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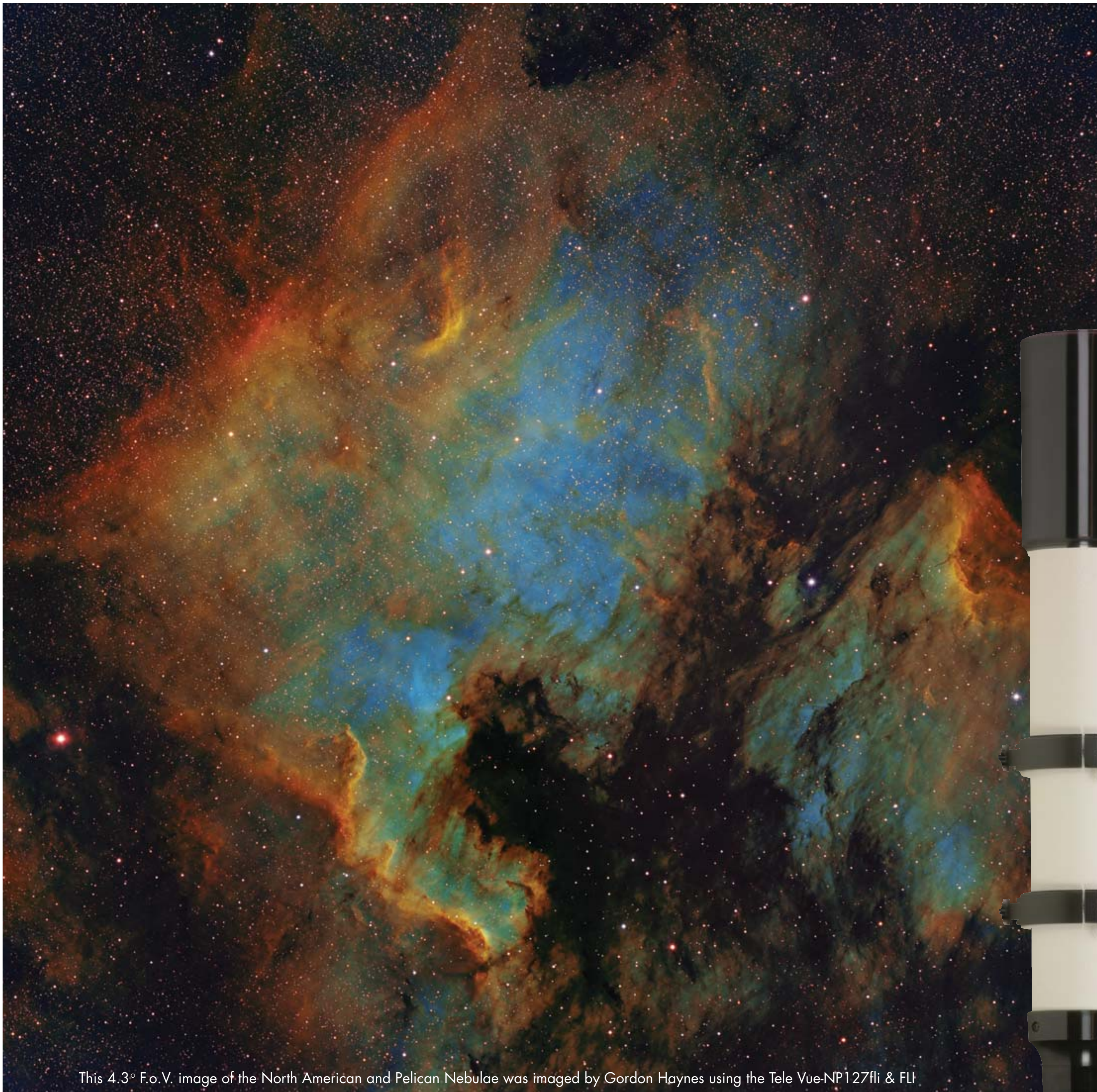
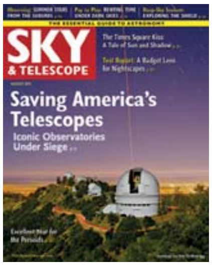


This 4.3° F.o.V. image of the North American and Pelican Nebulae was imaged by Gordon Haynes using the Tele Vue-NP127fli & FLI

SKY & TELESCOPE August 2015 VOL. 130, NO. 2



On the cover: The laser guide star on Lick's 3-meter Shane telescope at work. Lick is pulling through recent financial challenges.

PHOTO: LAURIE HATCH

FEATURES

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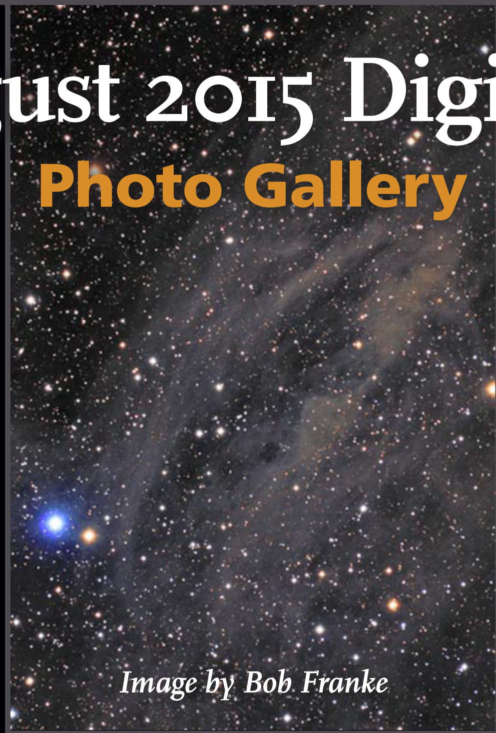

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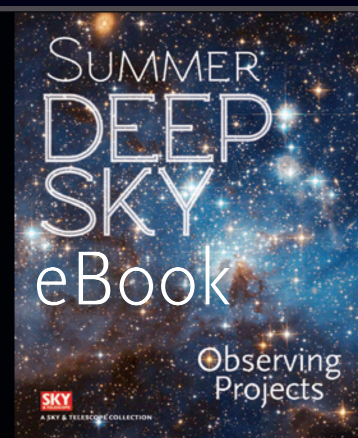

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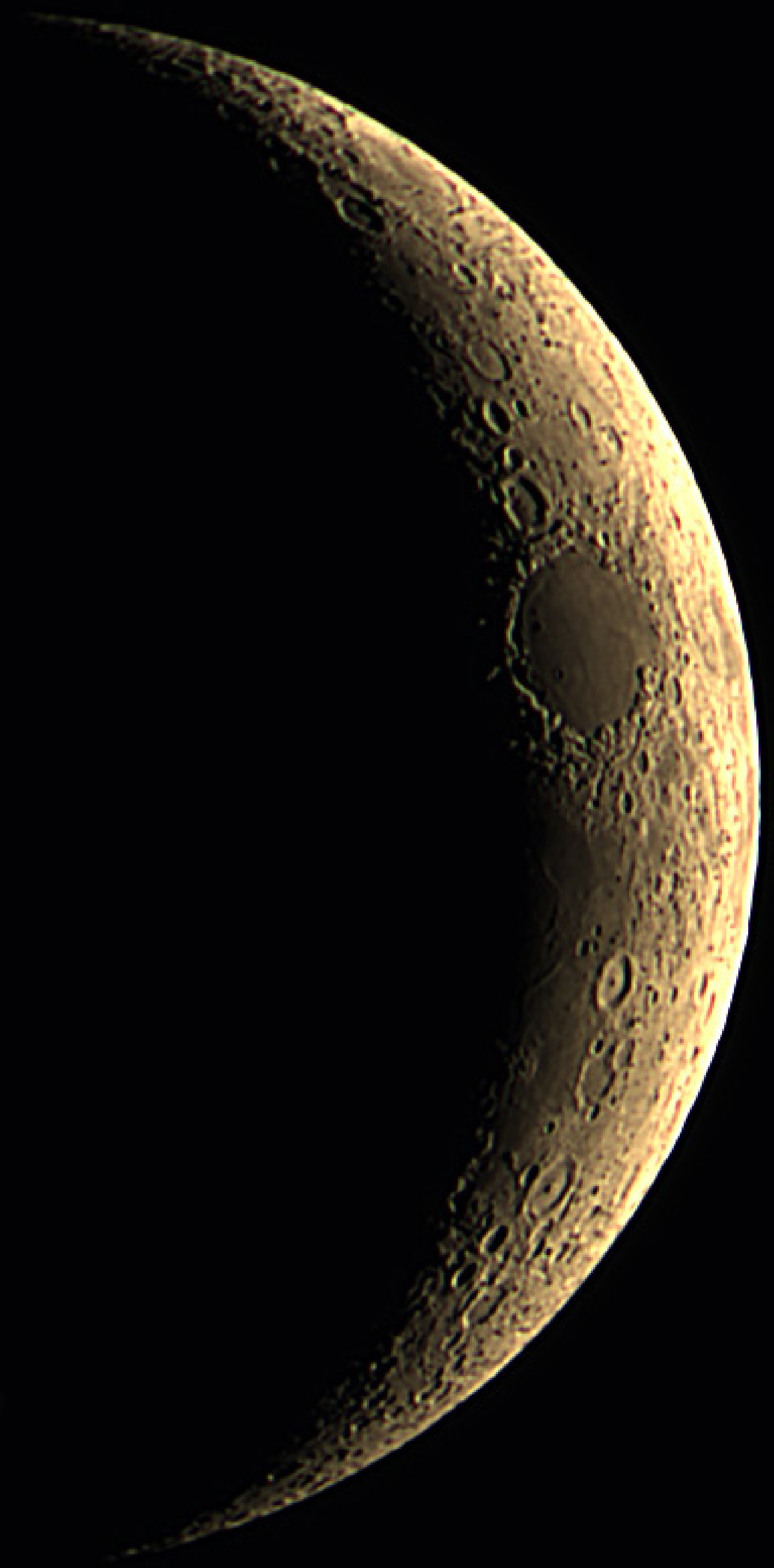

ONLINE PHOTO GALLERY

Mare Crisium emerges on the three-day-old Moon in this image captured by Jean-Claude Merlin.

Moonrise

THE OTHER NIGHT I undertook the most basic of stargazing pursuits: I watched the Moon rise. I was camped in the Chihuahuan desert of western Texas, and through a pair of 10×42 binoculars I observed the full Moon crest a distant ridge, silhouetting as it did a nearby ocotillo. I could see our satellite *actually moving* against the plant's spiny stalk; it floated up and off in a matter of seconds. What I was seeing, of course, was the rotation of the Earth.

It's one of those moments when suddenly the fact that our planet is a cog in a grand cosmic wheel becomes obvious. Our connection to the everyday workings of the solar system is right there to see, in action. It's an enlightening and humbling experience.

MICHAEL GIL/WIKIMEDIA COMMONS

And it never gets old, for me anyway. My son is autistic, and one of his obsessions is elevators. Every time he rides elevators, his eyes are as bright with unbridled wonder as they were the first time he laid eyes on an elevator some 15 years ago. I feel the same when I observe the Moon rise in such a way that I can actually follow its motion. I'm gobsmacked.

A little later that evening, I watched Orion set to the southwest. One moment Mintaka, the rightmost star in Orion's Belt, was there, and the next moment it wasn't. As I settled down for the night, I kept my eye on the southwest horizon until all three belt stars had winked out, leaving red-tinged Betelgeuse suddenly adrift. I enjoyed the spectacle, but it didn't leave me slack-jawed like the moonrise. Even as I knew in my gut the stars were moving, I couldn't actually *see* them moving (well, "moving").

We're always looking, or should be, for what really inspires us. For each of us it's different: what blows me away might be ho-hum for you, and vice versa. But one of the undeniable gifts of the night sky is how *many* of these ever-inspiring visions we can draw from.

For you, maybe it's discerning Jupiter's four major moons lined up on either side of the gas giant — as I did that night in the desert — and musing on their exalted place in the history of astronomy, courtesy of Galileo. Maybe it's witnessing a spectacular meteor shower, such as the one we're expecting in mid-August with this year's Perseids (see page 48). Or maybe it's every time you make out a challenging deep-sky object for the first time — objects like the planetary nebula IC 1295 (page 56) or the Sunflower Galaxy (page 74).

Whatever it is, there's nothing like that feeling of awe that sets you back on your heels and leaves you whispering, as I did the instant the Moon slipped off the ocotillo, "Wow." ✦

Peter
Editor in Chief

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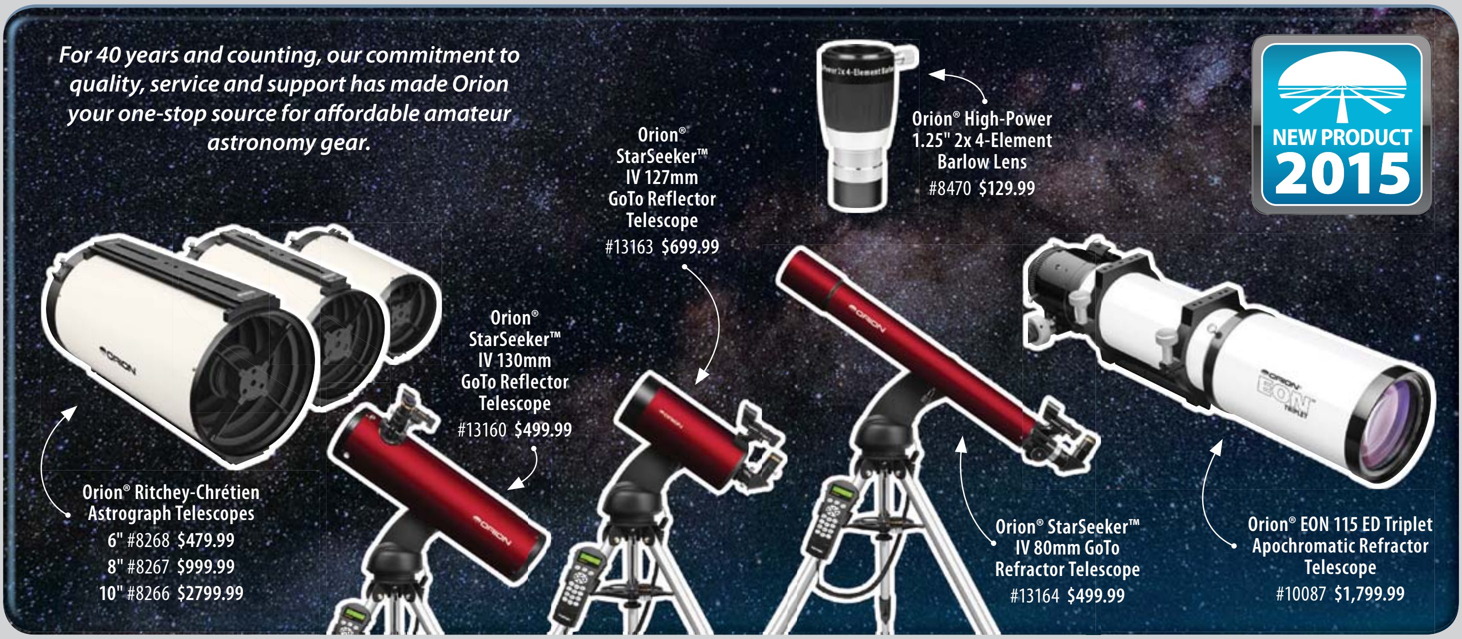

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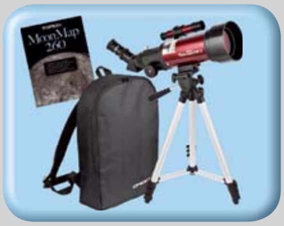

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A Century of Stargazing

I always bring the current issue of *Sky & Telescope* with me when I visit the dark skies in Tupper Lake, New York, to see my cousin Muriel Ginsberg, who celebrated her 105th birthday last November. She's so interested in the magazine that, for the last couple of years, I've been buying her a gift subscription, which she cherishes. (Caregivers read it to her.) Last summer, she even attended the opening of the nearby Adirondack Public Observatory, to which she donates. Kudos to everyone at *S&T* for enriching the waning years of perhaps their oldest subscriber.

Edward Ginsberg
Boston, Massachusetts

Still active at 105, Muriel Ginsberg enjoys keeping up with astronomy and visiting the local public observatory.

EDWARD GINSBERG

Lovecraft's Astronomy

Thanks for the awesome article about H. P. Lovecraft and his history with astronomy (*S&T:* Feb. 2015, p. 34). I'm an avid fan, and it was nice to read about his early works in amateur astronomy as well as the other delicious details. Thanks for including an article not just about science and the workings of our scopes. Please publish more like this.

Chan Webb
Bozeman, Montana

Go To Alignment Puzzler

Rod Mollise's article on aligning Go To mounts (*S&T:* Feb. 2015, p. 62) didn't address how a telescope's electronic compass can become confused by local magnetic-field anomalies. This is a real showstopper for amateur astronomers living in urban locations. In my neighborhood, magnetic north is almost *never* where it's supposed to be, and the main cause of trouble seems to be magnetic interference from steel handrails nearby. So when I set my telescope up on the sidewalk and start to align it, the result is typically off by more than 5°. It took me quite a few months to figure out what was going wrong. First I have to determine which star it's looking for and then center the star manually. Once I've done this (twice), it's fine.

Graeme Birchall
Jersey City, New Jersey

Rod Mollise replies: *Local masses of metal, often your vehicle, can indeed interfere with your scope's magnetic compass. Luckily, it's not as much of a problem as it used to be. Celestron's original GPS systems used an internal compass to point north, but this feature was eventually eliminated from all of its telescopes. Some Meade telescopes do still use an electronic compass, however. So what's the solution if you can't move away from all that metal? A routine in the Autostar hand controller allows you to "calibrate" the compass. You first point at Polaris manually and then tell the hand controller that's where north is. It's also possible to bypass the GPS (or Easy) Alignment and leave the compass totally out of the setup process — though that's not as convenient.*

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Please limit your comments to 250 words. Published letters may be edited for clarity and brevity.

Due to the volume of mail, not all letters can receive personal responses.

The "How" and "So What" of Astronomy

Having subscribed to *S&T* since 1970, I find that the magazine gives short shrift to an important aspect: the How of astronomy. I suspect that science illiteracy is driven partly because science reporting tends to emphasize results (the What of science) but neglects the How. People don't understand how the results come about. Moreover, one important part of How is Who. Only people do science — not computers, spacecraft, or telescopes. *S&T* could do more to expose the individuals involved in astronomy and space science.

Another aspect of How is observation. Nearly all astronomical and space-science observations are made indirectly — that is, some sort of instrument intervenes between the natural object of study and the human observer. *S&T* could do more to describe and explain modern astronomical and space-science instrumentation. One example is spectrographs. You and I know that spectrographs are among the most important astronomical instruments, but the public is largely unaware of this fact. Moreover, modern spectrographs have evolved greatly over the last few decades and are a far cry from the simple slit-and-prism schematic illustration that's usually trotted out to explain their function.

Could *S&T,* by better exposing the How of astronomy and space science, contribute more to overall scientific literacy?

Mark Holm
Monroeville, Pennsylvania

Camille Carlisle replies: *It's true that many people do not understand how science works. Part of that is specialization in knowledge: I know a few things about astronomy — but next to nothing about taxes.*

We do try to find the balance between

*What, How, and (equally important, in my opinion) So What. It's a difficult balance to strike. Take, for instance, the article I wrote on results from the Planck spacecraft (*S&T*: July 2015, p. 28). I made a point to discuss how cosmologists go from observing the cosmic microwave background to determining the basic physical parameters of the universe, because that's an important How step that's often skipped over. Without that, it's difficult to appreciate that these numbers aren't just pulled out of a hat. The cost to including such info is that it makes the article longer and more complicated, which (1) makes it more difficult for readers to follow and (2) means we have to take that space from something else. Finding the correct balance is an adventure in every article.*

We also strive to be conscious of your Who point. We try to bring in professional astronomers to write about their research; many of our science features are written by these scientists themselves. We do this specifically to help readers connect with the people who do the science, to bring out the human side of this endeavor.

*But in the end, I think the most important thing *S&T* has to contribute is the So What — what does this result mean in context, and what does it mean for this area of astronomy? Giving readers a sense of how our understanding changes and develops with time as we gather more information is a major part of the How of science, because science is a synthesis and not factoids floating by themselves. So when space is tight for a news story and I have to make a choice, I have a strong inclination toward keeping the So What sentence and cutting the How sentence. Part of my reasoning is that our readers generally already have a high level of know-how — you are all a savvy bunch — and so we often don't need to include the basic, step-by-step explanation that a more general reader would need. But the other part of it is this balance-finding when explaining the facets of science.*

Still, you make a great point, and we'll look for ways to integrate more How in our science discussions. In 80 or so pages we can't be exhaustive, but we can certainly whet the appetites of our readers.

Thank you for being such a longstanding and thoughtful subscriber. It's folks like you that keep us going.

My Moment of Syzygy

On April 21st, I was standing in my yard awaiting the passage of the International Space Station, as I often do. Right on schedule the ISS made its appearance, a beautiful sight as it passed not far from Venus and the Moon. As it approached Jupiter, high overhead, it got closer and closer. Then, to my surprise, the ISS passed *right over* Jupiter, and briefly the two points of light became one. I realized that the planet, the ISS, and I were all in perfect alignment. Even though I bought my first telescope in 1959 and I'm getting on in years, the excitement is still there.

Paul Vidal
Westport, Massachusetts

For the Record

✹ *May issue, page 67: The all-sky camera seen in the upper photo is an All Sky Cam by Moonglow Technologies.*

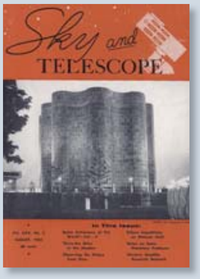
75, 50 & 25 Years Ago

Roger W. Sinnott

July-August 1940

Mother of All Spirals "For a long time the Galaxy, our Milky Way system, has been thought to be a 'spiral nebula,' resembling closely the great nebula in Andromeda, Messier 31, or that in Triangulum, Messier 33. But all attempts to determine its size have led to the conclusion that it is much larger. . . . Our Galaxy seems to be about 30,000 parsecs (one parsec = 3.26 light years) in diameter, with the sun 10,000 parsecs from the center, whereas the external galaxies are only a few thousand parsecs across. . . ."

Albert G. Mowbray had the size of the Milky Way right but grossly underestimated those of other spiral galaxies. This didn't mean astronomers clung to the notion that we were "special." The distances to all other galaxies, hence their deduced physical sizes, would double in the 1950s following Walter Baade's landmark reevaluation of how Cepheid variable stars are used as distance indicators.

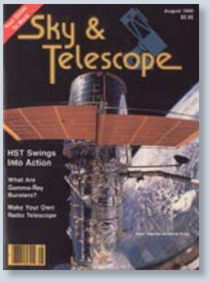


August 1965

Quasi-Stellar Things "Many objects hitherto regarded as very faint blue stars inside our own Milky Way are actually a strange variety of extremely distant galaxies, according to Allan Sandage of Mount Wilson and Palomar Observatories. These objects (which he calls QSG, for quasi-stellar galaxies) differ from the famous quasars (often called quasi-stellar sources) in not being strong sources of radio emission. . . ."

"[QSGs] are much commoner than the quasars, by a factor of about 500. . . ."

Today "quasar" is used as an umbrella term for both types. They're all extremely remote and luminous galactic nuclei, each thought to harbor a supermassive black hole. Radio-quiet quasars are the most common variety by far.



August 1990

Lightning on Titan? "Lightning occurs on Jupiter and probably on Saturn and Uranus. But how about on a small world like Saturn's moon Titan? The atmosphere of this satellite is slightly denser than Earth's. . . . [but Voyager 1 data suggest] lightning bolts on Titan are at least a thousand times weaker than terrestrial ones — if they exist at all. . . .

"[Yet lightning] may play an important role in the chemistry of Titan's atmosphere. The abundances of several hydrocarbons can be explained by reactions driven only by sunlight. However, the atmosphere contains too much ethylene (C_2H_4) to be produced in this manner. Lightning was considered a likely alternate catalyst. . . .

"The final word on Titanian lightning may come after the turn of the millennium when the Cassini spacecraft enters orbit around Saturn."

The verdict from Cassini is in: still no lightning. Astronomers remain puzzled as to the mechanism that created the strange mix of hydrocarbons found in Titan's atmosphere.

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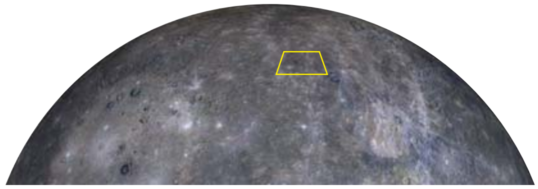

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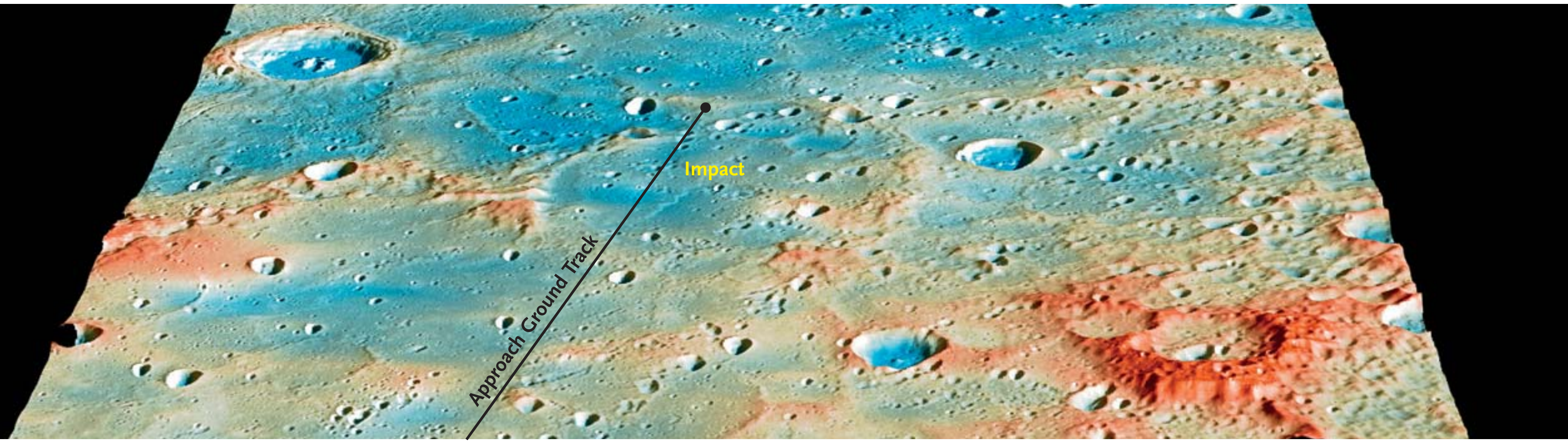


ZOOM: NASA / JHU-APL / CARNEGIE INST. OF WASHINGTON; GLOBE: S&T / NASA / JHU-APL / CARNEGIE INST. OF WASHINGTON

Messenger impacted Mercury's northern hemisphere (*top, outline approximates zoom*) on April 30th. The crater at upper left, Janacek, is 48 km (30 miles) across. Color indicates terrain elevation, with the tallest regions in red.

After orbiting Mercury for four years, NASA's Messenger spacecraft crashed into the planet on April 30th at 19:26 Universal Time. By then the orbiter had been operating on borrowed time for months, its fuel tanks nearly empty after a decade of interplanetary maneuvering. Ultimately Mercury's gravity — coupled with the Sun's perturbing pull — forced the inevitable collision.

The mood in the mission control center at Johns Hopkins University's Applied Physics Laboratory was both celebratory and somber as team members watched the craft's last transmissions arrive after 4,105 orbits around Mercury. In its final moments, Messenger (a contraction for Mercury Surface, Space Environment, Geochemistry, and Ranging) skimmed over the planet's unseen side before striking an unnamed ridge located at 54.5° north, 210.1° east.

Launched on August 3, 2004, Messenger first became acquainted with Mercury during three close flybys in 2008 and 2009. When the spacecraft finally settled around the planet for keeps on March 18, 2011 (UT), it assumed an elliptical orbit that ranged in altitude from 15,000 km (9,300 miles) to as close as 200 km (120 miles) every 12 hours.

The nominal mission was to last only a year, but with the spacecraft healthy NASA managers opted to continue the mission and, in March 2014, to lower the *periapse* (close point) of each orbit to less than 50 km. These extensions, and particularly the spacecraft's movement closer in, paid big dividends in terms of surface photography and geochemical assays (see below for one example).

■ **J. KELLY BEATTY**

IRON PLANET | Why Is Mercury So Dark?

One of the Messenger mission's most unexpected results is that the rocks and dust on Mercury's surface contain very little iron. It's so surprising because this planet has a huge, iron-dominated core that takes up 85% of its diameter and more than half of its volume (*S&T:* Apr. 2012, p. 26). So geochemists expected that the planet's surface would contain lots of iron.

This finding, curious in itself, has a bearing on another Mercurian mystery. The planet's surface is very dark, even more so than the Moon's, reflecting only about 7% of the sunlight striking it. Researchers have long known that the Moon's surface darkens over time because tiny meteorites pepper the lunar dust, momentarily flash-melting iron-bearing silicate minerals and creating submicroscopic bits of metallic iron. These iron particles are what make the lunar landscape appear dark. But given Mercury's iron-poor surface, some other process must be involved.

In the March 31st *Nature Geoscience,* Megan Bruck Syal (Lawrence Livermore National Laboratory) and others offer a possible cause: a veneer of carbon-rich organic compounds derived from comets. Syal and colleagues first estimated that the infall of comet stuff during the past 200 million years could have infused the top layer of Mercurian dirt with 3% to 6% carbon. Then they conducted impact simulations at the NASA Ames Vertical Gun Range to confirm that comet-borne carbon would actually stick around, in the form of tiny particle clusters.

The resulting surface layer would have a bland spectrum, exactly what Messenger found. "We show that carbon acts like a stealth darkening agent," explains team member Peter Schultz (Brown University). "From the standpoint of spectral analysis, it's like an invisible paint" that has been building up for billions of years.

■ **J. KELLY BEATTY**

GALACTIC CENTER
Mysterious X-rays Spotted in Milky Way

NASA's NuSTAR mission has detected an unexpected haze of high-energy X-rays in our galaxy's crowded center. Kerstin Perez (Columbia University) and colleagues found the X-rays emanating from within our galaxy's central 10 light-years or so, they report in the April 30th *Nature*. In and of themselves, X-rays from the galactic center aren't unusual. But the X-rays NuSTAR detects don't seem to be associated with structures already known to exist, such as the supernova remnant Sgr A East or the dust and gas clouds of Sgr A West that are falling toward the supermassive black hole.

Instead, the team proposes that thousands of dead stars could be responsible for the high-energy X-rays: massive (and still-growing) white dwarfs, spun-up pulsars, or black holes and neutrons stars feeding on low-mass companion stars. But each of the proposed explanations has its own set of challenges, and astronomers don't know which is correct.

Take millisecond pulsars, potentially the best option. These neutron stars flash energetic beams in our direction as they spin like blindingly quick lighthouses. They began as the cores of massive stars that went supernova, then spun themselves up with gas stolen from companion stars. Many massive stars die in the galactic center, so these pulsars' existence seems inevitable. Such a population might even help explain a mysterious excess of gamma rays seen from this region.

But although astronomers expect to see lots of millisecond pulsars in the galactic center, so far they've spotted *none*. That might be because the gas and dust between the galactic center and us smears out the pulsing radio signals. But millisecond pulsars' hot surfaces also emit low-energy X-rays, so if there were a large number of these pulsars, then other X-ray telescopes such as NASA's Chandra X-ray Observatory should have spotted them. They haven't.

■ **MONICA YOUNG**

GALAXIES | Ghosts of Quasars Past

Astronomers have found eight echoes from active galactic nuclei (AGN) that recently went dormant. The echoes are glowing clouds of gas, ionized by intense radiation beamed out from the galaxies' cores. This radiation came from supermassive black holes that were voraciously swallowing hot gas, but the black holes have since gone quiet. Even so, the echo of light in the glowing clouds remains, because the gas atoms' stripped electrons take a long time to find new homes in the sparse intergalactic environment.

William Keel (University of Alabama) led the charge of nearly 200 Galaxy Zoo volunteers hunting for these objects in Hubble Space Telescope images. The search began after a Dutch schoolteacher discovered a galaxy-size blob of gas glowing south of the spiral galaxy IC 2497. The gaseous object, known as Hanny's Voorwerp (Dutch for "Hanny's Object"), was ionized roughly 30,000 years ago, when IC 2497's supermassive black hole created a blazing quasar in the galaxy's core.

The volunteers searched for blobs with the same distinctive color as Hanny's Voorwerp (blue or green, depending on the processing) and offset by more than 33,000 light-years from the nearest galaxy. Out of almost a million galaxy images, only 19 made the cut. Of these, eight clouds were echoing light from quasars that had faded from their former glory, the team reports in the May *Astronomical Journal*.

Keel's team found that the host galaxies of all eight faded quasars show signs of recent or ongoing mergers, such as tidal tails or dusty disks warped by an encounter. The lit-up reservoirs outside the galaxies are probably the gaseous remains of these mergers: the clouds are roughly in the same spot as the tidal debris and they're also rotating, motion that's likely left over from the now-cannibalized galaxy.

Surprisingly, none of these mergers appears to have triggered much, if any, star formation, despite large reservoirs of gas. Did the once-bright quasars quench any existing star formation, as the authors speculate? Or could we be witnessing these mergers early on, before activity has had a chance to ignite?

"It is absolutely possible that . . . either star formation, AGN activity, or both will be triggered later on, after the gas settles more," says Freeke van de Voort (University of California, Berkeley). But, she cautions, it could be that a gas-rich spiral merging into a gas-poor elliptical simply doesn't trigger stars.

■ **MONICA YOUNG**

IN BRIEF

Early Galaxy Caught Merging? A rare type of gravitational lens has offered astronomers a close look at a young, dusty galaxy. Light from the distant galaxy SDP.81 traveled for 12 billion years to arrive at Earth. The light encountered a massive elliptical galaxy 8 billion years into its flight, lensing SDP.81's image into a ring only 3 arcseconds across. New ALMA observations have taken advantage of this natural spyglass, revealing details spanning just 100 light-years, Catherine Vlahakis (ALMA and European Southern Observatory, Chile) and colleagues report in *Astrophysical Journal Letters*. A separate analysis by Simon Dye (Nottingham University, UK) and others reconstructed SDP.81's shape using both ALMA and Hubble images. Oddly, while ALMA's radio image shows a rotating disk of dusty gas, the visible-light image from Hubble shows a blob of gas offset from the disk. The disk and blob might be two distant galaxies only seemingly close due to our perspective, or perhaps one galaxy has passed through another, leaving behind a dusty disk galaxy that's popping with stars — about 500 Suns' worth a year.

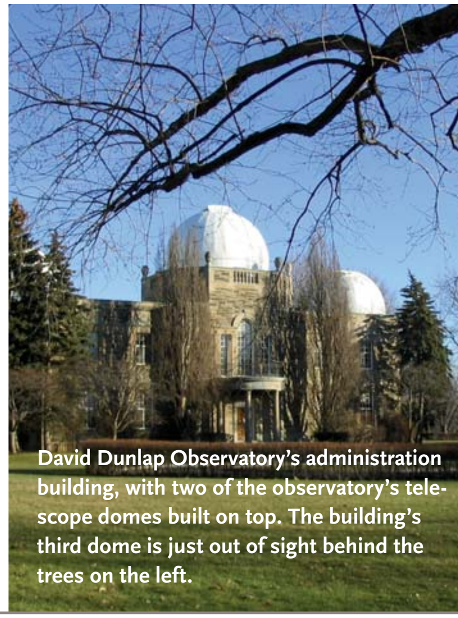
■ **MONICA YOUNG**

OBSERVATORIES | Amateurs Get Keys to David Dunlap

On April 15th, the Royal Astronomical Society of Canada (RASC) announced that its 900-member Toronto Centre is taking ownership of historic David Dunlap Observatory, located in the suburb of Richmond Hill. The observatory and its administrative building are being donated by Corsica Development, which purchased the facility and 190 acres of land around it for $70 million from the University of Toronto in 2009. That's when local RASC volunteers, who had been involved in the observatory's outreach programs for decades, stepped in to maintain and operate the historic facility. Since then all parties involved have been working amicably toward this final arrangement. Corsica is also giving 100 acres of the property to the town, which will keep it from being developed.

The observatory got its start in 1935 after the widow of David Alexander Dunlap, a wealthy mining executive and astronomy enthusiast, provided the funds for construction. Its premier instrument, a 1.9-meter (74-inch) reflector, was then the second largest in the world and remains the largest telescope in Canada. But urban growth long ago made the site unsuitable for most types of observational research, and the university's astronomical interests shifted to larger facilities elsewhere. Dunlap is just one of several observatories adapting to changing management or financial circumstances (see p. 17).

■ **J. KELLY BEATTY**



David Dunlap Observatory's administration building, with two of the observatory's telescope domes built on top. The building's third dome is just out of sight behind the trees on the left.

JOHN H. MARTIN / WIKIMEDIA COMMONS

DARK MATTER | How Slippery Is Dark Matter?

In their effort to understand the unseen matter that holds spinning galaxies together and forms the skeleton of cosmic structure, astronomers are trying to determine how much this dark matter interacts with itself. The answer seems to be: not much.

Weakly interacting massive particles (WIMPs), physicists' most popular dark particle candidate, are downright antisocial — they glide right past one another.

But in simulations, slippery dark matter particles pool too easily, creating deep gravitational wells in which galaxies crowd more densely than observed in the real universe.

One way to overcome the pooling problem is to make dark matter less slippery. In alternative models, so-called "hidden-sector" dark matter particles make contact, explains Jonathan Feng (University of California, Irvine). Many of these models have the added benefit of explaining a mysterious X-ray spectral line seen in some galaxies and galaxy clusters (*S&T*: Oct. 2014, p. 16).

Perfectly slippery dark particles should have a *self-interaction cross section* (a measure of how strongly they interact) near 0 cm^2/g. Hidden-sector models propose values that range from 0.1 to 10 cm^2/g.

Astronomers can indirectly measure dark matter's stickiness by looking at galaxy cluster collisions. When clusters collide, most galaxies sweep right past one another, but their tenuous gas halos crash together and produce beautiful, complex X-ray emission.

If it's slippery, dark matter will stay closely aligned with the galaxies. (The dark matter isn't seen directly but by its gravitational distortion of background light.) But if dark matter particles interact with one another, then they'll do one of two things: the dark mass will slow down, lagging behind the galaxies' motion, or the dark particles will scatter, displacing the dark mass from the galaxies. Either would change the distortion pattern.

Previous observations have limited the cross section to less than 1.25 cm^2/g. Narrowing the possibilities further has proven a challenge, mostly because it's difficult to understand individual systems' 3D geometries.

But now David Harvey (Observatoire de Sauverny, Switzerland) and colleagues have taken a statistical approach, averaging out the measurements of 30 galaxy clusters to do away with any 3D uncertainty. Drawing from the archives of the Hubble Space Telescope and Chandra X-ray Observatory, the team measured the offset between the galaxies and the dark mass. The astronomers found that, across 30 clusters, the offset was essentially zero. Dark matter must be slippery indeed, with a cross section less than 0.47 cm^2/g, the team reports in the March 27th *Science*.

The analysis is excellent, but there are limitations, says Douglas Clowe (Ohio University). For one, it's all archival data, collected for disparate science goals. To level the playing field, the team opted to limit the analysis to observations through one filter. But that makes it difficult to separate cluster galaxies from foreground and background galaxies.

Even with the tighter limit from Harvey's study, hidden-sector models have enough wiggle room to remain viable. "The really interesting message here," Feng says, "is that these observations are getting tighter and tighter in a very interesting region of parameter space."

■ **MONICA YOUNG**

IN BRIEF

Ancient Galaxies Seen Dying Inside-Out. In the April 17th *Science*, Sandro Tacchella (ETH Zurich, Switzerland) and colleagues report their analysis of 22 galaxies forming stars 10 to 11 billion years ago (average redshift: 2.2). The team tracked starbirth inside the galaxies and found that, in the most massive ones, star formation is shutting down, beginning in the galaxies' centers and moving out from there. These big galaxies rival the Milky Way in number of stars, and even with death approaching they should be able to churn out stars for another 2 or 3 billion years. The team suggests such galaxies will form enough stars to grow into some of today's large elliptical galaxies. But the most massive ellipticals probably grew by merging with smaller galaxies.
■ CAMILLE M. CARLISLE

Black Holes More Certain. A team of astronomers has found indirect evidence of the event horizon of M87's supermassive black hole, providing further proof that these wacky objects actually exist. Avery Broderick (Perimeter Institute for Theoretical Physics, Canada) and colleagues peered into the heart of the elliptical galaxy using three radio telescopes in the still-developing Event Horizon Telescope network (*S&T*: Feb. 2012, p. 20). As material streams onto any massive object, it heats up and emits torrents of high-energy photons. If there's a surface, then the infalling stuff will splash onto the surface, glowing hotter and brighter than it would if there wasn't one. The team found that, given the amount of material falling onto the black hole in M87, if there were a surface the gas should glow at least 10 times brighter than it does. Hence, the gas seems to be falling through an event horizon, the team concludes April 5th in a paper posted to arXiv.org. Previous studies have come to similar conclusions looking at stellar-mass black holes and the Milky Way's central beast, Sgr A*, but the new study expands the list of missing surfaces beyond our galaxy.
■ SHANNON HALL

SUN | Do Explosive Bursts Heat the Corona?

New evidence suggests that *nanoflares*, small but potent bursts of energy, might heat the Sun's outer atmosphere. But the evidence is still up for debate.

For decades, scientists have struggled to understand why the Sun's outer atmosphere, known as the corona, is a blistering-hot few million degrees when its visible "surface," the photosphere, bubbles away far below at only thousands of degrees. Theories range from waves rippling along magnetic field lines to field lines twisted so tightly they snap, releasing tremendous amounts of energy.

There's also another question to answer: is the heating process steady, or does it occur in explosive bursts?

These bursts would be small stuff — they release only a billionth the energy of regular flares, and they're too small, quick, and faint for telescopes to capture individually. But even a nanoflare would be equivalent to a 50-megaton hydrogen bomb, and millions going off per second could feasibly heat the corona.

Now astronomers have found indirect evidence that these small explosions heat the solar corona. On April 28th Adrian Daw (NASA Goddard) presented results from the Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS) sounding rocket mission at the first Triennial Earth-Sun Summit in Indianapolis. The EUNIS results point to short-lived pockets of superhot plasma that are about 10 million Kelvin, ten times hotter than the sizzling corona around them. The researchers argue that these temperatures could only come from the combined echo of many tiny flashes in the solar atmosphere.

But if nanoflares behave like mini versions of larger, well-observed flares (and we don't know whether that's true), then the energy they unleash ought to accelerate particles, which will emit a particular pattern of X-rays. Observations with NASA's NuSTAR spacecraft reveal X-ray emission from the super-hot gas, but the telescope sees no sign of the particle signature needed to cinch the case.

That might be because the Sun is still too active, overwhelming NuSTAR's bandwidth. As solar activity decreases, NuSTAR will have a better shot at making out fainter, non-thermal emission — and perhaps providing definitive evidence for nanoflares.
■ MONICA YOUNG

GALAXIES | Runaway Compact Galaxies?

Astronomers have discovered 195 compact elliptical galaxies, upping the known number of these weird objects sixfold. These dwarf galaxies are puny balls of old stars, each having maybe a few billion solar masses. Most lie in clusters, and observers have found debris around some, suggesting that they were once larger but had their outer edges ripped from them by other galaxies. But a couple sulk off by themselves, making the tidal disruption theory problematic: if there's nothing around to strip material off these galaxies, did they really shrink?

In the April 24th *Science*, Igor Chilingarian (Smithsonian Astrophysical Observatory) and Ivan Zolotukhin (Moscow State University, Russia) report their discovery of 195 of these objects, with 56 in clusters, 128 in galaxy groups, and 11 in isolation. Given the galaxies' motions and sizes, the authors suggest that interactions with two or more other galaxies could sling these diminutive ellipticals into the cosmic outback. That would explain how galaxies created via tidal disruption sit out in the sticks, where there aren't many galaxies to interact with.

But astronomers need to check this theory with rigorous computer simulations — it's by no means conclusive. Other researchers have suggested that isolated compact ellipticals might arise when dwarf galaxies merge. With no additional stuff nearby to feed on, the compact ellipticals would simply stop growing and never reach full size. This new, larger population will thus help astronomers explore these galaxies' origin. ✦
■ CAMILLE M. CARLISLE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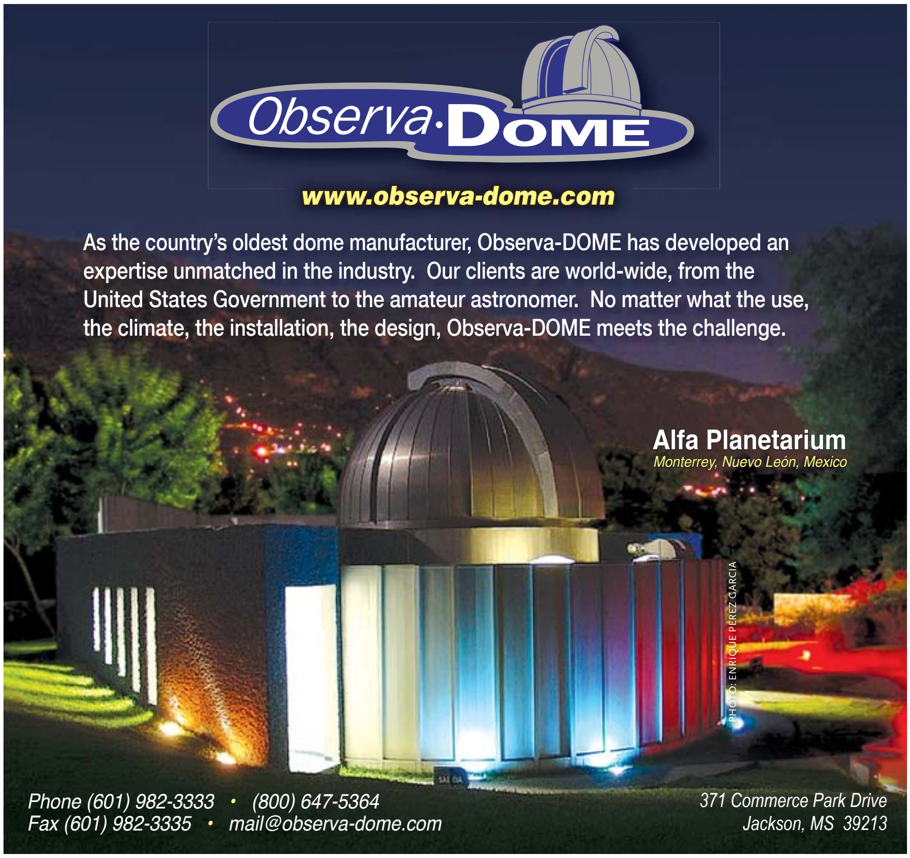
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Crises for Major Observatories

Even the most starry-eyed astronomer is brought back down to earth by one thing: money. Money, as much as we hate to admit it, makes astronomy possible. It pays for the telescopes, the CCD cameras, and the processing software, not to mention the research and maintenance costs at professional observatories. Yet in the last few years, we've seen several major facilities, both private and public, face uncertain financial futures.

In 2008, the David Dunlap Observatory and its 72-inch reflector passed from the University of Toronto to a private developer, then this April the developer donated the observatory to the Royal Astronomical Society of Canada, Toronto Centre (p. 12). In 2013, the University of California threatened to pull its funding from Lick Observatory, only to rescind the move a year later (p. 24).

On the public front, federal funding for U.S. national observatories and the country's astronomy community has flatlined, even as astronomers are seeking to build the next generation of superscopes — not a cheap endeavor. In a 2012 report, the National Science Foundation recommended that, in order to pursue the scientific priorities laid out in the astronomy community's decadal road map, NSF should "divest" itself by 2016 of the gargantuan Green Bank Telescope in West Virginia, the Very Long Baseline Array, and four telescopes on Kitt Peak (p. 18). These facilities are part of the cadre of federally funded observatories that are open to all U.S. astronomers.

The U.S. is not alone in its effort to re-divvy its publicly funded pie. Also in 2012, the UK's Science and Technology Facilities Council announced it was pulling funding from the 3.8-meter United Kingdom Infrared Telescope (UKIRT) and the 15-meter James Clerk Maxwell Telescope (JCMT) on Mauna Kea, so that it could support next-generation mammoth projects such as the Atacama Large Millimeter/submillimeter Array (ALMA). UKIRT was essentially auctioned off to the University of Hawai'i, University of Arizona, and Lockheed Martin, while JCMT went to the University of Hawai'i and the East Asian Core Observatories Association, a partnership of Chinese, Korean, and Japanese observatories and institutes. Other countries are also facing tough choices.

That's not to say the future is all dire. But the changes do give us pause. In the following pages, *S&T* contributing editors Robert Zimmerman and Trudy Bell look at two examples of how beloved but budget-crunched sites are weathering financial storms. Both raise larger questions about how to ensure our private observatories have a will and a way forward and whether fewer high-level amateurs and little-league professionals will be able to contribute to the next generation of astronomical discoveries.

— Camille M. Carlisle

2.1-Meter Telescope at Kitt Peak
PHOTO: STAN HONDA

Budget Scramble

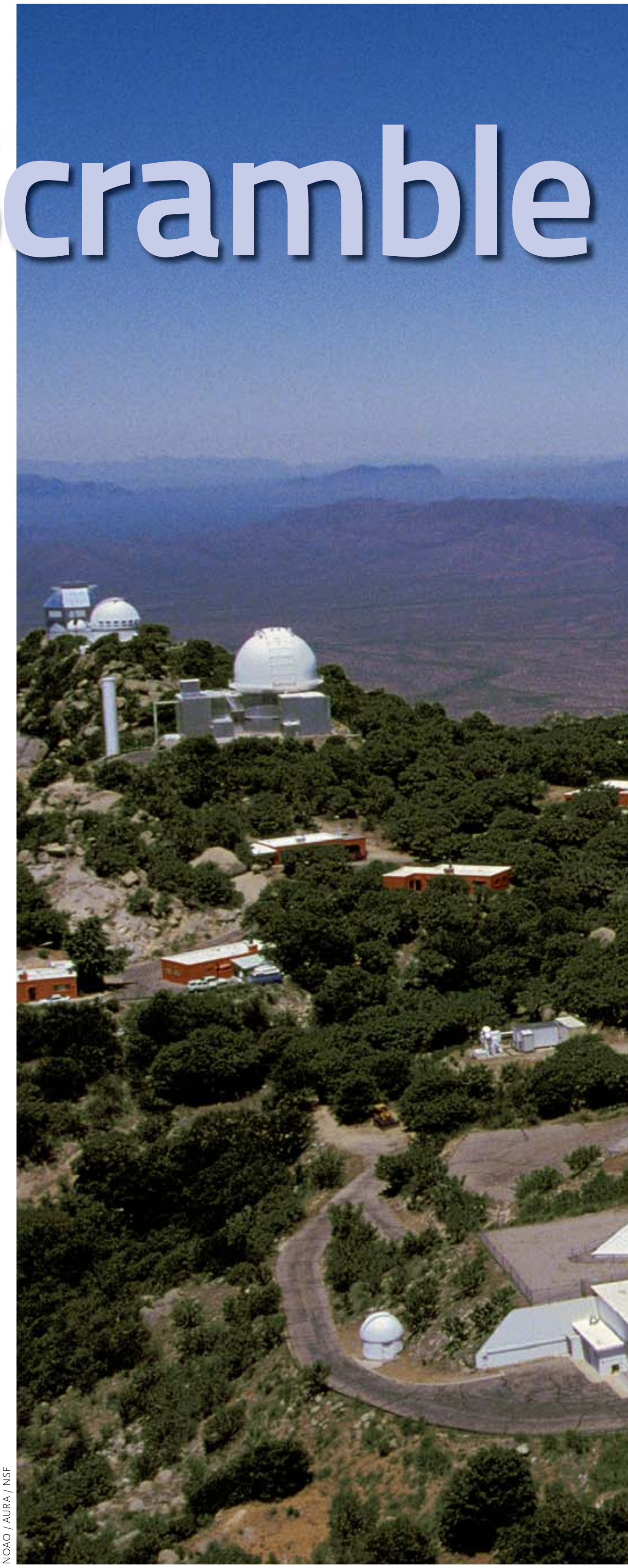
As federal agencies tighten their belts, several publicly funded telescopes are seeking inventive paths forward.

Robert Zimmerman

Although the future of the 2.1-meter telescope atop Kitt Peak in Arizona seemed quite dismal at the time, on May 22, 2014, I joined two "retired"-professionals-turned-amateurs, Mark Trueblood and Larry Lebofsky, for a night of observations there. Their goal was to capture new images of some potentially hazardous asteroids — having orbits that might slam them into Earth — so that dynamicists could better calculate those orbits.

At first their effort was stymied by clouds — what Lebofsky called "big, puffy, white things." So we hung out, waiting, and chatted about the state of observational astronomy and the impending loss of the 2.1-meter. A workhorse for decades, it was scheduled for shutdown in two months because of funding shortages. The instrument was one of only a handful of professional telescopes in the United States available to the general astronomy community and to highly skilled amateurs like Trueblood and Lebofsky. It was for this reason that both were willing to wait as long as necessary for the clouds to clear. As Trueblood noted that night, "I really want to get some data this last time."

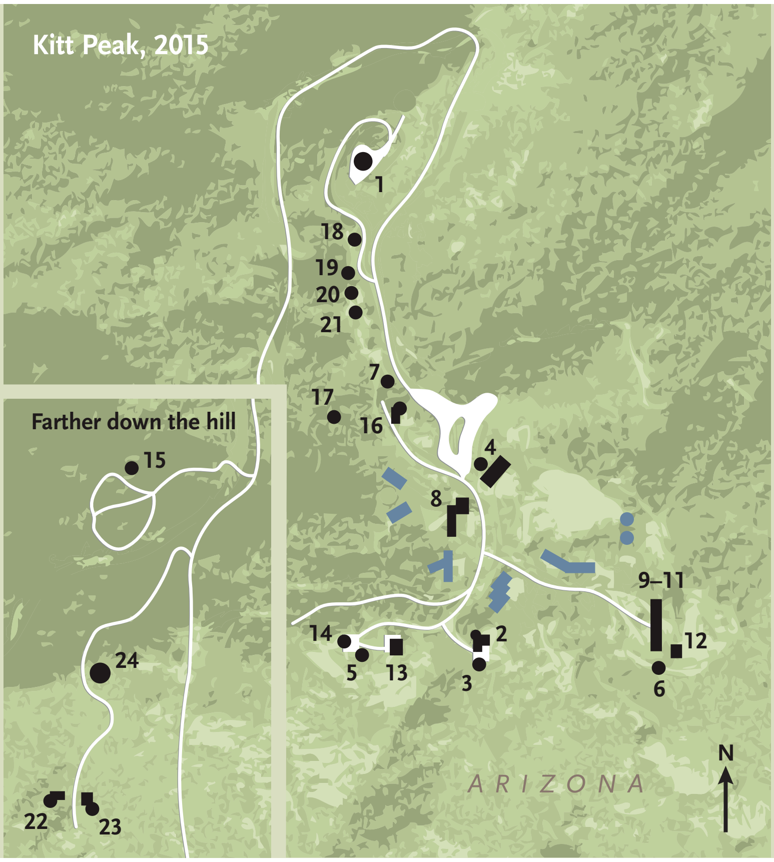
The threatened shuttering of the 2.1-meter, however, was part of a much larger financial crisis for four scopes on Kitt Peak (*S&T:* Dec. 2012, p. 34). With the National



NOAO / AURA / NSF

TELESCOPE MOUNTAIN Two dozen telescopes sit on or near Kitt Peak's summit, most shown here (the radio and MDM instruments are behind the hill). The peak's residents have changed several times since telescopes first arrived more than 50 years ago, with telescopes being added, removed, or sold to different operators. The unusual triangle shape of the McMath-Pierce Solar Telescope (foreground) was designed to mimic the shape of a sundial's gnomon. The diagonal tube extends deeper underground than it does into the sky.

at Kitt Peak



S&T: LEAH TISCIONE

Kitt Peak National Observatory	Date on Kitt Peak
1. 4-meter Mayall	1973
2. 2.1-meter	1964
3. 0.9-meter Coudé feed	1970
4. 0.5-meter Visitor Center	2003
5. 0.4-meter Visitor Center	2014
6. 90-mm and 80-mm Visitor Center/NSO	2008 *(refurbished)*
7. 0.4-meter Visitor Center	2006
Planetary Science Inst., Western Kentucky University, S. Carolina State, Villanova Univ., Fayetteville St.	
8. 1.3-meter *(formerly KPNO)*	1965
National Solar Observatory	
9. 2-meter McMath-Pierce (main)	1962
10. 0.9-meter McMath-Pierce (east auxiliary)	1962
11. 0.9-meter McMath-Pierce (west auxiliary)	1962
12. SOLIS (Synoptic Optical Long-term Investigations of the Sun)	2002 *(removed, 2014)*
WIYN Observatory (Univ. of Wisconsin, Indiana Univ., Univ. of Missouri, NOAO)	
13. 0.9-meter *(formerly KPNO, operated by WIYN for a 12-member consortium, no NSF funding)*	1960
14. 3.5-meter	1994

Science Foundation (NSF) faced with a flat budget, as well as increased costs to construct and operate several new state-of-the-art telescopes, something had to give. And as explained by David Silva, director of the National Optical Astronomy Observatory (NOAO), when the NSF asked the astronomical community to list its scientific priorities using existing facilities, "unfortunately Kitt Peak came up on the short end."

Nor was the NSF alone in putting its NOAO and National Solar Observatory (NSO) Kitt Peak scopes at the bottom of the list. During this same time period Yale University also decided to withdraw from the mountain.

As a result, in 2014 Kitt Peak was threatened with some major changes and cutbacks, with several of its two dozen telescopes on the financial chopping block.

"The astronomical community is facing a situation where the majority of astronomers who don't reside or work at institutions that own their own telescopes are just going to be out of luck," says John Salzer (Indiana University), president of the 3.5-meter WIYN telescope's board of directors. "They are not going to have access to ground-based telescopes."

Building a City of Telescopes

Kitt Peak's astronomical history began in the 1950s. At that time a panel of astronomers recommended that the NSF establish a national observatory for astronomical and solar research as well as for education. Such a facility would provide American astronomers access to professional-grade telescopes, even if their respective universities had no money to build or maintain such instruments themselves.

Based on this recommendation and after several years of site research, Kitt Peak was picked as the best location for the national observatory. The NSF signed a lease in 1958 with the Tohono O'odham nation for the use of about 270 acres on top of the mountain and then created cooperative agreements with what would later become NOAO and NSO for operating various telescope facilities on the summit.

During the next half century, Kitt Peak attracted telescopes of all shapes and sizes, capable of observing in optical, infrared, and radio wavelengths. Some, like the 4-meter Nicholas U. Mayall Telescope and the McMath-Pierce Solar Telescope, were national observatories planned and constructed for the mountain itself. When completed, the Mayall was the second-largest telescope in the world, while the McMath-Pierce still remains tied for world's largest solar telescope.

Other telescopes originally housed at different locations moved to Kitt Peak to take advantage of its dark skies and clear air. Case Western Reserve University's 0.6-meter telescope, for example, was built in 1939 in Cleveland but was relocated to Kitt Peak in 1979.

National Radio Astronomy Observatory	
15. 25-meter VLBA (Very Long Baseline Array) *(10-antenna array dedicated)*	1993
Case Western Reserve Univ. Observatory	
16. 0.6-meter Burrell Schmidt	1979
SARA Observatory (Florida Inst. of Technology, E. Tennessee St., Florida Int'l, Butler Univ., Valparaiso Univ., Agnes Scott College, Ball State Univ., Univ. of Alabama, Valdosta St., Clemson Univ.)	
17. 0.9-meter	1960
Steward Observatory (Univ. of Arizona)	
18. 2.3-meter Bok Reflector	1969
Univ. of Arizona Lunar and Planetary Laboratory	
19. 0.9-meter Spacewatch	1962
20. 1.8-meter Spacewatch	2001
Super-LOTIS (Livermore Optical Transient Imaging System)	
21. 0.6-meter	2000
MDM Observatory (Michigan, Dartmouth, Ohio St., Columbia, Ohio Univ.)	
22. 1.3-meter McGraw-Hill	1975
23. 2.4-meter Hiltner	1986
Arizona Radio Observatory (Univ. of Arizona)	
24. 12-meter radio telescope *(replaced previous NRAO 12-meter built 1967)*	2013

The ownership and operation of these telescopes also varied. Although NSF leases Kitt Peak from the Tohono O'odham nation, it does not actually own or operate most of the two dozen telescopes there. Instead, NOAO, under its agreement with NSF, acts as the landlord — maintaining the roads and providing the utilities — while numerous other universities, partnerships, and organizations (such as NSO) do the owning and operating (see table above).

For example, the WIYN 3.5-meter was built in the 1990s and operated by a partnership of three universities — the University of Wisconsin, Indiana University, and Yale — plus NOAO, with the four holding a 26%, 17%, 17%, and 40% share of the partnership, respectively.

Similarly, NSO controlled and operated the two solar scopes on the mountain, the McMath-Pierce Solar Telescope and (until 2014) the Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility, with NOAO again acting as landlord. NSF funds both NOAO and NSO, making the relationship even more convoluted.

Thus, despite being proprietor over this telescopic metropolis, NOAO fully owns only two telescopes there, the 4-meter Mayall and the 2.1-meter. For decades, both of these, as well as NOAO's 40% of WIYN time, were made available for serious research to anyone in the general astronomy community, including observers like Trueblood and Lebofsky.

Budget Squeeze

In 2014, however, this decades-long arrangement faced some major changes, including the threatened (temporary) slowdown of the Mayall and the shutdown of three telescopes: the 2.1-meter, the McMath-Pierce Solar Telescope, and WIYN.

The changes first began with NSO, which in 2003 decided that it needed to withdraw from Kitt Peak. This decision was part of NSO's long-term plan, which recognized that for it to operate the new 4-meter Daniel K. Inouye Solar Telescope (DKIST) in Hawai'i (slated for first light in 2019), the agency needed to find additional operating funds. Those funds were to come from the money used to operate facilities at Kitt Peak.

NSO therefore decided to remove SOLIS to an as-yet-undetermined new location, while handing off the operation of the McMath-Pierce Solar Telescope to someone else or closing it down entirely. Originally the plan called for a slow ramp-down of operations and funding, to be completed in 2019, so that there would be time to find another entity to take over McMath-Pierce.

In 2012, however, a NSF review by a committee of astronomers mandated that this ramp-down be accelerated and that NSO be off the mountain no later than the end of 2015. As a result "there will be a little bit of a gap," explains NSO Deputy Director Mark Giampapa. "We are working hard to find potential partners who could operate the telescope facilities during and after this ramp-down period."

As part of this effort NSO has solicited the solar sci-

PETE MARENFELD / NOAO / AURA / NSF

THE MAYALL The 4-meter Mayall is the largest optical/infrared telescope on Kitt Peak. Built in the 1970s, it's sturdy enough to handle the planned Dark Energy Spectroscopic Instrument, which astronomers will use to conduct a 5-year survey documenting the universe's expansion over time.

MARK HANNA / NOAO / AURA / NSF

THE WIYN *Above:* The 3.5-meter WIYN telescope, named for its original partners (University of Wisconsin, Indiana University, Yale, and NOAO), sits at the southern end of Kitt Peak. NOAO's portion of observing time will now be dedicated to exoplanet studies. *Facing page:* A complex control system for adaptive optics and mirror cooling covers the 3.5-meter's back end.

ence community. They have so far assembled a tentative consortium of about eight scientists from both NASA and various universities who "are in the process of seeking funds" for the telescope's continued operation, he says. So far, however, this effort will only keep the telescope operating through 2015.

Beyond that date the future remains unknown. NSO is even looking into what it would cost to decommission McMath-Pierce. This decommissioning could range from "mothballing to total site deconstruction and reclamation," Giampapa says.

Crises and Comebacks

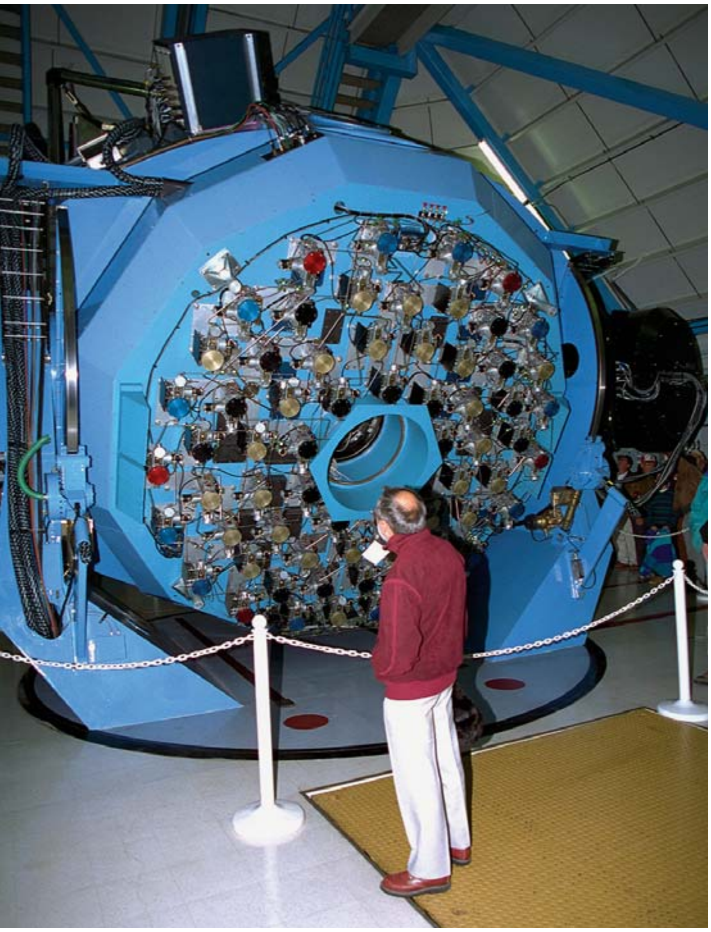
That same 2012 NSF review also accelerated NOAO's exit from Kitt Peak and the divestment of its telescopes there. The NSF reduced funds for the Kitt Peak optical telescopes to pay for operations elsewhere, chiefly the Atacama Large Millimeter/submillimeter Array in Chile and NSO's DKIST, explains Robert Blum, NOAO's deputy director. Eventually these savings will also help pay for the Large Synoptic Survey Telescope when it begins operations in the next decade.

The review also decided, however, that NOAO would remain as Kitt Peak's landlord, maintaining the utilities and roads as it has for decades.

The 4-meter Mayall fortunately had a new collaboration under way. Based on the 2014 recommendations of a panel of physicists, the Department of Energy's Lawrence Berkeley National Laboratory will use it to undertake a 5-year survey to study dark energy. The project will use the Dark Energy Spectroscopic Instrument, to be installed sometime in the 2018–2019 time frame. NOAO will continue to operate the telescope, but the Department of Energy will fund it.

As with NSO, NOAO's plan had been to ramp down its budget slowly until then, to maximize use of the telescope during this transition. The NSF review mandated, however, that NOAO also divest itself from Kitt Peak by the end of 2015. As a result, the use and availability of the 4-meter during the transition period will be greatly curtailed. "We will have to do some things like take some instruments out of rotation, provide fewer instruments on the telescope, and most likely go to longer, survey-type programs," explains Lori Allen, director of Kitt Peak National Observatory.

Throughout 2014 and into the beginning of 2015 the 2.1-meter telescope remained completely orphaned, however. Kitt Peak issued a call for proposals from the community, for anyone who wanted to operate the 2.1-meter. By mid-2014 it had received four proposals with serious



NOAO / AURA / NSF

inquiries from a total of six parties, but none could be finalized before 2015.

Thus, on July 31, 2014, the 2.1-meter was officially shut down.

In March 2015, however, a university partnership won the right to take over the telescope. The agreement was not yet public when this article went to press, but if all goes well, Allen hopes the telescope will reopen for research sometime this year.

Then there are the budget problems at the 3.5-meter WIYN telescope. In 2013 Yale decided that its research and academic priorities no longer included WIYN, and it formally pulled out of the partnership in 2014. This pull-out, combined with NOAO's decision to cease its participation, left WIYN with a loss of 57% of its financial support.

Since then the remaining partners have been scrambling to find others to pick up the shortfall, with mixed success. In late 2014 they obtained one new partner, the University of Missouri, but as Salzer noted then, "We are not at the point of having filled our dance card. We are substantially short of that."

Early in 2015, however, NASA stepped forward and proposed that, in partnership with the NSF, it assume the NOAO portion of WIYN's partnership. The deal will have NASA build and install on WIYN an extremely precise radial-velocity spectrometer, designed to observe candidate exoplanets and confirm their existence while also obtaining their masses. NOAO will manage this program for the agencies and so will remain a WIYN partner. Its share of telescope time will still be open to the community, but with priority given to proposals devoted to this work.

In early 2015 NASA put out a call for proposals to build this instrument. In the meantime WIYN remains fully open and funded, available for exoplanet as well as general research.

The Future

Of the four Kitt Peak observatories faced with a budget crunch, only one, the McMath-Pierce Solar Telescope, currently faces shutdown. There is a strong effort to prevent that shutdown or make it very temporary.

Despite Kitt Peak's improved situation, my evening with Trueblood and Lebofsky at the 2.1-meter remains bittersweet. While the telescope might be saved, it wasn't going to be saved for them. Under the telescope's new partnership, serious, independent researchers will only have access to 20 nights per year; the other nights now belong to those paying for its operation.

And although the larger national observatory instruments in the works will also be open to all, competition will be stiffer on these big-aperture scopes, and there will be fewer nights available. The question of where independent astronomers will go in the future for telescope time remains unanswered. ✦

When he isn't watching astronomers locate dangerous asteroids, S&T *Contributing Editor* ***Robert Zimmerman*** *is posting regularly on his website, Behind the Black, on science, technology, politics, and culture:* ***behindtheblack.com***.

PETE MARENFELD / NOAO / AURA / NSF

CLOUDY SKIES FOR SOLAR TELESCOPE **The McMath-Pierce Solar Telescope ties with Big Bear Observatory for world's largest solar telescope, with an aperture of 1.6 meters. This interior shot looks up the instrument's tunnel (the telescope has a focal length of 87 meters). The telescope's financial future remains unclear.**

Lick Observatory's

In autumn 2013, the University of California targeted Lick Observatory for zero funding by 2018. Last fall, that decision was reversed. What happened? And what could other endangered observatories learn from Lick's experience?

Trudy E. Bell

The axe fell on September 16, 2013. A letter to the University of California Observatories stated that, starting no later than fiscal year 2016–17, the UC Office of the President (UCOP) "will implement a glide path of funding for Lick Observatory ending with the elimination of UCOP funding for Lick by FY 18–19 at the latest."

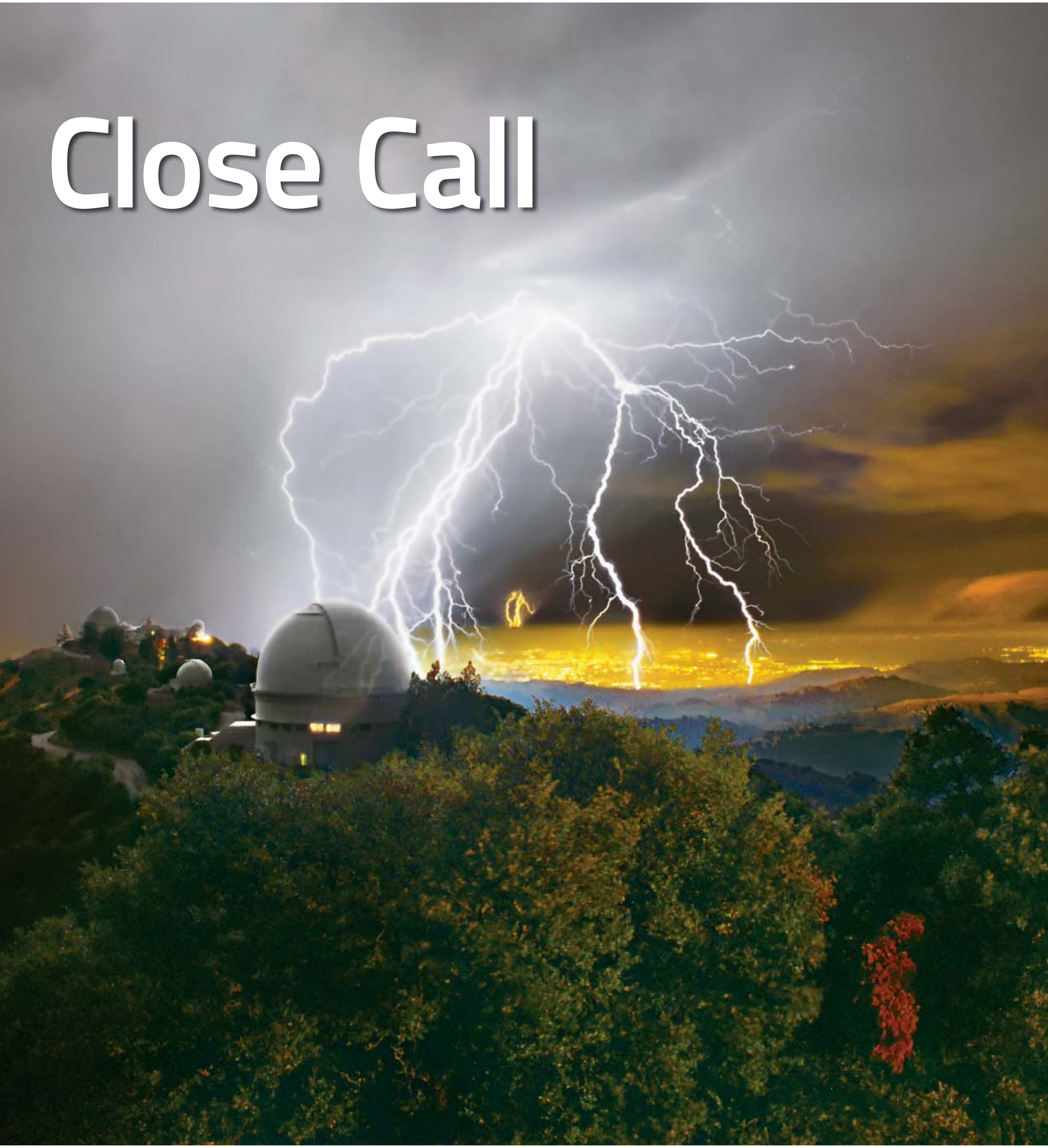
Sitting atop 4,200-foot Mount Hamilton, east of San Jose, Lick was the world's first permanent mountaintop observatory when transferred to UC control in 1888. It has remained at the forefront of optics and astronomy research ever since. Cutting off funds did not, technically speaking, mean that the university system was closing Lick Observatory and its half dozen active research telescopes. It meant the UC system would no longer manage or pay for it — as if your employer told you, "You can still work here. You just need to find someone else to be your boss and pay your salary."

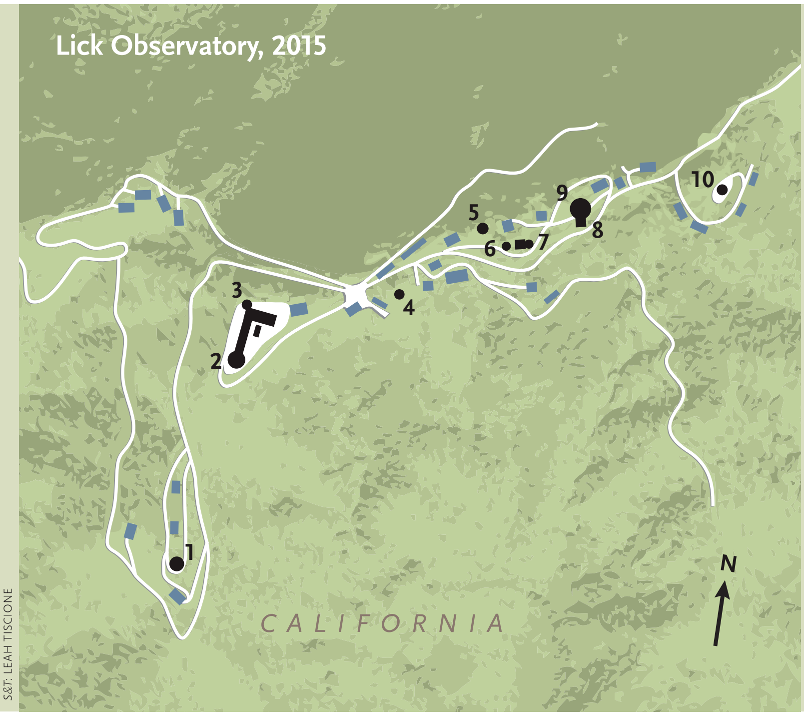
Although UC astronomers and other Lick supporters had been battling to save the observatory for several years, the news threw them into higher gear. And after more than a year of their perseverance, on October 29, 2014, UCOP rescinded its requirement that Lick become self-supporting and be managed by an entity other than the University of California Observatories (UCO).

LIGHTNING STRIKE Long a leader in astronomical research and optics, Lick was temporarily on the University of California's financial chopping block.

ALL LICK OBSERVATORY PHOTOS: LAURIE HATCH

Close Call





Name	Date Installed
1. 0.9-meter Crossley reflector *(not in use)*	1895
2. 0.9-meter Clark refractor	1888
3. 1-meter Nickel reflector	1979
4. 0.5-meter Tauchmann reflector	c. 1955
5. Crocker dome *(empty: 0.2-meter removed)*	c. 1892
6. 2.4-meter Automated Planet Finder	2013
7. Double Astrograph, each 0.5 meter *(not in use)*	1941, 1947
8. 0.6-meter Coudé Auxiliary Telescope	1969
9. 3-meter Shane reflector	1959
10. 0.76-meter Katzman Automatic Imaging Telescope	1996

This list doesn't include smaller instruments that are not in use or are dismounted, such as the 0.3-meter (12-inch) Clark refractor, which in 1881 was the first telescope mounted at Lick. (The Nickel reflector replaced it.) Find a detailed list of past and present instruments at **www.ucolick.org/~sla/mtham/instruments.html**.

The drama that Lick endured is a complicated, politics-laden tale, and the observatory does not yet stand on financial bedrock. But its experience holds important lessons for supporters of other threatened observatories.

An Iconic California Institution

During the California gold rush, entrepreneur James Lick bought land being sold cheaply by men headed for the state's gold fields. Soon, Lick owned vast tracts of prime real estate in San Francisco, San Jose, and elsewhere. Inspired by other philanthropists seeking immortality by establishing major observatories (*S&T:* June 2011, p. 28), in the 1870s Lick bequeathed $700,000 — equivalent to $1.45 billion today in terms of relative share of GDP — to build "a powerful telescope, superior to and more powerful than any telescope ever yet made . . . and also a suitable observatory."

When transferred to the 20-year-old University of California (then occupying a single campus at Berkeley), the observatory instantly conferred on the fledgling university the status of a world-class research institution. Lick astronomers have conducted research continuously since its 0.9-meter (36-inch) Clark refractor — then the largest in the world — was dedicated in 1888. In 1892 E. E. Barnard used it to discover Amalthea, the first Jovian moon discovered since Galileo's observations nearly three centuries prior. Lick's 3-meter Shane reflector was the world's second largest when built in 1959, and it's used today for a wide range of astronomical research.

As it grew and evolved, Lick mothballed older instruments and installed new ones. Today the observatory is home to several active research telescopes ranging in aperture from 0.76 to 3 meters (see table above), plus a handful of smaller instruments. For nearly two decades its 0.76-meter Katzman Automatic Imaging Telescope has conducted one of the world's most successful searches for extragalactic supernovae. The fully robotic 2.4-meter Automated Planet Finder (APF) began science operations in 2013 and uses precision spectroscopy to detect the tiniest — down to a half meter per second — wobble of stars' positions, created by the gravitational tug of the stars' orbiting planets.

Meantime, as UC established other campuses around the state, Lick became the prime teaching and research facility for their astronomy faculty and students. Thanks to Lick, astronomers at all campuses — even from smaller departments such as that at UC Riverside — had access to instrumentation they could not afford to build themselves. Its optical and machine shops also helped develop the twin 10-meter telescopes for the W. M. Keck Observatory atop Mauna Kea and designed the first practical laser guide-star adaptive optics system to "de-twinkle" stars — first installed on the Shane reflector and now used at many observatories worldwide.

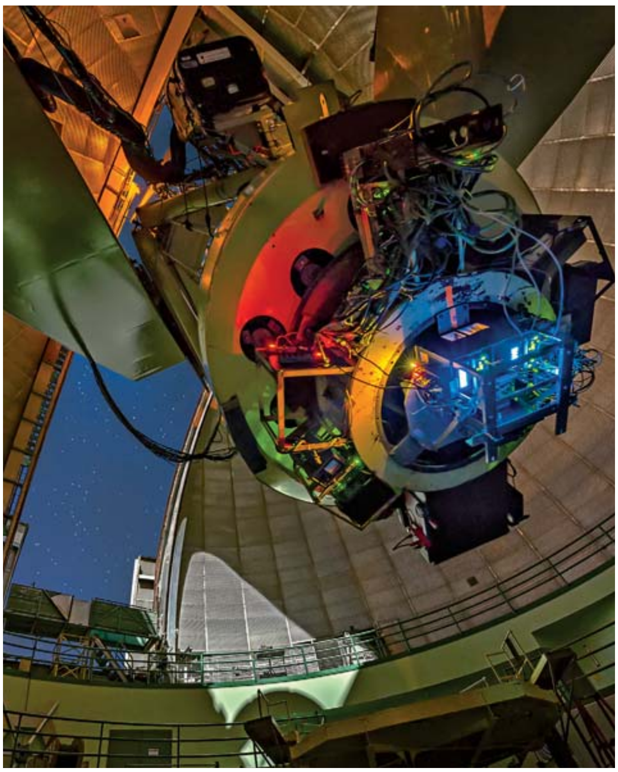
Budget Crunch and Henhouse Fox

Beginning in 1978, however, a series of legislative changes and financial squeezes shrank state support for the UC system. After the 2008–09 economic meltdown, the state slashed UC's budget by a quarter billion or half billion dollars at a go, sometimes twice in a year. Cuts of such magnitude are not readily absorbed even by a complex with an overall budget of some $20 billion. By 2011, California was spending more on state prisons than on higher education. Overall, state support fell from 78% of the total cost per student in 1990–91 to 39% in 2013–14.

In this fiscal context, academic research was under pressure, including UC's astronomy and astrophysics programs, widely regarded as UC's crown jewels. In 2008, UCOP hired former Space Telescope Science Institute director Steven Beckwith as Vice President for Research and Graduate Studies. Beckwith's top challenge was to save money as the state cut its intercampus research funding by 40% over the next five years. At the same time, UCO was trying to adequately fund its more expensive collaborations on Keck and the planned Thirty Meter Telescope (TMT), also on Mauna Kea.

But Lick supporters contend that Beckwith's influence was destructive. Letters, articles, and reports (many publicly accessible online) document a complex history of deliberations held in closed executive sessions, where he expressed skepticism and half-truths not just about Lick but also about the practicality of adaptive optics and the viability of TMT.

UC astronomers argue that, since Beckwith was the official spokesman and supporter of UC research, his words sowed doubt in the minds of colleagues, funders, and others outside the UC system. Astronomers laid out Lick's cost-effectiveness and importance, to no avail. Ultimately, the UCO Board pushed recommendations that led to UCOP's letter instituting a "glide path" to end Lick funding.



RESEARCH WORKHORSE The 3-meter Shane telescope is Lick's technology test bed. Astronomers installed on it the first laser guide-star adaptive optics (AO) system in 1995, and today its two spectrographs and state-of-the-art AO make it useful for a range of projects, including large surveys.

The threats to Lick and the questionable proceedings behind them stirred up criticism in local outlets, plus national attention in publications such as *Science* and the *New York Times*. Bay Area amateur and professional astronomers and other Lick supporters, led by retired UC astronomer Robert Kibrick, founded Friends of Lick Observatory, dedicated to fundraising and public outreach. Two-thirds of California's congressional representatives petitioned the UC president in a letter spearheaded by U.S. Representative Zoe Lofgren. The renowned cosmologist Alex Filippenko (UC Berkeley) took a sabbatical semester in fall 2013 and devoted much time the following year to publicizing Lick's plight further and raising funds.

Although verbally and in letters Beckwith and UCOP insisted their intention was not that Lick close, they put no visible support behind fundraising. "Private donors and foundations want to feel they are putting up matching funds — that UC is a fully engaged but cash-strapped contributing partner," explains Kibrick. "Lack of UC support sent a message that UC did not have interest or commitment."

Then events took a fundamental turn. In the summer of 2014, Beckwith left UCOP to return to teaching at UC Berkeley. A few months later, adaptive optics pioneer Claire Max (UC Santa Cruz) became UCO interim director. "From the very beginning, the UCOP provost [Aimée Dorr] and I established a strong working relationship," Max says. "We looked at each other and said, 'Let's make this work.'" Max and her team developed a budget plan the provost accepted. On October 29th, UCOP rescinded its decision to defund Lick.

As soon as UC was a partner again, donations for Lick began materializing — first $300,000 from the Heising-Simons Foundation in December 2014, to upgrade the Shane reflector's Kast Spectrograph, then in February 2015, $1 million over two years in unrestricted funds from Google.

Strategic Planning

Lick emerged with an annual budget from UCOP of $1.5 million, down from about $2.5 million a half decade earlier. "UCOP put a base under us, so it's now possible to go after the money we really do need," Max says. UCO is working to publish a strategic plan this year that will focus on a twin path: education and public outreach, and forefront science.

Outreach plans include expanding the summer visitor programs and the popular Music of the Spheres concerts, designing a self-guided walking tour of the

THE CLARK Now 127 years old, the 0.9-meter (36-inch) Clark is still one of the world's largest refractors. Astronomers use the telescope for occasional research and public outreach.

mountain and telescopes, and renting out the beautiful marble main building and wood-paneled Clark refractor dome for weddings. Additional revenue options under consideration range from selling telescope time to non-UC researchers and entities to exploring the potential of corporate retreats and astronomical or nature tourism. Also in the mix are plans for greater involvement with schools and renovating exhibits in the main building. A long-term dream is a major visitor's center.

Regarding forefront research, Lick is focusing on projects that can make good use of its medium-size instruments. UCO is now sorting through suggestions for 16 long-duration survey projects of three different types: continuous examination of the same objects night after night for a year or longer (such as the APF), "cadence" projects that would examine a large number of objects at a set frequency (several times per night or several nights apart), and "targets of opportunity" projects for transient events such as gamma-ray bursts and supernovae. Meantime, the second generation of laser guide-star adaptive optics just installed on the Shane reflector has resolution "as sharp as the Hubble Space Telescope!" exclaims former UCO interim director Sandra Faber (UC Santa Cruz), keeping that instrument viable for research for years to come.

Read more about Lick's struggle at www.ucolick.org/SaveLick.

"We're not out of the woods yet," cautions Filippenko. "We can't declare victory, because we'd like Lick to live not just at the subsistence level." He feels he will not be able to rest until Lick's long-term future is secured with an endowment of $30 to $50 million: the annual interest on $30 million would be about $1.5 million, enough for "Spartan core operations," but annual interest from $50 million would be closer to the former $2.5 million, enough to expand, add new instrumentation, and do or even define cutting-edge research, he says.

Notes to Self, Lessons for Others

Lick is not alone. Other well-known observatories facing funding challenges include McDonald, Lowell, and Mount Wilson. Outside the U.S., Subaru will suffer a major budget cut to enable Japan to be a partner in

TMT, and other countries are choosing between funding successful but smaller-aperture telescopes and the next generation of superscopes.

But medium-sized instruments are essential to astronomy. What many projects require is not aperture but time, Max says. Astronomers need long-term monitoring of hundreds or even thousands of objects to catch transient phenomena or to understand how common individual objects are in the universe, projects prohibitive on the biggest telescopes because telescope time is so precious. "Keck time is valued at $100,000 per night," said Kibrick. Time at Lick can be less than 10% of that.

With smaller telescopes, astronomers can try riskier projects that might not get approved at the largest instruments. Moreover, telescopes of 1 to 4 meters' aperture offer graduate students and postdocs — whom Keck and most other big observatories will not allow to be principal investigators — essential experience in proposing original projects and working with research-class instruments. "That's how a student becomes a grown-up scientist," Max says.

Another lesson: emphasize unique assets. Near-infrared emission from atmospheric hydroxyl (OH) molecules intensifies toward the equator, so for near-infrared astronomy at wavelengths of 1 to 2.5 microns, Lick at mid-latitudes actually has a darker sky than the Keck scopes in Hawai'i, Faber says. At these wavelengths, telescopes can see through interstellar dust and into regions hidden at visible wavelengths, ranging from star-forming nurseries such as the Orion Nebula to the centers of distant galaxies.

Importantly, not all the lessons from Lick's redemption are merely about demonstrating relevance in astronomy. Part of Lick's success has come from cultivating support over many constituencies: faculty, students, former students, astronomers, historians, educators, media, local governments, Congress, and the general public. As Faber sums up, "Your continued existence depends on people's caring about you." ✦

S&T *Contributing Editor* ***Trudy E. Bell (www.trudyebell.com)*** *is a former editor for* Scientific American*, former senior editor for* IEEE Spectrum *magazine, and former senior writer for the University of California High-Performance AstroComputing Center. She has written a dozen books and more than 500 articles; her journalism prizes include the 2006 David N. Schramm Award of the American Astronomical Society.*

In addition to the people quoted, the author thanks former UCO director Michael Bolte, UCSC astronomer Garth Illingworth, Lick Observatory staff astronomers Elinor Gates and Paul Lynam, and UCO astronomer Graeme Smith. Steven Beckwith was interviewed for 75 minutes, but later requested not to be quoted.

TWO DOMES, ONE SKY Lick's main building houses the Clark refractor (left dome) and the Nickel reflector.

Astronomy & the

Sun and shadow have finally pinpointed a moment of history and ruled out the widely accepted scenario for an iconic photograph.

Donald W. Olson, Russell L. Doescher, & Steven D. Kawaler

VJ Day — Victory over Japan Day, August 14, 1945 — marked the end of World War II. As rumors of Japan's surrender spread, Americans poured into the streets. Amid the celebration in New York's Times Square, Alfred Eisenstaedt captured one of the iconic images of the 20th century when he shot four photographs in quick succession of a sailor kissing a woman in white. Victor Jorgensen, standing just a few feet away, photographed the same kissing pair at the moment of Eisenstaedt's second frame.

We have recently used astronomy to determine new information about these famous photographs.

The questions of identity — who is the sailor? who is the woman in white? — have been a source of much controversy over the decades, in part because their faces are largely hidden. Glenn McDuffie, George Mendonsa, and Carl Muscarello are among the dozens of men who have claimed to be the sailor. Candidates for the woman in the white dress include Edith Shain, Barbara Sokol, and Greta Friedman (Greta Zimmer in 1945).

We have used the position of the Sun to solve a related mystery — at what time were the Kiss photographs taken? — and thus to rule out some of the candidates for the real sailor and woman in white.

Kiss After 7:03 p.m.?

After rumors and false alarms throughout the day, radio networks carried a brief statement from the White House at 7:00 p.m., and by 7:03 p.m. the moving electric sign on the Times Building displayed the long-awaited words: "OFFICIAL *** TRUMAN ANNOUNCES JAPANESE SURRENDER ***." The current Wikipedia page assumes that the Kiss followed shortly thereafter: "Eisenstaedt was photographing a spontaneous event that occurred in Times Square as the announcement of the end of the war on Japan was made by U.S. President Harry S. Truman at seven o'clock."

Sixty-five years later in 2010, a front-page *New York Times* story on the VJ Day anniversary expressed the same opinion: "For decades, the world has believed that the photographs were taken after — perhaps just seconds after — President Truman's announcement at 7:03 p.m."

Kiss Near 6 p.m.?

However, that same anniversary story went on to propose a scenario with an earlier time. The reporter interviewed Gloria Bullard, who identified herself as a figure in the background of the Jorgensen photograph. She gave an account of witnessing the famous Kiss and contradicted the conventional wisdom by implying that the event occurred not after 7:03 p.m. but instead "earlier — before the war was officially over."

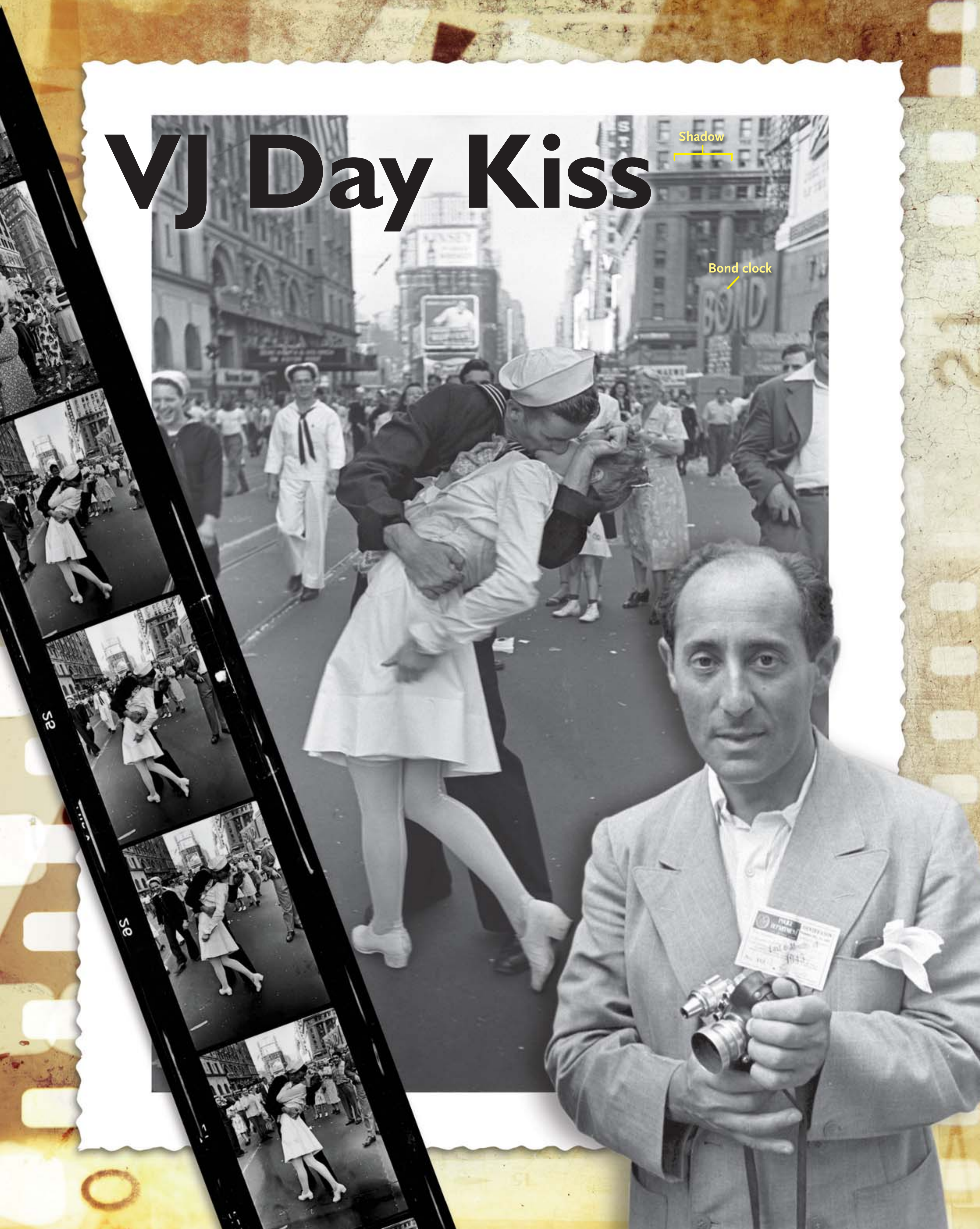
Bullard, after leaving Times Square on VJ Day, spent a few minutes walking to 8th Avenue. She estimated that it then took two more hours to reach her home town of New Canaan, Connecticut, by bus and train. She noticed that dusk was settling and the streetlights were just coming on as she walked the final blocks near her home.

Here astronomy first enters. For New Canaan, we calculate that sunset fell at 7:54 p.m. that day and the end of civil twilight followed at 8:24 p.m., expressed in Eastern War Time, equivalent to modern daylight saving time. We can be certain that this is the correct time system in use because the *New York Times* that day listed Manhattan sunset at 7:56 p.m.

THE KISS Any collection of the 20th century's iconic images is likely to include this *Life* magazine photo taken by Alfred Eisenstaedt in New York's Times Square on the day World War II ended. The shadow on the Loew's Building (labeled) allows us to determine that he clicked the shutter at 5:51 p.m. An archived contact sheet from Eisenstaedt's roll of film shows the four Kiss shots to be negatives #24–27. The numbers are another smoking gun; the roll's earlier #10 and #11 are Eisenstaedt's Peace At Last images, which shadows reveal to have been taken around 5 p.m. — long after the 2 p.m. claim for the Kiss.

THE PHOTOGRAPHER This on-the-spot snapshot of Alfred Eisenstaedt was taken by William Shrout, another *Life* photographer assigned to cover the VJ Day celebration in Times Square.

VJ Day Kiss



U. S. NAVY PHOTOGRAPH / NATIONAL ARCHIVES

2 P.M. RULED OUT Victor Jorgensen took this photo at almost exactly the instant of the second of Eisenstaedt's four images. He was standing just to Eisenstaedt's right. They cannot have been taken near 2 p.m. because Jorgensen reached Manhattan on a train that arrived at 3:00 p.m. Gloria Bullard has identified herself as the nurse in the far background, under the "W" of "Walgreen Drugs" at the extreme left edge.

We checked 1945 rail timetables and found that relatively few trains ran on the New Canaan branch. The train best matching Bullard's description reached her hometown station at 8:12 p.m. Bright twilight prevailed then, with the Sun 4° below the horizon, and the twilight would have been deepening as she walked home.

Subtracting somewhat more than two hours from Gloria's arrival time in New Canaan suggests that the Kiss in Times Square would have occurred about 6 p.m.

Kiss Near 2 p.m.?

In their recent book *The Kissing Sailor* (Naval Institute Press, 2012), Lawrence Verria and George Galdorisi propose that the Kiss photographs were taken much earlier in the day, around 2 p.m. The authors also offer detailed arguments supporting George Mendonsa and Greta Zimmer as the kissing pair.

According to the book, George Mendonsa attended a 1:05 p.m. movie at Radio City Music Hall. After only a few scenes had played, theater employees interrupted the show with the dramatic announcement of the war's impending end. Mendonsa left the theater and made a brief stop for some drinks. The authors deduce that he reached Times Square and kissed a woman in white about 2 p.m.

Greta Zimmer in 1945 worked as a dental assistant in a white uniform resembling a nurse's. According to her account of VJ Day, the dentists returned from their lunch at about 1 p.m. She then took a late lunch hour and began walking from the dental office on Lexington Avenue to Times Square, to see if she could confirm the rumors she had heard from the morning's patients. She was reading the messages on the animated electric signs when a sailor grabbed and kissed her without warning. Greta returned to the dental office and reported the news from Times Square. The doctors then told her to cancel the rest of the afternoon's appointments and close the office.

These details are entirely inconsistent with both the 6 p.m. and 7:03 p.m. times theorized for the Kiss. The accounts of George Mendonsa and Greta Zimmer appear to mesh consistently only with a time near 2 p.m.

The Kissing Sailor received much favorable media attention that treated the book's scenario as a definitive answer at last. David Hartman, longtime host of ABC's *Good Morning America,* wrote the book's foreword and stated that its authors had "finally revealed, with certainty, what millions have wanted to know for decades." Photographer David Hume Kennerly wrote a jacket endorsement and called the book a "whodunit that provides once and for all the identification of the world's best-known smoochers." NBC journalist Tom Brokaw also wrote jacket copy for what he described as a "wonderful detective story." *Publishers Weekly* judged that the "authors deliver a convincing conclusion."

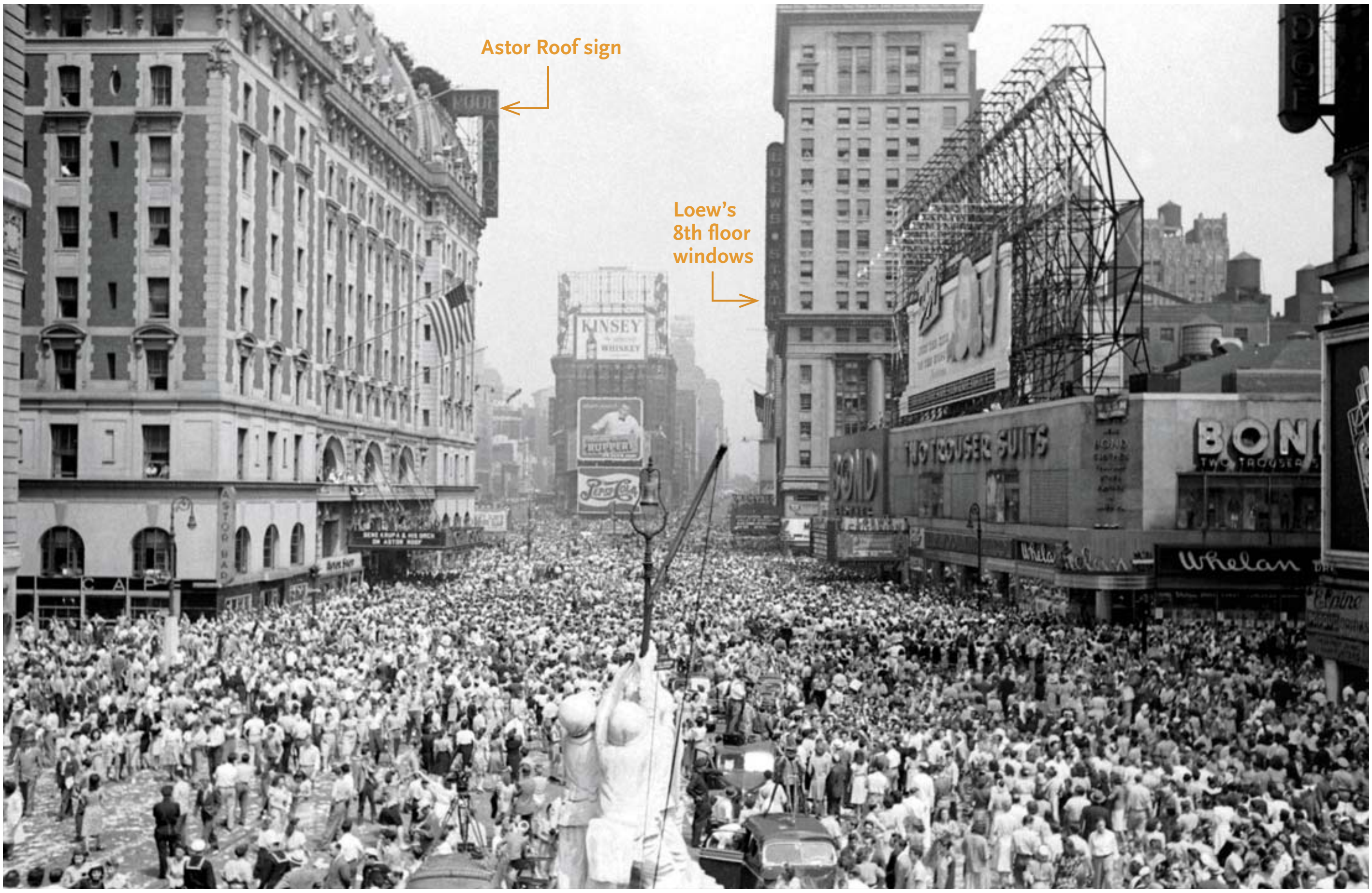
So, which is it? Did Eisenstaedt take his Kiss photographs near 2 p.m., near 6 p.m., shortly after 7:03 p.m., or at some other time?

The Bond Clock

The *New York Times* online version of the story about Gloria Bullard drew 144 comments, with much debate

COLLECTION OF DONALD OLSON

THE BOND CLOCK By coincidence, this amateur VJ Day photo of the Bond Clothes clock shows the exact time of Manhattan sunset, 7:56 p.m. Unlike the prominent minute hand, the short hour hand of the Bond clock is hard to make out in the oblique views of Eisenstaedt's Kiss series.



ALFRED EISENSTAEDT / *LIFE* (© TIME INC.)

GNOMON AND SUNDIAL Earlier on VJ Day, Eisenstaedt shot this northward view. The Hotel Astor with the Astor Roof sign appears at left. Just left of the sign are bushes lining the Roof Garden. The 16-story Loew's Building is on the right. Intruding diagonally across the Times Square crowd from right toward center is the shadow of the Hotel Claridge, matching the Sun's position at 12:30 p.m.

about the time of day depicted in the Kiss photographs. One of us (SDK) was apparently the first to notice that the Eisenstaedt photographs include, in the background, a large clock on the Broadway façade of the Bond Clothes store. He suggested that the time it displays might be either 5:50 or 6:50, with the uncertainty due to the oblique angle of view from Eisenstaedt's location.

A later commentator was more certain that the clock showed 5:50 p.m., while another opted for 4:50 p.m. on the clock face. The Bond Clothes clock had a prominent minute hand but an unusually short hour hand, adding to the difficulty of reading the time from the photo.

Half a dozen online comments to that same article made the intriguing point that a prominent shadow appears on a building in the background. Analysis of the Sun's position might thus determine the time of the photograph.

We pursued this suggestion and have obtained a precise result.

Buildings as Sundials

Every tall building in Manhattan acts like the gnomon of a sundial. But how to read its face? Our Texas State University group has experience using the astronomy of sunlight and shadows. For Ansel Adams' photograph "Moon and Half Dome," the shadow of a ledge helped to fix the precise date and time of this iconic Yosemite image (*S&T:* December 1994, p. 82). Mountain shadows played a similar role in our dating of Ansel Adams' "Autumn Moon" (*S&T*: October 2005, p. 40).

We studied hundreds of photographs from the 1940s to become familiar with all buildings in and near Times Square in 1945. We also collected vintage maps from the Sanborn Map Company and the G. W. Bromley & Co. Manhattan Land Book series, and photographs taken by the Hamilton Aerial Map Service.

From this topographic evidence we could see that the prominent shadow in Eisenstaedt's photos was on the 45th Street side of the Loew's Building, home to the theater known as Loew's State. The top of the shadow runs horizontally along the center of the windows on the 8th floor. From the known dimensions of the 16-story Loew's Building, we determined that the shadow stands 94 feet above street level.

Now we needed to identify the building casting the shadow. We first considered the Hotel Astor, across the street to the west. The shadow on the Loew's Building has a flat top only about 16 feet wide, so our thought was to search old photographs and blueprints to find a flat-topped water tower on the Astor roof. This theory immediately foundered because we learned that the summit of the Astor Hotel held no standard water tanks at all! Instead, the top was known as the Astor Roof Garden, an elegant site for music, dining, and dancing.

But we were able to rule out other buildings one by one: the Paramount Building, the Hotel Lincoln on 8th Avenue, the Times Building. A Schlitz Beer sign on the roof of the Bond Clothes building was too short to cast a shadow of the length in the Kiss photographs. Nothing fit.

Astor Roof Sign: 5:51 p.m.

The breakthrough came when we looked at vintage photographs of the Hotel Astor with its elegant roof garden. The hotel had a sign in the shape of an inverted "L" projecting a little above roof level, advertising the Astor Roof. Blueprints preserved at Columbia University show that the vertical arm of the sign was 40 feet high, its horizontal top was 18 feet wide, and the top edge stood 150 feet above street level.

Measurements on old photographs and maps established that the top of the sign and the top of the shadow on the Loew's Building had a horizontal separation of 134 feet and a difference of 56 feet in height above street level. A line from the shadow on the 8th-floor windows of the Loew's Building to the Astor Roof sign would point to the upper limb of the Sun being at azimuth 270° (exactly due west) and at an altitude of +22.7°. As seen from the Loew's Building 8th floor, the solar disk was disappearing behind the Astor Roof sign at 5:51 p.m. Eastern War Time.

Because the Sun's disk has a finite size, with a diameter of 31.6′ on August 14th, the 18-foot-wide top of the sign would project an umbral shadow about 16 feet wide at the distance of the Loew's Building, also in good agreement with the shadow in Eisenstaedt's photographs.

Our topographical analysis ruled out every other tall structure in or near Times Square. Only the Astor Roof sign could cast the photographed shadow, and it did so at exactly 5:51 p.m.

We then checked our mathematical results by building a scale model of the buildings, including the L-shaped sign. A large, flat mirror allowed us to project the Sun's rays onto the model from any desired altitude and azimuth. The location, size, and shape of the shadow on our model Loew's Building exactly matches the shadow in Eisenstaedt's Kiss photographs.

Confirmation: Pennsylvania Railroad

Victor Jorgensen took his Kiss photograph at the same time as Eisenstaedt's second of four frames. Two days later, Jorgensen's wife wrote a letter describing how on VJ Day they had traveled up to Manhattan on a train departing Washington, D.C., at 11:00 a.m. Railroad timetables show this train arriving at New York's Penn Station at exactly 3:00 p.m. Allowing some time for checking into a hotel, where Jorgensen dropped off some photographic gear, and then proceeding to Times Square, Jorgensen cannot have reached Times Square until at least 3:30 p.m. and perhaps even after 4:00 p.m.

Thus Jorgensen's train trip provides additional evidence to rule out the proposed 2 p.m. time for the Kiss photographs, but it's consistent with our calculated time of 5:51 p.m.

Confirmation: "Peace At Last"

Two more Eisenstaedt VJ Day photographs, known as Peace at Last, show a couple looking up at the Times electric news sign. In the background, the shadow of the Times Building falls onto the last word in a sign reading "PUBLIC TELEPHONE CENTER for the ARMED FORCES." Vintage photographs and maps show that this

ALFRED EISENSTAEDT / *LIFE* (© TIME INC.)

ON THE SAME ROLL This Eisenstaedt VJ Day photograph, known as Peace at Last, shows a couple looking up at the moving electric news scroll on the Times Building. In the background, the shadow of the Times Building on the façade of the Public Telephone Center for the Armed Forces (the shadow's edge crosses the R in "Forces") allows us to determine that this image was captured near 5 p.m. Eisenstaedt's roll of Kodak Plus-X film includes Peace at Last, then a dozen other scenes, and then the famous Kiss series.

shadow corresponds to a solar azimuth of 261° (9° south of due west) and a time of 5:00 p.m.

The connection? In the archives of *Life* magazine, a contact sheet for a roll of Kodak Plus-X film includes Peace at Last (negatives #10 and #11 at 5:00 p.m.), followed by a dozen other photographs (#12–23) of revelers on the west side of the Times Building and near the New York movie theater, and then the famous Kiss series (#24–27, shown on page 31). This sequence is consistent with our result that Eisenstaedt and Jorgensen took their Kiss photographs at 5:51 p.m.

On another roll of film, Eisenstaedt's last VJ Day photographs look down from high positions onto the denser crowd packing Times Square after the 7:03 p.m. official announcement of the war's end. Several of these images include the large Toffenetti Restaurant clock showing times between 7:40 and 7:47 p.m. Eisenstaedt later recalled that he turned in his film to the *Life* office at about 8 p.m.

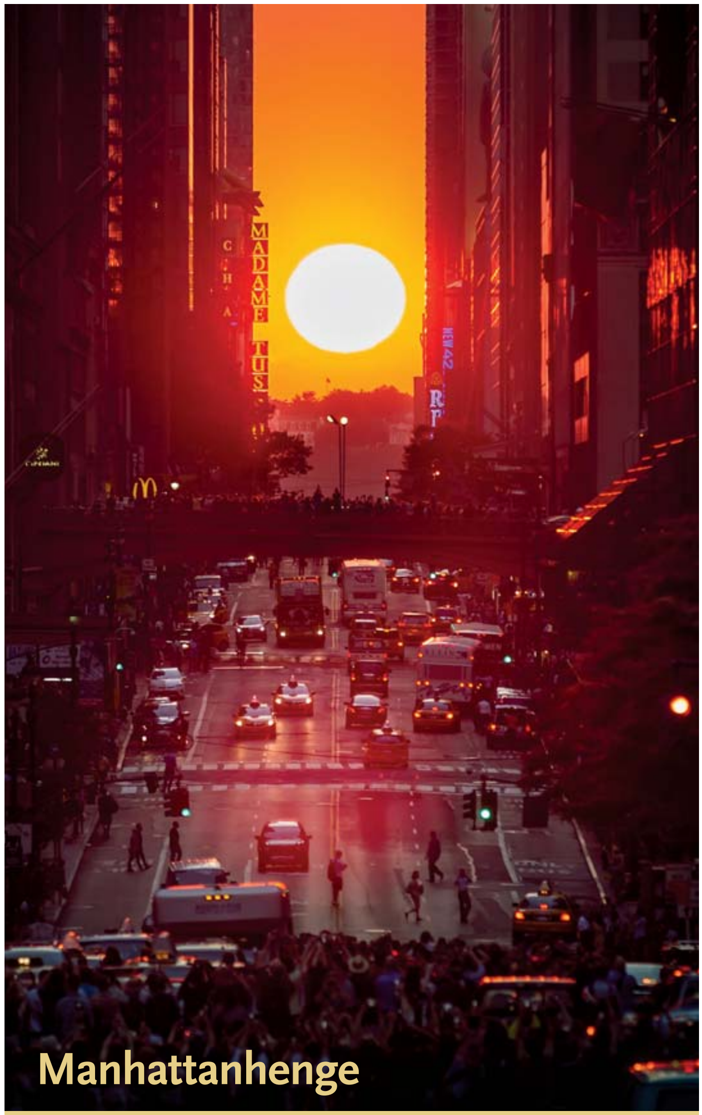
Who Is the Sailor? Who Is the Woman in White?

The widely accepted scenario placing the Kiss photographs near 2 in the afternoon doesn't stand up. We also point out that the identities of the kissing pair became a public controversy only after August 1980, when *Life* magazine published an article about the identity of the nurse and asked: "Now, if the sailor can recognize himself, would he please step forward?" This brought forth dozens of candidates for the sailor and several more for the woman in white.

It's possible that most of these claimants were present in Times Square and that each kissed someone. Which are in Eisenstaedt's photos? Maybe none. The actual subjects may not have read the August 1980 issue of *Life* or, indeed, even been alive in 1980.

Some mysteries are beyond the reach of astronomical calculations, but the August 14th late-afternoon shadows provide the key to unlocking at least some of the secrets of the iconic VJ Day images. ✦

***Don Olson** and **Russell Doescher** teach physics and astronomy at Texas State University. **Steve Kawaler** teaches astrophysics at Iowa State University. They thank Barbara Baker Burrows, director of photography at Life Books, for permission to reproduce the Eisenstaedt and Shrout images and for much expert advice. The authors also received research assistance from Russell Burrows, Daniel Okrent, Lawrence Verria, Lee Anne Willson, Robert Sullivan of Life Books, Rebekah Burgess at the Life picture archives, Leica experts Jim Lager and Jonathan Davis, the staffs of the University of Wisconsin-Milwaukee Library, the Avery Library at Columbia University, and the Map Division at the New York Public Library, and Margaret Vaverek of the Alkek Library at Texas State.*



Manhattanhenge

EDUARD MOLDOVEANU PHOTOGRAPHY

Maps of Manhattan often show the avenues running vertically and the numbered streets running horizontally for convenience, but the Manhattan street grid is actually tilted 29° clockwise from true north. Knowing the correct azimuths of the streets and avenues was essential to our VJ Day shadow analysis.

The tilt of the street grid also determines the dates of the phenomenon known as "Manhattanhenge," popularized since 2001 by Neil deGrasse Tyson, director of New York's Hayden Planetarium. New Yorkers see the setting Sun aligned with Manhattan's numbered streets not at the spring and fall equinoxes, but rather for a few days near May 30th and July 12th, when the azimuth of the setting Sun is near 299° (that is, 29° north of due west). The steel, glass, and concrete towers lining the Manhattan streets make this sunset phenomenon especially spectacular.

COSMIC ALIGNMENT Unlike Stonehenge, Manhattan wasn't built to align with the Sun on particular dates; it just does. On July 11, 2014, a crowd gathered at 42nd Street to witness the celestial event popularized by Neil deGrasse Tyson.

An f/13 Holcomb Reflector

This sturdy planetary Newtonian utilizes a neglected mount design.

IT MAY BE TRUE that there's nothing new under the Sun, but when it comes to building telescopes, there are so many different approaches that it can take a while for an idea to resurface once it has fallen out of favor. Yet sometimes a particular observing goal leads down a nearly forgotten road, as the long-focus 8-inch Newtonian reflector built by Dunedin, New Zealand, telescope maker Vaughn Malkin demonstrates.

To begin with, Vaughn's scope bucks the current trend for fast and superfast primary mirrors with focal ratios of f/4 or less. To satisfy his planetary observing needs, he went long — all the way to f/13. Such mirrors aren't as easy to figure as is generally believed.

VAUGHN MALKIN

Although unusual in appearance, form follows function with this long-focus planetary reflector built by New Zealand telescope-maker Vaughn Malkin. The scope is ideally suited to provide detailed views of the Moon and planets.

Apart from a generous image scale, a long-focus primary also allows the use of a small secondary mirror to minimize diffraction effects that can mute low-contrast planetary details. Vaughn's scope is equipped with a secondary mirror only 32 mm (1.26 inches) across its minor axis, yet it still maintains a generous fully illuminated field. This size amounts to only a 16% obstruction — well under the 20% recommended for a planetary reflector.

With the optics sorted, the next challenge was to come up with a tube assembly rigid enough to hold the mirrors in perfect alignment as the telescope is aimed at different parts of the sky. At 9 feet long, Sonotube wasn't going to be the answer. After some hunting online, Vaughn secured a length of 10-inch-diameter unplasticized polyvinyl chloride (uPVC) tubing. Although more expensive than regular PVC, uPVC is substantially more rigid. The piece was too short for the mirror's focal length, so he cut the tube in two and joined the sections with eight 20-mm-diameter aluminum poles clamped at each end with pillow blocks affixed to the uPVC pieces. The tube housing the primary mirror is 35 inches long; the upper section is about 62 inches. "The assembly turned out to have plenty of rigidity," Vaughn reports.

In addition to its long tube, the telescope's other striking feature is its Holcomb mount. This obscure design saw its heyday in the middle of the 19th century. "I stumbled across the Holcomb mount only after countless hours trawling the internet," Vaughn says. The website of well-known telescope maker Mel Bartels (**bbastrodesigns.com/HolcombeMount.html**) provided the solution.

The mount was invented by America's first commercial telescope maker, Amasa Holcomb. And while it may look unusual, it's an elegant solution to the problem of pointing a telescope with a very long tube. How does it work? Think of a tripod in which one of the legs is the telescope itself with its back end resting on the ground. The scope is crudely aimed by picking up the front legs and pivoting the scope toward the region of sky you want to examine. Fine motion is facilitated by adjusting the lengths of the two front legs by means of two pulley systems — one for each leg. Adjusting both legs raises or lowers the front of the scope, while adjusting just one causes the telescope to move diagonally, allowing objects

VAUGHN MALKIN

The altitude motion of the Holcomb mount is controlled by a pair of winch-and-pulley mechanisms that shorten or lengthen the assembly's two front legs. An adjustable brake mechanism (a pad bearing against a disk) regulates the friction of each control. The mount mates to the telescope by means of a universal joint.

in the eyepiece to be tracked. The legs attach to the telescope tube via a universal joint that permits a full range of motion. The Holcomb mount's chief limitation is that the scope can't reach the zenith or the horizon. Vaughn's instrument works over an elevation range of less than 26° to about 70°, which is well suited to planetary viewing.

Although it might appear ungainly, the Holcomb mount actually performs very well. "I guess all telescopes are compromises — here I'm sacrificing quick and easy access to the whole sky for fine control and stability over a much smaller region," Vaughn says. "For a visual planetary observer, it works great since there's no waiting for things to settle after you touch the focuser or adjust the aim."

While not for everyone, this combination of a long-focus instrument equipped with a small secondary mirror and a sturdy mount yields excellent lunar and planetary views. "Jupiter shows tantalizing hints of detail in the belts," Vaughn reports. "But the Moon was something else — a nice clean image with more detail than I could ever hope to draw."

To learn more about Vaughn's scope, visit his website, **homepages.ihug.co.nz/~Svmalkin/home.htm**. ✦

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*Read about Contributing Editor **Gary Seronik**'s own long-focus Newtonian at his website, **www.garyseronik.com**.*

▸ **DELITEFUL VIEWS** Tele Vue unveils its latest creation for the discerning observer. The new DeLite series eyepieces ($250) provide a generous 62° apparent field of view with comfortable eye relief of 20 millimeters. These 1¼-inch oculars are based on the advancements of the company's popular Delos series, in an economical and lightweight body. Available in 18.2-, 11-, and 7-mm focal lengths, each features a unique, extendable twist-lock eye guard. The DeLite eyepieces are parfocal with others in the series, as well as Tele Vue's 1¼-inch Plössl, Panoptic, Nagler, and Delos eyepieces, and accept its Dioptrx correctors.

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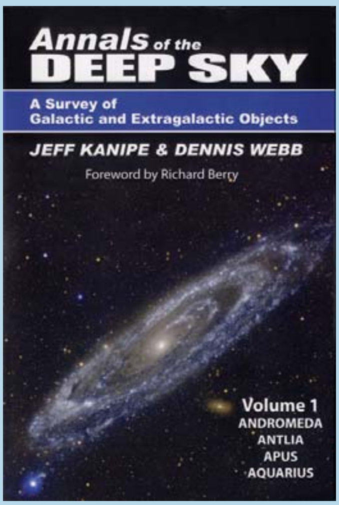

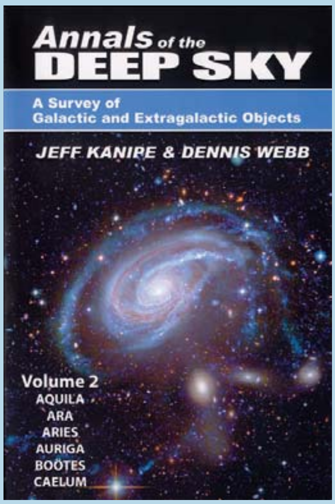

DEEP-SKY COMPENDIUM Publisher Willmann-Bell announces *Annals of the Deep Sky: A Survey of Galactic and Extragalactic Objects* by Jeff Kanipe and Dennis Webb ($24.95 each). The series promises to be the most up-to-date and comprehensive observing guide available today. Each richly illustrated volume of *Annals* features current astrophysical profiles of the major stars and deep-sky objects by constellation, paired with extensive historical and observational information. Volumes 1 and 2 cover the constellations Andromeda through Aquarius and Aquila through Caelum, respectively. When completed, the series will cover all 88 constellations. Each 6 by 9 inches. Vol. 1: 358 pages, ISBN 978-1-942675-00-6; Vol. 2: 344 pages, ISBN 978-1-942675-01-3.

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▾ **ALIGNED ADAPTER** Starlight Instruments, in partnership with Howie Glatter, announces the SCT Parallizer ($60). This accessory adapter is designed to attach to any telescope that uses an SCT-threaded interface and hold 2-inch accessories in nearly perfect alignment using Howie Glatter's patented Parallizer design. A non-marring clamp screw holds your 2-inch eyepiece, diagonal, or camera securely, and guarantees repeatable alignment to within 15 arcseconds with no possibility of wiggle or play.

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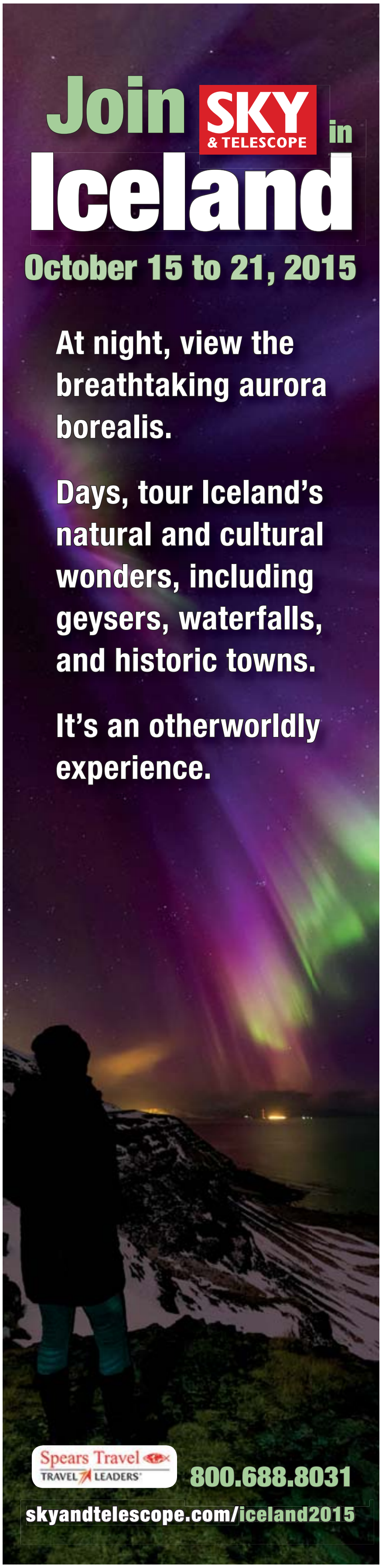
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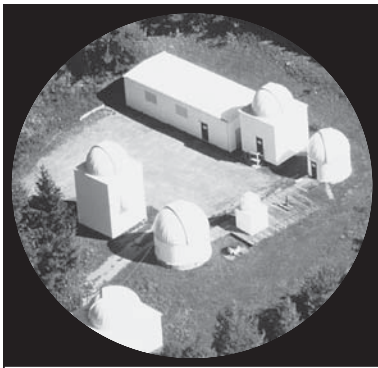


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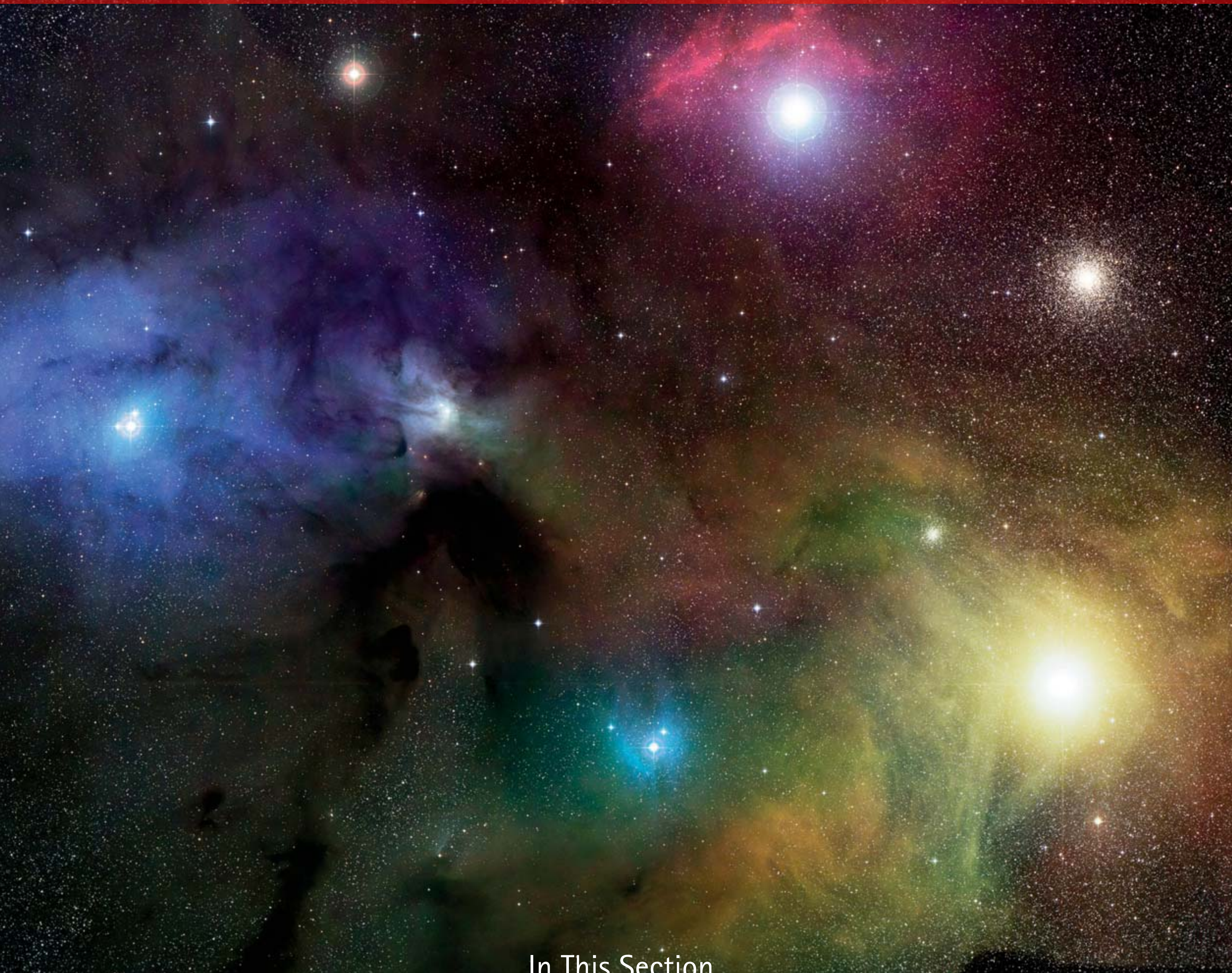


In This Section

M4 sparkles above the golden glow of Antares and to lower right of the red emission nebula surrounding Sigma Scorpii. North is to the left. **PHOTOGRAPH: DAVID MALIN**

AUGUST 2015

1 DUSK: All month, look about 5° left of Saturn in the south-southwest sky about an hour after sunset for the telescopic double star Beta (β) Scorpii. Left or upper left of Beta is another fine double, Nu (ν) Scorpii. High power in good seeing reveals Nu as the Southern Double-Double.

8 MORNING: The Moon, just past last quarter, forms a triangle with the Pleiades and Aldebaran in Taurus.

DAWN: Look for the orange glint of Mars as the planet rises in the east-northeast. Find it approximately 8° below Pollux as the sky brightens.

11 DAWN: On this or the next few mornings, look low in the east-southeast about 20 minutes before sunrise for the heliacal rising (first dawn visibility) of Sirius as it emerges from the Sun's glare.

12–13 LATE NIGHT TO DAWN: The Perseid meteor shower peaks tonight; a waning crescent Moon makes for ideal viewing conditions this year. This is a long-lasting shower, so it's worth observing on the preceding and following nights as well; see page 48.

16 DUSK: Binoculars show Mercury about 6° right of the thin crescent Moon, very low in the west.

22 DUSK: The first-quarter Moon shines less than 4° from Saturn, just above and right of Beta Scorpii.

29 DAWN: Look due east about a half hour before sunrise, where Venus is now about 10° above the horizon.

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

Planet	◀ SUNSET — MIDNIGHT — SUNRISE ▶
Mercury	Hidden in the Sun's glare all month
Venus	Visible starting August 22 (E)
Mars	Visible starting August 5 (E)
Jupiter	(W) Visible through August 5
Saturn	S — SW

Moon Phases

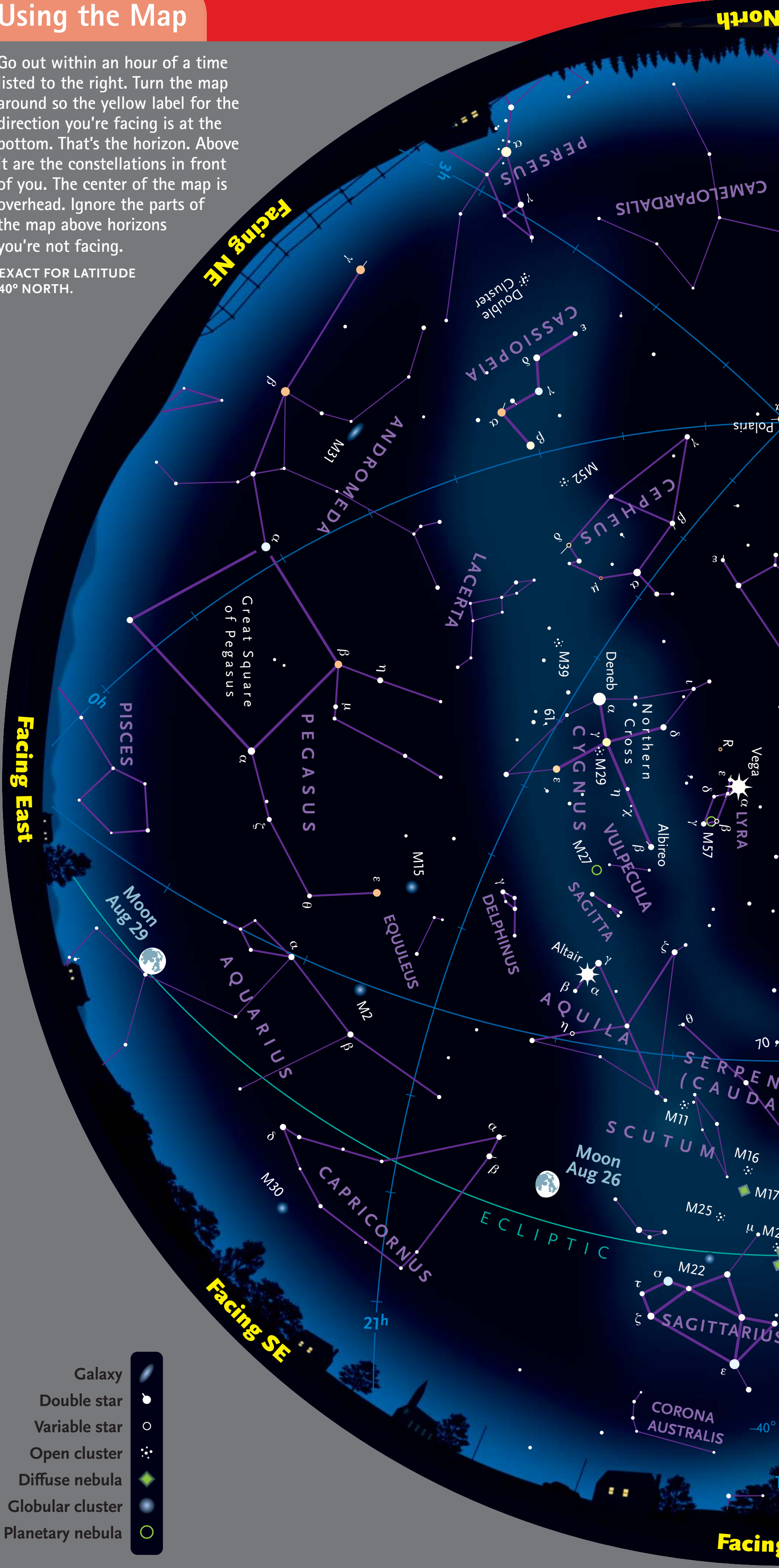
Last Qtr	August 6	10:03 p.m. EDT	
New	August 14	10:53 a.m. EDT	
First Qtr	August 22	3:31 p.m. EDT	
Full	August 29	2:35 p.m. EDT	

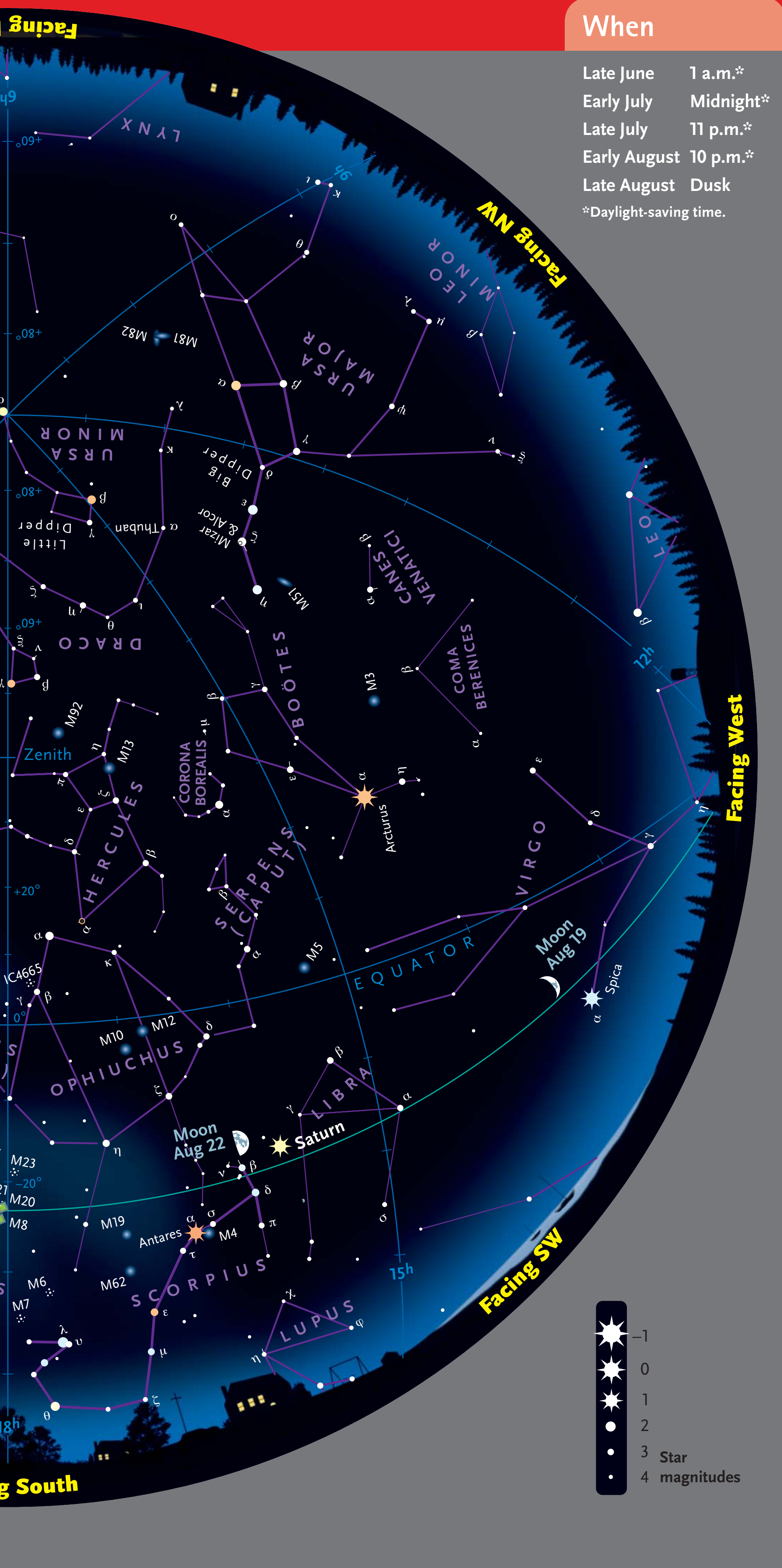
SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23 / 30	24 / 31	25	26	27	28	29

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 June	1 a.m.*
Early July	Midnight*
Late July	11 p.m.*
Early August	10 p.m.*
Late August	Dusk

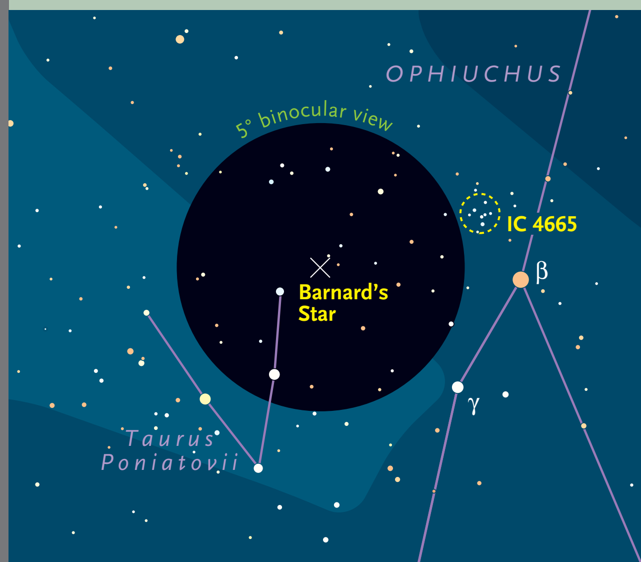
*Daylight-saving time.

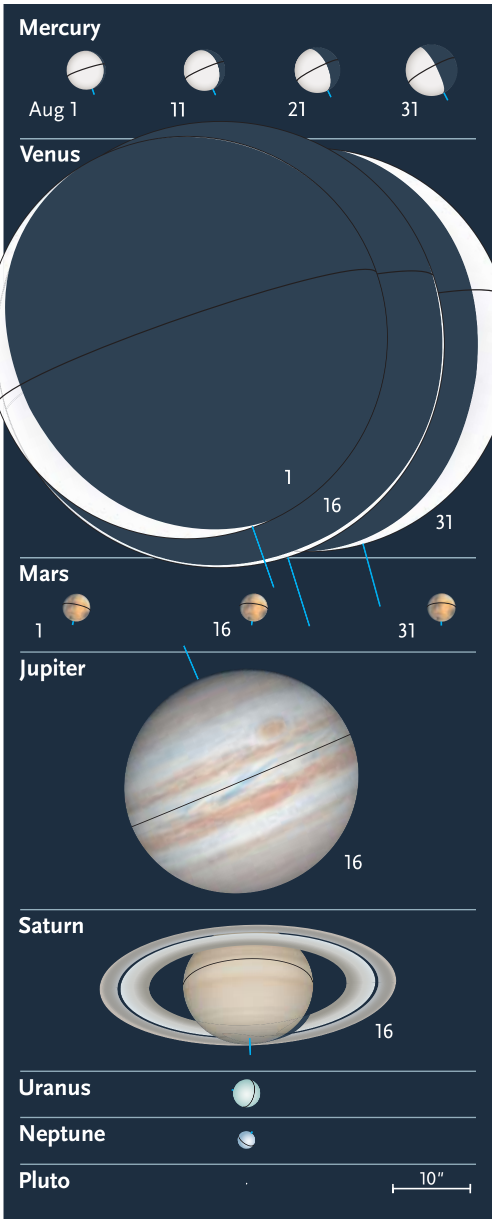
A Trip to Barnard's Star

One of the most memorable events of my childhood was a rare visit to the H.R. MacMillan Planetarium in Vancouver, British Columbia. The show I saw that day concerned the possibility of planets beyond our solar system. It was a wondrous idea in the late 1960s, but one that was still unproved. And yet, even to a child, it just seemed so probable. The exoplanet excitement of the day was fueled by an obscure dot of light in Ophiuchus known as **Barnard's Star**. And though its wobbling motion — initially taken as evidence for an unseen planetary companion — turned out to be the product of instrument error, Barnard's Star is nonetheless remarkable. It lies only 6 light-years away, which makes it second only to the Alpha Centauri system, and the closest star visible from mid-northern latitudes. Its proximity contributes to its incredible proper motion — Barnard's Star moves the apparent diameter of the Moon every 175 years.

Sighting Barnard's Star in binoculars takes a little patience and care. Begin by locating the V-shaped asterism of 7th-magnitude stars known as Taurus Poniatovii, a lovely object in its own right. Use the chart below and proceed northwest from the western tip of the V to the location of Barnard's Star. The star itself is a magnitude 9.5 red dwarf. I have little trouble seeing it in my mounted 10×50 binoculars. Indeed, the greater challenge is sorting out which point of light is the correct one.

If Barnard's Star eludes you, or leaves you unsatisfied, head back to Beta (β) and enjoy the nearby, easy open cluster **IC 4665**. It's a fairly distinct gathering of about a dozen 7th- and 8th-magnitude stars. But in spite of the cluster's apparent proximity to Barnard's Star, IC 4665 lies comparatively far way at a distance of some 1,400 light-years. ✦





Sun and Planets, August 2015

	August	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	8h 42.7m	+18° 12′	—	–26.8	31′ 31″	—	1.015
	31	10h 35.2m	+8° 55′	—	–26.8	31′ 41″	—	1.010
Mercury	1	9h 20.6m	+17° 21′	9° Ev	–1.2	5.1″	95%	1.330
	11	10h 30.1m	+10° 32′	18° Ev	–0.4	5.4″	84%	1.254
	21	11h 26.1m	+3° 25′	23° Ev	–0.1	5.9″	73%	1.142
	31	12h 11.0m	–3° 05′	27° Ev	+0.1	6.7″	61%	1.008
Venus	1	9h 59.8m	+6° 41′	22° Ev	–4.4	52.1″	7%	0.320
	11	9h 40.7m	+6° 16′	10° Ev	–4.1	57.1″	2%	0.292
	21	9h 16.6m	+7° 16′	12° Mo	–4.1	57.1″	2%	0.292
	31	9h 00.6m	+8° 55′	23° Mo	–4.5	52.2″	8%	0.320
Mars	1	7h 46.8m	+22° 09′	14° Mo	+1.7	3.6″	99%	2.575
	16	8h 27.7m	+20° 12′	18° Mo	+1.7	3.7″	99%	2.551
	31	9h 07.0m	+17° 44′	23° Mo	+1.8	3.7″	98%	2.513
Jupiter	1	10h 00.2m	+13° 08′	19° Ev	–1.7	31.1″	100%	6.329
	31	10h 25.0m	+10° 51′	3° Mo	–1.7	30.8″	100%	6.397
Saturn	1	15h 45.1m	–17° 48′	110° Ev	+0.4	17.3″	100%	9.600
	31	15h 47.7m	–18° 03′	82° Ev	+0.5	16.5″	100%	10.090
Uranus	16	1h 15.3m	+7° 15′	123° Mo	+5.8	3.6″	100%	19.425
Neptune	16	22h 42.2m	–9° 05′	164° Mo	+7.8	2.4″	100%	28.988
Pluto	16	18h 56.3m	–20° 54′	140° Ev	+14.1	0.1″	100%	32.141

The table above gives each object's right ascension and declination (equinox 2000.0) at 0h 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-August; 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

Getting to Know "The Kneeler"

Hercules holds a number of unfamiliar yet wondrous objects.

He now crouches — no, kneels — near the zenith for evening viewers at mid-northern latitudes.

Who is he? He is none other than Hercules — well, not really the strongman of Greek mythology but the constellation that represents that legendary personage.

I find Hercules an underrated constellation. Part of the reason is that everyone focuses on the wastepaper-basket-shaped Keystone and the one outstanding deep-sky object that glows on one side of it. There is another marvelous object on the opposite end of Hercules that in recent decades seems to be almost entirely overlooked.

The underappreciated strongman. Amateur astronomers know the constellation Hercules for a spherical glow shot through with glittering pinpricks of light. I refer, of course, to the most famed of all globular star clusters, M13. Turn an 8-inch, 10-inch, or larger telescope upon M13 under good conditions and your knees might get a little weak: the sight is truly grand.

But do most stargazers know this rather dim constellation for much other than M13? They should. They should know Hercules for its smaller but still impressive globular M92. They should also know it for some sights that aren't extended objects — its many amazing double stars.

The most famous doubles of Hercules these days seem to be the fast-changing binary system Zeta (ζ) Herculis and the classic "optical double" Delta (δ) Herculis. Zeta Herculis is a tight pair consisting of magnitude 2.9 and 5.5 stars that orbit each other in just 34 years at a distance of only 35 light-years from Earth. Delta Herculis consists of 3.1- and 8.8-magnitude stars at greatly different distances from us but appearing along nearly the same line of sight.

There is, however, another double star in Hercules, quite neglected, which may be the most interesting star of all in this constellation. Its designation is Alpha (α) Herculis and even though it is only the fifth brightest star in Hercules, it has got to be one of the most overlooked great double and variable stars in all the heavens.

The head of the kneeler. The proper name for Alpha Herculis is Rasalgethi, which as a child learning the stars I pronounced rass-AL-guh-thi. The correct pronunciation is RAHS-ul-JAY-thee, with the stronger of the two stresses on the JAY. The name, used since medieval times, comes from the Arabic for "head of the kneeler." The Kneeler is a mysterious figure pictured in

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these stars long before any ancient Greek writings about Heracles (Hercules).

The first syllable of the name Rasalgethi also appears in the names of two other prominent stars that are at their highest at almost exactly the same time as Rasalgethi: Rastaban (Beta Draconis in the head of the Dragon) and Rasalhague (Alpha Ophiuchi in the head of the Serpent-Bearer).

Rasalhague is only a few degrees from Rasalgethi in the sky — the heads of Hercules and Ophiuchus are close together. At magnitude 2.1, Rasalhague is usually much brighter than Rasalgethi, which has an average magnitude of 3.5, and so in recent decades seems much better known to observers. But this was not always so. Before the marvelous Dobsonian revolution of the late '70s and '80s allowed us to afford the aperture to see thousands of galaxies and other "faint fuzzies," amateur astronomers paid lots more attention to double stars, so Rasalgethi was famous.

Rasalgethi is a star about 400 times wider than the Sun. For more information about it as a variable star and double star, see page 64 of this issue.

Mystery of the upside-down Hercules. In addition to being underappreciated, Hercules appears upside-down — standing on his head — as seen by observers at mid-northern latitudes. Why? Because in ancient times in the Near East, precession of Earth's axis placed Hercules farther north. So when invented, Hercules was probably entirely in the north sky, his body sloping down from a head just north of the zenith. ✦

Saturn Flies Solo

Evening belongs to the ringed planet, early morning to Mars.

This "Year of the Conjunctions" has an intermission in August — not an intermission in conjunctions, as there are several close ones, but in visibility. Mercury is troublesomely low at dusk, while Mars is somewhat higher at dawn but dim. The two brightest planets, Venus and Jupiter, pass the Sun — and so for a while move out of sight. This month, the only bright planet comfortably far from the Sun in the sky is Saturn, high at nightfall and not setting until the middle of the night.

DUSK

Venus passed 6° south of **Jupiter** on July 31st. While Jupiter continues to creep eastward relative to the starry background, Venus retrogrades westward from July 23rd to September 5th. Venus therefore leaves the evening sky before Jupiter does. On August 1st, viewers around latitude 40° north can use binoculars to glimpse Venus sparkling about 6° high at sunset and sinking below the horizon only 30 minutes later. That day, Venus shines at magnitude –4.4 and is less than 7% illuminated, a skinny crescent 53″ long. The light from Venus takes only about 2½ minutes to reach Earth as the month opens. Venus is at aphelion — its farthest from the Sun in space — so is closer than usual to Earth when it reaches inferior conjunction on August 15th. After that, the bright planet veritably vaults into the morning sky.

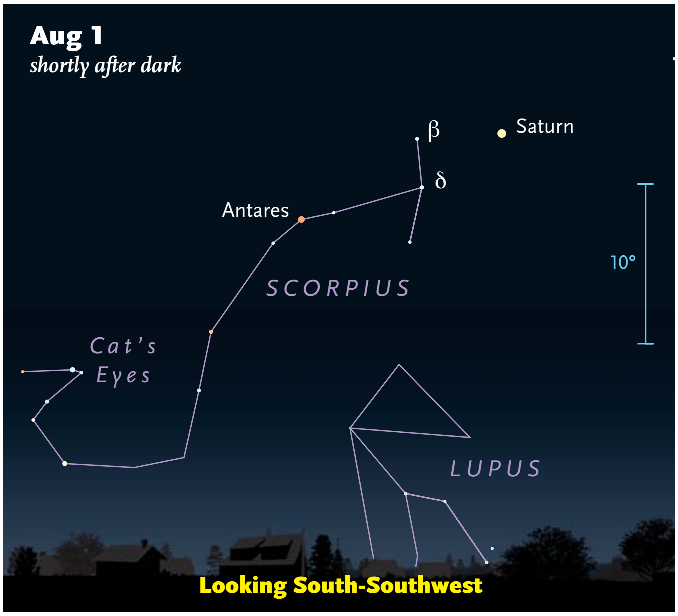
Jupiter and **Mercury** are passing each other, Jupiter exiting the evening sky, Mercury entering. Jupiter starts August setting a little less than an hour after the Sun for viewers at northern latitudes. By August 6th the interval between sunset and Jupiter-set is down to 45 minutes. On that evening, magnitude –1.7 Jupiter is only 0.6° lower left of magnitude –0.7 Mercury for those in North America. And the next evening, August 7th, these two planets and the magnitude +1.4 star Regulus fit within a circle only about 1° in diameter. Jupiter is fully lit, Mercury almost so, but Jupiter's 31″ disk appears about six times wider with a much dimmer surface brightness.

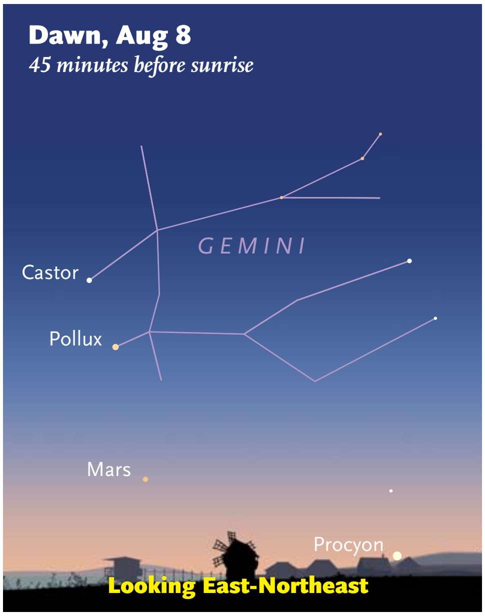
The last of the pairings among these objects has Jupiter 0.4° from Regulus around sunset on the American evenings of August 10th and 11th. This is the sole conjunction between Jupiter and Regulus in this cycle of Jupiter's 12-year orbit — but even in telescopes it will be hard to see Regulus so low in the Sun's afterglow.

Mercury gets a little bit higher in the dusk during the rest of August, but Jupiter is lost altogether by mid-month, on its way to its August 26th conjunction with the Sun.

DUSK TO LATE NIGHT

Saturn is the sole bright planet visible outside of twilight this month. It shines well up in the south-southwest as dusk fades away. Saturn ceases retrograde motion on August 2nd in eastern Libra, just west of Scorpius, as it fades just a trace from magnitude +0.4 to +0.5. The rings remain open 24° to our view, and

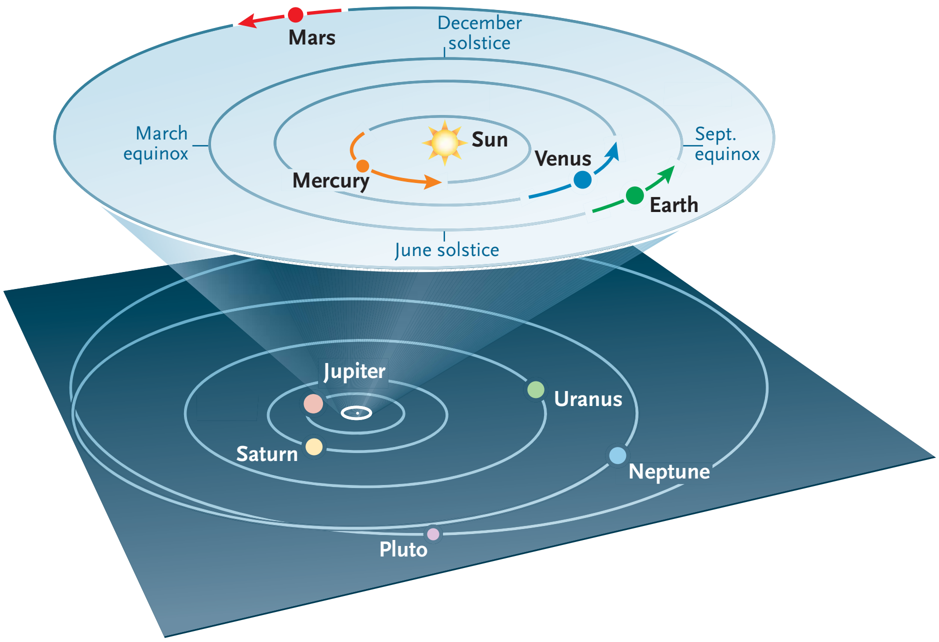




These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist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

ORBITS OF THE PLANETS

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



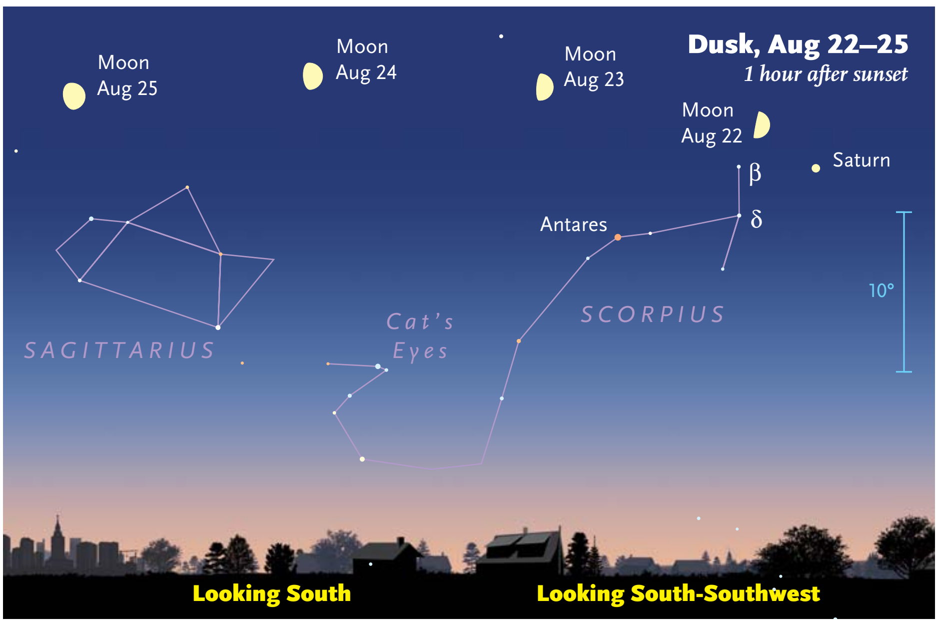
since Saturn is at eastern quadrature (90° east of the Sun) on August 21st, the shadow of the globe on the rings is at its maximum extent this month, accentuating the planet's three-dimensionality.

EVENING TO DAWN

The two outermost major planets and the most famous ex-planet are all visible for large parts of the night this month. **Neptune** reaches opposition on August 31st and is best observed when highest a few hours after midnight. Neptune shines at magnitude +7.8 in Aquarius and displays a disk just 3.7″ in diameter. **Uranus**, in Pisces, rises soon after evening twilight and is highest around morning twilight. The extremely dim world **Pluto**, in northern Sagittarius, is highest in the evening; see the finder chart in last month's issue (*S&T*: July 2015, p. 52).

DAWN

Mars rises about 70 minutes before the Sun as August starts but 2 hours before the Sun as the month ends. The red planet dims from a meager magnitude +1.7 to +1.8 in August and displays a disk no larger than that of distant Uranus. On August 8th, it stands about 5° high in the east-northeast, below Pollux and Castor approximately 45 minutes before sunrise. On the American mornings of August 20th and 21st, binoculars or a telescope may show it on the outskirts of M44, the Beehive Star Cluster in Cancer.



Venus rises with the Sun on August 18th, about 55 minutes before the Sun a week later, and more than 1½ hours before the Sun at month's end. During this time Venus brightens from –4.1 to –4.5, shrinks from 58″ to 52″ wide, and fattens in phase from 1% to 9% illuminated — fascinating changes to watch in telescopes and binoculars. The best time to view it telescopically will be well after sunrise, when it climbs out of the low-altitude atmospheric shimmering.

In the back half of the month, Venus vaults up into the dawn to the lower right of little Mars, though it won't catch Mars until November 3rd.

MOON PASSAGES

The **Moon** is a waning crescent well upper right of Mars on August 12th when the Perseid meteors fly; see page 48. The waxing lunar crescent is left of Mercury, low in the west, 30 minutes after sunset on August 16th and not far above Spica on the 19th. The first-quarter Moon is upper left of Saturn on August 22nd. The Moon is full on the 29th, less than 21 hours before perigee. Next month's full Moon, Harvest Moon and totally eclipsed, occurs less than 1 hour after perigee. ✦

Dark Nights for Fine Perseids

There's no Moon, and the meteors should peak during night for North America.

A bright Perseid fireball streaked down the southern sky behind yurts in Ulanqab, Inner Mongolia, while Ellie Yuan was exposing this image just after local midnight on August 13, 2013. "I found my face suddenly lit up, and shadows moving," she writes. The fireball crossed eastern Capricornus more than 90° from the Perseid radiant, which means it was traveling slightly away from the observer.

Every three years all the phases of the Moon repeat on the same calendar dates minus three days. So every three years, more or less, the Moon is new around the peak night of the Perseid meteor shower.

It's that time again. New Moon falls on August 14th. This gives us a dark sky for the entire prime Perseid night, August 12–13, and good meteor watching for several nights before and after.

Moreover, the shower's exact peak is predicted to run for several hours centered on 8^h UT August 13th (4 a.m. EDT, 1 a.m. PDT). This coincides with the best meteor-watching hours — from late evening to the first light of dawn — in the time zones of North America. Late night is when the shower's radiant point

(in northern Perseus) rises high in the sky. Or to say the same thing another way, it's when the meteors hit your side of the world most nearly head-on.

There's an added twist this year. The Perseid meteoroids are little bits of debris from Comet 109/P Swift-Tuttle, which is on a 130-year orbit and last passed through the inner solar system in 1992. Meteor-stream modeler Jérémie Vaubaillon finds that this year, Earth should pass very close to the debris trail that the comet shed during its return in 1862. This encounter will last for a few hours centered on 18:39 UT August 12th. Will there be an unscheduled outburst of Perseids around then? The timing favors observers in Asia. Meteor counters on that side of the world are especially needed to monitor what will happen.

Alex Conu assembled this composite image of six Perseids captured near Ursa Major on August 12, 2013, in the Lotrului Mountains of Romania. The lip of the Big Dipper is under the bear's ear; the handle-end is at the tip of his tail.

How to Watch

It's easy just to be a Perseid spectator. Many more people watch the shower now than did a generation or two ago, especially families on rural vacations under dark skies. In fact, America's national parks are getting unprecedented numbers of people who say in surveys that a dark, star-filled sky and genuine, natural night are reasons why they visit. For this we can credit the growing public awareness of light pollution (with big thanks to the International Dark-Sky Association, **dark-sky.org**) and the park system's own management, which is recognizing and working to preserve the parks' dark-sky assets (*S&T*: May 2012, p. 26).

A Perseid watch goes best if you know what you're doing. The later in the night you go out the better. Let your eyes dark-adapt, and plan to be patient. After midnight under a fairly rural sky you may see a meteor a minute on average, but earlier in the evening or under more ordinary skies, your waits will be longer.

Dress warmly and wear a hat; the cold under a clear sky late at night will be more like October than August, and you'll be lying still for a long time. Find a spot in advance that has an open view overhead and somewhat to the northeast, with no lights shining into the edge of your vision. Bring a reclining lawn chair and additional blankets or a sleeping bag. The wraps are for both warmth and mosquito protection; bring repellent for parts of you that are not covered.

Lie back and gaze into the darkest part of the sky, probably straight overhead. If much of the sky is dark, incline your gaze somewhat toward the radiant in the northeast. Many observers watch about halfway from a shower's radiant to the zenith. Relax and settle in.

On the other hand, some meteor aficionados plan to flout the standard wisdom and watch early in the evening. At that time, when the radiant is still low, the few Perseids that appear will be spectacularly long *Earthgrazers,* skimming far across the sky along the top of the atmosphere. For more about this facet of meteor watching, pull out your August 2014 issue and turn to page 64.

Making a Count

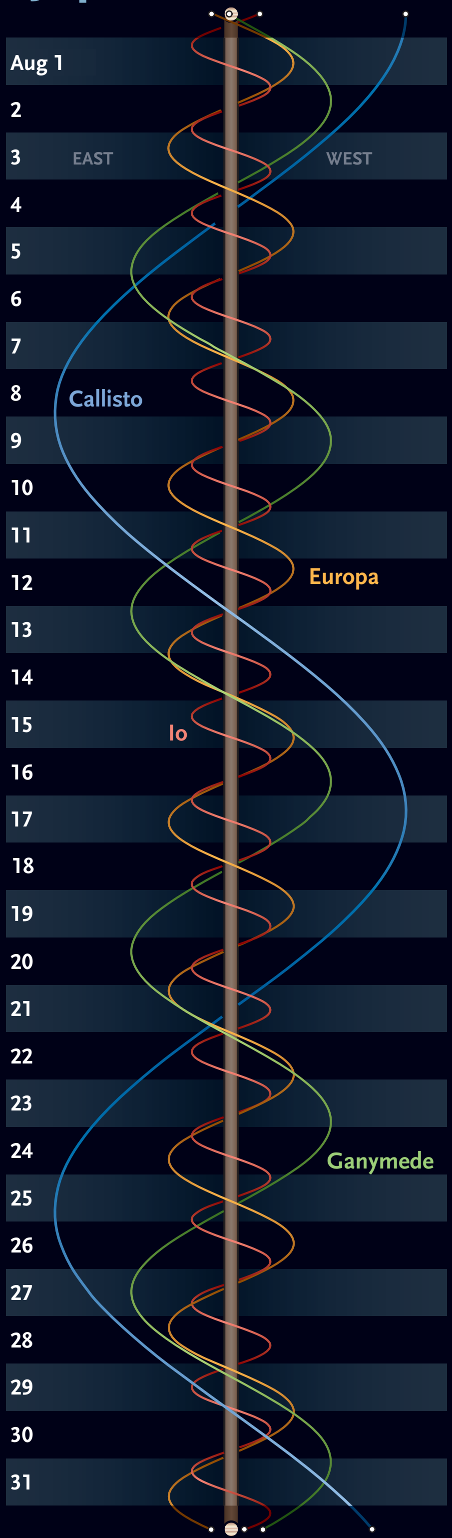
If you have a fairly dark sky and an hour or more to commit, why not try doing an actual scientific meteor count? This way you can help to determine the shower's behavior this year, contributing to records that will last for all time.

You'll need to follow the standard procedures of the International Meteor Organization, so that your count can be analyzed to yield the shower's actual strength — the standardized *zenithal hourly rate* (ZHR) — during the time you were watching. This way your count is

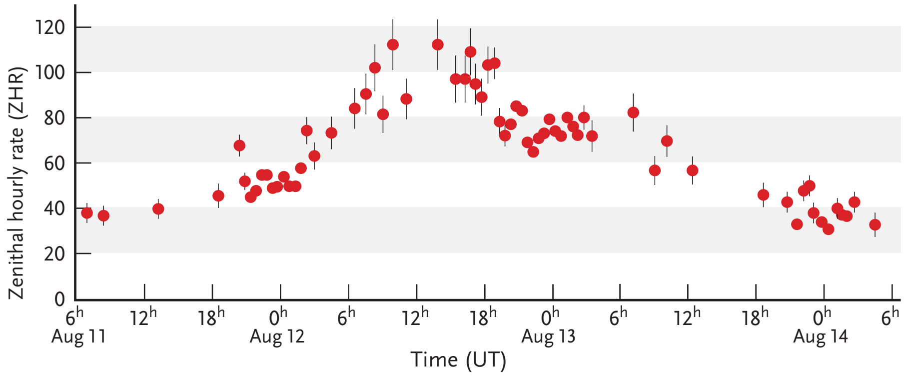
FOLLOW THE SHOWER ONLINE

As meteor watchers report their counts to the IMO, you can watch this year's Perseid activity curve develop hour by hour at **imo.net**.

Jupiter's Moons



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



In 2013, a total of 303 meteor counters used standardized International Meteor Organization methods to log 34,805 Perseids across a span of 20 days. Observers contributed from all around the world, enabling the IMO to create this nearly unbroken activity curve covering the shower's richest 72 hours. The more counters, the smaller the statistical error bars. The shower's zenithal hourly rate (ZHR) stayed around 100 or more for 12 hours.

a measure of the shower itself, rather than your light pollution or eyesight. The ZHR is how many meteors a single observer with a wide-open view would count if the radiant were at the zenith and magnitude-6.5 stars were visible.

Part of this process is determining the faintest naked-eye stars you can see in the area you're watching. Your rough latitude and longitude, the time every half hour or so, any minor obstructions by clouds or trees, and time spent looking away also need to be recorded.

This way hundreds of observers' counts from around the world will be intercompared to track what the shower is doing, hopefully for many days running as night circles and recircles the globe. That's how the IMO compiled the activity curve for the 2013 Perseids above. Find the instructions and how to report at **imo.net/visual/major**.

Saturn at Quadrature

By August Saturn is way past its June 3rd opposition, but so far is Saturn from Earth's orbit around the Sun that this hardly matters for good observing. By August 21st, when Saturn has moved the 90° from opposition to quadrature (90° from the Sun), it has shrunk by only 9% from its opposition diameter. That matters less than a change in the atmospheric seeing.

Quadrature is very nearly when sunlight strikes an outer planet from the greatest angle to Earth's line of sight. So this is when we see Mars most gibbous, Jupiter's eastern and western limbs most unequally lit, and Saturn casting the broadest visible shadow onto the rings behind it.

That, and the slight unequalness of the lighting on Saturn's own east and west sides, make the planet look a little more 3D than usual around these times.

Lunar Occultation

On the night of July 29–30, telescope users across most of North America except the northwest can watch the almost-full Moon occult Rho[1] Sagittarii, magnitude 3.9, the handle end of the Sagittarius Teaspoon. The star will snap out of view behind the very thin dark limb of the 98%-illuminated Moon: barely off the edge where a little bit of shadowing appears on lunar features.

Some times of the star's disappearance: Toronto, 12:27 a.m. EDT; Montreal, 12:36 a.m. EDT; Washington DC, 12:25 a.m. EDT; Atlanta, 12:05 a.m. EDT; Miami, 12:08 a.m. EDT; Chicago, 11:11 p.m. CDT; Austin, 10:31 p.m. CDT; Kansas City, 10:53 p.m. CDT; Denver, 9:34 p.m. MDT; Los Angeles, 8:03 p.m. PDT.

Chi Cygni's Summer Rise

What's the second-brightest Mira-type variable star after Mira itself?

If you picked Chi (χ) Cygni in the shaft of the Northern Cross, you get a gold star — a deep red-gold one that's brightening this summer to shine at 6th, 5th, 4th, or possibly 3rd magnitude around the end of August.

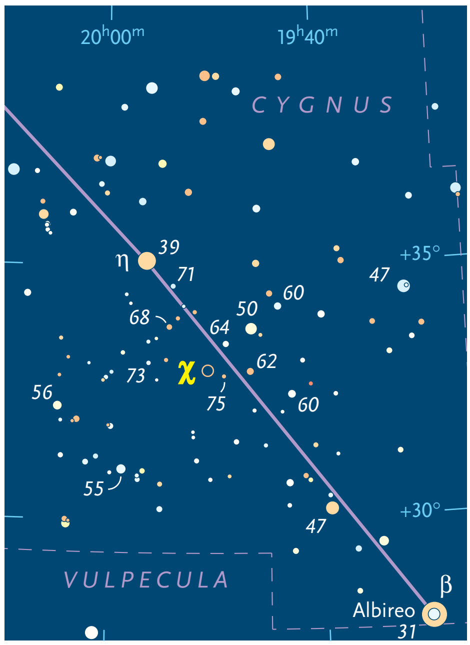
Chi Cygni pulses through a brightness change of about 10,000 times and back every 13.4 months. But its cycles are not all alike. Its maxima alternate quite consistently between bright and faint. At its last maximum, in July 2014, Chi rose to only magnitude 6.7. The time before that, in May 2013, it peaked at 3.8, giving the Northern Cross a distinct new naked-eye star. If this pattern continues, we're in for a bright maximum now.

At its minimum late last winter, Chi Cygni was a mere 14th magnitude according to visual observers reporting to the American Association of Variable Star Observers (AAVSO). Then it started jumping up unusually fast. By July 1st you may find it around magnitude 9. Pick it up as early as you can to watch the full drama of its summer rise. Its orange-red color helps to identify it in your scope.

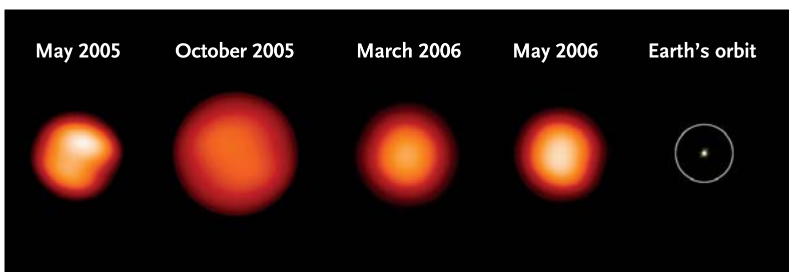
The discovery of its variability dates to 1686, when Gottfried Kirch in Germany was planning to observe the nova shining in Vulpecula at the time. He noticed that the star in Cygnus that Johann Bayer had labeled χ on his *Uranometria* atlas of 1603 was missing. Several months later Kirch saw that it was back again, acting like Mira in Cetus.

All Mira-type variables are red giants, and most of them are spectral type *M*. But Chi Cygni is in the unusual spectral class *S* (ranging from *S*6 to *S*10 during its pulsation cycle), meaning that it's an old, highly evolved star with zirconium oxide in its spectrum. At its maxima it's the brightest *S* star in the sky.

Chi Cygni's diameter expands and contracts by 40% during its pulsation cycle; it's smallest when brightening and largest when fading. Near maximum its surface seems to display large, irregular bright patches, as seen below. Like other red giants it has a fuzzy, poorly defined edge, and different molecules (including water vapor) have been found at different levels in its loose atmosphere. It's about 550 light-years away. ✦



Left: **Where to find Chi Cygni with the naked eye and in binoculars. The sky's brightest type-*S* star is likely to rise to an above-average peak by late August. Magnitudes of comparison stars are given to the nearest tenth with the decimal point omitted. You can get deeper charts at aavso.org; at "Star name here," type Chi Cyg.**
Below: **Chi Cygni's disk was imaged through most of a pulsation cycle by the Smithsonian Astrophysical Observatory's Infrared Optical Telescope Array (IOTA) at Whipple Observatory in Arizona. The star's infrared brightness varies much less than its visible light.**

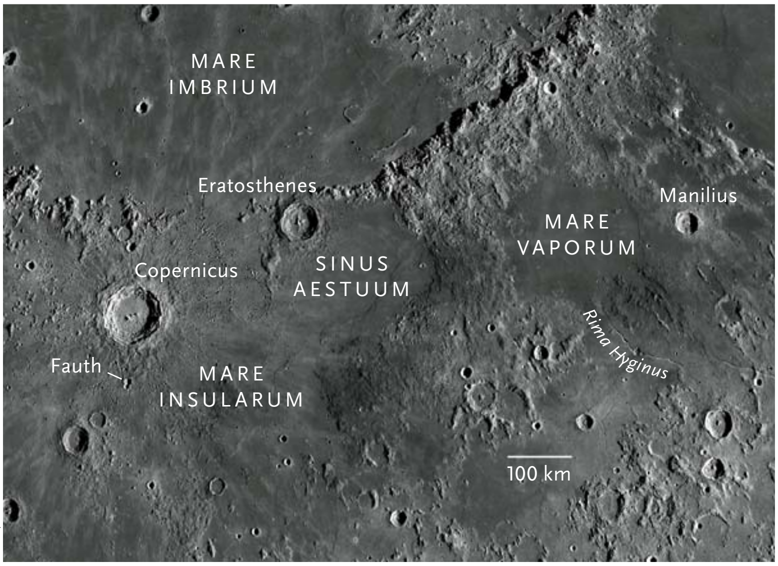


S. LACOUR, OBSERVATOIRE DE PARIS / IOTA

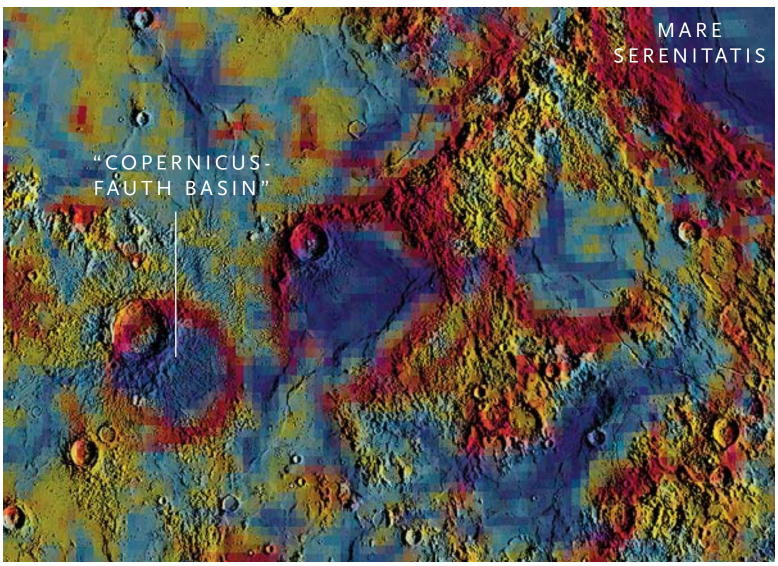
Three Holes in a Row

But one is a lava-filled lunar basin that we didn't realize was there.

The realization in the late 1940s that the Moon's dark, circular maria exist within very large impact craters (called basins) was profoundly important. Excavated during titanic impacts, these big, deep holes threw their ejecta widely across the Moon, later became filled with mare lava flows, and eventually developed concentric fractures and mare ridges as they subsided. Basins are thus the most important lunar landforms.



NASA / LUNAR RECONNAISSANCE ORBITER



J. C. ANDREWS-HANNA / NATURE

When observing the Moon, your eye is drawn to the major lava-filled basins such as Imbrium, Crisium, Humorum, and Nectaris, but numerous smaller ones are often overlooked.

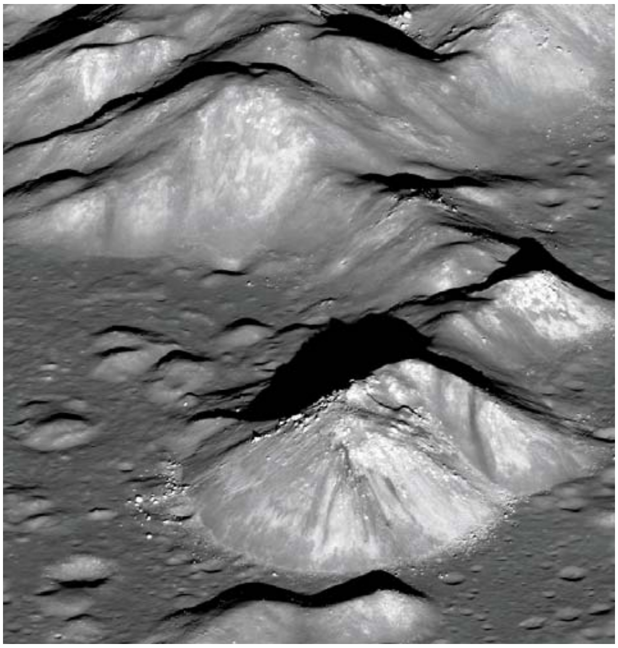
A powerful tool that has helped geophysicists recognize basins is the global gravity map created by NASA's Gravity Recovery and Interior Laboratory (GRAIL) orbiters, twin craft that circled in tandem at low altitude before crashing onto the lunar surface in December 2012 (*S&T:* June 2015, p. 54). New Zealand amateur Maurice Collins created the color map at lower left that is a mash-up of GRAIL gravity data with a visualization of Lunar Reconnaissance Orbiter digital topography. The area shown, about 1,000 kilometers (650 miles) wide, stretches from west of Copernicus to just east of Manilius.

Colors represent the local gravity field gradients (from an analysis by Jeffrey C. Andrews-Hanna of the Colorado School of Mines), with blue indicating where the field is stronger, and red weaker, than average. These variations result from the amount of mass present near the surface. A lower-mass signature can be caused by a big hole in the ground or by lower-density rocks such as those of the lunar highlands. Higher gravity readings require dense rocks such as lava flows or, more importantly, an upwelling of the lunar mantle beneath the surface.

Basins are usually surrounded by uplifted circular rims of pulverized, overturned rock that create gravity "lows" (notice the red rim of Serenitatis at upper right). The interiors of many basins are pronounced gravity "highs," the famous mass concentrations or mascons discovered in the early days of lunar exploration.

The exceptional spatial resolution of the GRAIL data allows unprecedented delineation of gravity highs and lows, and Collins' mash-up clearly defines three smaller basins southeast of Mare Imbrium. Two of these can be seen by eye in the topography, but the third is nearly invisible.

Top: **The lunar landscape between Copernicus and Manilius features several small maria. Two of these fill the basins Aestuum and Vaporum.** ***Bottom:*** **A third basin, now covered by Mare Insularum, only becomes evident in the gravity map of this region compiled by NASA's Gravity Recovery and Interior Laboratory (GRAIL) spacecraft. Red regions denote gravity fields that are lower than average and blue ones those higher than average.**



NASA / LUNAR RECONNAISSANCE ORBITER

The central peaks in Copernicus, as seen obliquely from the west by NASA's Lunar Reconnaissance Orbiter. They rise about 700 meters above a sharp boundary with now-solid lava that was liquefied by the impact's energy and flooded the floor of the crater in its final stages of formation.

Mare Vaporum very likely fills a small impact basin even though it isn't ringed with mountains. Instead, notice the modest gravity high caused by dense lava filling a depression. GRAIL data clearly show a curved red rim on the southern side of the mare. The diameter of the Vaporum basin, as defined by the partial red ring, is about 250 km.

At the telescope you can observe that the end of the rille **Rima Hyginus** abruptly stops when it reaches the southeast edge of Mare Vaporum, showing that those lavas are younger than the rille.

A more pronounced red gravity ring defines the basin of **Sinus Aestuum**, which retains no remnant of its topographic rim except for the isolated mountain southwest of Eratosthenes. We used to think this little elongated mountain was an isolated plop of Imbrium ejecta, but the gravity data suggest that in reality it's part of the small basin's rim. Based on the red gravity ring, the basin is about 275 km wide.

The Aestuum mascon is more pronounced than Vaporum's, perhaps indicating a thicker lava filling. The ridges that form an inner basin ring at Aestuum were produced by faulting in the mare when the underlying basin subsided.

A red ring and blue mascon "bull's-eye" defines a third small basin on which **Copernicus** later appeared. This small, 200-km-wide basin displays no convincing evidence of a topographic rim and, unlike Vaporum and Aestuum, wasn't identified previously. Some lunar geologists suspected it was the eastern half of a larger, rather speculative basin called Insularum. However, thanks to the GRAIL data, we now know that no basin underlies **Mare Insularum**. So, to avoid confusion, I informally call this newly recognized feature "Copernicus-Fauth basin," after the only two named craters within it.

The fact that Copernicus formed directly above the basin's now-absent rim might explain a peculiar compositional aspect of the crater's central peaks. These contain the mineral olivine, thought to be common in the lunar mantle. The rim of the Copernicus-Fauth basin might include olivine excavated from great depth and later brought to the surface as the Copernicus peaks.

Volcanism, which commonly occurred inside large basins, also marks all three of these smaller ones. For example, a small, steep-sided volcanic dome was recently recognized along the north shore of Mare Vaporum. The Moon's most extensive deposits of pyroclastic (ash) material occur along the eastern and southern shores of Aestuum, and a similar deposit lies along the southeast rim of my Copernicus-Fauth basin.

All of these volcanic features can be observed at the telescope, but it's a bigger challenge to find evidence for the rims of these three small basins. ✦

The Moon • August 2015

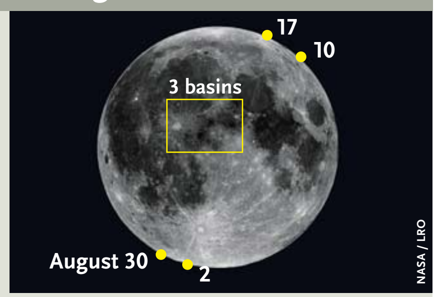
Phases

LAST QUARTER
August 7, 2:03 UT

NEW MOON
August 14, 14:53 UT

FIRST QUARTER
August 22, 19:31 UT

FULL MOON
August 29, 18:35 UT



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

Distances

Perigee 225,023 miles	**August 2, 10^{h} UT** diam. 33′ 13″
Apogee 252,182 miles	**August 18, 3^{h} UT** diam. 29′ 17″
Perigee 222,631 miles	**August 30, 15^{h} UT** diam. 32′ 59″

Librations

Pingré (crater)	August 2
Pascal (crater)	August 10
Mare Humboldtianum	August 17
Eichstadt (crater)	August 30

Good Things, Small Package

The shield of Scutum shelters a diverse collection of treasure.

For a constellation you could hide with your hand held at arm's length, Scutum the Shield parents an amazing wealth of deep-sky wonders. Its favored child is glorious Messier 11, whose magnificent rafts of pinpoint stars always deserve admiration. But Scutum's other celestial children are also noteworthy, so this month let's focus on some of them.

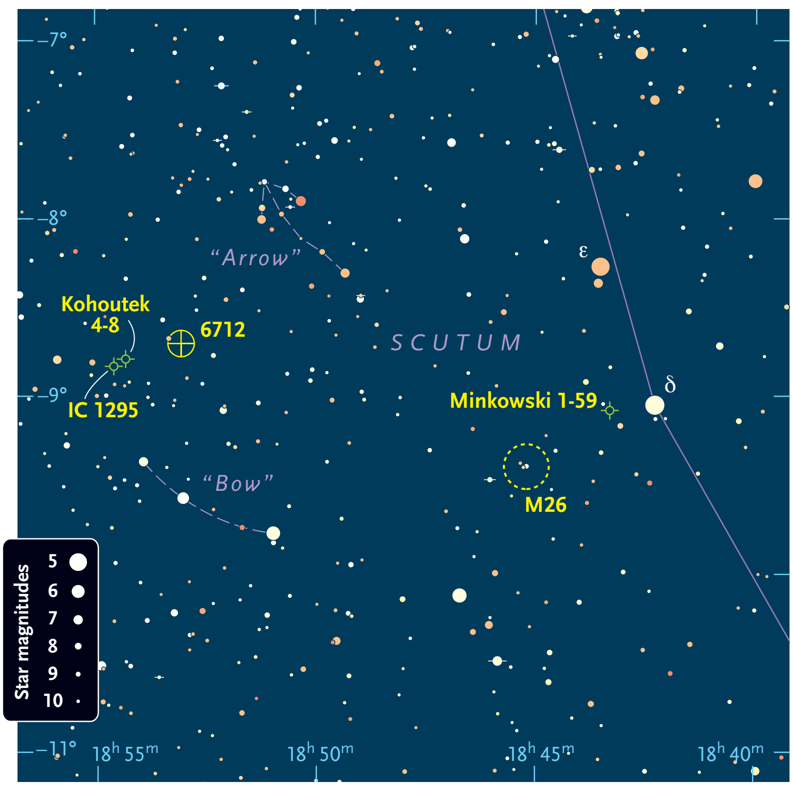
Only two objects from Charles Messier's famous 18th-century catalog dwell within Scutum, but that's the same number you'll find within Taurus the Bull. This seems impressive, considering Taurus is the 17th largest of the 88 constellations, while Scutum ranks 84th. Let's launch our tour with Scutum's often-neglected Messier object, **Messier 26**.

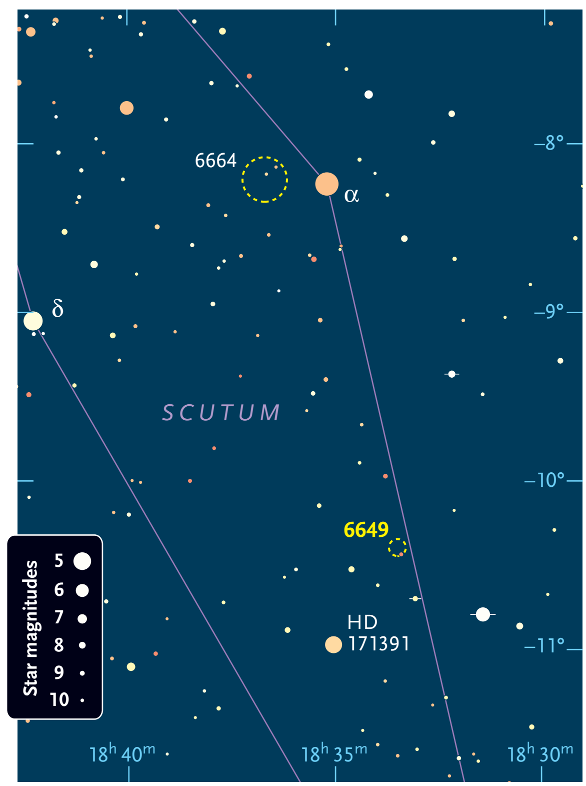
It's challenging to find star clusters amid the rich Milky Way star cloud that dominates Scutum, but Messier 26 is handily located 48′ east-southeast of Delta (δ) Scuti. The cluster is easily visible through 15×45 image-stabilized binoculars in my moderately light-polluted sky. Its modestly large, hazy glow sports a lone star. Through my 130-mm refractor at 48×, M26 is an attractive gathering of 25 stars that spans about 10′ and stands out well from its background. A magnification of 102× unveils about 40 stars. The western side of the group is sparsely populated, but a nice duo trims the west-southwestern edge.

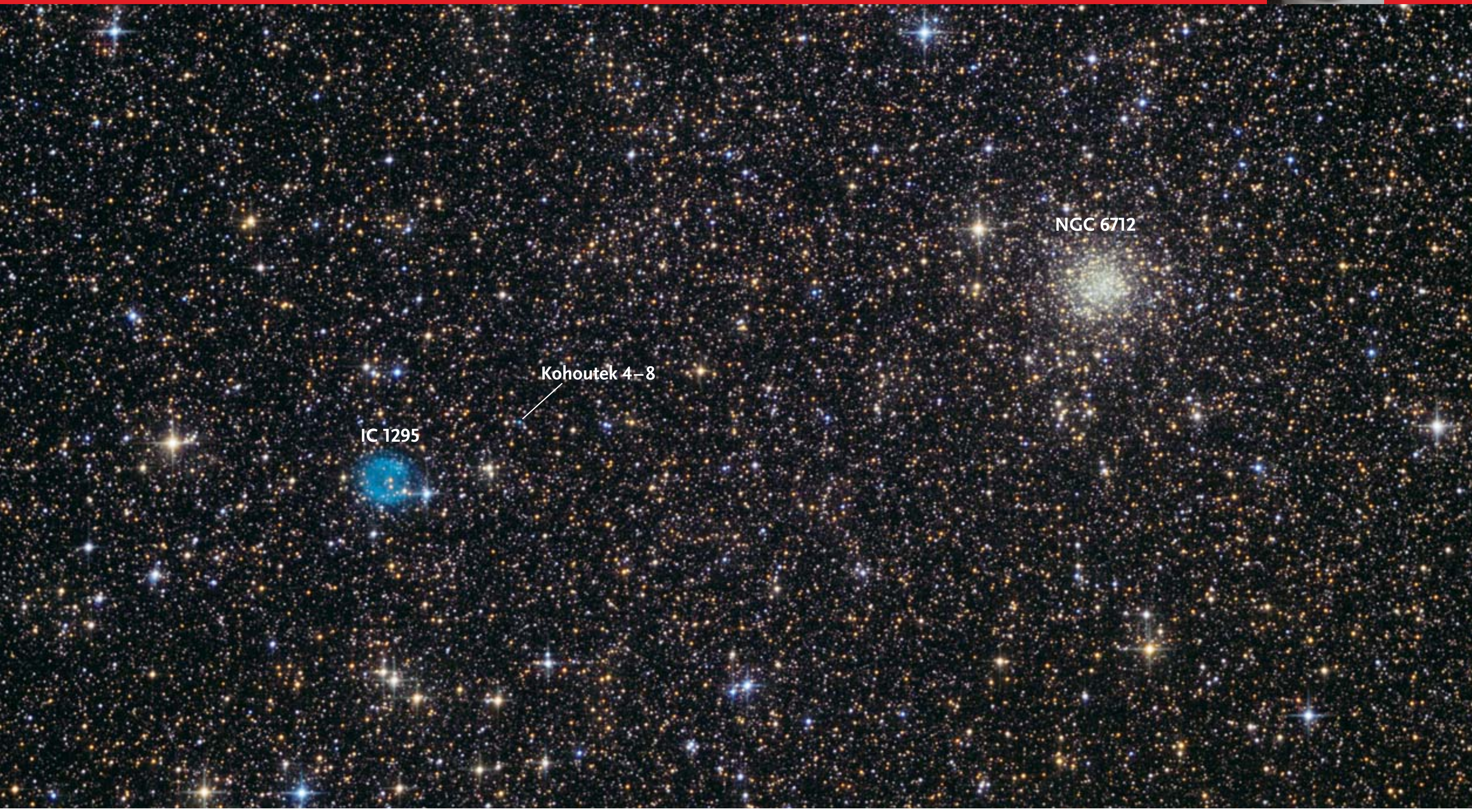
Maryland amateur Mike Rowles and his family enjoy looking at M26 through Mike's 10-inch reflector. He says it looks like a little jumping spider staring straight at them with its big, shiny eyes. I think that's a great description. Can you envision this cute celestial arachnid?

M26 is only 5,200 light-years away from us, but it suffers considerable dimming from intervening dust in the plane of our galaxy. If we could sweep the dust away, M26 would shine at magnitude 6.2 rather than the 8.0 we see in our sky. It's also young as open clusters go, having celebrated its 85 millionth birthday.

Moving 2.0° east-northeast from M26 takes us to







SERGIO EGUIVAR

The cyan glint of planetary nebula Kohoutek 4-8 can be seen in a short arc of stars about 4.7′ west-northwest of IC 1295.

Scutum's only globular cluster, **NGC 6712**. In 15×45 binoculars, it's a small, misty ball with a brighter heart and a faint star a little way off its east-northeastern edge. Through the 130-mm refractor at 23×, the cluster gleams as a granular haze and its attendant star becomes an orange ember. NGC 6712 is a lovely sight at 164×. Foreground stars are sprinkled over the cluster, but some very faint cluster stars, 13th-magnitude and dimmer, can also be seen. The cluster is quite pretty in my 10-inch reflector at 213×; moderately faint to very faint stars are scattered across its entire face. The bright core is about 2′ across and highlighted with two prominent stars in the southeast. A fairly bright fringe around the core spans 3′ and hosts an eye-catching star in its east-northeastern side. The large, diaphanous halo gradually fades into the starry backdrop, and it's difficult to tell where it truly ends.

NGC 6712 and M26 fit within the same field of view through binoculars or a telescope at very low power. When viewed together, consider their differences. NGC 6712 is about four times as distant, 140 times as old, and holds roughly 700 times as many stars as M26.

Californian Howard Lazerson told me about an interesting asterism that he noticed with his 5-inch refractor and dubbed the **Bow and Arrow**. The Arrow is quite conspicuous through my 105-mm refractor at 17×. It's about 1° west-northwest of NGC 6712, 51′ long, and flies northeast. Five stars in a V form the arrowhead, the star at the end of the V's northwestern arm shining with a deep red-orange hue. This is the semi-regular variable star S Scuti, whose typical range is magnitude 6.6 to 7.3. The

Sights in Scutum

Object	Type	Mag.	Size/Sep.	RA	Dec.
Messier 26	Open cluster	8.0	10′	$18^h 45.3^m$	–9° 23′
NGC 6712	Globular cluster	8.1	9.8′	$18^h 53.1^m$	–8° 42′
Bow	Asterism	5.1	50′	$18^h 52.5^m$	–9° 39′
Arrow	Asterism	5.3	51′	$18^h 49.9^m$	–8° 12′
IC 1295	Planetary nebula	12.5	107″ × 90″	$18^h 54.6^m$	–8° 50′
Kohoutek 4-8	Planetary nebula	14.0	stellar	$18^h 54.3^m$	–8° 48′
Minkowski 1-59	Planetary nebula	12.5	5″	$18^h 43.3^m$	–9° 05′
NGC 6649	Open Cluster	8.9	6.0′	$18^h 33.5^m$	–10° 24′

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.

shaft of the Arrow has three stars. One additional star, the asterism's faintest at magnitude 9.0, joins shaft to arrowhead. Hanging 52′ south of NGC 6712, the Bow is simply a gentle curve of three stars, magnitudes 5.8 to 7.0.

The large, low-surface-brightness planetary nebula **IC 1295** rests 24′ east-southeast of NGC 6712. There's an 11th-magnitude star near its west-southwestern edge and an 8th-magnitude, yellow-orange star 7′ to its east. I didn't see the nebula with my 130-mm refractor at 48× until I added an O III filter, and then a 1½′ glow popped into view. With the filter at 102×, IC 1295 looks slightly oval, tipped toward the nearby star, and it has a somewhat dimmer center. At this magnification, I can see the planetary without a filter. With an O III filter, my 10-inch reflector at 115× reveals some brighter patches along the nebula's rim. At 166× the nebula's rim is dimmer at the end facing the nearby star to its west, and there's a superimposed star west-southwest of the nebula's center.

IC 1295 has a limb-brightened outer halo that spans 2¼′ × 2′. Its surface brightness is only a magnitude or so fainter than the inner nebula. Although I couldn't see this with my 10-inch scope, German amateur Uwe Glahn's excellent sketch plainly shows that it's a viable target for large telescopes.

The material in the outer halo of IC 1295 and similar planetaries is thought to consist of mass lost by an aging red giant star during an early phase of instability while the central region is the result of its last gasp.

The starlike planetary nebula **Kohoutek 4-8** (PK 25-4.1 or PN G25.3-4.6) sits only 4.7′ west-northwest of IC 1295. With my 10-inch scope at 213×, I see a 50″-long arc of three faint "stars" at the nebula's location. My initial suspicion that that the middle one was the planetary was confirmed when I put an O III filter on the eyepiece. The western star disappeared, and the middle object then outshone the eastern star. In my 15-inch reflector at 192×, the arc gains two more stars, but K 4-8 still claims the middle.

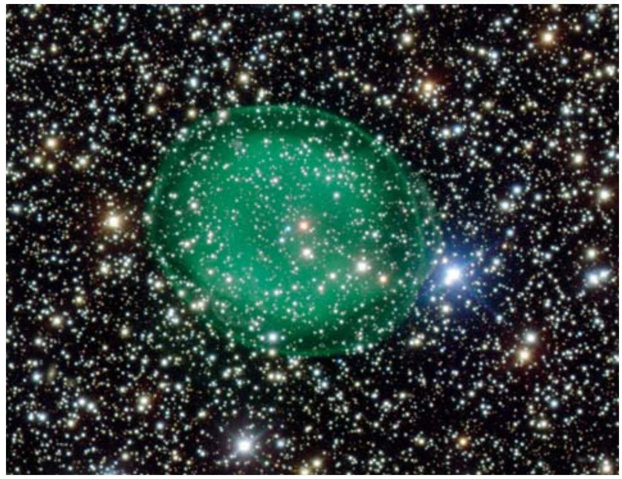
Hubble Space Telescope images show that the bright part of Kohoutek 4-8 has a barrel shape spanning roughly 0.7″ × 0.5″. There are also extremely faint, north-south ansae. According to a 2011 paper by Raghvendra Sahai and colleagues in *Astronomical Journal*, K 4-8 is a young planetary nebula. Youthful planetaries are still small, perhaps a couple tenths of a light-year across, a major factor in K 4-8's diminutive size in our sky.

The observations with the 130-mm refractor were made at one of my astronomy club's observing sites, whose sky is a fair amount darker than mine at home. When it clouded over that night, I packed up my equipment — so of course, the sky cleared again. I begged views through the 5-inch refractors of fellow club members Greg Nowell and Pete Fernandez for the remaining planetary nebula on my observing list, **Minkowski 1-59** (PK 23-2.1 or PN G23.9-2.3). I've also observed it with 6-inch and 10-inch reflectors. Summing up our observations, I'd say that at magnifications of 200× or so, the nebula is a tiny, faint disk with averted vision but tends to look stellar with direct vision. An O III or narrowband filter may help.

Look for Minkowski 1-59 in a 19′-tall L of stars that leans northeast. Delta Scuti marks the end of the L's base, and three evenly spaced stars (magnitudes 8.5 and 9.8) dominate the L's back. You'll find M 1-59 one quarter of the way from the back's middle star to its southwestern star.

Let's finish our tour with the diamond-dust cluster **NGC 6649**, located 41′ northwest of the deep-yellow, 5.1-magnitude star HD 171391 (SAO 161632). Through my 130-mm refractor at 23×, the cluster's grainy haze is about 5′ across, with a red-orange star at its south-southwestern edge. A magnification of 164× plucks 20 fairly faint to extremely faint stars out of the mist, but NGC 6649 teems with more than 470 stars. How many can your scope resolve? ✦

Uwe Glahn sketched IC 1295 as seen with his 27-inch Newtonian reflector at 293×.



This image of planetary nebula IC 1295 from the Very Large Telescope of the European Southern Observatory shows a dying central star surrounded by a delicate green shell of nebulosity.

Book Review
Tony Flanders

A Paper Atlas for the Digital Age

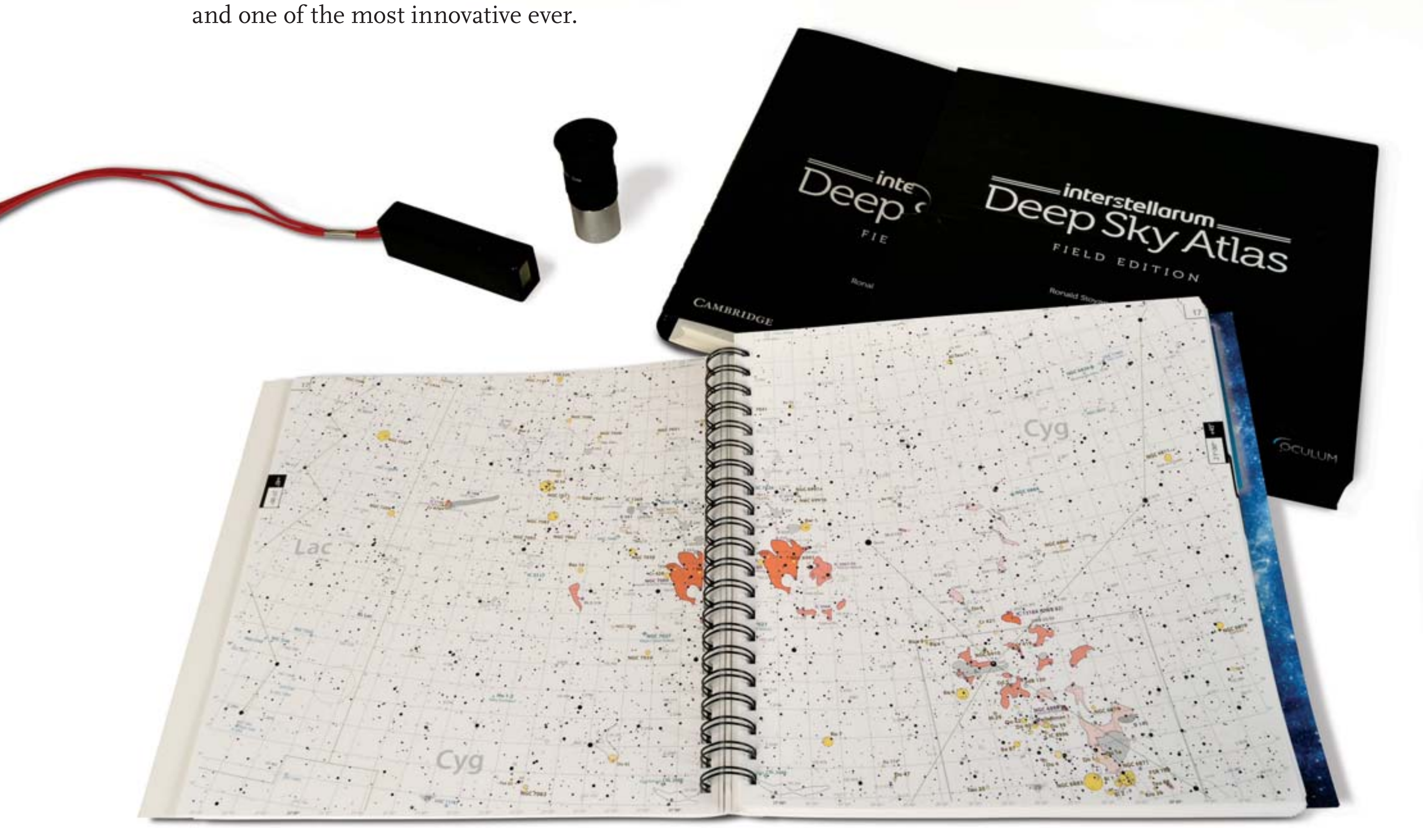
interstellarum Deep Sky Atlas

Ronald Stoyan and Stephan Schurig
Oculum-Verlag GmbH and Cambridge University Press, 2015
Desk Edition, 264 pages, ISBN 9781107503380
$109.99, spiral bound.
Field Edition, 264 pages, ISBN 9781107503397
$244.99, spiral bound.

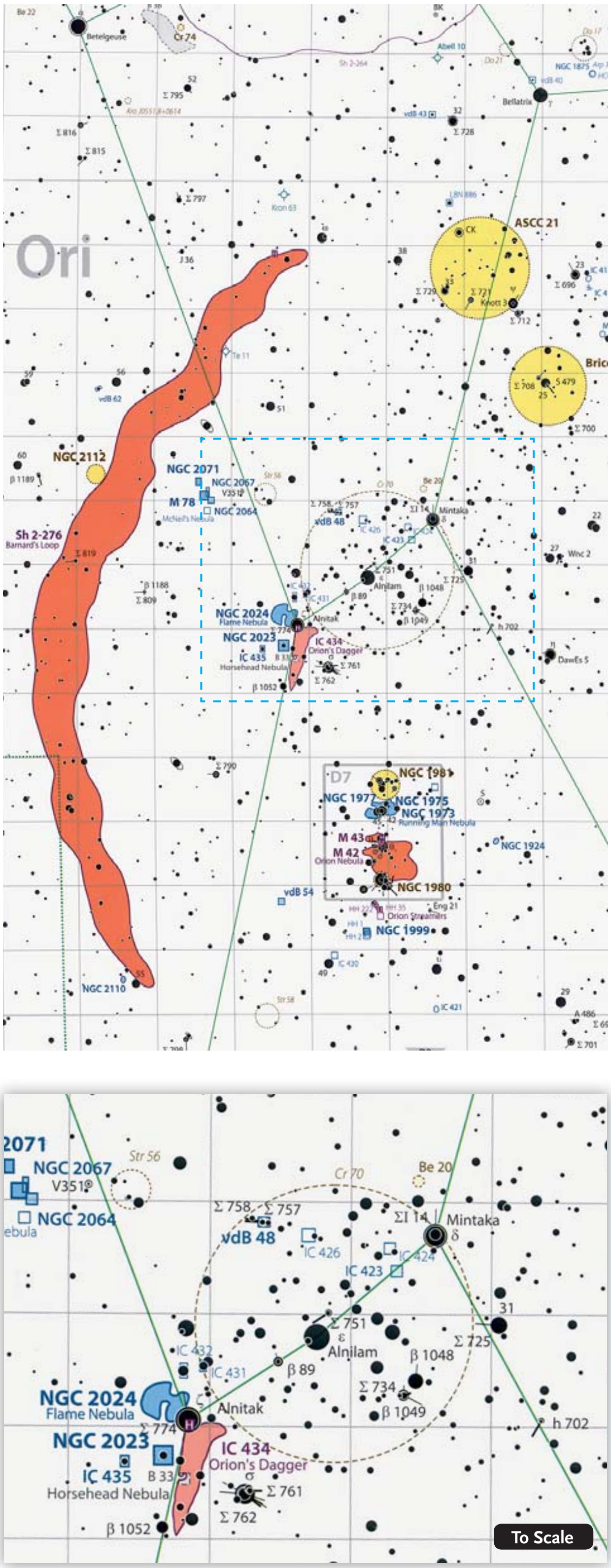
IS THERE A FUTURE for paper star charts in an era of computers and hand-held electronic devices? Cambridge University Press and German publisher Oculum-Verlag seem to think so. They've collaborated to produce an English-language version of the *interstellarum Deep Sky Atlas,* which has been available in German since late 2013. It's the most ambitious star atlas in many years and one of the most innovative ever.

Viewed in daylight, the atlas is gorgeous. It comes in two different editions with identical contents. The Desk Edition is printed on high-quality paper, while the Field Edition is printed on synthetic paper that's waterproof, light, and tough. Facing pages form a single spread when the atlas is laid open on a table, and the wire binding makes it easy to fold the atlas back into single-page format. I found the volume easy to hold next to the eyepiece of a telescope or finderscope by resting it in the crook of my elbow. That's much more convenient than running back and forth between the telescope and

At 28.7 × 28.5 cm (11.3 × 11.2 inches) and 1.3 kg (2.9 lbs.), the Field Edition is easy to hold next to the eyepiece of a telescope.



S&T: SEAN WALKER



As the chart of Orion shows, the more vibrant the color, the smaller the instrument needed to spot the target. Galaxies are shown in blue, reflection nebulae in a paler blue, planetary nebulae in green, and emission nebulae in salmon with a dark outline. Labels vary in size to reflect an object's visibility.

observing table when doing a complex star-hop.

With thicker, whiter paper, the Desk Edition is indeed slightly easier to read at a desk, while the Field Edition's lighter weight makes it easier to hold next to the eyepiece. The Field Edition will presumably hold up longer against dew, but the Desk Edition is also highly dew resistant. In fact, both editions work very well both day and night.

The color scheme is carefully chosen; it provides extra legibility during the day but also works well by red light. Unlike most recent atlases, this one depicts galaxies as blue, making them quite prominent by red light. Reflection nebulae are shown in paler blue and emission nebulae in a salmon color with a dark outline — a useful distinction not made in most star charts. For more of the atlas's many innovative features, see **deepskyatlas.com**.

The atlas aims to show all deep-sky objects visible through a 12-inch scope under dark skies, as well as some fainter objects of special interest. That adds up to 15,000 deep-sky objects, which are plotted on a field of 200,000 stars down to magnitude 9.5. In addition to the 114 basic charts, there are 29 detailed charts for crowded fields. Deep-sky objects are divided into four classes depending on the aperture needed to see them: 4 inches, 8 inches, 12 inches, or more. The objects' labels are scaled according to their visibility class, just as major cities get larger labels than do small towns on a conventional road map.

To see how this all works out in practice, I took the atlas out for two long nights of observing with my 12.5-inch Dobsonian. For comparison, I also brought my 7-inch tablet running a planetarium app.

The planetarium app is excellent in many ways. It's tremendously flexible and configurable, and it can display far more stars and deep-sky objects than any paper atlas ever produced. However, paper charts have compensating virtues. They're easier to read without losing dark adaptation and considerably easier to manipulate with cold fingers. Above all, paper can show far more information at a single glance.

The *interstellarum Deep Sky Atlas* charts are printed right to the edge of the page, with zero wasted space. (Page numbers and coordinate grid labels are overlaid on the corners and edges, in the space that's overlapped between adjacent maps.) Each two-page spread has 10 times the area of a chart on my 7-inch tablet. That allows a spread to cover more than 500 square degrees of sky, or about the size of an average constellation. Constellation lines are drawn in, which made it easy for me to get my initial fix on the sky. The stars plotted in the atlas are an excellent match to those visible through my 8×50 finderscope, so I could then star-hop to the correct low-power telescopic eyepiece field in just a minute or two. I could see all relevant levels of detail at a glance in the atlas. That would require several pan-and-zoom operations with my planetarium app; my tablet's tiny screen can show either the big picture or the small, but not both together.

It was only when I arrived at my destination that I started to appreciate the atlas properly. My usual observing style is to seek out a specific object and then poke around and see what else is worth looking at in the vicinity. That's hard to do with most highly detailed atlases, which show thickets of nearly identical symbols in any crowded galaxy cluster or Milky Way field. The different sized labels in the *interstellarum* atlas bring a crowded field to life, giving a sense of the character and diversity of the individual objects. I could then start with the most prominent ones and work as far down the visibility classes as I liked.

In addition, the atlas marks double and multiple stars with ticks whose length indicates the components' separation, and each of the 2,950 double stars is labeled with its name. I'm a huge double star fan, so this pleases me greatly.

Of course, no atlas is perfect, and due to its huge ambition and originality, the *interstellarum* atlas has more flaws than most. The biggest labels are delightfully legible, but the smallest are pretty hard to read. That's arguably appropriate when you're labeling a very faint object. But I rely heavily on right ascension, declination, and Greek Bayer letters for stars, and those are also in minuscule type. And the atlas never uses leader lines to connect symbols to their labels. That sometimes makes it hard to puzzle out the correspondence in a crowded field.

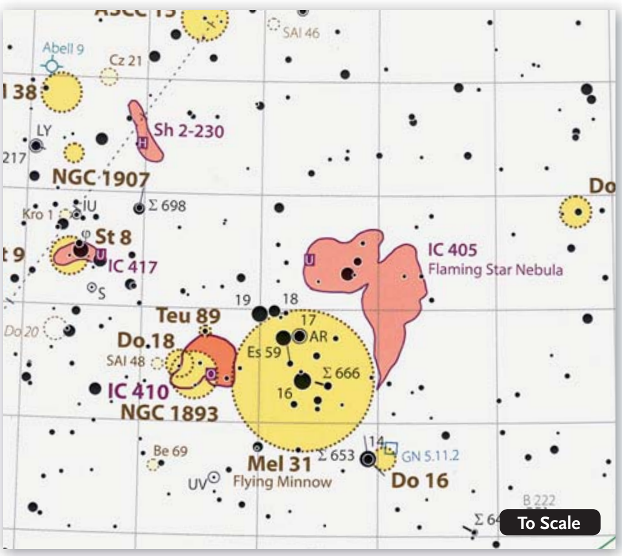
Although the atlas claims to be complete for 12-inch scopes, it doesn't plot all the objects I've spotted with my 12.5-inch scope. For instance, I found six galaxies inside Messier 44 with my 12.5-inch when I was working through the March 2009 Deep-Sky Wonders column. The atlas only plots two — and they're not the ones that I found easiest to see. Nonetheless, the atlas certainly shows almost all objects of interest to me or most other backyard astronomers.

The atlas is very strong on open clusters but possibly goes a little too far in this direction, showing some large, obscure open-cluster candidates with no little or no visual appeal. I would also prefer fewer asterisms and fewer nicknames for deep-sky objects.

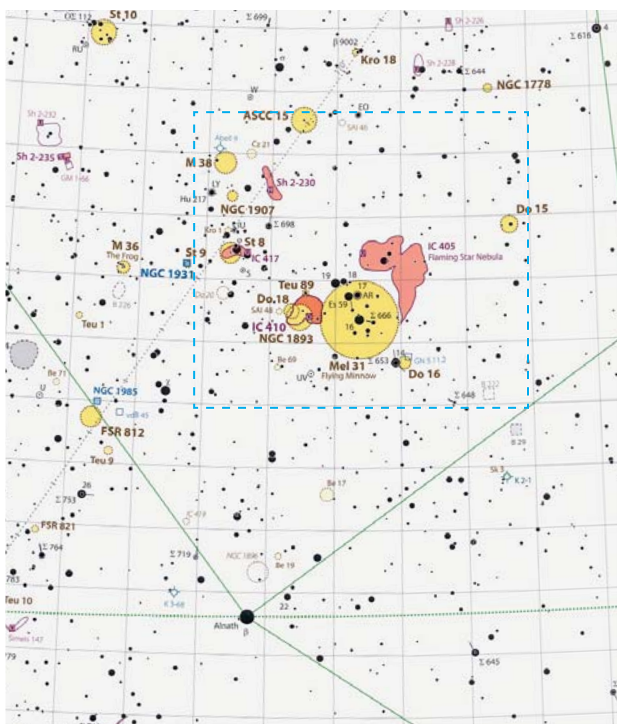
But to some extent this is quibbling. All star charts require choices and compromises. The *interstellarum Deep Sky Atlas* comes very close to maximizing the information that can be shown in a convenient, hand-holdable atlas without compromising clarity. I find that it adds more to my observing sessions than any other printed atlas I've used.

The atlas's biggest limitation is its scale and star depth: they aren't really adequate to pin down the locations of its faintest objects. But that's where my planetarium app comes into its own. If I can't spot my target immediately once I got down to the medium-power eyepiece level, I bring out my tablet, with its inexhaustible supply of faint stars, to help me finish the job. I don't see the atlas and app as competitors; instead I find that they complement each other perfectly — the atlas for the big picture and app for the nitty-gritty details. ✦

***Tony Flanders** produced almost 1,000 star charts while he was an associate editor at* Sky & Telescope.



The limiting magnitude of the atlas is 9.5. As is shown here with Σ666 in Auriga, double stars are marked with ticks, the length of which indicates component separation. Each of the 2,950 double stars included is labeled with its name. Also shown are 1,168 variable stars with a maximum magnitude brighter than 9.0.



 Jerry Lodriguss

Rokinon 16mm f/2.0 Lens

A fast lens for the budget-minded nightscape photographer.

Rokinon 16mm f/2.0 ED AS UMC CS

U.S. price: $364.90.
Available in the U.S. from Adorama (adorama.com)

The Rokinon 16mm f/2 ED lens is a hidden gem among the crowded field of wide-angle APS-C lenses. All photos are courtesy of the author.

WHAT WE LIKE:
Fast, f/2.0 focal ratio
Excellent value
WHAT WE DON'T LIKE:
Only APS-C coverage
Uneven corner performance

ASTROPHOTOGRAPHERS ARE always on the lookout for a new toy, particularly one that promises to expand the horizons of their hobby. For nightscape photographers, a big part of this quest is to find a good lens that can perform well under the stars while fitting into their budgets: quality camera lenses can often cost upwards of $1,500 or more.

The Rokinon 16mm f/2.0 ED AS UMC CS lens is a wide-angle lens designed specifically for cropped sensor (APS-C format) DSLR cameras, and it promises to perform like a big-bucks lens for a small-bucks cost. This bargain-priced, manual-focus lens touts sharp stars across its entire 69.7° × 49.9° field of view. It accepts 77-mm threaded filters.

Rokinon lenses are manufactured by Samyang in South Korea and sold under a variety of additional brand names, including Bower and Vivitar. The lens comes with a front and rear dust cap, a petal-style lens hood, and a cloth pouch. It's offered with mounting systems for most popular DSLR APS-C–sized cameras, including Canon EF-S, Nikon F, Pentax K, and Sony Alpha. It's also available for mirrorless cameras, including Canon EF-M, Fujifilm X, Sony NEX, Samsung NX, and Micro Four Thirds. The version I tested used the Canon EF lens mount.

This lens contains 13 elements in 11 groups, with 2 aspherical elements and 1 extra-low-dispersion (ED) element to minimize chromatic aberration. Its UMC coatings also minimize ghosting and flare.

As a manual-focus lens, the Rokinon 16mm has no electronics or motors, so it won't work with some of your camera's automatic exposure settings, such as shutter priority or program mode.

Fortunately, this isn't a concern when photographing the night sky, since these functions generally do not work on the dim subjects of astronomy anyway: you'll mostly be using the bulb setting in M (manual) mode. If you do need to use some form of auto exposure to keep exposures consistent, in most cameras you can use the "A" or "Av" (aperture priority) mode in which the aperture is fixed and the shutter speed is varied based on the light in your scene.

The aperture ring is also manual, and you'll need to set it to your desired focal ratio before an exposure. The lens has half-stop click detents, ranging from f/2 to f/16. For astrophotography, you'll probably never use this lens stopped down past f/5.6.

Also note that lens information, including focal length and aperture, are not recorded in the EXIF image metadata when using the Rokinon 16mm, so be sure to take notes while you are shooting with this lens.

Stellar Performance

As most astro-imagers know, photographing star fields is an unforgiving test for any lens, and reveals almost any lens aberrations. While most lenses will record good images with daylight subjects, stars are point sources; they'll show every one of a lens's optical defects, particularly when you view the image at full resolution.

I tested the optical performance of the Rokinon 16mm f/2 lens at various apertures, from f/2 to f/5.6, on star fields in the Milky Way. I alternately placed the bright star Vega in the center of the field and at each of the corners to check for reflections and other defects.

Like the majority of modern lenses, the focus travel range on the Rokinon 16mm allows it move slightly beyond the infinity (∞) mark on its printed scale. Users shouldn't assume that reaching the end of travel will naturally be at infinity focus, where stars would be sharpest. Live focus mode at full magnification in your DSLR should be used to establish critical focus, particularly when shooting at f/2. I found the focus ring to be very smooth and easy to use; there's no play or backlash as is often the case with many inexpensive lenses. To ensure focus wouldn't slip during the night I placed a small piece of tape on the focus ring to lock it in place, particularly since I intended to handle the camera multiple times throughout the night.

The Rokinon 16mm f/2 ED is available in multiple configurations to fit a wide variety of camera bodies. Its compact design allows the use of Astronomik's clip-in filters for astrophotography.

Wide open at f/2, the lens has remarkably good performance. Stellar images display a small amount of coma and astigmatism in the frame's corners and some minor lateral chromatic aberration as well, but not as much as many wide-angle zoom lenses display when used at full aperture.

As a rectilinear lens design, the Rokinon 16mm attempts to keep straight lines in the scene also straight in the image. But it does suffer from some minor radial barrel distortion, causing straight lines to curve as they move away from the center of the frame. In astrophotography, barrel and geometric distortions are unnoticeable in single frames and are often automatically dealt with when assembling mosaics in most panorama software.

A bigger issue with a fast lens like this one is vignetting — noticeably darkened corners of an image compared with the center of the frame. The Rokinon 16mm exhibits

The lens includes front and rear caps and a petal-style lens shade.

about one stop of vignetting when used wide open at f/2 but improves quickly when stopped down to f/2.8, and the effect is virtually undetectable by f/5.6. Flat-field calibration can remove this effect when shooting at f/2, and some software programs, including *Adobe Photoshop*'s RAW converter, can also compensate for the effect.

When shooting constellations on a tracking mount, stopping down to f/5.6 is not a problem, but smaller apertures don't let in as many photons. You'll need to expose about eight times longer at f/5.6 to achieve the same signal-to-noise ratio as an image shot at f/2.0.

This quality-versus-speed dilemma is a trade-off with any lens: fast focal ratios produce higher signal with reduced image quality, while slow focal ratios generate superior optical performance at the cost of longer exposures. Which compromise is better depends on the situation. For example, a fast focal-ratio lens used wide open is best for meteor photography, because it will record fainter meteors. In fact, even exceptionally bright meteors appear notably less impressive when shooting at slow focal ratios. This is because aperture is an important factor in meteor photography — you can't simply expose longer for an object that is gone in a second or two. Likewise, great comets and bright aurorae will photograph better at f/2: you'll get more of the comet's faint tail in a short exposure and keep its nucleus from trailing, particularly in untracked exposures, when compared with slower lenses. And rapidly changing aurorae also require short exposures to avoid blurring.

Time-lapse nightscapes on a fixed tripod or a moving track will also benefit from the Rokinon's fast f/2 focal ratio — you'll record the star clouds and dust lanes of the Milky Way in shorter exposures, as well as some large, faint nebulae, particularly if you're shooting with a modified camera.

Optical Alignment

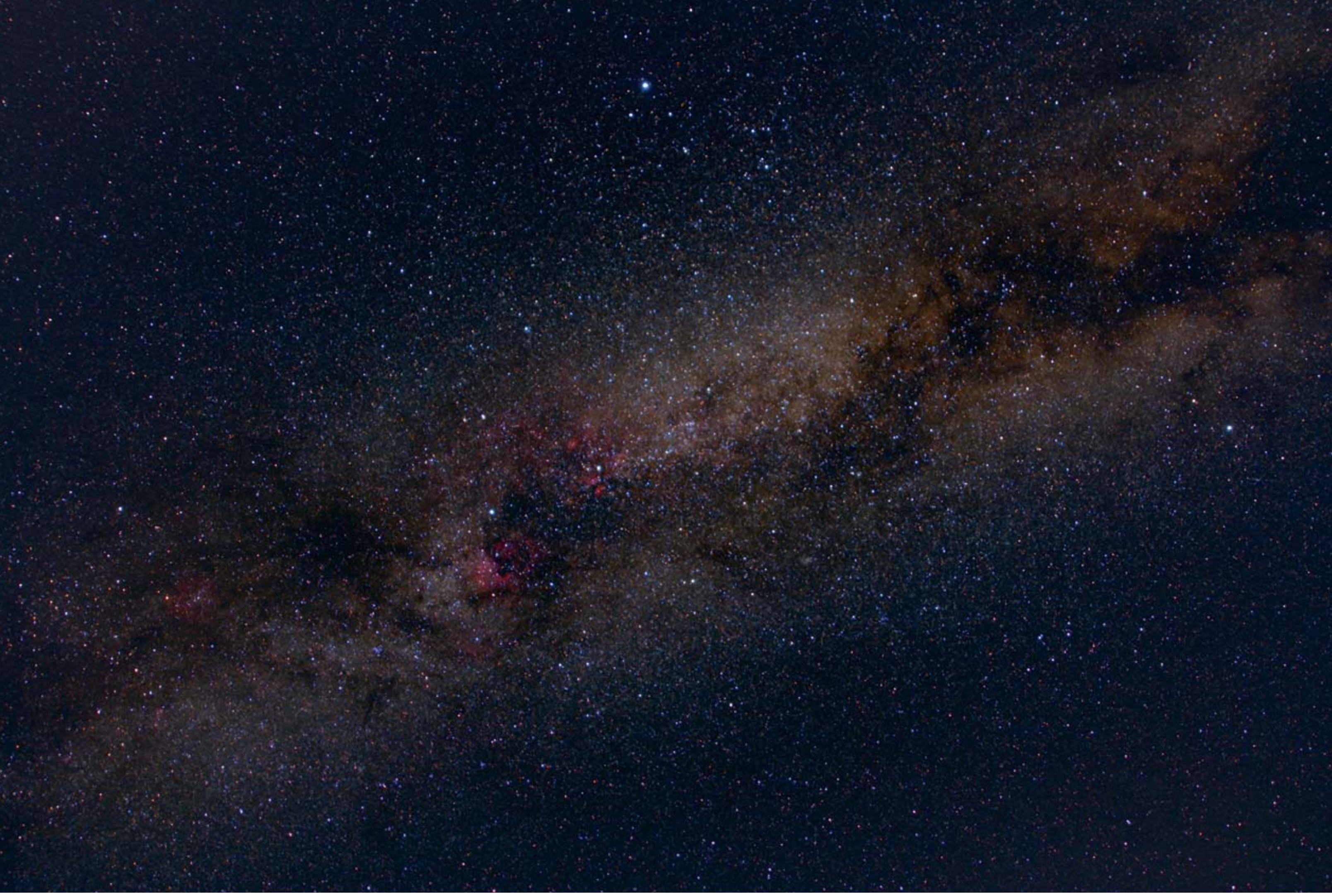
One issue with inexpensive lenses you should watch out for is the misalignment of one or more optical elements. Misalignment reveals itself as asymmetrical coma around the stars throughout the field. I tested two samples of the Rokinon lens, and both were very similar, though neither was perfect. It's hard to say if this sample-to-sample variation is representative of the model.

While my testing revealed some asymmetrical coma, I still judge the performance to be very good. I've seen similar results in top-of-the-line lenses that cost many times more than the Rokinon, and these minor distortions quickly disappear when stopping down the lens (see the test strips below).

Imaging with Filters

Since I live far from truly dark skies, I often use a clip-in light-pollution filter sold by Astronomik (**astronomik.com**) that installs inside the camera body behind the lens, just in front of my Canon DSLR's mirror box. While clip-in filters won't work with certain lenses that extend too far into the camera body, my Astronomik CLS-CCD clip-in filter worked well with the lens, even at f/2. But the combination did produce slightly increased optical aberrations in the frame's corners. Stars became radially elongated away from the center of the frame, and the filter also introduced lateral chromatic aberration, with the stars splitting into three non-overlapping red, green, and blue images. Note that these effects are caused by

Star images recorded with the lens and a Canon T5i DSLR exhibit minor asymmetrical coma around stars across the entire field, which is reduced when you stop the lens down. The top strip displays stars in the center of the frame shot at f/2, f/2.8, f/4, and f/5.6. The second strip shows the stars at the extreme top-left corner of the same frames.



Top: In practice, the lens produces excellent images when shot wide-open under a dark sky. This image taken at f/2 shows round stars nearly to the extreme corners. Total exposure was 116 minutes (232 × 30 seconds) with a modified Canon T3i at ISO 1600. *Below:* The author shot himself on a night of deep-sky imaging using the lens with Orion and Taurus setting in the western sky.

the *filter* and are not a fault of the lens itself. Again, post-processing software can greatly mitigate these issues.

The Bottom Line

The Rokinon 16mm f/2.0 ED AS UMC CS lens is an excellent wide-angle lens for astrophotography. Its price, mechanical quality, smooth manual focus, and impressive optical performance, even wide open at f/2, make it a very attractive lens. The fact that it is completely manual is no drawback at all for aurorae photography and astrophotography.

I highly recommend this lens for astrophotography, particularly for specialized subjects such as meteor showers, bright comets, aurorae, and time-lapse starscapes. Stopped down it has excellent performance for wide-angle nightscapes as well as constellation and general Milky Way photography. ✦

Jerry Lodriguss is an author and photographer based in suburban New Jersey. Follow his blog at **astropix.com**.

Summer Stars

ESA / HUBBLE & NASA

Seek out these targets for small scopes and binoculars in August's evening sky.

Tony Flanders

I started stargazing by learning the constellations with my unaided eyes and 7×35 binoculars. My first "serious" telescope was a 70-mm refractor, which I used primarily near my home in Cambridge, Massachusetts, one of the most densely populated cities in North America. So I've always had a soft spot for bright stars and star clusters, which look great through small instruments and don't suffer too much from light pollution.

As luck would have it, August's evening sky has many bright clusters that lie near prominent stars, making them especially easy to locate. Let's start at 2.8-magnitude Lambda (λ) Sagittarii, also known as Kaus Borealis. Lambda isn't outstandingly bright, but it's instantly recognizable as the northernmost star of the Sagittarius Teapot. Telescopes show that Lambda has an orange or reddish hue. It is, in fact, an orange-red (class *K*0 IV) subgiant, a star that's transformed most or all of the hydrogen in its core to helium.

Just 2½° northeast of Lambda, readily visible in the same binocular or finderscope field, is **Messier 22**, the

IN THE NEIGHBORHOOD ***Above:*** **M22 is the brightest globular in the Northern Hemisphere's sky; at 10,500 light-years away, it's also one of the closest globular clusters to Earth.**

third-brightest globular star cluster in the sky, and the brightest that's visible from the northern U.S. (Omega Centauri and 47 Tucanae, the brightest and second brightest, can only be seen south of latitudes 43° and 28° north, respectively.)

Messier 22 also ranks very high in the quality that makes globular clusters so spectacular: the number of individual stars visible through a telescope. Amateur astronomers sometimes describe globulars as "resolved to the core," but we can only see the tip of the brightness pyramid; the overwhelming majority of any globular's stars are too faint to see even in the biggest backyard scopes. The closer the cluster, the more stars reach the visibility limit of any given telescope. M22 is the fourth-closest confirmed globular cluster, just 10,500 light-years from Earth, so it's one of the easiest globulars to resolve in small telescopes.

For those of us at mid-northern latitudes, M22 never rises very high in the sky, so it suffers badly from atmospheric extinction. And in cities and suburbs, it lies deep in the bright skyglow that cloaks the horizon. But M22 is bright enough to overcome those obstacles. Even from my local city park, less than 5 miles from the center of Boston, Massachusetts, M22 is visible through 7×35 binoculars, stands out as a very bright fuzzball in my 70-mm refractor, and displays several pinprick stars over a bright haze through my 7-inch Dobsonian at 120×. (See my online Urban and Suburban Messier Guide at **tonyflanders.wordpress.com** for detailed observations of this and all other Messier objects from bright-sky sites.) Under dark skies, M22 is faintly visible to the unaided eye. It displays about a dozen individual stars through my 70-mm refractor at 60× and at least 100 stars through my 7-inch Dob at 120×.

While you're in the neighborhood, take a look at **Messier 28**, which lies just 1° northwest of Lambda Sagittarii, making it even easier to locate than M22. M28 would be famous if it lay anywhere else in the sky, but it pales in comparison with M22. That's because it's 30% less luminous and 70% farther from Earth. M28 is a little difficult to detect in small instruments under urban and suburban skies, but it forms a fine binocular field together with Lambda and M22 under dark skies. Through my 7-inch Dob, M28 appears quite bright regardless of light pollution, but I can only resolve a handful of its stars with that scope even under pristine dark skies.

The closest confirmed globular cluster is **Messier 4**, just 7,000 light-years from Earth. It's even easier to locate than M22 and M28, because it lies just 1.3° due west of Antares, the bright red star that marks the heart of Scorpius. But easy to locate and easy to see are two different things. According to the online database by William E. Harris of McMaster University at **physwww.mcmaster.ca/~harris/mwgc.dat**, M4 is the second-brightest globular observable from my latitude, just a hair brighter than Messier 5 and Messier 13. But it's very large and diffuse, with an apparent area 2½ times bigger than M5's. That means that M4 has low surface brightness (intensity), so it's easily swamped by light pollution. M4 is one of those paradoxical objects that's extremely prominent through small instruments under dark skies, but notoriously challenging to novice stargazers in cities and bright suburbs even in the biggest telescopes.

Like M22, M4 is extremely easy to resolve into individual stars. In fact, at 120× in my 7-inch Dob from my local city park, the brightest stars appear more prominent than the overall glow, a very unusual situation for a globular cluster. This is the only globular cluster that Charles Messier was able to resolve; he described it as "a cluster of very small stars" rather than "a nebula without stars."

Antares, the signpost star for M4, is every bit as remarkable as the globular cluster. It's a red supergiant, one of the largest, most luminous, and coolest stars in the sky. It's 600 million miles (almost 1 billion km) across, so big that if the Sun were at its center, Mars and most main-belt asteroids would orbit inside it. Like most red supergiants, it's a semi-regular variable, ranging roughly from magnitude 0.9 to 1.1 over a period of a few years. It's also a notoriously challenging double star, with a 5.4-magnitude companion 2.9″ from the primary. That would be an easy split in a small scope if both stars were equally bright, but the modestly bright companion is tough to tease out from the supergiant's glare.

Alpha (α) Herculis, also called Rasalgethi, is a much

JEREMY PEREZ

FROM THE FUZZ A small telescope resolves many of the stars of M22 to distinct points of light. This sketch represents the view seen with a 6-inch f/8 Newtonian at 120× magnification.

easier supergiant double to split. Although it's the alpha star of its constellation, it's not especially bright — usually around magnitude 2.9, though varying from magnitude 2.7 to 4.0. It's closer than Antares (380 as opposed to 550 light-years), so the fact that it appears fainter than Antares indicates that it's quite a bit less luminous. In fact, Alpha Herculis is at the lower end of the supergiant class, sometimes categorized as a "bright giant" instead.

The easiest way to find this star is to start with nearby Alpha Ophiuchi (Rasalhague), the brightest star in the huge chunk of sky that's bounded by Antares on the bottom, Vega on top, Altair on the left, and Arcturus on the right. Rasalgethi lies just 5° west-northwest of Rasalhague. *Ras* is Arabic for "head," *gethi* is the giant Hercules, and *hague* is Ophiuchus. Indeed, right-side-up Ophiuchus is traditionally shown bumping heads with upside-down Hercules above him.

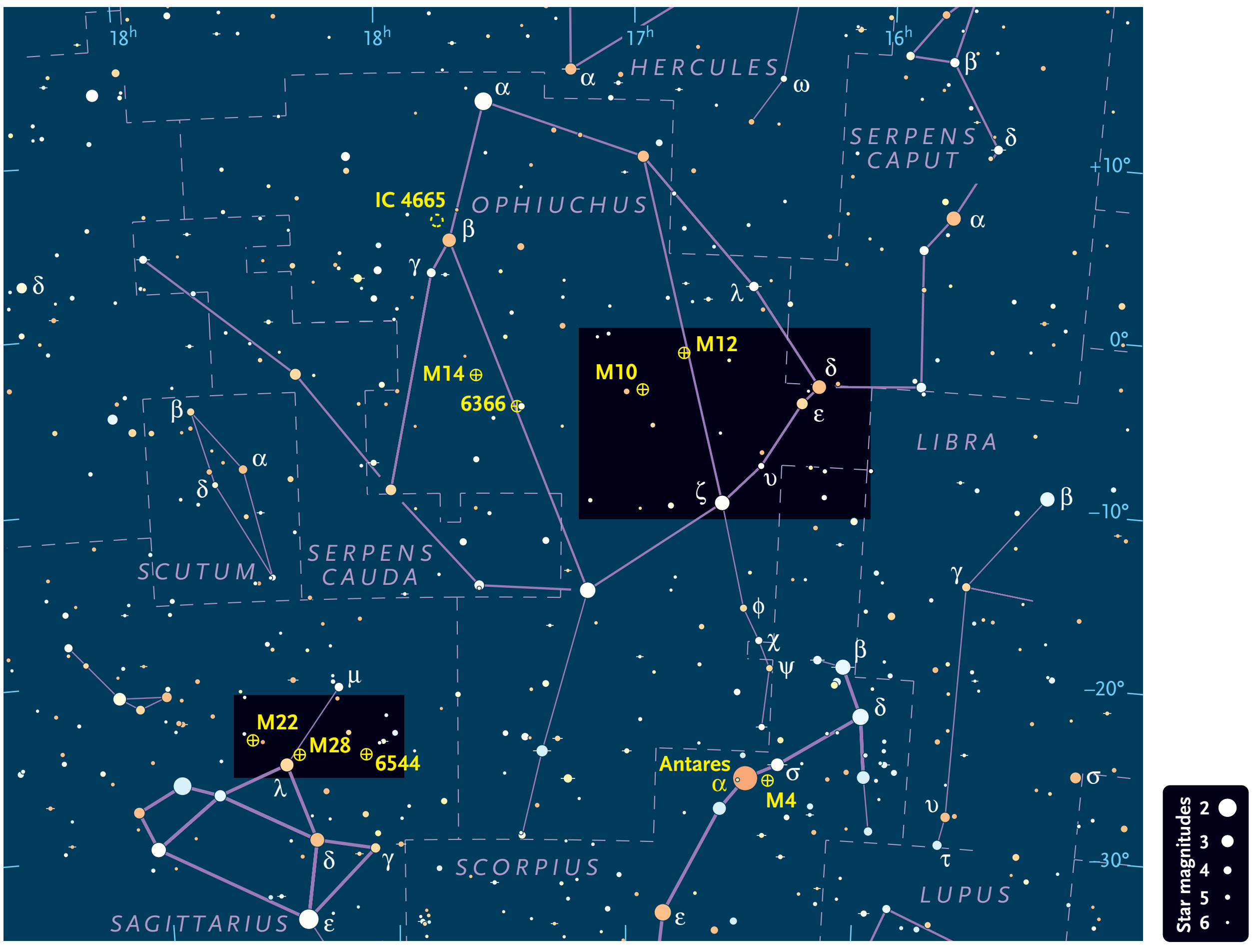
Alpha Herculis is one of the prettiest double stars in the sky. Its 5.4-magnitude secondary lies 4.9″ from the primary, making it an easy split at 100× in any good telescope when the atmosphere is steady. But the stars are sufficiently different in brightness so that they sometimes smear together when the "seeing" is bad. Many people report the fainter star as appearing greenish, which is

STELLAR SPECTACLE ***Facing page:*** **This image from the Wide Field Imager attached to the MPG/ESO 2.2-meter telescope at ESO's La Silla Observatory shows the heart of Messier 4.**

likely due to its contrast with the strikingly red supergiant.

Antares and Rasalgethi are famous, but I didn't know much off the top of my head about Rasalhague. So I turned to my favorite resource, Jim Kaler's website at **stars.astro.illinois.edu/sow/sowlist.html**. Kaler, Professor Emeritus of Astronomy at the University of Illinois, is one of the world's leading experts on stars, and nobody writes on the subject with more clarity, authority, and passion. To Kaler, there are no boring stars; each one has its own unique personality. Kaler's website informed me that Rasalhague is a rather unusual class *A*5 giant. It has probably recently run out of hydrogen in its core, but is now powered by gravitational contraction, and unlike most giant stars, has not yet commenced fusing helium.

Beta (β) Ophiuchi, also called Cebalrai, lies 8° south-southeast of Rasalhague. It's a fairly typical orange-red (*K*2) giant, though Kaler notes that it exhibits strange pulsations over its 13-day period. Moving 1.4° north-east from Cebalrai you will find the open star cluster **IC 4665**, one of the sky's brightest and most attractive

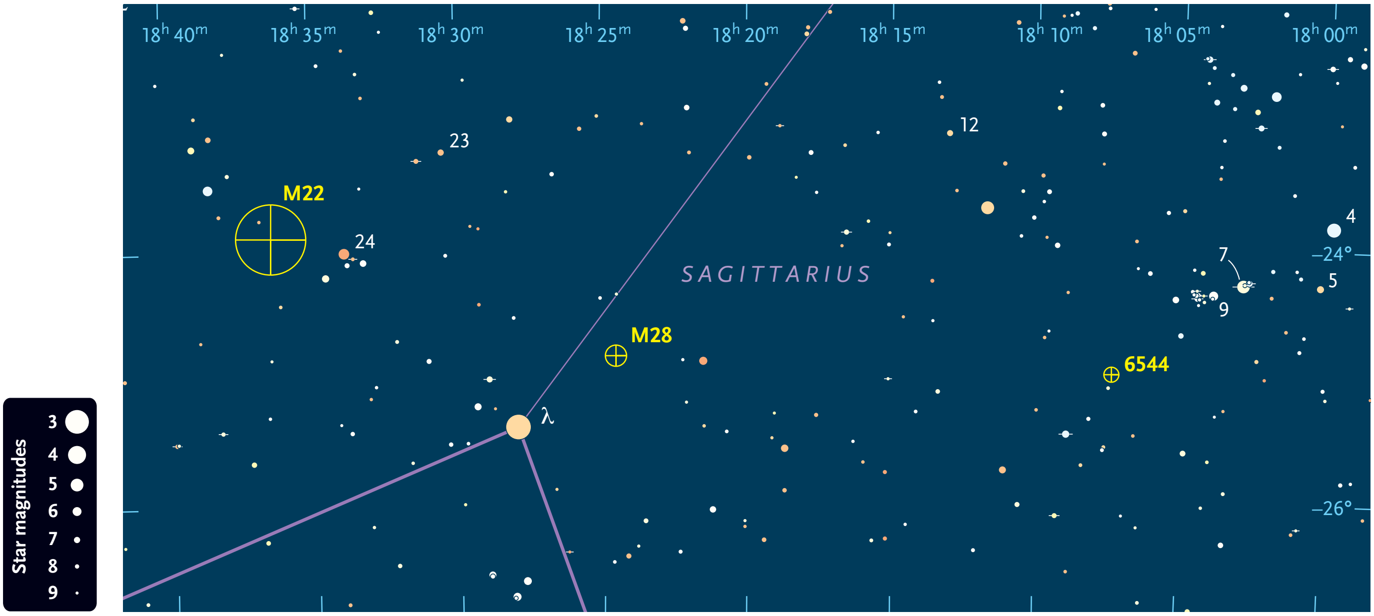


ESO

The Stars of Summer

Object	Constellation	Type	Magnitude (v)	Size/Sep	RA	Dec.	Distance
Messier 22	Sgr	Globular cluster	5.2	24′	$18^h\ 36.4^m$	–23° 54′	10,500 l-y
Messier 28	Sgr	Globular cluster	6.9	11′	$18^h\ 24.6^m$	–24° 52′	18,000 l-y
Messier 4	Sco	Globular cluster	5.4	26′	$16^h\ 23.6^m$	–26° 32′	7,000 l-y
Antares	Sco	Double star	0.9–1.1, 5.4	2.9″	$16^h\ 29.4^m$	–26° 26′	550 l-y
Alpha Herculis	Her	Double star	2.7–4.0, 5.4	4.9″	$17^h\ 14.6^m$	+14° 23′	380 l-y
IC 4665	Oph	Open cluster	4.2	70′	$17^h\ 46.3^m$	+5° 43′	1,400 l-y
Messier 10	Oph	Globular cluster	6.6	15′	$16^h\ 57.2^m$	–4° 06′	14,500 l-y
Messier 12	Oph	Globular cluster	6.1	15′	$16^h\ 47.2^m$	–1° 57′	15,500 l-y
Messier 71	Sge	Globular cluster	8.4	7.2′	$19^h\ 53.8^m$	+18° 47′	13,000 l-y
NGC 6544	Sgr	Globular cluster	7.5	8.9′	$18^h\ 07.3^m$	–25° 00′	10,000 l-y
NGC 6366	Oph	Globular cluster	9.5	8.3′	$17^h\ 27.7^m$	–5° 05′	11,500 l-y

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



targets for small scopes and binoculars. It's a very young cluster, about 40 million years old, and dominated by about a dozen very bright, blue stars. It can be resolved by small, hand-held binoculars and shines well even through heavy light pollution. In telescopes, use the lowest magnification available to frame this huge cluster.

My favorite stars in Ophiuchus are Delta (δ) and Epsilon (ε), also known as Yed Prior and Yed Posterior, respectively. *Yad* is Arabic for "hand," and these stars mark the western hand of Ophiuchus, the Serpent Bearer, where he grasps the neck of Serpens, the Serpent. Prior and Posterior indicate that Delta marches ahead of Epsilon in their slow nightly procession across the sky.

Delta and Epsilon shine at magnitudes 2.7 and 3.2, respectively, and they're just 1.4° apart, one of the closest and best-matched star pairs in the sky. I love star pairs because they're instantly recognizable regardless of their placement and orientation and the level of light pollution. Whenever I see two 3rd-magnitude stars 1.4° apart in the summer sky, I know that they're the Yeds, just as I know that a golden 1st-magnitude star and somewhat fainter bluish star 4.5° apart in the winter or spring sky are Castor and Pollux. The Yeds are particularly helpful in orienting me to the mass of medium-faint stars that form the huge, rambling constellation Ophiuchus.

Despite their proximity in the sky, Delta and Epsilon Ophiuchi are completely unrelated. They're both giants, classes *M*1 and *G*9, respectively, but Delta is more remote and much more luminous.

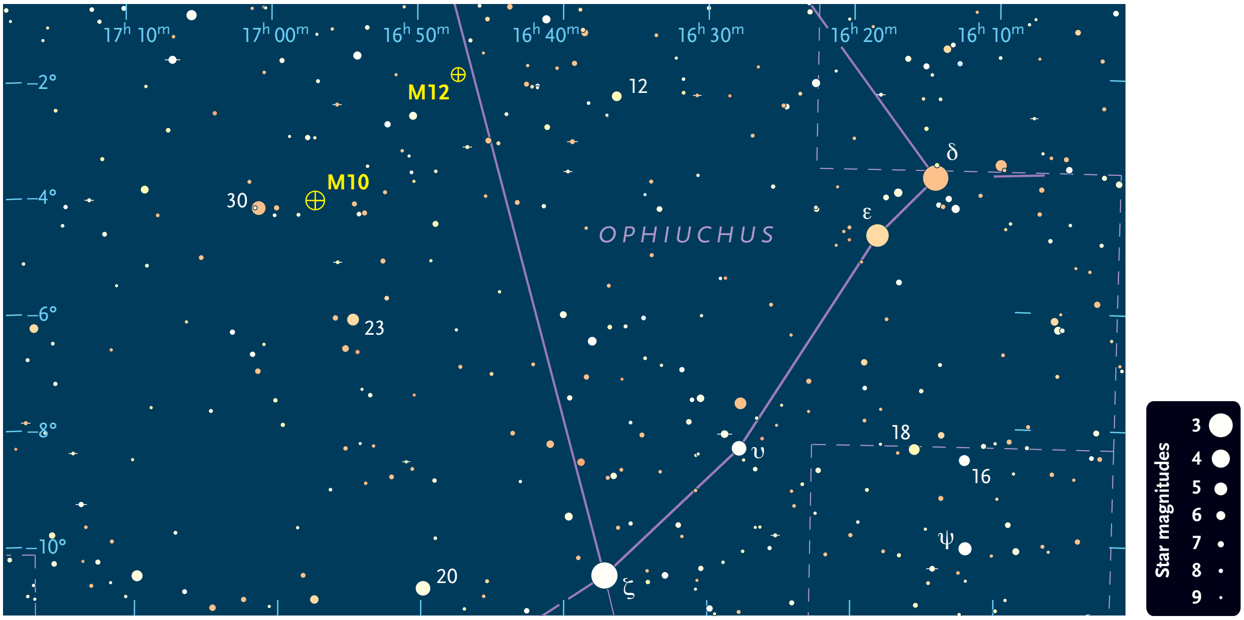
You may have noticed that most of the stars mentioned so far are either giants or supergiants. That's not entirely an accident. Although fewer than 1% of the Milky Way's stars are giants, and fewer than one in a million are supergiants, these categories are represented disproportionately among the naked-eye stars because of their brilliance, which allows them to be visible from great distances.

Together with 2.6-magnitude Zeta (ζ) Ophiuchi to their southeast, Delta and Epsilon Ophiuchi also point the way to the excellent globular clusters **Messier 10** and **Messier 12**. M12 forms an almost equilateral triangle with Delta and Zeta, and the line from M12 to M10 is almost parallel to the line connecting Delta to Epsilon, and about twice as long.

M10 and M12 tend not to get the respect they deserve. They're a full magnitude fainter than blockbuster M5 and M13, but they make up for that by being significantly easier to resolve into individual stars. That's because M10 and M12 lie 14,500 and 15,500 light-years


POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

BLOOM OF YOUTH At 40 million years, expansive IC 4665 is one of the youngest open star clusters in the universe.



from Earth, compared to 23,000 and 24,500 light-years for M13 and M5.

Unlike M4, M10 and M12 are nice and compact, so they stand out well even in light-polluted skies. They're fairly easy to spot in 7×35 binoculars from my local city park, but they're small enough that they're a little hard to distinguish from stars at 7×. They appear quite similar through my 70-mm refractor under urban and suburban skies, though M10 seems a little more concentrated. When I first viewed them through that scope under dark skies, they appeared grainy but not really resolved. But they sprang to life when I cranked the magnification up to 93× — unusually high for that scope — displaying about 15 pinprick stars in each cluster.

This is a case where aperture acts as a good weapon against light pollution. From a suburb, my 7-inch Dob at 120× resolves both clusters about as well as my 70-mm refractor does under dark skies. And under dark skies, M10 and M12 are truly gorgeous through the 7-inch, showing dozens of stars apiece.

August's evening skies are so full of showpieces that it's sometimes hard to choose among them. But the six clusters described here are so easy to locate that I pay each of them a quick visit almost every time I go out to view the summer sky. ✦

Contributing Editor ***Tony Flanders*** *loves to view the deep sky from dark skies, from cities, and everything in between.*

Other Nearby Globular Clusters

M4, M22, M10, and M12 are thought to be the first-, fourth-, tenth-, and twelfth-closest globular clusters, respectively. However, the precise order isn't clear. The far-southern globular NGC 6937 is listed as the second closest, but best estimates put it just 5% farther than M4, which is probably within the error of measurement. Also, some researchers think that there are one or two other, closer globular clusters (FSR 1767 and/or FSR 584) that are heavily obscured by interstellar dust and observable only in infrared, which penetrates dust clouds much better than does visible light.

As it happens, three of the other dozen closest are on good display in August's evening sky. The best and brightest of these is **M71**, eight-closest, which lies at the heart of the tiny constellation Sagitta. It's easy to resolve but very sparse for a globular cluster. In fact, it was thought to be a rich open cluster for many decades.

The others are **NGC 6544**, third-closest, which lies 3.9° due west of M28, and **NGC 6366**, fifth-closest, 7.7° east of M10. Both of these are dimmed about 2¼ magnitudes by interstellar dust, and NGC 6366 has the additional liability of being inherently faint and diffuse. But under dark skies both clusters are readily visible in a 6-inch scope and resolvable in a 12-inch.

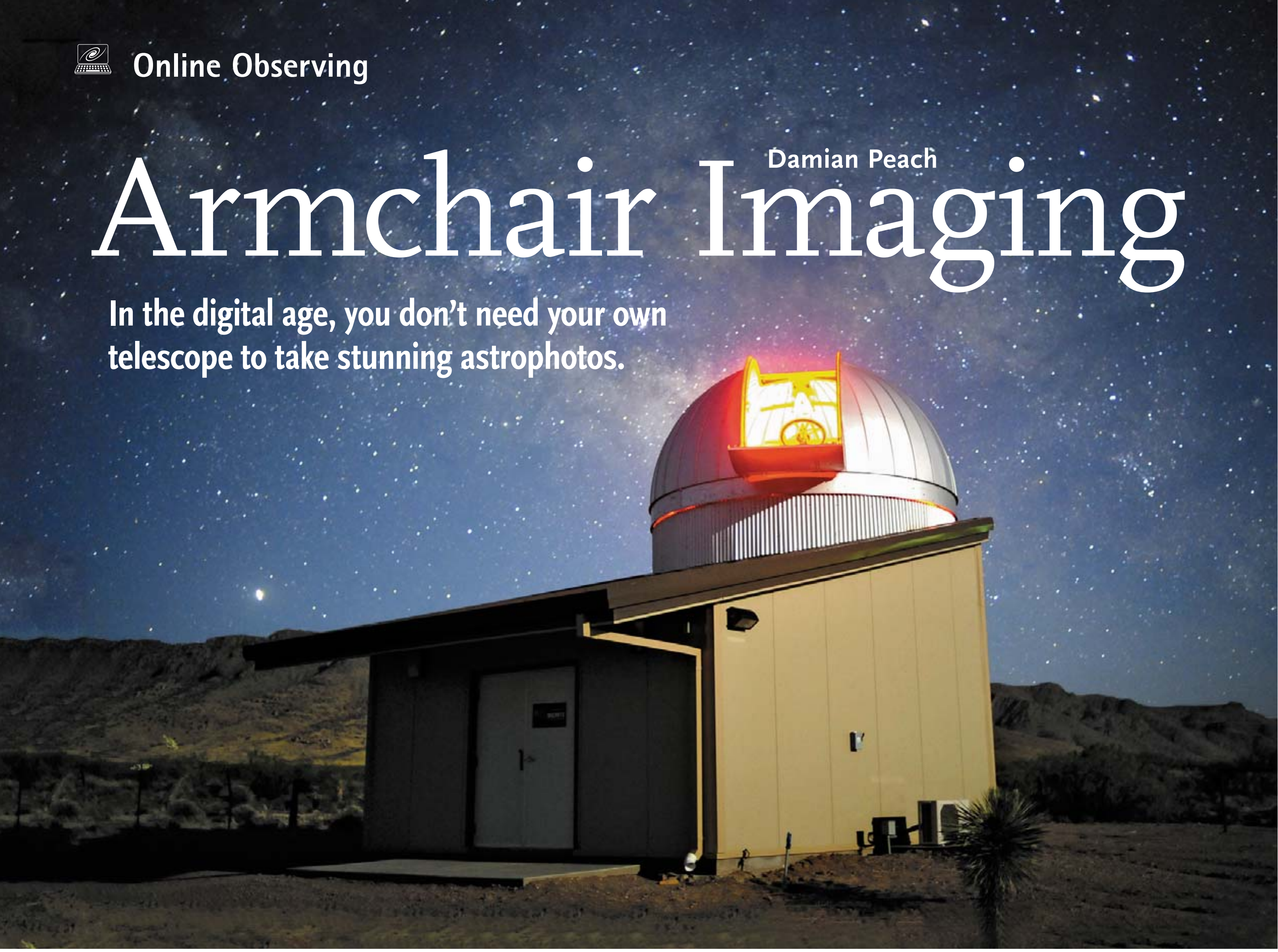
That (including NGC 6937) accounts for eight of the twelve closest confirmed globular clusters. Two of the others, NGC 6752 and 47 Tucanae, are magnificent far-southern objects. And the remaining two, 2MASS-GC01 and GLIMPSE01, are dimmed more than 15 magnitudes by interstellar dust and observable only in infrared.

ESA / HUBBLE & NASA

Armchair Imaging

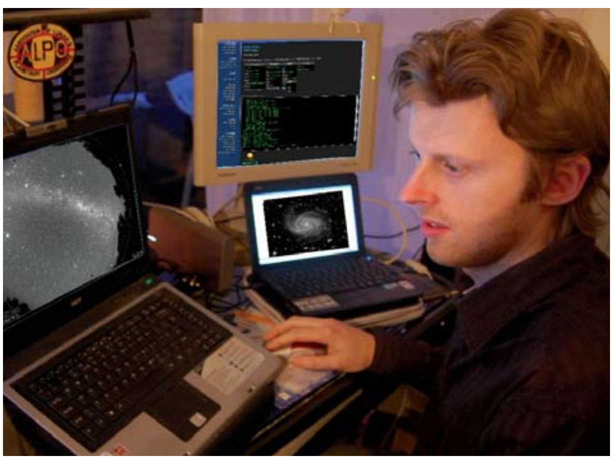
Damian Peach

In the digital age, you don't need your own telescope to take stunning astrophotos.



LIGHTBUCKETS

VIRTUAL DARK SKIES Facilities like the LightBuckets Dome in southern France offer amateurs access to dark-sky conditions that would otherwise require hours of travel or more to reach. *Below:* Author Damian Peach monitors conditions in Australia while imaging from half a world away.



DAMIAN PEACH

The internet age has brought about many radical changes to our hobby, not least to astrophotography. Yet while the advent of large-format CCD detectors has revolutionized both amateur and professional imaging techniques, a second revolution has been occurring in recent years that has totally changed the game for imagers. That is the rapidly expanding access to high-speed internet, which has made it possible to use high-end telescopes in remote locations worldwide.

These days it's not necessary to drive to remote dark-sky sites to take deep, colorful astrophotos. In fact, owning a telescope of your own is no longer a requirement to produce jaw-dropping images. Renting time on remote telescopes via the internet has become an increasingly popular way for both amateur and professional astronomers to conduct observations.

Location, Location, Location

Imaging with telescopes thousands of miles away is quickly becoming commonplace. Several entrepreneurial companies have established "telescope farms" that provide access to sky conditions far superior to what most of us encounter in our own backyards — and at a reasonable cost.

Currently three businesses offer completely independent time on their instruments to provide raw, uncalibrated data: iTelescope (**itelescope.net**), LightBuckets (**lightbuckets.com**), and the Sierra Stars Observatory Network (**sierrastars.com**). Their facilities are located under some of the darkest skies in the U.S., including in New Mexico, Arizona, and California. Additional facilities are open in Siding Spring Observatory in Australia and Europe. Spreading the facilities out worldwide in various longitudes offers users a good chance that an instrument will be available at any given time.

Rental telescopes vary greatly in aperture, focal ratio, and detector size, with each setup specialized toward specific tasks. For example, small fast astrographs such as the popular Takahashi FSQ-106, coupled with large-format CCD cameras, are best suited to capturing expansive vistas several degrees across. These are ideal for shooting large nebulous regions within the Milky Way, open clusters, or the rare bright comet. On the other end of the range are large-aperture instruments geared toward shooting faint galaxies or planetary nebulae, or doing variable-star photometry. Currently there are no telescopes dedicated to planetary imaging, though I'm sure this will eventually change.

As should be expected, each instrument rides atop the best robotic mounts, which offer extremely accurate pointing and tracking. Additionally, most are equipped with a wide range of filters from broadband red, green, and blue to specialized narrowband and photometric filter sets. Some smaller telescopes offer one-shot-color cameras that are great for beginners and deliver surprisingly good results.

Because these services cater to different levels of interest and experience, it's important to understand how to use the equipment to get the most out of it. Most rental facilities available to amateurs are interfaced using *ACP* (Astronomer's Control Panel) by DC-3 Dreams, which was detailed in the May issue, page 64.

To help beginners get comfortable with using remote systems, most providers offer a free trial that lets you use one of the smaller telescopes to take an image. This is a great way to experience firsthand how the service operates without making a major commitment. After that, the hourly rates are very reasonable, especially when you consider the cost of setting up and operating a remote observatory yourself.

It's All in the Planning

To get started, check the services provided by each facility and find the one that best fits your interests. Then create a user account with the provider through its website. Once registered you're ready to book your time. Costs vary depending on the telescope — larger scopes are costlier to operate than smaller ones — and the length of exposure you desire. With some providers the cost is also affected by your membership level.

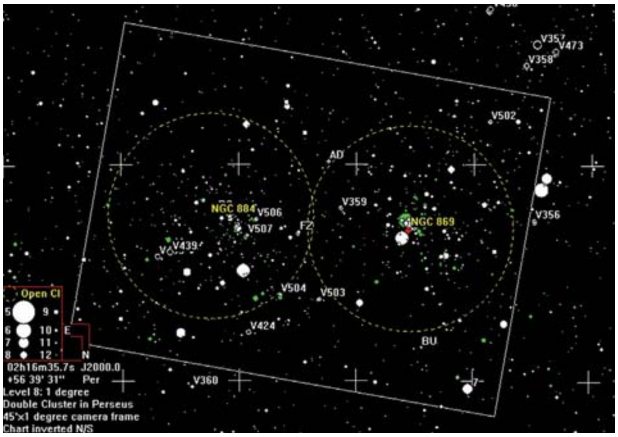
Before simply diving in and taking images, however, it's important to plan ahead so that you aren't wasting precious time and money haphazardly shooting targets. A critical piece of equipment you'll need in addition to your processing software to get the most out of your rental experience is an advanced desktop sky simula-

DRONE SCOPES Using rental telescopes such as the iTelescope observatory at Siding Spring Observatory, Australia, anyone can take gorgeous images of galaxies, star clusters, or comets from the comfort of home.

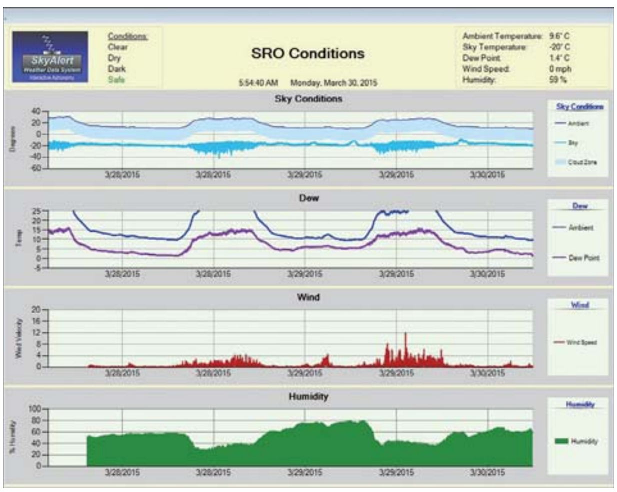
ITELESCOPE.NET

DAMIAN PEACH

VIRTUAL OBSERVING Taking advantage of online telescope services, author Damian Peach captured Comet Oukaimeden (C/2013 V5) as it passed by the colorful Rosette Nebula in Monoceros on the morning of August 24, 2014, without leaving his home in Southampton, England.



PLAN AHEAD Get the most out of your imaging time by planning your compositions using an advanced planetarium program such as *Guide 9.0* (above). This is particularly important when targeting moving objects such as comets and asteroids.



WEATHER MONITOR Each online service offers extensive weather monitoring services.

tor. Software such as *TheSkyX* (**bisque.com**) or *Guide 9.0* (**projectpluto.com**) permits you to input all of the relevant information that the remote facility provides on the imaging system you choose, including the detector size, telescope focal length, and camera position angle. You can then use these specifications to precisely plan your composition and take the best photo within your means. The more options available to you, the better your images can potentially be.

Planetarium software is especially vital for planning compositions involving multiple targets, which you can strategically position in the field of view to help balance your composition. Additionally, moving targets such as asteroids and comets require exact position info, and you want to be sure your exposures are short to keep their movement from compromising your image.

Once your planning is complete, you're ready to book your shots. Many users reserve time slots weeks in advance, so the most popular telescopes can become quite heavily booked around new moon. Reservation schedules on all telescopes are listed in local time at the observatory, so you'll need to convert this to your local time if you want to control the equipment manually during your reservation time.

Once you've logged in, you're greeted with the main overview page of the network. This displays a wide variety of information such as a world day/night map, telescope rental rates, and what instruments are available for use. Live all-sky cameras and remote weather stations monitor conditions at each location. If adverse weather occurs, you will immediately be alerted. Aborted sessions can occur for a variety of reasons, not just cloudiness. High winds or very high humidity can, for instance, result in the observatory closing.

Scheduling an imaging run is almost just like using your own equipment at home. Exposure length, filter sequence, binning mode, and choosing a star to autoguide exposures on can all be customized to your preference. You can also request a live preview JPEG of each exposure as it's completed. This is always helpful as it lets you can check that the images are being captured as planned. Imaging runs can be aborted at any time for any reason.

Most facilities using *ACP* provide a live script from the telescope that tells you exactly what the telescope is doing in real time. Before capturing begins, the telescope will slew to a nearby star and perform a focus routine. This typically takes around 2 to 3 minutes. Occasionally the process will fail, and the telescope will default to using pre-defined filter offsets. While these settings are usually adequate, you can abort the run at any time if you are not happy and want to try again. You aren't charged for routine actions such as focusing or autoguiding calibration; you only pay for time actually collecting data.

DAMIAN PEACH

EASY BOOKING Setting up your exposures through iTelescope.net is easy and intuitive. Note the extensive list of options. *Left:* Remote observing facilities permit users to shoot with the scope of their dreams. This image of M20, the Trifid Nebula, was captured from the iTelescope facility at Siding Spring Observatory in Australia, using a 27-inch PlaneWave CDK700 and FLI PL16803 CCD camera. Total exposure was 1 hour through color filters.

Most telescope systems also "plate solve" the images recorded. This means the operating software matches the star field in the image to an extensive database to ensure the system is pointed precisely where you designated. All rental facilities' pointing is extremely accurate, so if you planned the observations well, your images should look exactly as envisioned.

Once the run completes, the system will automatically log you off the telescope and begin transferring your images to a private FTP user account. You can download these via an FTP client or through a web interface. Regardless of the telescope, data captured during any run is saved in the 16-bit FITS format, which is compatible with any software used for processing astronomical CCD images. Calibration images — dark frames, bias, and flat-field images — are also provided, as well as fully calibrated images that have been automatically dark- and flat-corrected.

Once you have your data, you can process your image like any other astrophoto.

Cost and Benefits

Having been a dedicated amateur for more than 20 years, I initially felt odd being detached from the experience of being out there under the night sky with the equipment while recording my images. However, I've come to appreciate what a tremendously powerful resource these rental facilities are. No longer are truly dark skies reserved for those lucky enough to live at favorable locations far from city lights.

But, of course, this comes at price. The longer you plan to expose to produce an image, the greater your expense will be. This is still comparatively cheap compared to the cost of purchasing a similar setup of your own. Even a modest robotic observatory can be rather expensive to assemble and operate, and it is never truly autonomous; even private remote observatories require support staff to handle problems and routine maintenance.

Remote astronomy has rekindled my own interest in deep-sky astrophotography and comet imaging. It also represents a better value when spending my money on astronomy. I enjoy actually making these observations, rather than investing in a system located under a mediocre-quality sky that can sit idle for weeks and months at a time. Renting remote systems enables you to make very high-quality observations so your money is spent in actually doing astronomy rather than on equipment. This also means you no longer need to be a seasoned imager to produce astrophotos that you'll be proud to show your friends and family. ✦

Best known for his world-class planetary images, ***Damian Peach*** *often images comets and other deep-sky objects using rental observatories worldwide.*

Remote Imaging Facilities

Service provider	Telescopes	Apertures (inches)	Sites	Initial cost	Hourly rate	Website
iTelescope.net	19	3½ - 27	CA, NM, Spain, Australia	free	$35	itelescope.net
LightBuckets	5	4¼ - 33	France	free	$75	lightbuckets.com
Sierra Stars Obs. Network	5	14½ - 32	AZ, CA, Australia	$50	$50	sierrastars.com

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.

▲ SPLENDORS IN AURIGA
John Vermette
Southern Auriga is rich with deep-sky sights. From upper left are IC 110 (Spider Nebula), larger IC 410, and dramatic IC 405 (Flaming Star Nebula). The field is about 3° wide.
Details: *Sky-Watcher Esprit 80-mm ED Triplet APO refractor and SBIG STL-11000M CCD camera with hydrogen-alpha and RGB filters. Total exposure: 9 hours.*

▶ DELICATE SUNFLOWER
Mitch Green
Messier 63, the Sunflower Galaxy, belongs to the M51 group of galaxies in Canes Venatici. This 9th-magnitude spiral, as big as the Milky Way, features many short arm segments.
Details: *TPO 14-inch Ritchey-Chrétien astrograph, SBIG STT-8300M CCD camera, and Baader filters. Total exposure: 4 hours.*

Visit SkyandTelescope.com/gallery for more of our readers' astrophotos.

◂ **DOUBLE IRIDIUM FLARE**

Giuseppe Petricca

The brief, bright glints of sunlight reflecting off Iridium satellites are striking, but capturing two of them in quick succession adds even more drama. The open cluster Melotte 111 is at lower left. **Details:** *Canon EOS 700D DSLR camera and 24-mm lens used at ISO 800. Composite image with total exposure of 6 minutes.*

▾ **AURORA**

Stan Honda

Skywatchers in Longyearbyen, Svalbard, got a double treat on March 20, 2015: a total solar eclipse by day and, 12 hours later, this spectacular "corona" aurora. **Details:** *Nikon D810 DSLR camera and a 14-to-24-mm zoom lens used at 14 mm and ISO 3200. Exposure: 8 seconds.*

◀ **SIGNPOST OF SUMMER**

Kfir Simon

Summer stargazing wouldn't be complete without viewing the 11½-billion-year-old Great Globular Cluster (NGC 6205) in Hercules, 22,000 light-years away, and admiring its hundreds of thousands of stars.

Details: *ASA 12N astrograph and FLI MicroLine 8300 CCD camera with LRGB filters. Total exposure: 1¾ hours.*

▼ **MILKY WAY**

Will Calver

A rare, crystal-clear night in the Cotswolds district, northwest of London, provided this springtime view of the Milky Way rising over the rural landscape.

Details: *Canon EOS 100D DSLR camera with a 11-to-16-mm lens used at 11 mm and ISO 3200. Exposure: 30 seconds.*

▲ **NORTHERN CONVERGENCE**

Juan Ignacio Jimenez

Straddling the Cassiopeia-Cepheus border is the aptly named Lobster Claw Nebula (Sh2-157). Bright, compact NGC 7538 is at far left and dimmer Sh2-159 at center. NGC 7635, along the bottom, is better known for the Bubble Nebula at its center.

Details: *APM-TMB 105/650 Triplet Apo refractor and QHY9M CCD camera with Baader Hα, O III, and S II narrowband filters. Total exposure: 7½ hours.*

◄ **BUBBLE NEBULA CLOSE-UP**

David Mittelman

Although it looks delicate, the Bubble Nebula has been blown into the surrounding nebula by fierce winds and radiation from a massive *O* star near its center.

Details: *PlaneWave CDK20 astrograph and SBIG STX-16803 CCD camera with Astrodon filters. Total exposure: 32 hours.* ✦

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Why Astrology Works

People pay attention to astrology for a good reason. Astronomers should know it.

Did that get your attention? As a *Sky & Telescope* editor who's not shy about explaining pseudoscience to its believers' faces, and ranting about "pathetic woo" behind their backs, I'm treated with a certain caution by the three professional astrologers among my friends and acquaintances.

By "professional" I mean they've cast horoscopes for pay. They apparently give good value; customers come back. They've learned better than to try to give me lame physics woo, such as the stuff you'll hear about our bodies being mostly water and celestial objects raising tides within us. They've been well instructed that each of the millions of pebbles in your yard has a greater tidal effect on your body (water or otherwise) than Jupiter, Mars, or Venus do. (Here's the math: **http://is.gd/pebbletides**.)

And they know I'll also tell them about the many experiments showing that you can take the best professional horoscopes, shuffle them up, and people will deem a random one just as amazingly insightful as their own. Nor can people pick their own reading from a selection more often than chance. The planets have nothing to do with it.

But that's not the point. If you want to get through to your believing sister-in-law or your uncle in Cincinnati, the way to do it is not to argue physics or astronomy, but to explain why astrology works.

I tell this with my own story. When I was in elementary school, I practiced a form of divination that you could call bazookamancy. Back then, Bazooka Joe bubble gum was popular. It came wrapped in a little comic strip about Bazooka Joe and his gang. The wrappers were on the ground wherever kids littered. As everyone knew, when you saw one, you stopped and asked it a question. Then you picked it up and read it. The comic was a parable that answered your question. Often you had to look mighty hard to find your answer. But if you looked hard enough, it was always there.

Even at age 10, I explain, I was smart enough to know that cosmic forces had not placed the comic in my path. It was there because some kid threw it away. But it confronted me with *a random reading*, a random input from outside of myself,

just like a horoscope: an assertion about me and my situation. It forced me to see things from an outside perspective. And that could be a dash of cold water.

Two Bazooka Joe revelations that I remember: a friend was teasing me not because he wanted my attention as my mother said, but because he *actually disliked me*. It was a wake-up I needed. The other: I shouldn't join a group that was planning to get a ladder and climb into a second-story window after school, because trouble was brewing. *As it was*. It took a prompt for me to grasp that.

I've described my practice of bazookamancy to two of my astrologer friends. Each of them lit up and said, "You've got it!" So at some level they know it isn't about the planets, not if one form of divination is as good as another. Any reading or fluke or chance — any *metaphor looking for its referent* — will serve your uncle in Cincinnati just as well.

With that out of the way, he may be more willing to talk about how the planets and tides really work — and maybe how humans work too. ✦

***Alan MacRobert**, a* Sky & Telescope *editor for 33 years, happily participates in solstice drum circles, visionings in clouds, and other forms of woo that stay in their place.*


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