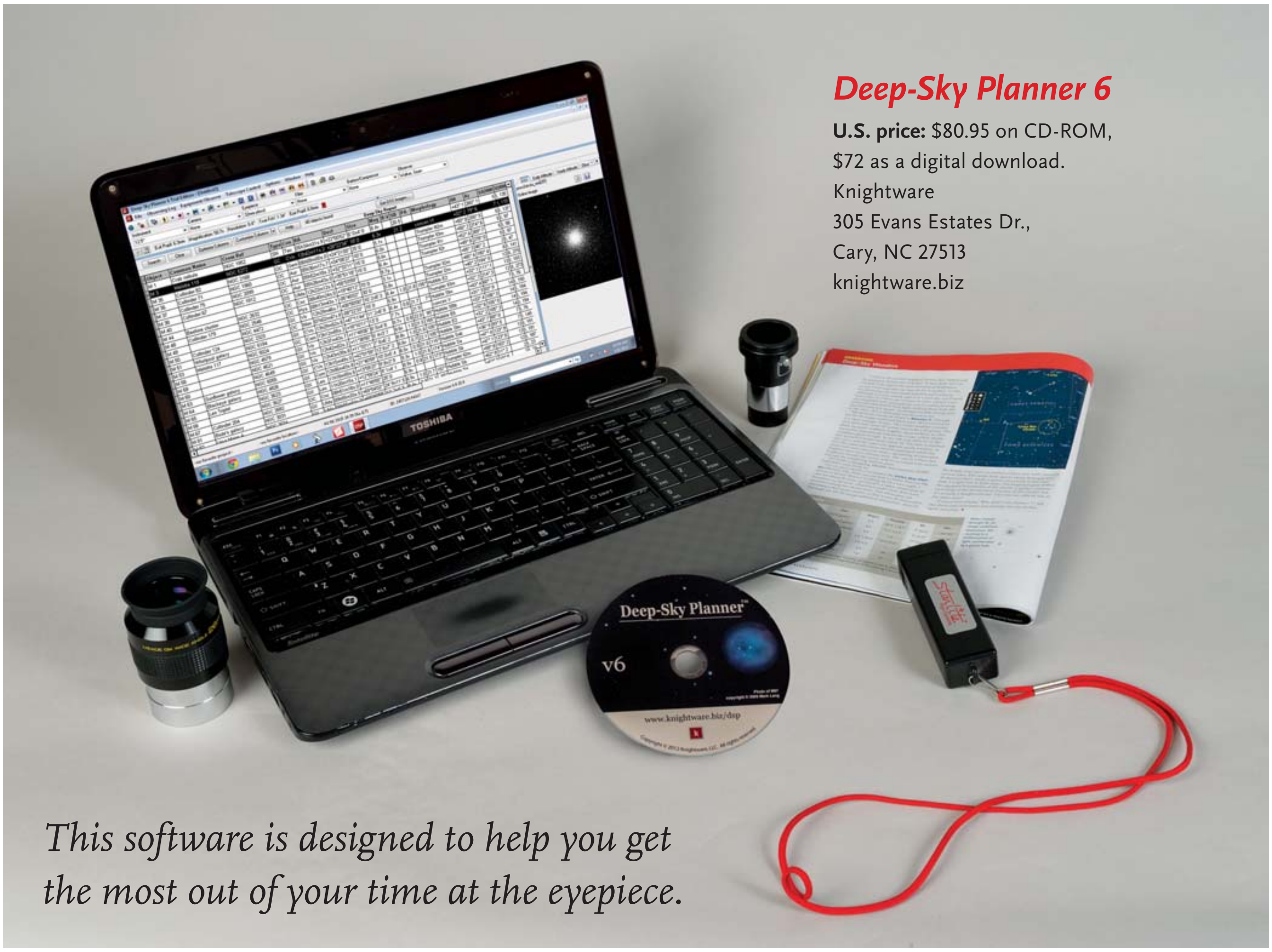
The Crescent, a 20′ x 10′ arc of nebulosity thrown off by a Wolf-Rayet star, is admittedly tough, even with a filter. With a 12-inch scope on an outstanding night in my backyard, I might barely glimpse a wisp or two in an unfiltered eyepiece. The addition of a filter (an O III "line" filter works best) makes it easier, but hardly easy. At best, the loop of nebulosity is broken, with only the brightest patches being visible.

The backyard summer sky is filled with wonders. The main problem I have with it, besides the weather here on the Gulf Coast, is its celestial abundance. When I'm out touring the starry reaches of Scorpius, Hercules, Ophiuchus, and Cygnus, the short summer nights just fly by. Not much to see? There's plenty if only you look. ✦

Rod Mollise keeps an astronomy blog at ***uncle-rods.blogspot.com*** *and is author of several books including* The Urban Astronomer's Guide.

Rod Mollise

Making Plans:
Deep-Sky Planner 6



Deep-Sky Planner 6

U.S. price: $80.95 on CD-ROM, $72 as a digital download.
Knightware
305 Evans Estates Dr.,
Cary, NC 27513
knightware.biz

This software is designed to help you get the most out of your time at the eyepiece.

S&T: SEAN WALKER

I'LL ADMIT I'M NOT the most organized person in the world. It's all too common for me to forget to pick up the bread at the grocery or take a wrong turn on the highway. But on the observing field it's different for me. I always know where I'm going and what I want to see with my telescope. That's because I have a plan in the form of an observing list.

Making observing lists used to be a pain, particularly when paging through dusty books and atlases to choose my targets of interest. Fortunately, there's software that takes the pain away. The main purpose of a planner is to help you easily compose observing lists and record

WHAT WE LIKE:

Large databases

Works with popular planetarium software

WHAT WE DON'T LIKE:

"Slew-to" button hard to find

Does not automatically open last observing plan

Whether you're traveling to a dark-sky site or observing in your backyard, it's always helpful to have a plan when at the eyepiece. *Deep-Sky Planner 6* is a comprehensive planning and logging program that promises to help you see more on clear nights.

your observations of objects. Of the numerous observing planners on the market, Knightware's *Deep-Sky Planner 6* (*DSP 6*) is the most mature, having been continuously updated for more than 20 years.

Deep-Sky Planner 6 is available on CD-ROM or as a digital download from the company's website. The file is only 59 megabytes, so it doesn't take long even with sluggish download speeds.

Having used previous versions of the software, I was eager to try *DSP 6* because author Phyllis Lang has added some useful new features and improved on the existing ones. Particularly welcome was the program's new ability to automatically download images for nearly all the objects in an observing list.

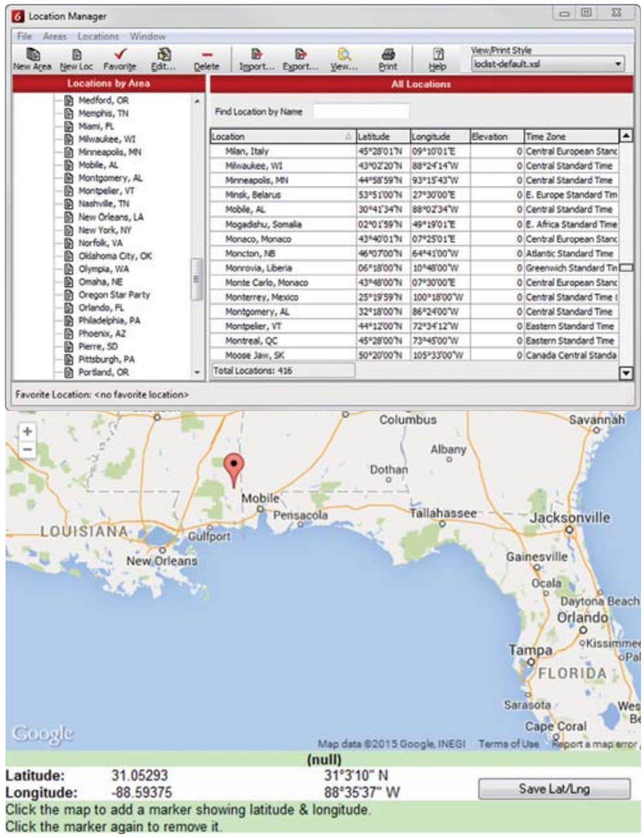
Getting Started

If you're new to planning programs, your first look at *DSP 6* may be a little daunting. What comes up on your display is a blank screen with a fairly standard Windows pull-down menu across the top. Beneath it is an icon bar, and below that are additional menus with a clear astronomical bent: Instrument, Camera, Eyepiece, Filter, Barlow/Compressor, and Observer.

So where to start? As with most astronomy programs, begin by entering the particulars of your location and equipment. Most important is location, which is opened by selecting the Options > Location Manager. A new window opens, with two primary categories: Location By Area at left, and All Locations at right. If you're located in the United States, for example, find it in the left column and click the arrow beside it, which will then display a list of U.S. cities.

Once you choose your city, a window with the location's particulars filled in will appear. Make sure everything is correct — latitude, longitude, time zone, etc.— make any changes if needed, then click OK and you're done. If your city is not on the list, you can select "New Location" and enter the particulars of your site manually.

Next up is inputting your equipment. Select Equipment/Observer > Instrument Browser from the pull-down menu at the top of the screen. Now click the "New" button at top left of this new window and key in your scope's statistics. Do the same for other gear you're using in each category. The program requires this data because *DSP 6* is

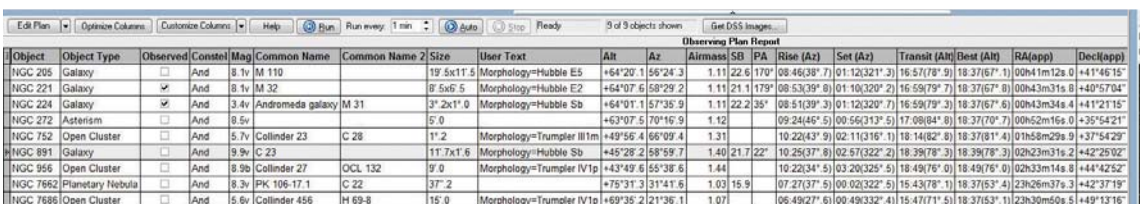


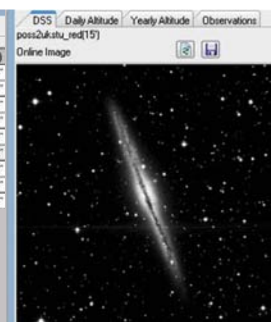
As with all planning programs, the first thing you'll need to do is input your location and your equipment. You can select your city from an extensive built-in list or find your area in the Map (Web) tab, which is a link to Google Maps.

a planning *and* logging program. Entering this information means *DSP* can insert it in log entries automatically, meaning less typing in the field.

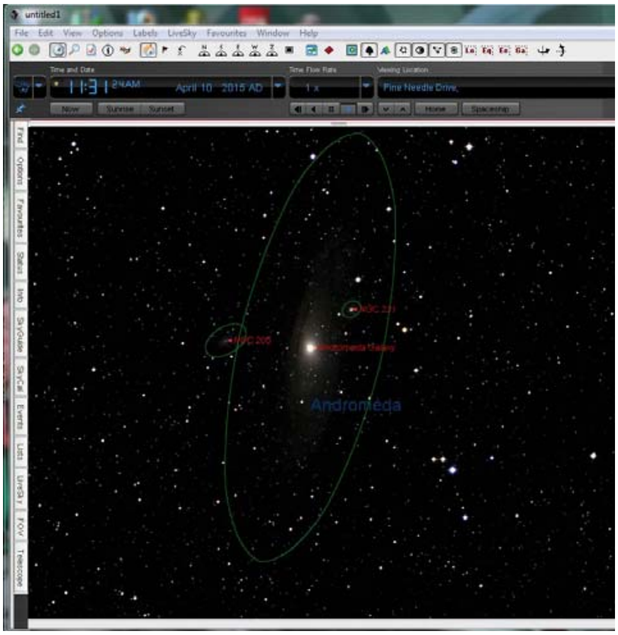
Your basic setup is complete, so it's time to get to know the program. The main purpose of *DSP 6* is to help you build observing lists by choosing objects from its database. There's no lack of objects to choose among here. *DSP 6* includes more than 1.25 million entries in its deep-sky and star databases: 841,000 star clusters, galaxies, nebulae, and 411,000 stars.

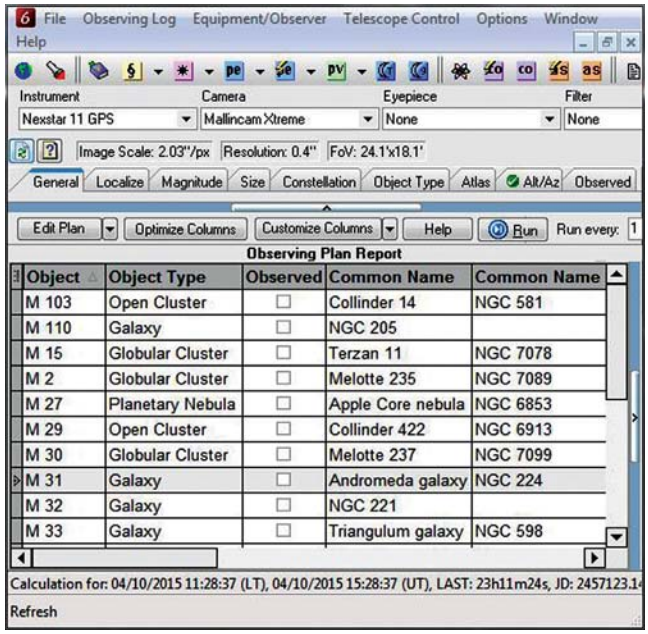
Before making an observing list, note that Knightware provides a sizable library of Observing Plans on its website. Nearly 350 plans are available, encompassing every-





The program offers you many options to narrow down your observing list, with options to ignore objects that never rise from your site, or target only objects within a designated constellation. Additionally, *DSP 6* can download a Digitized Sky Survey image of nearly any deep-sky object you want to observe.





Deep-Sky Planner 6 **allows users to link to most popular planetarium programs to create finder charts. Simply select your preferred software in the pull-down menu Options > Star Chart Programs.**

thing from binocular objects to galaxy clusters. You can access and download any of these pre-generated observing plans by selecting Help > Community Page (Online).

If none of the plans in the library fit your specific needs, it's easy to make your own. Let's assume you're after deep-sky objects (*DSP* 6 also includes a large selection of solar system objects including asteroids and comets). Click the spiral galaxy icon on the toolbar: this opens the obliquely named but powerful "Deep-Sky catalog search documents" search engine.

The first step is choosing the deep-sky catalogs you want to search. Click the General tab in the search window, which displays a list of the program's catalogs. For example, I highlighted NGC: Revised New General Catalog. Clicking the Search button now will retrieve all the NGCs, but I certainly didn't want 7,840 objects in my Plan. Fortunately, you can simply use the other tabs to help narrow the search.

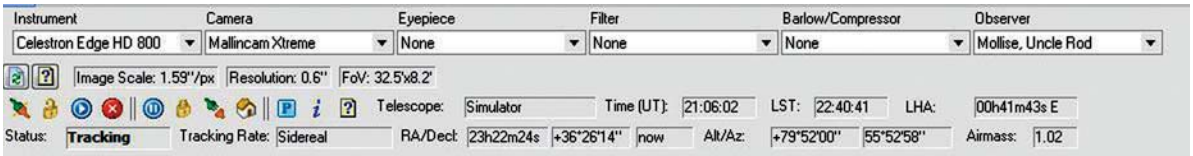
Given my experiences with other planners, I expected to wait awhile after clicking the Search button, but in just a couple of seconds *DSP* 6 produced a comprehensive list of all the 10th-magnitude and brighter NGC objects in a spreadsheet containing plenty of information about each. These results can then be ordered in any way you prefer by clicking the title above each column.

To make these search results into an observing plan, select New > Observing Plan from the pull-down menu. You then populate your Observing Plan by dragging and dropping single or multiple objects from the search results window. Highlight multiple objects by holding the shift key while clicking objects in the search window before dragging them into the Observing Plan window.

Deep-Sky Planner 6 also allows you to import plain text (ASCII) files of objects. The program took a little over a minute to import my list of 700 objects and convert them into an Observing Plan.

With my completed plan on screen, I took a look at the program's other options. One button on the Observing Plan window titled "Run" puzzled me at first, though it turned out to be one of the program's most useful features. In the tabs at the top of the this window, the Alt/Az tab allows you to specify observing altitude parameters to filter out objects that are too low to observe, or prevent an alt/az mounted Go To scope to point at the zenith. Clicking the Run button updates your plan to show only objects within these parameters, and adds new objects as they meet these criteria. "Run" is a great feature, but I wish the

SYSTEM REQUIREMENTS
PC with Intel Pentium processor (or equivalent), 1 GHz or faster.
32- or 64-bit edition of *Windows XP* or later including the latest updates from Microsoft
128 MB RAM for *Windows XP*, 512 MB RAM for *Windows Vista*, 1 GB RAM if operating 32-bit *Windows* 7 or 8, 2 GB RAM if running 64-bit *Windows* 7 or 8.
Installation requires about 366 MB of hard disk space.
XGA (1024 x 768) or better graphics, *Windows XP* or *Vista*, DirectX 9 graphics device with WDDM 1.0 or higher driver on *Windows* 7 or 8.



Deep-Sky Planner 6 **can also control most Go To telescopes, allowing you to slew to your next target, though it isn't immediately apparent how to do this. Right-clicking on an object in your Observing List opens a dialog box that includes the "Slew To" function halfway down the screen.**

button were more clearly labeled, perhaps as "Update."

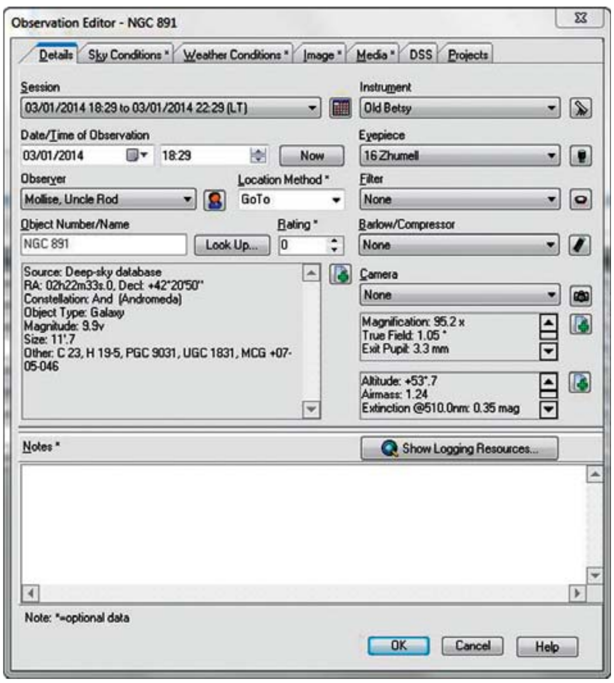
The Run feature can be used to filter objects based on magnitude, observed/not observed status. It can also be set to specify how often your spreadsheet will be automatically updated using the Auto button.

At the Telescope

Now that you've got a plan, what do you do with it? You could print it out and carry the hard copy into the field, though *Deep-Sky Planner 6* is well-suited to running on a computer at your telescope. The program, which includes a useful red-screen, night-vision mode, is as useful for non-computerized Dobsonian telescopes as it is for Go To rigs, but it is a joy to use with a Go To-enabled telescope.

The program incorporates the ASCOM universal telescope protocol, so it will communicate with most computerized scopes and mounts. Simply connect your mount to your computer and find your model in the Telescope Control menu, and you can issue go-to commands by right-clicking an object in the Plan and selecting "Slew To." This works well, though it would be helpful if the button were on the main screen.

I often find it helpful to look at the photo of an object



Once you've successfully observed a target, click on the Observations tab at the far right of your Observing List window to enter any notes on the object.

I am hunting, and *DSP 6* makes that easy. Click the "Get DSS Images" button on the right side of the Observing Plan window, and you can retrieve an image for the highlighted object. "DSS" refers to the Digitized Sky Survey, the online version of the Palomar Observatory Sky Surveys. You can download DSS pictures for objects individually or in batches. The images are then saved on the hard drive for future use and can be viewed at any time.

Sometimes a picture isn't enough; sometimes I need a star chart. Rather than generating its own maps, *DSP 6* works with third-party planetarium software, including *TheSkyX*, *Starry Night*, and *Cartes du Ciel*. Select your planetarium program in the Options menu, and *DSP 6* will link to it for your charting needs. Right-click an object in your Observing Plan, select Show Chart, and *DSP 6* will minimize and the planetarium program will open centered on the target.

So after you've taken a good, long look at an object, it's time to record your observation. To do so, select the "Observations" tab in the same right-hand pane you see the DSS image. Click "Add Observation" and the program's logbook will open. Most information, including date, time, and the telescope and other currently selected equipment is already filled in for you. All you have to do is record your impressions.

I won't hesitate to say *Deep-Sky Planner 6* was one of the most professional, best-working astronomy programs I'd used in a while, but that doesn't mean it was perfect. What software is? It would be nice if the program would load my last Observing Plan at startup. I'd also like to be able to set an object's status in the Plan spreadsheet to "Observed" without having to make a log entry. Finally, a couple functions weren't clearly named; fortunately, its excellent help menu always made their purposes clear.

Using *Deep-Sky Planner 6,* I'm seeing more objects, and — thanks to being prompted to make descriptive log entries — I'm seeing more details than ever in those objects. I won't say *Deep-Sky Planner 6* has changed my life, but it's definitely improved amateur astronomy for me, and that is a big part of my life. ✦

S&T *contributing editor* ***Rod Mollise*** *writes an astronomical blog at* ***uncle-rods.blogspot.com***.

Done in One

Today's one-shot color cameras can take world-class astrophotos. Here's an easy way to make your images shine.

Warren Keller

In the realm of deep-sky imaging, single-shot color cameras have long played second fiddle to their monochrome cousins paired with color filters. While monochrome cameras are generally more sensitive and produce the best results, the difference isn't so obvious anymore. Today's one-shot color cameras, combined with the latest processing software, can produce stunning astrophotos that rival the best, typically with less money and time spent.

What Is One-Shot Color?

One-shot color (OSC) cameras are actually monochrome sensors with one important addition. Unlike a monochrome detector, OSC sensors are covered with a microscopic grid of filters known as a Bayer matrix, named for its inventor, the late Dr. Bryce Bayer. This grid places a red, green, or blue filter over each individual pixel. When an exposure is made, the color information is immediately available, unlike with monochrome cameras, in which users must take individual exposures through separate filters then combine them to reveal the color. Most digital SLRs (DSLRs) are built around OSC CMOS sensors, and some astronomical cameras are available with OSC CCD detectors. While an OSC device eliminates the need to shoot through individual color filters, making it easier than ever to take color astrophotos, it does have some limitations.

ALL IN ONE The best color deep-sky astrophotography used to be the exclusive realm of monochrome cameras equipped with individual filters, leaving many amateurs to assume that images like this photo of the Leo Trio of galaxies are beyond their reach. Author Warren Keller shows you how this really isn't the case anymore. All images are courtesy of the author.

The Bayer matrix's ability to collect color in a single exposure prevents the collection of unfiltered luminance. As each pixel always "looks" through an attenuating filter, the detector's quantum efficiency (or sensitivity to light) is limited by those same filters. Because the Bayer filter divides the sensor into three images (50% green, 25% red, and 25% blue), the information is inherently of lower resolution than images captured with a monochrome camera. The OSC color channels are interpolated to fill in the gaps between the pixels, though the latest interpolation routines make this difference nearly imperceptible. Finally, while narrowband filters are available for OSC cameras, the loss of light sensitivity when combined with the Bayer filter makes imaging through them a challenge.

Despite these limitations, OSC cameras can be fantastic performers, particularly when used under dark skies with fast focal-ratio optics, and they are the perfect complement to fast astrographs such as Celestron's Rowe-Ackermann Schmidt Astrograph (reviewed in the June issue, page 66).

Recording OSC Astrophotos

Capturing images with an OSC camera is certainly simpler than with monochrome detectors, but most of the technique is the same. As with all deep-sky imaging, exposures should be long enough to produce adequate signal. Depending on your focal ratio, 16 or more five- to ten-minute exposures should be adequate to produce a smooth result.

Image calibration is nearly as important with OSC images as it is with monochrome cameras. Most recent models of DSLR cameras and many astronomical OSC CCD cameras are based around extremely low-noise sensors, making dark frame subtraction (and bias calibration) often unnecessary. However, flat-field calibration frames may still be required. These are exposures of an evenly illuminated surface that record vignetting or out-of-focus dust in your optical system. These images are then applied to your light exposures to remove their effects from your images.

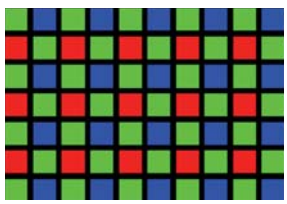
Debayering

Before calibrating and combining your images, your first task is to determine your particular sensor's filter pattern. I enjoy using *Astroart* (**msb-astroart.com**) when processing my OSC images, because it includes many tools designed specifically for OSC data. Opening an unprocessed OSC FITS or RAW file in *Astroart* reveals a grayscale image with a grid-like appearance. As mentioned earlier, the detector in your camera records a monochrome image with a pattern of tiny filters over the sensor, so what you see here is the difference in light sensitivity of your sensor to red, green, and blue light. This now requires converting into color images through a process called debayering, which extracts the color information from the grid.

With your first image open in *Astroart*, select Color > CCD Color synthesis. *Astroart* requires users to establish the order of the Bayer filters in their sensors by adjusting the Synthesis, XY Offset ? numbers and clicking OK. In this new window, a grayscale and color grid representing the filter matrix is displayed. Matching the brightness value of the greyscale grid to the color grid should help to guide you to the proper setting. Try the default settings first by clicking the OK button, but if the result appears monotone green or blue, these default offsets are incorrect. Try different combinations by changing the top offset from 0 to 1, and continue until a natural color image is produced. Once the conversion parameters are established, close the image without saving any changes; the software will store these settings until you change them to accommodate a different camera. They will be applied momentarily.

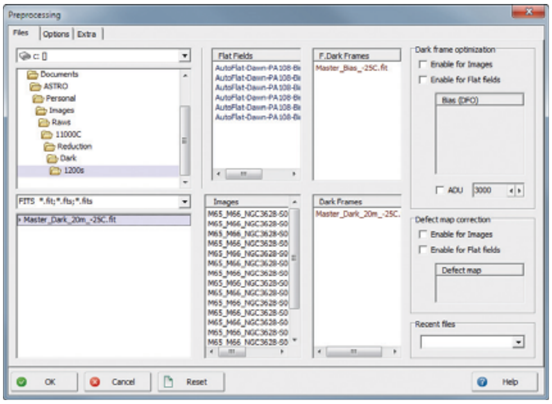
Calibration and Stacking

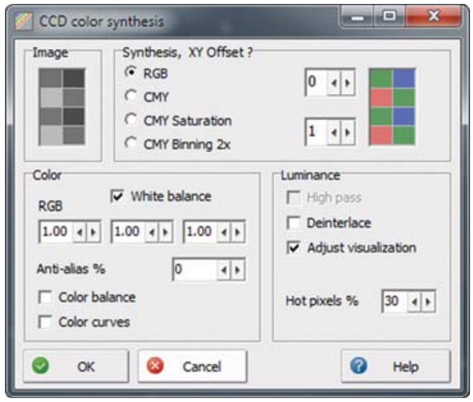
Now that you've established your debayer settings, open the Preprocessing tool (Tools > Preprocessing). In this window you'll select, combine, and apply your calibration frames to your light images, as well as execute a number of other actions that will result in a final calibrated stack of all your images. Beginning with the Files tab, navigate



BAYER MATRIX Color cameras have monochrome detectors with a microscopic grid — known as a Bayer matrix — of red, green, or blue filters placed over each pixel. This information is then re-interpreted as the color image.

RAW GRID Unprocessed RAW or FIT astrophotos appear as black-and-white images with a grid-like appearance.





DEBAYER *Left:* Converting your RAW or FITS image in *Astroart* requires you to experiment with the order of the filters. Change the Synthesis, XY Offset ? from 0 to 1 and click OK to find the proper order of your camera's filter array.

PREPROCESSING *Astroart* combines all of the routine calibration, image alignment, and stacking actions into one easy-to-use tool called Preprocessing (above left). Here you can add all of your light images and calibration frames and perform everything necessary to produce a smooth image ready for enhancement.

to the image folder where your light exposures reside and drag them to the Images section at the right. Do the same for any corresponding flats, darks, and bias images and place them in their respective boxes.

Next, click on the Options tab at the top left of the Preprocessing tool to select the actions that will be applied to all your images. Begin here with the Result image section, and choose the type of image stacking algorithm you prefer to use. Sigma (Average) is my preferred combination method. This produces a strong signal-to-noise ratio, while rejecting outlier pixel values such as satellite trails, hot pixels, and other random signal that doesn't repeat in every exposure.

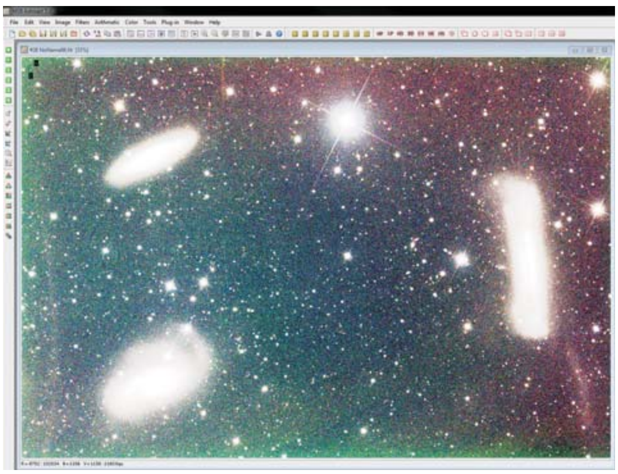
Adjust any other settings you want to apply to your images here. For example, select Auto Alignment to open another dialog box that offers a few alignment options depending on your subject and guiding. You can experiment to determine which alignment method best suits your images.

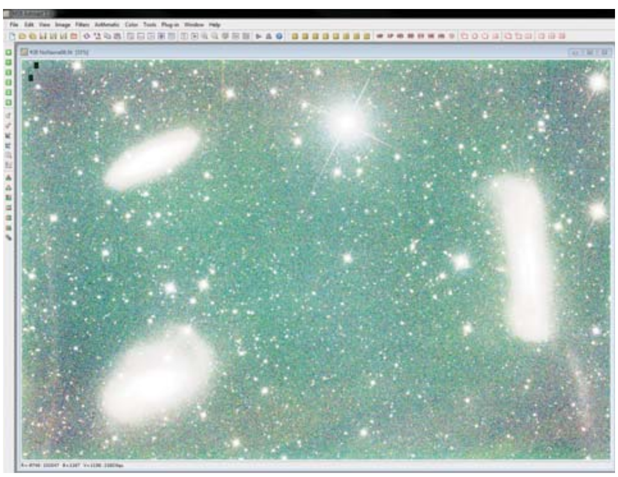
Clicking on CCD color synthesis reopens that dialog we explored earlier. Confirm that your offset settings are correct, though you may want to increase the Hot pixels threshold, particularly if you forgo dark calibration.

If you're combining multiple calibration frames, you'll need to choose the method of combination for each at the bottom of the tool window. Finally, the Extra tab offers additional options which, when enabled, may be applied before or after calibration. This section is particularly useful for removing bad columns and rows from your images before combining the result.

Now that you have all your preprocessing actions prepared, click OK, and *Astroart* will methodically reduce all your data into a final, smooth result ready for additional processing. Be sure to save this image before applying any additional processing; this is your "master" stack.

Your stacked image should look pretty good. At this stage you should address any color gradients. Press F5





GRADIENT REMOVAL Once you've calibrated and stacked your images, address any gradients. Clicking F5 on your keyboard will equalize the image and help reveal any gradients in your image. Select Filters > Remove gradient and select the tool that best describes the gradient or vignetting present in the image. If you're unsure which filter is the best fit for your data, Adaptive (subtract) is the most powerful and versatile choice.

END RESULT Final tweaks to your photo, including sharpening, noise reduction, and color saturation adjustments, can all be performed in *Astroart 5* to produce a final result indistinguishable from images assembled using the tri-color method. This detailed image was captured through a 10-inch Ritchey-Chrétien telescope equipped with an Atik 11000C one-shot color CCD camera.

on your keyboard to activate the "Equalize" function. This displays the image with a strong non-linear stretch, which helps to reveal any background illumination issues (clicking F8 returns your image to a linear display). Be sure to crop away any black border in the image that is leftover from aligning the individual frames. If there are gradients, simply apply Filters > Remove gradient > Adaptive (subtract). This should produce a much more even background. At this point you can experiment with the program's various deconvolution filters (Filters > Deconvolution) to tighten up any small-scale details.

Once you have sharpened and addressed any gradients in your image, it's time to "stretch" the data into an artful photograph. *Astroart*'s DDP (Digital Development Process) is an easy and effective way to perform non-linear stretches in your image as well as enhance subtle contrasts. You can apply the default setting or lower the Threshold and High pass: Sigma levels to compress the dynamic range of your image to better display the entire brightness levels in your image. Also adjust the High pass: Strength to between 0 and 10 to enhance details in your nebulae and galaxy images. Clicking OK yields a beautiful, non-linearly stretched image with enhanced midtones and compressed highlights.

While the image remains a bit dark, you can fix this with the Filters > Histogram stretch. Activating this filter displays a histogram with a few options; click the CURVES button, which allows you to manipulate the high, low, and mid-points of the histogram, if needed.

Finishing Touches

With our image now nonlinear, you can increase the color saturation (Color > Saturation). This tool allows you to limit the saturation increase to only the brighter areas and avoid increasing color noise in the sky background.

At this stage, you may want to suppress any graininess in the sky background. Use the Low Pass filter (Filters > Low pass) to address this issue. Be sure to check the "Enabled" box to activate the Adaptive function. This helps you limit the filter's effects to the background and low-signal areas of your image.

Now your photograph is just about complete. You can further enhance it using *Astroart*'s Unsharp Mask filter (Filters > Unsharp mask) or by increasing contrast before saving the final results. Experiment with some of the other tools found in the program until you're satisfied with the results — there are no hard rules to adhere to at this point. After all, you are your biggest critic!

Today's one-shot color cameras, combined with the latest image-processing software, are capable of producing stunning deep-sky images that are virtually indistinguishable from those produced with a more complex setup. So if the cost and patience required for tri-color imaging is more than you are currently willing to invest, a one-shot color CCD or DSLR camera may be your best shot at producing beautiful astrophotos. ✦

Warren Keller *produces a series of image-processing tutorials to help you get the most out of your images — go to* ***ip4ap.com****.*

A Minimalist Ultralight

This portable Newtonian is optimized for quick and easy setups.

As I've noted here before, telescope making can be a bit of a scavenger hunt. Every amateur telescope maker I know of has a collection of bits and pieces acquired over the years from friends or at star-party swap tables. But we also scavenge ideas. Most home-built scopes are variations on existing designs, but through little tweaks and additions become something unique. The 14¾-inch Newtonian reflector made by Ottawa, Ontario ATM Michael Wolfson is a fine example.

MICHAEL WOLFSON (2)

Right: **Ottawa, Ontario ATM Michael Wolfson's 14¾-inch f/4.6 Newtonian reflector combines excellent portability and performance.** ***Bottom:*** **Friction in the altitude axis is controlled by turning a hand knob, which pulls a pad of Teflon against the inside surface of one of the aluminum side bearings.**

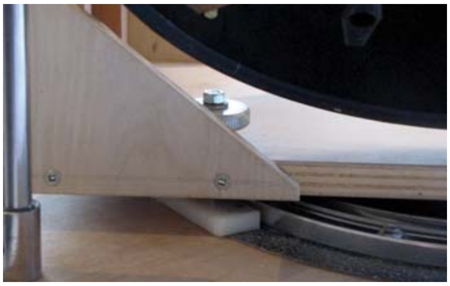
"After acquiring many telescopes while searching for the sweet spot between portability and performance, I concluded that an ultra-light Dobsonian was the way to go," Michael says. His goal was to combine the greatest aperture with the least weight, in a scope that he could use without standing on a ladder or step stool.

Albert Highe's book, *Engineering, Design and Construction of Portable Newtonian Telescopes* (Willmann-Bell), which details building highly portable large-aperture scopes, was one source of inspiration and ideas. Michael had also seen a single-strut Newtonian at a star party, which prompted him to build several smaller versions to gain experience with the design. So when he acquired a high-quality, 14¾-inch f/4.6 quartz primary mirror, the broad outlines of his new scope were set.

One feature that Michael put his own spin on was the scope's bearings. "Instead of counting on Teflon and Formica to provide just the right balance of stiction and friction," he explains, "I decided to start with bearings that move as freely as possible, and then increase the friction in a controlled manner."

His solution uses a 13-inch-diameter Lazy Susan bearing in azimuth, and aluminum semi-circle plates riding on cam-follower bearings for the altitude. This arrangement is well suited to a motor-drive system Michael plans to add in the future. But for controllable manual slewing, some additional friction is required.

To achieve the friction he desired, Michael resorted to some old-school Dobsonian technology. On the azimuth axis, he affixed a 15-inch-diameter circle of Ebony Star laminate between the ground board and the lazy Susan bearing, with only the outer inch of the laminate exposed. With the turn of a knob located inside the rocker box, a thick pad of Teflon gradually presses against the outer edge of the laminate disk, increasing friction. For the altitude motion, the aluminum bearing on the focuser side of the scope moves between two pieces of Teflon: one attached directly to the interior of the rocker box, the other screwed to an adjustable, spring-loaded aluminum plate. Tightening a knob forces this second Teflon piece against the altitude bearing, sandwiching it between the two pads — similar to an automobile disk brake — and introducing extra friction.



MICHAEL WOLFSON

A Teflon pad bears against Formica to regulate friction in the scope's azimuth axis. A knob on the upper side of the rocker box controls the pressure exerted by the Teflon piece.

His scavenging skills were also put to good use when it came to the primary mirror tube assembly. For this part, Michael repurposed a 16-inch-diameter, ¼-inch thick drum shell, salvaged from a local music store. He sanded off the drum's original finish, then applied several layers of clear Varathane to the outside and a coat of flat-black paint to the interior.

Another nifty refinement he incorporated into his scope is the ability to move the focuser and secondary mirror assembly up and down the strut pole. "If I want to use my bino viewer," he explains, "all I have to do is loosen the U-bolt clamps, slide the assembly closer to the primary mirror, then recollimate and rebalance."

Michael's lightweight and versatile scope is tailored to his observing needs. "In summer I use the scope at a cottage on a remote lake in Quebec," he says. "There are many lovely trees around, so depending on which part of the sky I want to observe, it's helpful to be able to easily relocate the scope — exactly why I wanted one that's lightweight and quick to set up."

To learn more about Michael's scope, you can e-mail him at Michael.Wolfson@uOttawa.ca. ✦

*Contributing editor **Gary Seronik** is an experienced telescope maker and observer. You can see some of his lightweight scopes on his website at* **garyseronik.com**.

Do you have a telescope or observing accessory that *S&T*'s readers would enjoy knowing about? Get featured in Telescope Workshop by e-mailing Gary Seronik at gary@garyseronik.com.

▲ **BIG BINOS** Lunt Engineering now offers big apochromatic binoculars — really big. The Lunt Engineering 100 mm ED APO Large Format Binoculars (starting at $2,950) are designed for serious observing with both eyes open. These premium 4-inch binoculars are built around two-element, air-spaced ED glass objectives, providing superb color correction. Its multi-coated roof prisms fully illuminate the field of view. The eyepieces are seated at a comfortable 45° viewing angle with an adjustable interpupillary distance range of 54 to 75 mm. The unit also accepts most 1¼-inch eyepieces seated in helical focusers, with non-marring brass compression rings in collet-style locking mechanisms. Weighing 14.52 lb (6.59 kg), the binoculars include a sturdy tripod mounting bracket, heavy-duty carry handle, and a unit-power finder to quickly and accurately aim at your chosen targets in the sky. Each purchase includes a matched pair of 20-mm eyepieces.

Lunt Engineering
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877-344-7348; luntengineering.com

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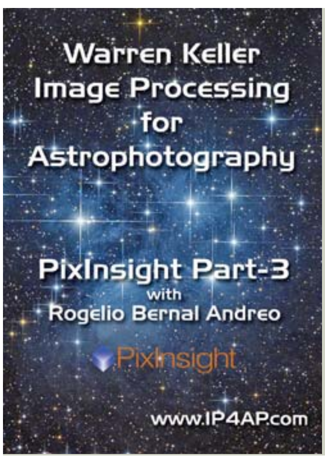
▼ **TRAVEL DOBS** Teeter's Telescopes unveils its latest custom Dobsonian telescope, the TT/Journey ($2,550 without optics). This compact 11-inch Dobsonian is designed to be as light as possible, with adequate aperture to provide generous detail on the planets as well as many deep-sky targets. Weighing a total of only 39 pounds, the telescope collapses into a compact area to fit in most small vehicles or checked luggage. Its mirror box weighs just 19 lb, including its optional primary mirror, and stands just 46 inches when pointed at the zenith. Each TT/Journey Dobsonian travel-scope features a lightweight Feather Touch Focuser, 3-vane curved secondary spider assembly, and Teeter's spring-tension virtual counterweight system. The TT/Journey is also available with an f/4.5 primary mirror manufactured by Lightholder Optics ($3,900) or Zambuto Optical ($4,300). See the manufacturer's website for additional options.

Teeter's Telescopes
270 Rt. 46, Suite B, Rockaway, NJ 07866
732-991-1248; teeterstelescopes.com



PROCESSING LESSONS Premier astrophotographers Warren Keller and Rogelio Bernal Andreo team up to bring you their latest video tutorial in the IP4AP series. "Image Processing for Astrophotography: *PixInsight* Part-3" ($65) is available for online streaming or as a DVD. It contains almost 3 hours of information in 26 scripted *Adobe Flash* tutorials that continue to familiarize you with the powerful software *PixInsight*, an affordable digital darkroom alternative to *Adobe Photoshop* designed specifically for astrophotography. Part 3 of the series details advanced image-processing techniques, including high-dynamic-range (HDR) composition, assembling mosaics, multi-scale processing with wavelets, and much more. Each tutorial runs about 4 to 6 minutes and contain walkthrough demonstrations of each concept to help you get the most out of your astroimages.

IP4AP.com
2730 Upper Mountain Rd., Sanborn, NY 14132
716-864-7400; ip4ap.com

▼ ROSE IN A DIFFERENT LIGHT

Steve Mazlin

Although challenging to spot visually, the Rosette Nebula is a large star-forming region 5,200 light-years away with a young open cluster (NGC 2244, discovered in 1690) lighting up its center. **Details:** *Takahashi FSQ-106ED astrograph, SBIG STL-11000M CCD camera, and Baader Hα and O III filters. Total exposure: 32 hours.*

▲ TIBETAN NIGHT

Jeff Dai

The Milky Way's central bulge glows brightly over the Tibetan village of Zhaxizong, located 13,600 feet above sea level and east of Mount Everest. **Details:** *Canon EOS 6D DSLR camera at ISO 3200 and Nikkor 14-to-24-mm zoom lens used at 20 mm. Exposure: 30 seconds.*

► FROZEN CORONA

Kevin Morefield

The hardy souls who traveled to Longyearbyen in Svalbard (78°N) for March 20th's total solar eclipse were rewarded with crimson prominences at the base of a dazzling, picture-perfect corona. **Details:** *Canon EOS 70D DSLR camera and 400-mm lens at ISO 800. Composite of 1/20- and 1/125-second exposures.*

Gallery showcases the finest astronomical images submitted to us by our readers. Send your best shots to gallery@SkyandTelescope.com. See SkyandTelescope.com/aboutsky/guidelines.

◄ **CHASING THE MOON'S SHADOW**

Glenn Schneider

As seen from an altitude of 35,000 feet, the Moon's advancing shadow had a dramatically distinct and ominous edge during the total solar eclipse on March 20th.

Details: *Canon EOS Mark III DSLR and 14-mm lens at ISO 1600. Exposure: 1⁄60 second.*

◄▼ **GLOWING CRESCENT**

Ron Brecher

The Crescent Nebula (NGC 6888) is a sizable, medium-bright emission nebula that lies along the long neck of Cygnus. William Herschel discovered it in 1792.

Details: *ASA 10N astrograph, SBIG STL-11000M CCD camera, and Baader narrowband filters. Total exposure: 4.9 hours.*

▼ **DIAMOND PROMINENCES**

Tunç Tezel

As the last bit of photosphere disappeared behind the Moon on March 20th, eclipse watchers were treated to a bevy of large, crimson-hued prominences and a fine arc of the innermost corona along the Sun's eastern limb.

Details: *500-mm Maksutov lens, 2× teleconverter, and Hutech-modified Canon EOS 5D DSLR camera at ISO 800. Exposure: 1⁄800 second.*

▲ **SILENT SENTINEL**
Antonio Peña
A 16th-century watchtower in the mountains near Madrid, Spain, accompanies concentric arcs from the northern sky's circumpolar stars.
Details: *Canon EOS 70D DSLR camera with 8-mm fisheye lens. Total exposure: 50 minutes. Flashlights used to illuminate the foreground and tower interior.*

◄ **LUNAR ECLIPSE DOWN UNDER**
Dean Hooper
On April 4th, two weeks after a total solar eclipse, the Moon plunged through Earth's umbra and was itself eclipsed. This inverted view shows what Australians saw.
Details: *Meade 8-inch LX90 Schmidt-Cassegrain telescope with f/6.3 focal reducer and Nikon D3100 DSLR camera at ISO 200. Exposure: 2 seconds.* ✦

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A Tale of Two Sites
Lick Observatory and several telescopes on Kitt Peak recently faced closure due to budget woes. What led to their endangerment, and how are astronomers beating back the mothballing?

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Reading History in the Heavens

The night sky offers a visual narrative of astronomical advances.

As director of a small college observatory, I have long treated community residents to the wonders of the night sky. Like many outreach astronomers, I've compiled a roster of celestial objects to display, featuring the usual descriptors for each one: category, brightness, distance, and so on. But a purely data-driven tour of the night sky disregards a highly inspirational aspect of the cosmic landscape — the human dimension. Astronomers should present the wonders of the cosmos, as the Nobel Prize–winning physicist Isador Rabi said about teaching science, "in the light of the history of human thought and human effort, rather than as the geography of a universe uninhabited by mankind."

Over the millennia, our species has engaged in a heroic enterprise to measure, analyze, and ultimately comprehend the cosmos. From a state of complete bewilderment about the dark province above our heads, we have advanced to a deep understanding of the universe and its components. How we garnered that knowledge is as important as the knowledge itself, for it endows humanity with a reason for being as well as a lofty incentive to sustain our collective exploration.

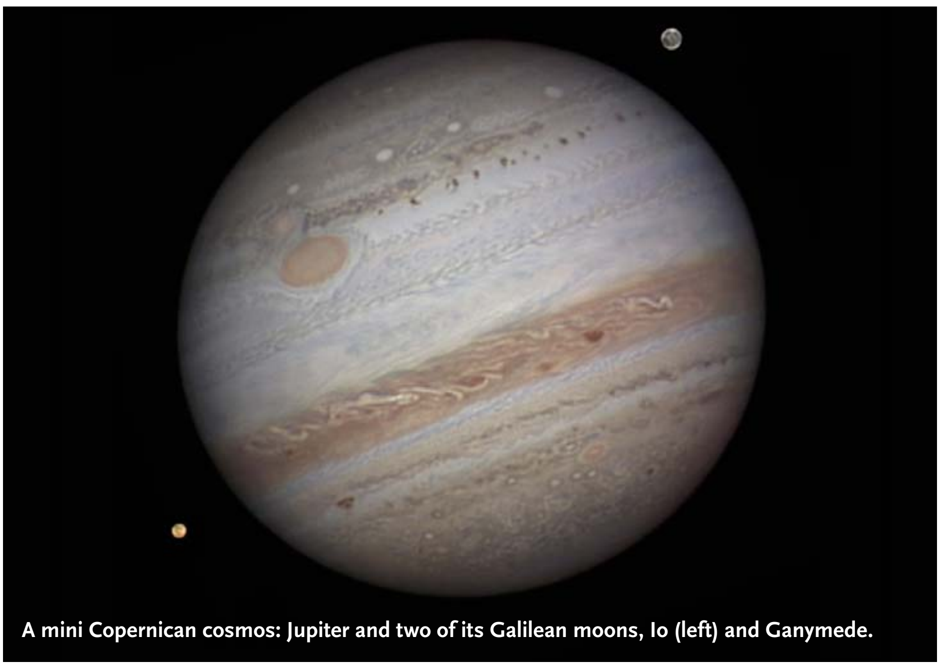
Tying the history of astronomical advancement to a tour of celestial objects gives viewers a palpable sense of that time when the camera and the spectrograph turned the firmament's enigmatic specks and wisps into actual physical entities scattered through space. In a historical context, the night sky becomes a visual chronicle of scientific achievement and technological inventiveness.

During early autumn, for example, I point out the cross-shaped constellation of Cygnus the Swan and recite the stock superlatives that characterize its major stars. But then I direct visitors' attention to a 5th-magnitude star tucked between the swan's tail and its eastern wing. This nondescript dot, 61 Cygni, gleams in the annals of science history: in 1838, astronomer Friedrich Bessel measured 61 Cygni's distance, making it the first star outside the solar system to be pinpointed in space.

The famous double star Mizar and Alcor, in Ursa Major, bears multiple historical imprints. It is the first double star detected in a telescope (by Benedetto Castelli in 1617) and captured in a photograph (by George Bond in 1857). And the brighter of this Mizar pair, too, is double, as Edward Pickering announced in 1889. It was the first stellar binary discovered by its spectroscopic signature.

The Moon evokes that perilous era in Western intellectual history when Galileo first cast his telescopic eye over the lunar landscape and pronounced it Earthlike. His measurement of the height of a lunar peak, in 1609, planted a virtual flag to human ingenuity centuries before astronauts walked on the Moon. History likewise imbues Jupiter and its satellites with human drama: Galileo's clash with church authorities, which was sparked by the sight of what appeared to him to be a diminutive Copernican cosmos.

In sum, as awe-inspiring as the night sky is to the eye and to the mind, its reflection of humanity's quest for knowledge heightens its inspirational power. ✦



NASA / DAMIAN PEACH, AMATEUR ASTRONOMER

A mini Copernican cosmos: Jupiter and two of its Galilean moons, Io (left) and Ganymede.

Alan Hirshfeld *is an astronomer at UMass Dartmouth and author of, among other books,* Starlight Detectives: How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe.

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