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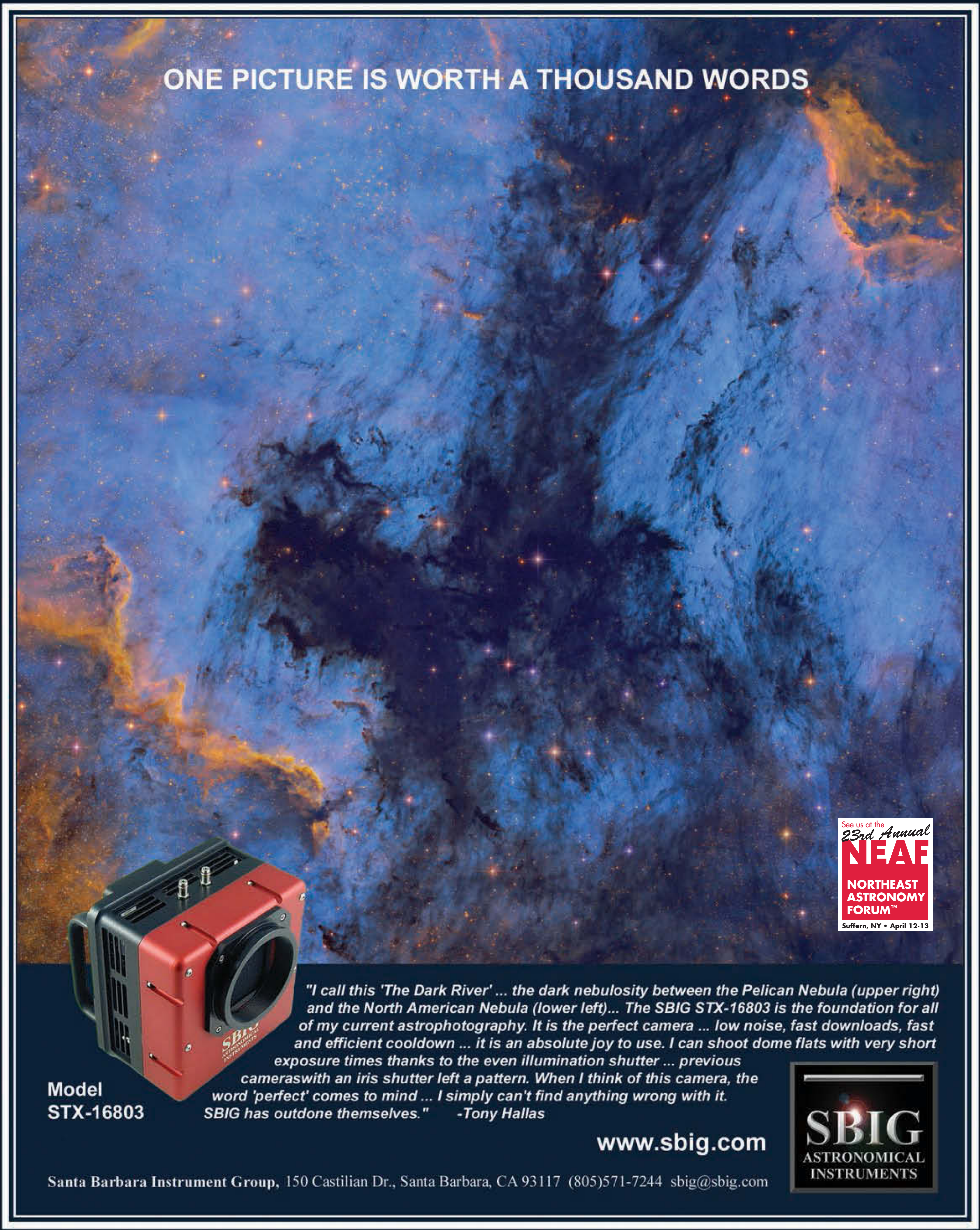

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SKY & TELESCOPE

May 2014 VOL. 127, NO. 5

On the cover: A new meteor shower might pepper our skies with comet debris near month's end.

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Image by Geoff Smith

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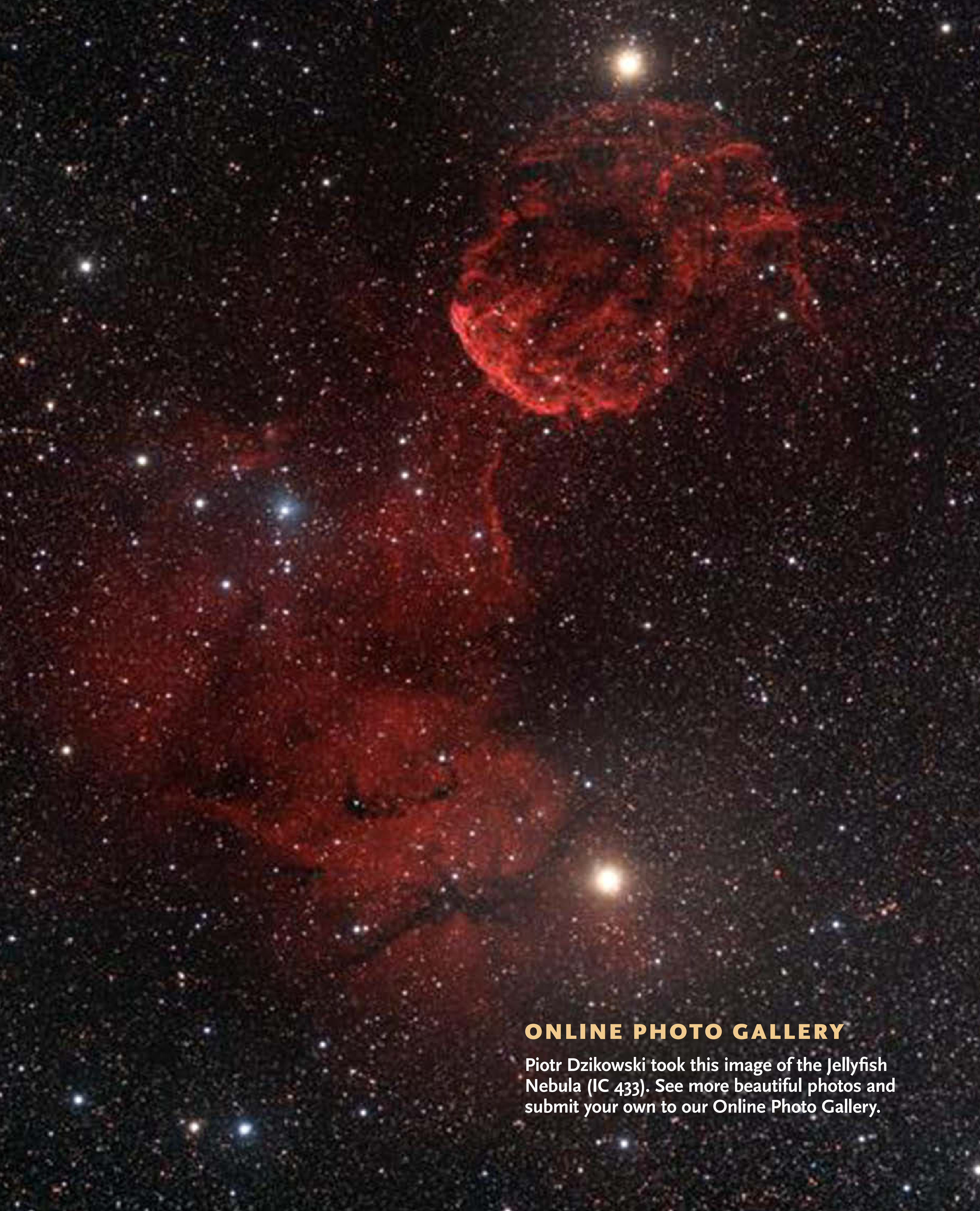

ONLINE PHOTO GALLERY

Piotr Dzikowski took this image of the Jellyfish Nebula (IC 433). See more beautiful photos and submit your own to our Online Photo Gallery.

Robert Naeye
Spectrum

New Ownership, New Globe, New Tours

AS I BRIEFLY NOTED last month, *S&T* has new corporate owners. On January 17th, F+W Media acquired New Track Media, a transaction that involved more than a dozen magazines, and offices based in seven states. This is obviously a big change for us, but my colleagues and I are excited about this transition and think it will be beneficial to *S&T* and the amateur astronomy community.

From the initial meetings with our new F+W colleagues, it's clear that F+W has substantial internal resources and expertise in areas related to internet development, video production, and multimedia. This will enable us to significantly expand our efforts in these crucial areas. As I write these words in mid-February, we're already discussing ideas for future products and services, and a major upgrade to our website. F+W is also a big player in book publishing, so we're expecting to get back into that arena with both printed books and new e-books.

S&T: SEAN WALKER

I also want to assure you that we're not planning any changes to the overall editorial content and technical level of *S&T*. And the same can be said for our other products and services. F+W is asking us to maintain our long-standing values and traditions of accuracy and integrity. F+W has also demonstrated a strong commitment to customer service and fulfillment. We're going to continue our annual issues *SkyWatch* and *Beautiful Universe*. We're confident that F+W will help us stay ahead of the curve as the media world rapidly evolves.

On other notes, I wanted to update you on three exciting developments:

- We have recently produced the first-ever complete photographic globe of the planet Mercury. See the photo above and page 66 for more details.
- We're following up last spring's successful Iceland aurora tour with another tour from October 19–25. Besides evening aurora excursions, Spears Travel and *S&T* have put together an exciting package of daytime activities. Visit **skypub.com/Iceland** for details.
- Working with InSight Cruises, we're in the final stages of putting together a cruise to view the western Pacific total solar eclipse of March 9, 2016. Visit **skypub.com/2016eclipse** for more information. ✦

Robert Naeye
Editor in Chief

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ONE HALF OF THIS IMAGE WAS TAKEN WITH A $2,499 ESPRIT
THE OTHER WAS TAKEN WITH A SCOPE THAT COST TWICE AS MUCH
Imager: Jerry Keith of Fort Worth, Texas (Three Rivers Foundation Volunteer)
Scopes: Sky-Watcher Esprit 100mm EDT f/5.5 World-class 4-inch astrograph
Mount: Takahashi EM200 Temma2M
Guiding: Orion SSAG Magnificent Mini AutoGuider
Camera: Canon 60Da @ 800 ISO
Exposure: 20 light frames and 20 dark frames @ 300 seconds. No flats, dark flats or bias frames were used. 30 light frames and 15 dark frames @ 30 seconds were used for toning down the core of M31. The same processing was used for both scopes.
Actually, the other telescope cost **more** than twice as much as the Esprit, but that's not really the point. The point is, do you see twice as much performance on one side of the page than the other? Take a close look. Are the stars twice as pinpoint? Is the color doubly corrected?
We don't think so.
If you don't think so either, perhaps you should consider purchasing a Sky-Watcher Esprit triplet. At Sky-Watcher USA we pride ourselves on offering products with world-class performance at affordable prices. Because we know there are other things you could be spending that money on. Like a mount. Or a camera. Or even a really, really sweet monster flat-screen television, just for fun.
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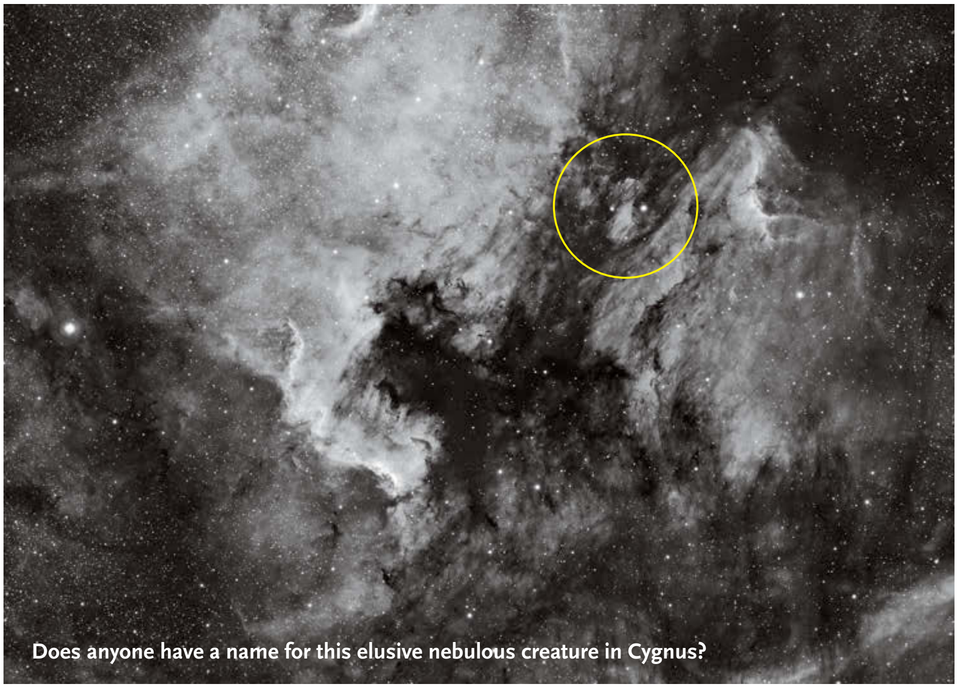


Does anyone have a name for this elusive nebulous creature in Cygnus?

S&T: DENNIS DI CICCO AND SEAN WALKER

Catching the Moon

Thank you for your recent article on transient lunar phenomena associated with the crater Aristarchus (*S&T*: Dec. 2013, p. 54). I was interested to read the evidence that these transients might simply be artifacts associated with poor observing conditions. All three Apollo 11 astronauts observed unusual light emanating from Aristarchus during one of their early lunar orbits on July 19, 1969, as reported in the book *First on the Moon*. Although they did not orbit directly over the crater, they observed this TLP with their unaided eyes and excellent seeing. I should note that Mission Control prompted the astronauts to examine Aristarchus, due to reports of a TLP at that time, and the suggestion could have influenced them. Nonetheless, this observation from a relatively short distance is noteworthy.

Scott Lee
Toledo, Ohio

Reflecting on the iconic Earthrise photograph taken by Apollo 8 astronaut William Anders, Chad Moore wrote, "It's ironic that perhaps the most memorable aspect of our journey outward into space was looking back upon our planet" (*S&T*: Dec. 2013, p. 86). Not so ironic, perhaps, but just the way things work. Here is how T. S. Eliot expressed it in his *Four Quartets*:

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

Bob Prokop
Ellicott City, Maryland

On January 1st, my calendar reminder popped up to alert me to that evening's record-thin Moon (*S&T*: Jan. 2014, p. 52). Around 17:00 local time (0:00 UT January 2nd), I made my way over to a local church, which has an unobstructed view to the west (save for the White Tank Mountains about 15 miles away). I set up my 5-inch f/5 refractor — I call it the "Fredericksen 5," because it belonged to David Fredericksen — on a Super Polaris mount, with a Canon DSLR hanging off the back (IR filter removed).

At exactly 18:00 local time I picked up the lunar sliver in my binos and acquired it in the scope seconds later. If I've calculated correctly, the Moon was 13 hours 46 minutes old at that moment. It set 7 minutes later behind the White Tanks.

I realized as I sat out there drinking in the twilight that I had been so caught up in locating, imaging, and watching the Moon in the eyepiece that I didn't think to make a solid attempt to see it with my naked eye! Oh well, maybe next time.

Jimmy Ray
Glendale, Arizona

Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send e-mail to letters@SkyandTelescope.com. Please limit your comments to 250 words.

Elusive Celestial Critter?

It was with great pleasure that I viewed the extraordinary image of the North America and Pelican Nebulae taken by Richard S. Wright, Jr. (*S&T*: Jan. 2014, p. 76). While enjoying this marvelous image, I noticed that the region between these nebulae contained two stars of similar brightness, with a small nebulous patch between them.

One of these stars is 57 Cygni, the very star that Piper Reid targeted for spectroscopic study (*S&T*: Feb. 2014, p. 66). The two stars and the nebulosity between them are also clearly depicted on page 69 of that article (reproduced above).

To me the two stars look like staring eyes, and the nebula looks like the long snout of an animal. Collectively, they have a remarkable likeness to a crocodile's head sticking out of the water and leering at the reader. It's as though the Croc is slowly and purposefully stalking the unsuspecting Pelican.

Has anyone noticed this optical illusion before? Perhaps, due to its stealthy nature, the Croc has eluded detection.

Frank Ridolfo
Bloomfield, Connecticut

The Darkest Night

The review of Paul Bogard's book *The End of Night* (*S&T*: Jan. 2014, p. 42) suddenly brought to mind the most vivid experience I've ever had with the absence of artificial light. This experience occurred some years ago, a few miles outside of the small Alaskan village of Galena on the banks of the Yukon River — a remote area to be sure. As I stood along the frozen river in absolute stillness, utter darkness, and an ambient temperature of about –70°F, the

Milky Way unfolding overhead was stunning and never to be forgotten. Take that in, the rarest of opportunities — and then return to the realities of survival!

Bruce Currier
Dundee, Oregon

Zippy Neutrinos

The article on the IceCube Neutrino Observatory (*S&T*: Jan. 2014, p. 18) notes that supernova neutrinos arrive at Earth before the visible light of the explosion. Does this mean that the neutrinos are formed in advance of visible light? Why does this happen and, if it does, why would there be a significant time difference between the arrival of both types of emission from the supernova? Wouldn't they be instantaneous?

It was a fascinating article and a very interesting description of the efforts under way at such an extreme place. Thank you!

Ted Olsson
West Newbury, Massachusetts

Editor's Note: *The neutrinos* are *formed earlier than the visible light. Neutrinos are produced during the collapse of the dying star's core, and because these particles interact so little with matter, they whiz out through the star's layers and flood into space in a matter of minutes. Photons created deep inside the star can't do this. After the neutrinos are released, the core rebounds, triggering a shock wave that propagates outward. The wave takes several hours to move through the star's interior. The supernova's visible light is emitted when the star's surface starts to expand, which might be either from the shock wave blowing the layers out or from the shock heating the outer layers — or both.*

Educational Start-up Advice?

I am part of a team of people attempting to create the STEM Telescope. We've developed a plan to place a professional-level planetary telescope at the Siding Spring Observatory in Australia. This telescope would see dark skies during class time in the United States. Every participating classroom would then be able to view the scope's images, broadcast live to the students from Australia.

We have a location for the scope, educator support, and some investors, but we haven't raised enough money to fully fund the project. Grant funding organizations such as the National Science Foundation want to see university affiliation, with related research. This drives up the cost considerably, and we want to make the service free for any classroom in the U.S.

Do any of your readers know of funding sources we could approach, or another organization already pursuing a similar goal, that we could join forces with? Our primary goal is to use a robotic telescope to teach a wide variety of science and mathematics topics.

Richard Clements
Alto, Michigan
clementsrb@charter.net

For the Record

✷*February issue, page 50: For the chart of Vesta and Ceres's orbital paths, the asteroid labels are swapped: Vesta should be Ceres and vice versa.*

✷*March issue, page 57: NGC 2129 lies 42′* west *of 1 Geminorum, not east as stated.*

✷*April issue, page 55: Lunar apogee occurs April 8, 15^h UT; perigee is April 23, 0^h UT; other data are correct. Find the full list of 2014 errors at* **skypub.com/errata**.

75, 50 & 25 Years Ago *Roger W. Sinnott*

May 1939

Here-and-Gone Hermes "No human eye ever saw the tiny planet; it may be that no human eye ever will. A diminutive world no larger than a mountain mass came into the earth's neighborhood in space, recorded itself on a few astrophotographic plates, and rushed away again with unconscionable velocity before astronomers could learn enough about it to establish a good orbit.

"The story of Hermes is unusual. It was over a year ago that discovery took place. That was on October 28, 1937. . . . The asteroid has come much nearer the earth than any other one known. . . ."

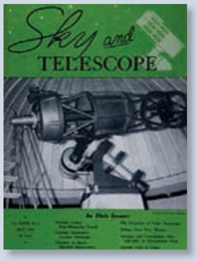
Hermes remained lost until October 2003, when it was recognized on survey images during another close pass. The recovery brought a surprise: Hermes is double! The two bodies, each about 300 meters wide, orbit every 14 hours.

May 1964

Nantucket Program "When I was invited to take over the directorship of [Maria Mitchell Observatory] in 1957 . . . my first concern was to consider what Maria herself would have liked. She had left her beloved island [of Nantucket] to teach astronomy to able young women. I made it my purpose to bring just such girls to Nantucket, to instill in them, if possible, both love for research and respect for the past.

"The old equipment is admirable for training purposes, particularly with endless numbers of variable stars crying for attention."

Dorrit Hoffleit led these Nantucket summer programs from 1957 to 1978, and they're still going strong. Since 1977 they've included men (the first was John Briggs, later an S&T *editor). Today, interns have access to 24- and 17-inch telescopes and do research in cosmology, stellar populations, star clusters, and the history of astronomy.*

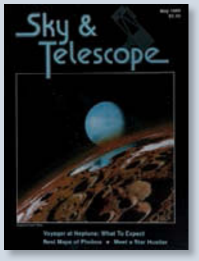


May 1989

North Star(s) "While investigating [stellar motions and precession] with my Atari ST computer, I discovered a most intriguing sight that our ancestors must have witnessed about 425,000 years ago: a very bright double star formed by Aldebaran and Capella. Both stars were nearer our Sun at the time, and they probably appeared brighter than they do today.

"Even more exciting, Capella was only 1° from the north celestial pole, and Aldebaran was about 1° from Capella. Together they formed an incredible double polestar!"

Modern Hipparcos astrometry pushes the double polestar's date back to about 450,000 years ago but leaves more or less intact the details calculated by German amateur Andreas Kammerer. Nobody knows how (or whether) our Homo erectus *ancestors incorporated this amazing sight into their cosmology.*



COSMOLOGY | Missing Galaxy Clusters

The young, massive cluster ICDS J1426.5+3508 contains the mass of as many as 500 trillion Suns. It's rarer than it should be: Astronomers haven't found as many galaxy clusters in the universe as they expected to.

NASA / ESA / A. GONZALEZ (UNIV. OF FLORIDA) / A. STANFORD (UC DAVIS AND LLNL) / M. BRODWIN (UNIV. OF MISSOURI-KANSAS CITY AND HARVARD-SMITHSONIAN CFA)

Astronomers have counted the number of galaxy clusters in the cosmos and found a problem: there aren't enough of them.

Galaxy clusters are essentially big lumps in the distribution of matter in the universe. The lumpiness they reveal grew from matter's lumpiness in the primordial universe, which we see preserved in the minuscule temperature fluctuations in the cosmic microwave background (CMB). With the right theoretical model, astronomers should be able to match up the two sets of observations, explains David Spergel (Princeton).

But as researchers reported at the winter American Astronomical Society meeting, it's not proving that easy. James Bartlett (JPL and APC Université Paris Diderot-Paris 7, France) presented a map of 189 galaxy clusters based on the "shadows" these clusters leave in the CMB as observed by ESA's Planck spacecraft.

The number of galaxy clusters found using this shadow method matches those tallied using X-ray and optical surveys. But it doesn't match what researchers predict based on the clumpiness in the CMB. In fact, as Brad Benson (Fermilab and the University of Chicago) explained in a subsequent talk, the CMB as seen by Planck suggests that the universe should have 2.5 times more galaxy clusters than astronomers actually observe. His team's preliminary analysis of about 300 clusters' shadows in data from the South Pole Telescope also conflicts with Planck's CMB-based cosmology.

There are several potential explanations. One, the tension might not actually be there. If the masses calculated for clusters are too low by a factor of about 1.4, that would resolve the issue. Astronomers often calculate a cluster's mass by extrapolating from its X-ray luminosity, and the assumptions involved might be off.

But masses calculated using X-rays and weak gravitational lensing are consistent within about 10 to 15% of each other, Benson says. The chances of the measurements being off enough to match CMB predictions are less than 1 in 300 at best.

Two, neutrinos might be to blame. Scientists know the particles have some tiny yet still-undetermined mass. Neutrinos four to five times heavier than the lower limit calculated from experiments could erase the problem. Some researchers are currently pursuing this solution.

Three, perhaps scientists' analysis of the CMB temperature map is off, and the primordial matter fluctuations aren't as strong as the Planck team proposes. An independent analysis by Spergel's team suggests such could be the case.

Or maybe something else is going on.

"This is, I think, a wonderful situation," Spergel said at the meeting. In the next year or two, astronomers will either have evidence for new physics or have done away with the tension, he explained. "It's an exciting moment."

■ **CAMILLE M. CARLISLE**

IN BRIEF

Circumbinary Planets Migrated. Binary star systems are dangerous: the stars' powerful tidal forces can easily grind to dust an exoplanet forming close to the binary. Yet astronomers have found planets tightly orbiting their host stars. Using computer simulations, Stefan Lines (University of Bristol, UK) and colleagues determined that most of these planets likely migrate in from farther out. The team created mockups of Kepler-34, a system with a Saturn-like planet circling two Sun-like stars, to analyze the system's protoplanetary disk over time. Catastrophic collisions dominated out to 1.1 a.u., leading to a hostile environment at Kepler-34b's current location. The planet likely formed beyond 1.5 a.u. and migrated inward, the team reports in the February 10th *Astrophysical Journal Letters*.
■ **SHANNON HALL**

Small Galaxies Delay Star Birth. Two teams have independently pinpointed the same key player in postponing galaxy star formation. Simulations have suggested that galaxies should form stars willy-nilly, building up most of their stars in the universe's first 3 billion years. But in real life, observations show that more than half of the stars in galaxies Milky-Way-size and smaller form after 6 billion years. Work by both Philip Hopkins (Caltech) and colleagues and by Sebastian Trujillo-Gómez (New Mexico State University) and colleagues shows that the secret behind this delayed growth lies with a galaxy's youngest, most massive stars. These stars pump out radiation that heats and expels gas, limiting the amount of cold, dense gas available to form stars. But these massive stars only live a few million years. After they've died, the gas they've blown out into the galaxy's halo cools and rains back into the inner galaxy, fueling a new round of star formation. The whole process — young stars, heating, stellar death, cooling — repeats itself. As a result, star formation in less massive galaxies proceeds in fits and spurts, stretching the gas consumption out much longer than would otherwise be possible.
■ **CAMILLE M. CARLISLE**

ASTEROIDS | Mixed Message for Rock Makeup

In the asteroid belt, rogues are the rule, not the exception. Research by Francesca DeMeo (MIT) and Benoît Carry (Paris Observatory) shows that, contrary to previous thinking, this region is a well-stirred mix of rock types and not a segregated population.

A decade ago, scientists thought the composition of the asteroidal region between Mars and Jupiter changed with distance, with asteroids closer to the Sun distinct from those farther out. Space rocks found outside their predicted zone were classified as "rogues."

Thinking of rogues as exceptions worked until recently, when their numbers increased beyond those predicted by traditional models. Compiling a map using data from the Sloan Digital Sky Survey of more than 100,000 asteroids, DeMeo and Carry found rogues throughout the main belt and with a broad range of compositions — some similar to Kuiper Belt objects or Jupiter's Trojans, others that look like fragments of larger, differentiated objects.

A well-mixed asteroid belt supports the current consensus about solar system formation, which is a combination of the Nice and Grand Tack models. These theorize that Jupiter initially wandered as close to the Sun as Mars's current orbit (with Saturn trailing behind), before heading outward to its near-final orbit. The dramatic movement swept out the region between 2 and 4 a.u., scattering about 15% of the asteroids into deeper space. Then, before heading to their current neighborhood, Jupiter crept in a bit and Saturn slid farther out, mixing up the asteroids via orbital resonances.

"It's like Jupiter bowled a strike through the asteroid belt," commented DeMeo. The paper appears in the January 30th *Nature*.

This migration occurred in the first billion of our solar system's 4.5-billion-year history. It explains the current placement of water-poor, heated asteroids and water-rich, primitive asteroids in the main belt, as revealed by the new map.
■ **EMILY POORE**

MISSIONS | Glitch for China's Lunar Rover

Something went wrong as the solar-powered rover Yutu settled in for its second lunar night in late January. It's still alive: after the Sun rose again on the Chang'e 3 mission's landing site in mid-February, amateur radio monitoring picked up a downlink signal from the rover. But the rover's status is unclear.

To survive a lunar night's bitterly cold temperatures (dropping as low as –180°C, or –290°F), Yutu is supposed to carefully hunker down. Its color camera and high-gain antenna are attached to a central mast, which folds down against the rover's body. Once that is secure, one solar panel folds over the instruments like a blanket, tucking the equipment in with a radioisotopic heater to withstand the frigid night. The rover points the other solar panel toward the horizon to catch rays from the Sun when it rises again.

Although reports are vague, it sounds like some part of this origami sequence malfunctioned before Yutu went into full hibernation in January.

Before this glitch, the rover had about 40 Earth days of work under its belt and had logged more than 100 meters (300-plus feet) across the Moon's surface, following its successful landing in December (*S&T*: Mar. 2014, p. 12). The robotic mission also returned panoramas of the lunar surface and the first views of Earth from the Moon in more than 30 years.

Despite the unresolved glitch, Yutu carried out fixed-point observations during its third lunar day, before it went to sleep again on February 22nd. Its radar, panoramic camera, and infrared imaging equipment appeared to functioning normally.
■ **EMILY POORE**

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

GALAXIES | Lighting Up the Elusive Cosmic Web

Astronomers have found a rare cosmic flashlight to illuminate a piece of the universe's large-scale structure, Sebastiano Cantalupo (University of California, Santa Cruz, and Lick Observatory) and colleagues report in the February 6th *Nature.*

In simulations of cosmic evolution, gravity transforms the primordial soup into weblike structures of material, in which growing galaxy clusters are fed by gas that spools in along thin filaments of dark matter. These simulations match the observed universe reasonably well. But although we can see galaxies throughout the universe, we rarely see the webs' filaments. What little visible matter they contain is sparse gas — there are virtually no stars.

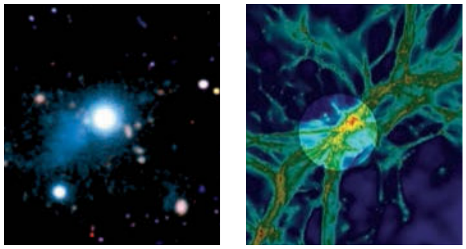
Cantalupo's team observed UM 287, a quasar that lived 3 billion years after the Big Bang. Using the 10-meter Keck I telescope in Hawaii, the team detected Lyman-alpha radiation emitted by cold hydrogen atoms spotlighted by the quasar's intense ultraviolet beam.

This so-called Lyman-alpha blob is twice as big as those previously discovered. And at 1.5 million light-years across, it's far too long to be contained within UM 287's host galaxy.

"I believe the authors make a convincing case that they have indeed observed relatively cold filamentary gas," says Jörg Dietrich (University Observatory Munich, Germany), whose team reported in 2012 the direct detection of a filament of hot gas connecting two galaxy clusters. He adds that his team's results and those in the new study are complementary, because they deal with gas in different states — one hot, one cold. "This will lead to a fuller understanding of filaments and their makeup on all scales."

The new blob appears to store a trillion Suns' worth of mass in its cold gas. That amount is 10 times more than expected from simulations. Dietrich cautions that the discrepancy isn't a big surprise: "universe-in-a-box" simulations tend to watch the cosmos evolve on extremely large scales, with "boxes" about 1 billion light-years across. It's difficult to resolve the small scales on which these blobs exist in simulations. Observations of individual filaments are therefore the perfect laboratory for testing theory.

■ **MONICA YOUNG**



S. CANTALUPO / UCSC (2)

Left: The Lyman-alpha blob (blue fuzz) surrounding the quasar UM 287 (white dot in center) extends 1.5 million light-years, far too big to be contained within the quasar's host galaxy or the galaxy's halo. The blob is likely part of the cosmic web. *Right*: This shot from a high-resolution computer simulation of gas and dark matter shows part of the cosmic web. The square is 10 million light-years across. The intense radiation from a quasar can, like a flashlight, illuminate part of the surrounding cosmic web (highlighted in the image) and make a filament of gas fluoresce.

OBITUARY | Jean Texereau, Master Optician (1919–2014)

Just 3 days after his 95th birthday, Jean Texereau — France's doyen of optical fabrication — passed away on February 6, 2014. For half a century Texereau made, refigured, or tested optics for large observatory telescopes. He also promoted amateur telescope making through the Société Astronomique de France.

But his enduring gift to "glass pushers" around the world was his book *La Construction du Télescope d'Amateur*, which first appeared in 1951. An English edition, titled *How to Make a Telescope*, followed 6 years later. Compared with the American mirror-making books of the 1950s, Texereau's was more sure-footed in its discussion of the diffraction effects in telescopes. The technique he described for evaluating a mirror's figure was a significant advance, mathematically, over those used elsewhere. A subsequent, expanded edition was greatly sought after — before it came back into print in 1984, copies were selling for $1,000 on the second-hand book market.

Texereau's first telescopes were homemade 10- and 20-inch reflectors. Then in about 1946, astronomer Gerard de Vaucouleurs introduced him to André Couder of Paris Observatory. Couder, who headed the optics laboratory there, promptly hired Texereau to be his right-hand man. Among Texereau's projects at the observatory were making the optics of a 24-inch Cassegrain reflector for Meudon Observatory and work on the primary mirrors of the 76-inch reflector at Haute-Provence Observatory and the 42-inch reflector at Pic du Midi.

In 1964 Texereau was invited to McDonald Observatory in Texas to see what could be done about the soft star images of the 82-inch reflector. That summer he performed 17 daily figuring steps on the 28-inch secondary mirror, and after each step he put the uncoated mirror back on the telescope for star tests at night. Before Texereau's arrival, the telescope's overall wavefront error had exceeded 1 wavelength of light. By the time he left, this error had been reduced to just ⅛ wave. ✦

■ **ROGER W. SINNOTT**

Looking Back in Wonder

Seeing Earth as a dot helps prepare us for the exoplanets.

In July 2007 I had a surreal experience — not just out of body, but truly out of planet. Because of a thought I had, something happened above Venus. No, I wasn't on drugs or having a psychotic episode. I was doing science.

I'm on the science team of ESA's Venus Express, a plucky spacecraft that is running low on fuel but still orbiting our sister world, studying a greenhouse climate run amok. By my second team meeting in Leiden in 2006, I was feeling secure enough in my role to propose something new. Would it be possible to turn the spacecraft around, momentarily diverting its gaze from Venus for a look back at Earth? Even if we wouldn't discover anything new about our home planet, what could we discern on a living world such as Earth when we examine it from afar?

In 2007 commands were sent from a radio dish in Spain instructing our little friend at Venus to turn homeward, taking pictures and spectra. Along with shifting colors as the world turned, we picked up whiffs of oxygen, methane, and ozone. My suave French colleague Jean-Loup Bertaux mused at our next team meeting, in Paris: "A congress of Venusians is declaring today that the solar system's third planet contains plenty of ozone in its atmosphere, enough to protect life (if any) at ground level. An audacious conclusion from Venusian scientists: maybe life has produced both oxygen and ozone!"

Curiosity images Earth

NASA / JPL-CALTECH / MSSS / TAMU

Earlier this year the world was given, by NASA's Curiosity rover, the evocative image of Earth as an "evening star" through the frigid, dusty dusk of Mars. We've now snapped long-distance views of Earth from the vicinity of Mercury, Venus, Mars, Jupiter, Saturn, and Neptune, and from the EPOXI spacecraft in interplanetary space. Unlike the classic, evocative views of Earth from the Moon or nearby spacecraft, which reveal the stunning complexity of our world, these distant views reduce us to a wandering point of light, as the visible planets were to our ancestors.

Our missions to other worlds are still risky and rare. So, compared to Earth science, with its firehouse of information, planetology is thirsty for any trickle of data. Paradoxically, this deprivation can help us see the big picture more clearly. If Earth's geological history is a convoluted epic novel, the rest of the solar system is a collection of short stories, each a parable with a different lesson for Earth. And now with the exoplanet revolution we've suddenly learned that our galaxy is brimming with such stories, a vast library we're poised to enter. In reducing Earth's complexity to a single pixel, we gain a hint of the challenge before us as we reach with our instruments across the much vaster distances to planets around other stars.

Comparative planetology is the science that gives us a cosmic perspective on our life-infused world and its current human-induced metamorphosis. We may, increasingly, be running this planet, but if we're going to do a decent job of it, we still have a lot to learn about how planets work. As a planetary explorer, I feel that we have begun this process of looking outward — and back — just in the nick of time. ✦

***David Grinspoon** is Baruch S. Blumberg Chair of Astrobiology at the Library of Congress. Follow him on Twitter at @DrFunkySpoon.*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Weird Weather on Alien Worlds

Astronomers have gone beyond merely counting exoplanets to studying their atmospheres.

Jonathan Fortney

Our solar system is a marvel filled with magnificent specimens of planets. Yet for all its beauty, we now know that it is a poor showcase for the remarkable diversity of known planetary systems. Nature does not have any particular interest in our system's regular ordering of rocky planets on inner orbits and gas giants on outer orbits. The final outcomes of haphazard planetary-system evolution can lead to planets ending up in strange places (*S&T:* May 2013, p. 26), far from where they formed and with properties where our Earthbound intuition fails.

A closer look at extrasolar worlds highlights their diversity. We observe water clouds on Earth and methane clouds on Titan, but we have no solar system equivalent of the clouds of rock dust and iron that we detect on the hottest planets. We live within Earth's weather systems and observe storms on Jupiter and Saturn. But other planets face weather far more extreme, where winds gust faster than the speed of sound and shock waves ripple through the air. How can we understand these worlds when they lie so far outside our realm of experience?

Studying exoplanet atmospheres requires several cutting-edge techniques. And since a planet's atmosphere either samples the nebular gas from which it formed, or arises out of gases liberated from the planet's interior, atmospheric study can do more than just describe current average conditions. Exoplanet atmospheres are the key to understanding planet formation and evolution, including the physical and chemical processes at work in the past as well as in the current day.

Characterizing Atmospheres

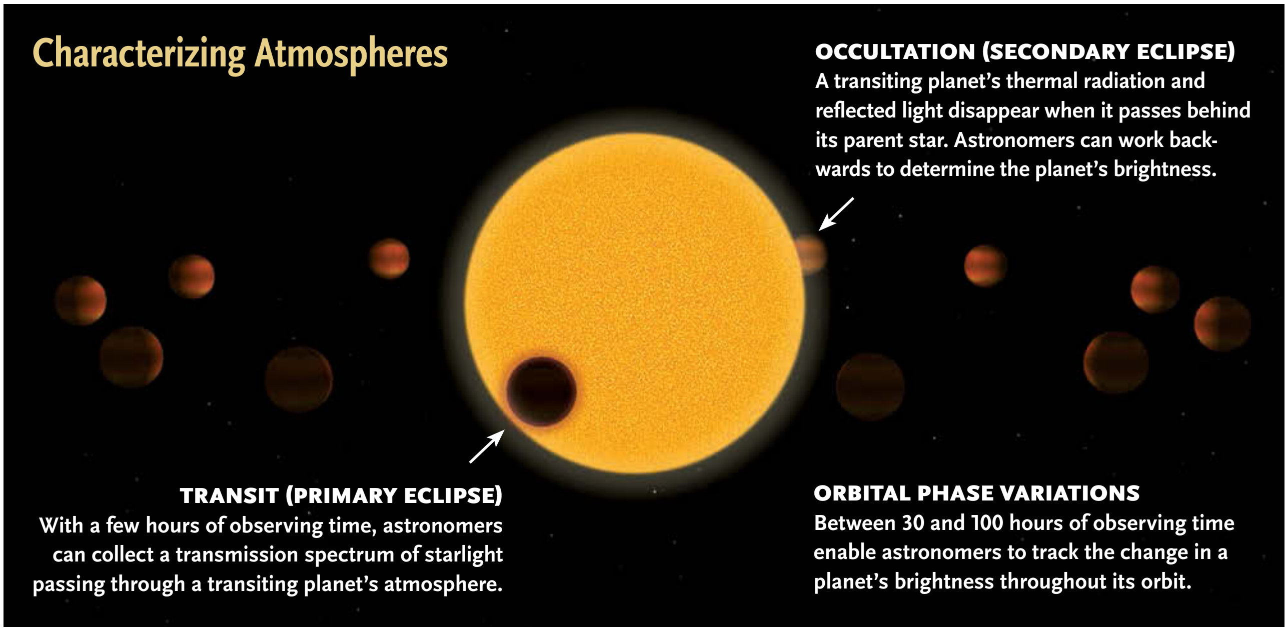
The easiest atmospheres to study are those of transiting hot Jupiters, gas giants that swing across the faces of their parent stars once every few hours or days. Astronomers can capture light emitted from, transmitted through, and reflected off their atmospheres. Astronomers can also image infrared light emitted from young, still-warm planets orbiting very far from their host stars.

A well-studied example of the former is HD 189733b, a hot Jupiter 63 light-years away. Slightly larger than Jupiter, this planet passes in front of its parent star every 2.2 days as seen from Earth, blocking about 2.4% of the star's light. HD 189733b has been observed with every technique in the transiting-planet toolkit.

The first method, which works only for those planets that happen to transit their parent star, is *transmission spectroscopy*: during the transit, astronomers collect the spectrum of starlight that passes through the planet's atmosphere. Water vapor, gaseous metals such as sodium and potassium, and the droplets or crystals that form in clouds can all selectively absorb the host star's light, making the transiting planet's diameter appear larger at some wavelengths. This tiny effect (HD 189733b's atmosphere blocks only about 0.05% of its star's light) is most commonly observed using the Hubble and Spitzer Space Telescopes and large ground-based telescopes.

HD 189733b's transmission spectrum is well known in exoplanet circles for its lack of features — none of the expected molecules absorb the star's light at visible or near-infrared wavelengths. Instead, clouds are most likely absorbing or scattering light across a wide wavelength range. And since the planet's close orbit keeps it simmering at temperatures between 1200°F and 1800°F (between 900K and 1250K), these clouds are unlike anything we see on Earth. The conditions are just right for molecules that are typically gaseous in hotter worlds to condense into liquids and solids — in other words, it's possible HD 189733b has clouds and rain of silicate and iron droplets.

NASA / ESA / GREG BACON (STSCI)



S&T: GREGG DINDERMAN

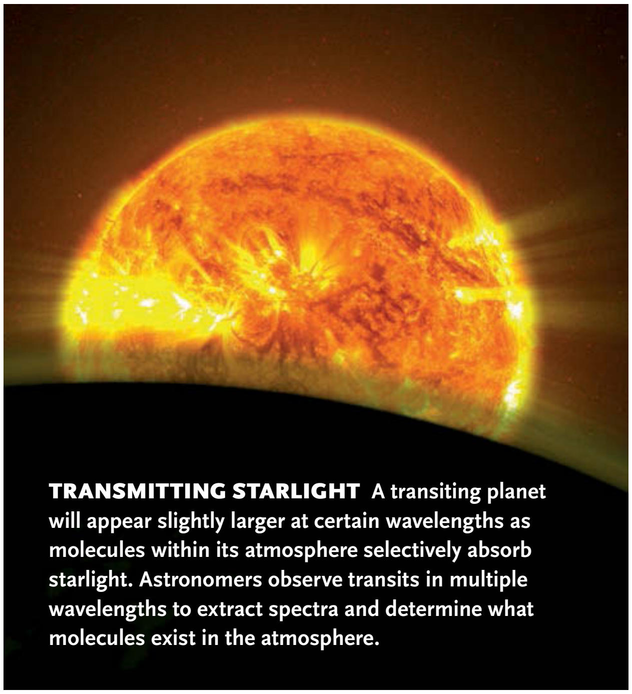
Because Hubble's near-infrared transmission spectra can detect water vapor in the steamy atmospheres of other hot Jupiters, such as HD 209458b, XO-1b, WASP-12b, WASP-17b, and WASP-19b, we know they must be less thick with clouds. But the water absorption features are far weaker than expected for clear atmospheres; layers of clouds or haze are probably common among hot Jupiters.

Another opportunity to characterize planetary atmospheres occurs when a planet passes behind (or is occulted by) its parent star in a *secondary eclipse*. Molecules and clouds in the planet's atmosphere scatter starlight, and that light disappears when the star itself blocks our view. Hubble observations of one of HD 189733b's occultations determined that the planet would appear an azure blue if we could see it up close. The color likely comes from *Rayleigh scattering*, the scattering of light by small particles that is responsible for Earth's blue sky. But whereas molecular nitrogen scatters sunlight, it's not yet clear what molecules scatter the starlight in HD 189733b.

Hot Jupiters, like irons in the fire, emit thermal infrared radiation that also disappears when the star occults the planet. Spitzer has measured occultations of nearly 50 planets to date, detecting absorption features due to water vapor, which is seen in HD 189733b using this technique, as well as methane, carbon monoxide, and carbon dioxide in other planets. Determining the abundances of carbon- and oxygen-bearing molecules might enable us to pinpoint where these planets formed. Planets forming outside the snow line, where molecules such as water and carbon monoxide condense into solid ice grains, might incorporate less of these molecules into their gaseous envelopes than planets that form inside the snow line.

Observing occultations in infrared radiation also allow for the best constraints on a planet's dayside temperature. Spitzer data show that HD 189733b's dayside temperature hovers around a decidedly uncomfortable 1700°F.

Astronomers can learn even more about a planet by measuring its *orbital phase variations*, the changes in thermal emission throughout its orbit. Most hot Jupiters orbit so closely that they become tidally locked, rotating so slowly that they always show the same face to their star. So if Spitzer observes an entire planetary orbit (over the course of a few days for a hot Jupiter), then it will capture thermal emission from both the permanently illuminated dayside and the permanently shadowed nightside.



TRANSMITTING STARLIGHT A transiting planet will appear slightly larger at certain wavelengths as molecules within its atmosphere selectively absorb starlight. Astronomers observe transits in multiple wavelengths to extract spectra and determine what molecules exist in the atmosphere.

NASA GSFC

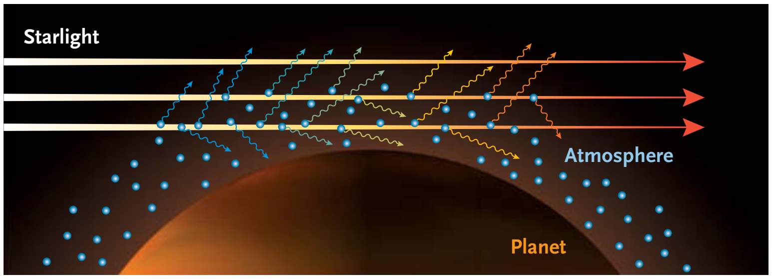
Phase variations for HD 189733b show that the nightside is only about 400°F cooler than the 1700°F dayside, a much smaller difference than expected. Day-to-night winds might redistribute heat between the two hemispheres, but to match observations, they would have to gust at speeds up to 8,000 miles per hour, faster than the local speed of sound. If slower (30 mph) vertical winds help mix up gas layers, then the day-to-night winds might blow slightly less fiercely, at 4,000 mph or so. Three-dimensional atmospheric models show that wind circulation patterns would feature only a few wide jets, rather than the fine bands seen on Jupiter and Saturn, because tidal locking forces hot Jupiters to rotate more slowly, on the order of days rather than hours. Planetary-scale jet streams exceeding the speed of sound could leave parts of the atmosphere riddled with shock waves.

Another method for characterizing atmospheric flow is *eclipse mapping*, a more detailed way of analyzing an occultation. During the beginning and end of a planet's secondary eclipse, the star gradually obscures and reveals a planet's dayside. Monitoring the planet's light at fine time resolution, astronomers can measure deviations from a uniformly bright dayside and map the planet's brightness as a function of longitude and latitude. So far, this data-intensive method has only been applied to our favorite planet, HD 189733b, showing a "hot spot" blown slightly downwind from high noon, but work is underway to extend this technique to several others planets.

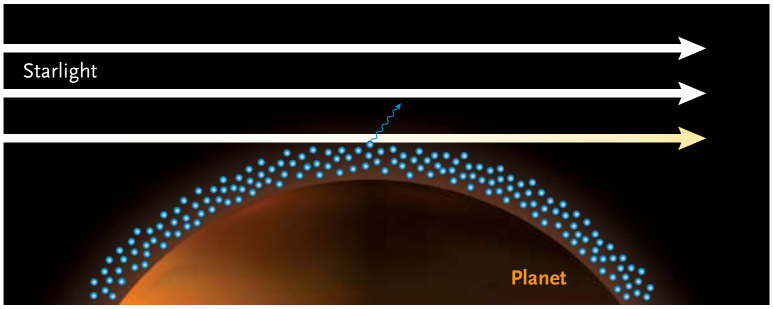
Beyond Hot Jupiters

Hot Jupiters, with their large size and puffy atmospheres, present the easiest targets for the current suite of observing techniques. But more recently astronomers have begun observing a smaller class of planets. These systems are scaled-down versions of hot Jupiters. Between Earth and Neptune in size, these planets circle small, cool stars in tidally locked orbits. No such mini-Neptune (or super-Earth) equivalent exists in our solar system, so we have little to guide atmospheric studies.

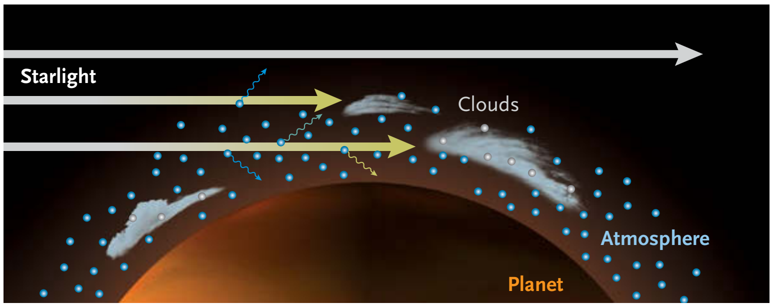
The smallest of these planets observed so far is the mini-Neptune GJ 1214b, which contains the mass of six Earths (though it's only 2.6 times Earth's diameter), and transits a star only 42 light-years away. A wide range of ground- and space-based telescopes have observed the planet's transmission spectrum, including a recent intense campaign by Hubble. Like HD 189733b, the observations show an atmosphere blanketed by thick clouds.



IDEAL TRANSMISSION SPECTRUM As the host star's light passes through a planet's atmosphere during the planet's transit, molecules in the atmosphere reveal themselves by absorbing some wavelengths and not others.

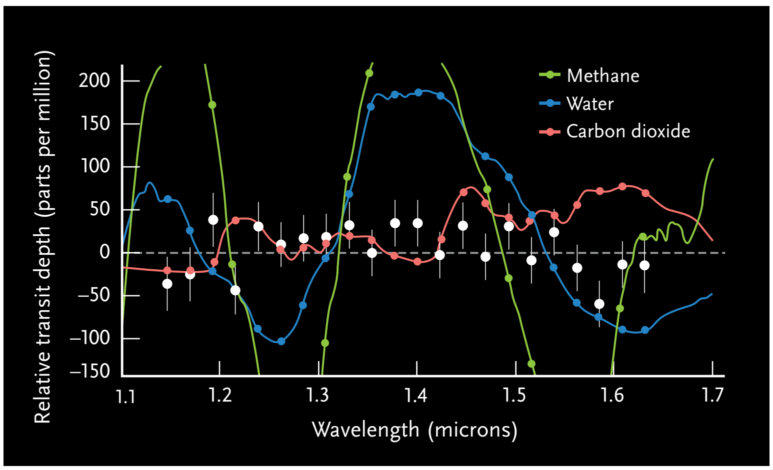


HEAVY MOLECULES But an atmosphere made mostly of heavy molecules, such as water vapor or carbon dioxide, will hug the planet more closely. Most starlight will pass by unabsorbed, and the resulting transmission spectrum will appear featureless. Detecting molecules in such atmospheres is still possible, but requires much more observing time.



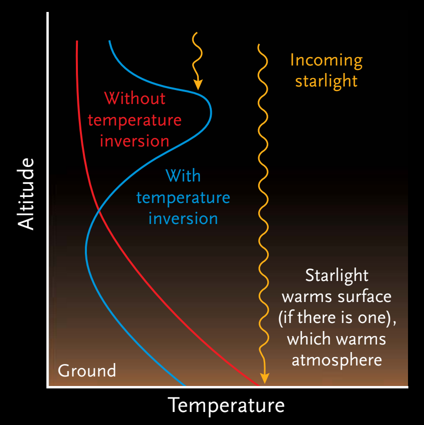
S&T: LEAH TISCIONE; SOURCE: NAOJ (3)

CLOUDY FORECAST It's also possible that thick clouds in the atmosphere might block the host star's light. In that case, even longer observing times will not enable astronomers to detect the atmosphere's molecular imprint.



S&T: LEAH TISCIONE; SOURCE: KREIDBERG ET AL. / *NATURE* 2014

CLOUDS ON A MINI-NEPTUNE Hubble collected GJ 1214b's transmission spectrum (*right*) over the course of 15 transits, showing data (white circles) that lack absorption features. With the long observation, astronomers were able to rule out "heavy" atmospheres of pure methane, water, or carbon dioxide (shown as green, blue, and red lines, respectively). Instead, it must be clouds that block any starlight attempting to penetrate the atmosphere in this wavelength range.



ATMOSPHERE STRUCTURE Temperature generally increases deeper in the atmosphere, but absorbent molecules high in the atmosphere invert that trend, creating a warm layer up high (blue line). Without the absorbing layer, starlight can penetrate to heat the atmosphere from the ground up (red line).

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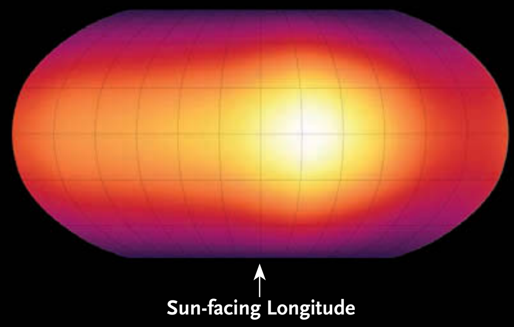


HOTSPOT By observing the changes in HD 189733b's brightness as it orbits its parent star every 2.2 days, astronomers produced this global temperature map. Gusty winds apparently blow the hotspot 30° east of high noon.

NASA / JPL-CALTECH / HEATHER KNUTSON (HARVARD-SMITHSONIAN CFA)

The transmission spectrum shows no absorption features in any wavelength range. Neptune-size planets such as GJ 436b show similar results. Clouds may complicate the characterization of many small planets' atmospheres.

Perhaps the most intuitive method for characterizing planetary atmospheres is to image a planet directly. Planets orbiting too close to their parent stars become lost in the glare of starlight, but direct imaging becomes feasible for planets on wider orbits. Large telescopes resolve planets far dimmer than their parent stars by using a coronagraph to block much of the starlight and adaptive optics to pick out the planet. So far, telescopes have directly imaged 18 planets (that is, objects less than roughly 10 Jupiter masses). The benchmark system is HR 8799, where four gas giants orbit on long periods of 50, 100, 190, and 470 years, respectively. This young system has only been around between 30 million and 90 million years, so the planets radiate at infrared wavelengths due to heat left over from their formation. Infrared spectra and brightness measurements show that water vapor and carbon monoxide probably exist in these atmospheres.

A new instrument, the Gemini Planet Imager on the 8-meter Gemini South telescope in Chile, saw first light in November 2013. It can detect and measure spectra of planets that are up to 1 million times fainter than their host star. SPHERE, a similar instrument on the Very Large Telescope in Chile, will be commissioned later this year. Both of these instruments will open the door to the atmospheric study of cooler, Jupiter-like giants.

The Structure of Atmospheres

You might expect deeper air to be warmer in a planet's atmosphere, with the atmosphere cooling at higher altitudes. But on Earth, ozone in the stratosphere absorbs the Sun's ultraviolet light, warming the upper atmosphere. All of the solar system's gas giants also have temperature inversions; in these cases a layer of haze high in the atmospheres absorbs sunlight at visible wavelengths.

Using Spitzer's occultation observations, astronomers have detected temperature inversions in some hot Jupiters — but far from all. If exotic molecules such as titanium oxide and vanadium oxide are stable on the hottest planets, as they are in the coolest stars, they would absorb starlight in the upper atmosphere. Planets that lack temperature inversion tend to orbit the most active stars, suggesting that intense ultraviolet radiation breaks up the absorbing compounds. But searches for direct detections of these compounds have so far been in vain.

The existence of a temperature inversions affects the deeper atmosphere. If molecules at high altitudes absorb incoming starlight, less starlight will penetrate to lower altitudes. For rocky worlds, the existence of these molecules helps set the surface temperature, along with greenhouse gases that absorb escaping infrared emission. On Earth, the ozone layer only slightly cools the surface, but on Titan, haze high in the atmosphere produces an "antigreenhouse" effect, absorbing sunlight that would otherwise warm the ground and heat the ground-level air. This cools the surface by 16°F. By testing our ability to find antigreenhouse compounds on distant hot Jupiters, we hope to eventually do the same for smaller worlds.

The Atmospheres of Rocky Worlds

A rocky planet's atmosphere — especially its surface temperature and pressure — dictate whether it can support liquid water. Detecting whether life actually inhabits a planet depends on our ability to understand the planet's atmosphere and predict the changes life would produce.

Many of the molecules detected in the atmospheres of gas-giant exoplanets, including water, methane, and carbon dioxide, would also be components of atmospheres hospitable to life as we know it. Take considerable care when thinking of molecules as "biomarkers," features whose presence or abundance requires life. Oxygen and methane can be used as biomarkers on Earth, but only because we know how much of these gases come from a

Exotic Atmospheres

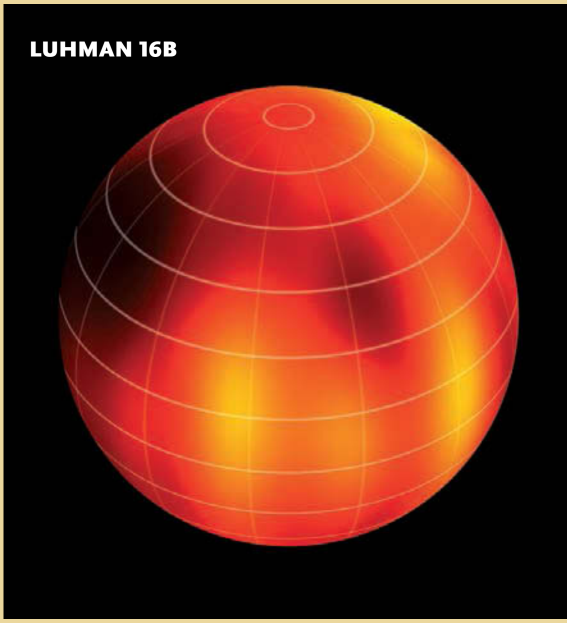
Hot Rocks: The rocky transiting planets Kepler-10b and CoRoT-7b orbit their parent stars so closely that their surfaces heat beyond 2500°F (1600K). Such planets appear to be Earth-like, made of rock and iron. But they are likely tidally locked, so models suggest their permanent daysides could feature lava oceans and a thin atmosphere of vaporized silicates, which could snow onto the very cold nightside.

Steamers: Planets made predominantly of rock and ice that form beyond their disk's snow line, where it is cold enough for water to freeze solid, might later migrate closer to their star to become "ocean planets." A deep layer of liquid water would cover such a planet's surface and water vapor would dominate its atmosphere. 55 Cancri e, a super-Earth on an extremely short-period orbit, could be such a world.

Seasonal eccentrics: We experience seasons on Earth because its axis tilts relative to the orbital plane, not because of its slightly elongated orbit. However, exoplanets often have far from circular orbits; their average eccentricity, or elongation, is around 0.3, compared to Earth's 0.0167. In the most extreme case, the gas giant orbits with an eccentricity of 0.97, similar to Comet Halley. In this case, the energy hitting a planet will vary by a factor of more than 4,000 throughout the orbit. But even at an eccentricity of 0.3, it will still vary by a factor of 3½. We can expect many exoplanets to undergo extreme seasonal changes compared to the relatively steady climates of the solar system.

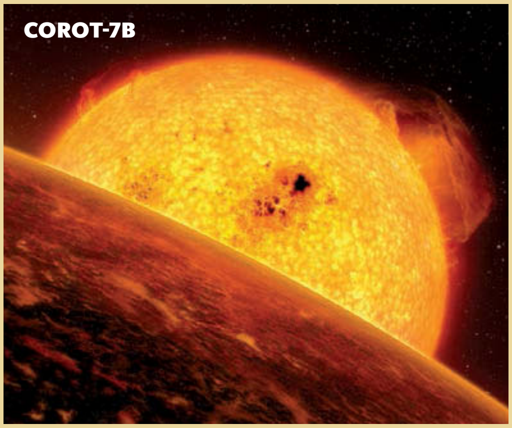
Hot Jupiters: Roughly one out of 200 Sun-like stars hosts a giant planet zipping around on an orbit less than five days long. Silicate and iron cloud decks might make some of these planets highly reflective, but most are dark as coal. One hot Jupiter, TrES-2b, absorbs 99% of incoming light. Sodium and potassium vapor, and possibly titanium oxide, could permeate these planets' atmospheres, absorbing nearly all visible light. (The planets still emit thermal radiation, though.) Moreover, wide planet-scale jet streams might reach several thousand miles per hour, sometimes surpassing the local speed of sound.

Circumbinary planets: The first transiting circumbinary detected, Kepler-16b, orbits two stars every 229 days. Even though this planet's orbit is nearly circular, its temperature likely changes as the stars orbit each other every 41 days. And if the stars eclipse from the planet's point of view, brief dim periods would ensue.



Brown Dwarfs: Astronomers have found more than 1,000 brown dwarfs, "failed stars" with masses too low to sustain fusion. They cool over time, some to temperatures as low as 80°F. Astronomers can test models of planetary dynamics and chemistry on these objects without the energy input or interfering glare of a parent star. Recently, scientists created this infrared brightness map of Luhman 16B, a brown dwarf 6.5 light-years away.

NASA / JPL-CALTECH / TIM PYLE



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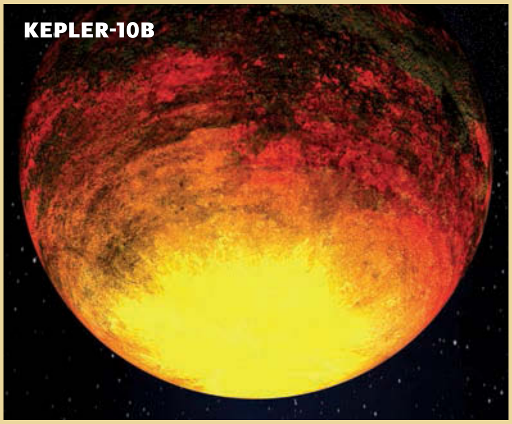

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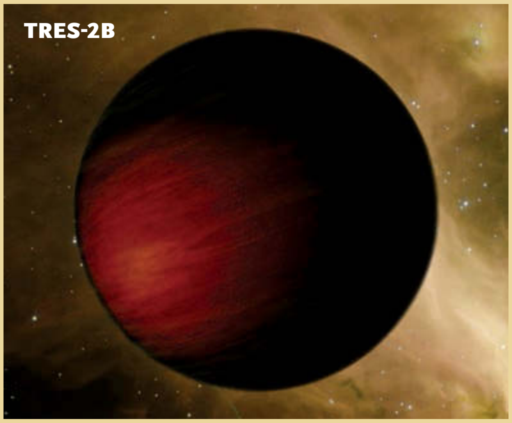

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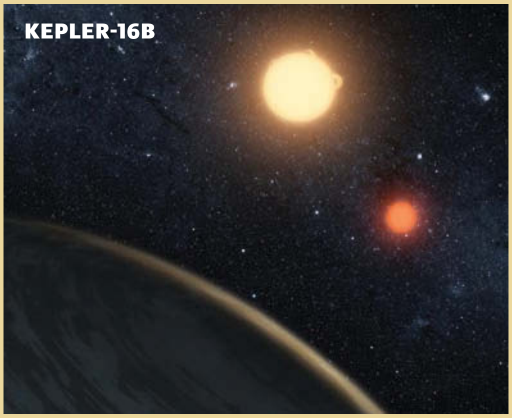

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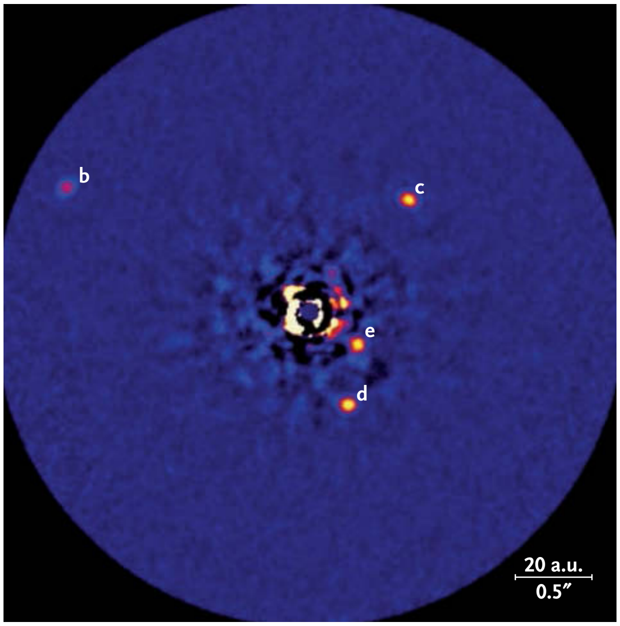


RC-HIA / C. MAROIS / KECK OBSERVATORY

DIRECT LIGHT In this image from the Keck II telescope in Hawaii, four young gas giants (b, c, d, and e) orbit the young star HR 8799, emitting their own near-infrared radiation due to heat left over from their relatively recent formation.

purely geological origin. To find evidence for the presence of life on an exoplanet, we would first have to show that atmospheric and geological chemistry cannot create the same signature. One day we may detect biogenic molecules on extrasolar terrestrial worlds, but since determining their origin will require detailed study, we will need to be cautious in our interpretation.

The Near Future

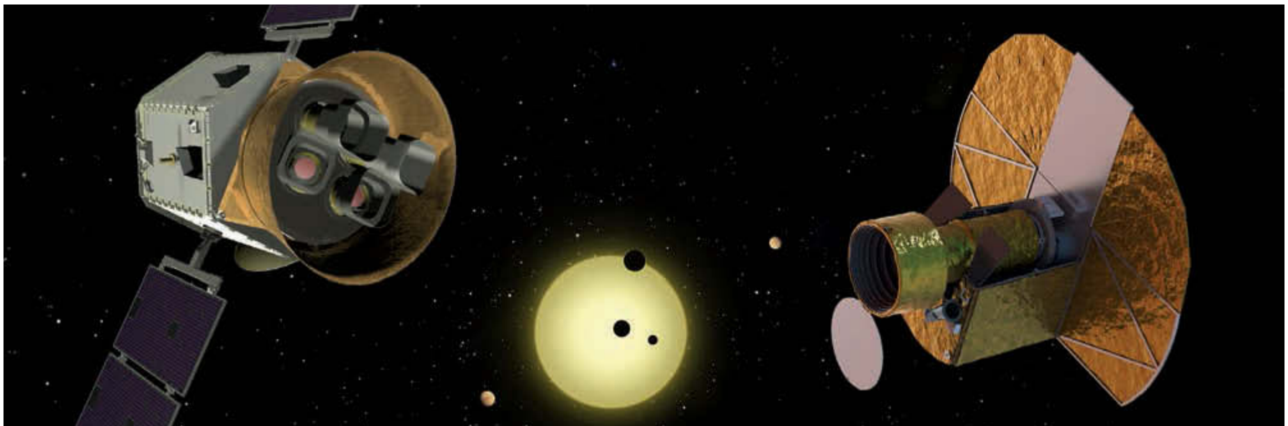
So far the study of exoplanet atmospheres has mostly been limited to gas giants. Tremendous excitement has centered on the characterization of the mini-Neptune GJ 1214b, and the realization that we can use our very same observational techniques on smaller planets. This has opened the door to even smaller planets, and the prospects for characterizing the atmospheres of a wide range of small exoplanets are promising. To do that, we'll need to find more (and closer) transiting planets with additional observing power.

To that end, two space satellites are scheduled to launch in 2017: the European Space Agency's CHEOPS (CHaracterising ExOPlanets Satellite) and NASA's TESS (Transiting Exoplanet Survey Satellite). These small telescopes will find and measure small transiting planets around nearby bright stars. The following year NASA is scheduled to launch the James Webb Space Telescope (JWST), which will collect infrared spectra of these exoplanets. The observations will transform the field, as astronomers move from simply identifying molecules in atmospheres to determining their abundances.

To be sure, the atmospheres of true Earth analogs — Earth-size planets in Earth-like orbits around Sun-like stars — certainly lie beyond JWST's reach. But we will likely characterize atmospheres of temperate super-Earths orbiting cool, small red dwarfs. Observations of their thermal emissions would show day-to-night temperature contrasts and atmospheric circulation.

Transit or occultation spectroscopy, which would detect molecules in these atmospheres, will require more stellar photons, which would in turn require significant commitments of telescope time from the astronomical community. Within a few years, we may be detecting water, methane, or carbon dioxide molecules in a small handful of the most promising super-Earths. ✦

Jonathan Fortney is an associate professor in the Department of Astronomy and Astrophysics at the University of California, Santa Cruz. His research focuses on understanding planetary atmospheres, interiors, and compositions.



CHEOPS: CHRISTOPHER BROEG (UNIVERSITY OF BERN, SWITZERLAND); TESS: TESS TEAM

FINDING MORE EXOPLANETS NASA's Transiting Exoplanet Survey Satellite (TESS, left) and the European Space Agency's CHaracterising ExOPlanets Satellite (CHEOPS, right) are both scheduled to launch in 2017, with the aim of finding and characterizing exoplanets orbiting bright, nearby stars.

Out-Of-This-World OUTREACH

With a showbiz attitude and some preparation, you can spread your passion for astronomy to the local community.

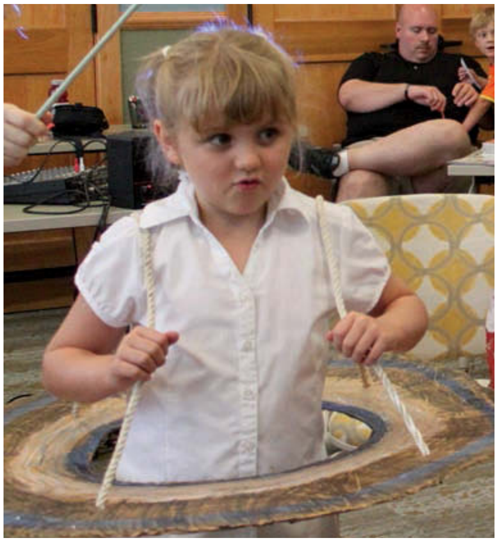
Mark Steven Williams

Astronomy has been my avocation for nearly 40 years. By day I'm a radio broadcaster; at least I play one on radio. The skills I've learned on the air — pacing, brevity, timing, and an offbeat sense of humor — lend themselves well to presenting "Out-of-This-World Outreach" astronomy events.

My astronomy outreach began with a very practical objective. In 2000 I moved to suburban Harrison County, Indiana, near Louisville, Kentucky. Three years later I began a campaign to establish a county-wide outdoor lighting ordinance. I reasoned that if the neighbors learned to appreciate backyard astronomy and the night skies, public support for the ordinance would grow. Initially, the proposed ordinance was one of the most controversial topics in the county. Some suggested I move to Montana, others supported the ordinance, and a few bragged about the wasted kilowatts they were beaming into the sky. A decade later I'm still fighting the light-pollution battle.

During the intervening decade I've held dozens of public astronomy events at parks, in malls, and on sidewalks. I've worked with nonprofits, a local astronomy club, and

WAVING AT CASSINI Author Mark Steven Williams (seated, with hat) organized an event at the Elizabeth branch of the Harrison County, Indiana public library system. Participants waved at NASA's Cassini spacecraft as it was imaging Earth from Saturn on July 19, 2013. Such special events are a great way to attract a crowd. MARK STEVEN WILLIAMS / SARA DEATRICK



MARK STEVEN WILLIAMS / SARA DEATRICK (3)

COSTUME CONTEST ***Above:*** **The author poses with winners of a children's planet costume contest. Craft activities and contests encourage student participation in astronomy outreach events.**

at private functions. My methods and techniques have evolved and I'd like to share some of them with you.

Planning and Organization

My programs consist of indoor presentations coupled with outdoor observing. Doing this effectively requires an indoor facility or meeting area. Partner with your local public library, YMCA, church, or school.

Recently I began presenting programs at a new branch of the local public library system. The library has a small conference room, projector, ceiling mounted screen, collapsible tables and chairs, and a kitchen. I can set up my laptop, audio gear, show-and-tell items, handouts, and prizes in about 30 minutes.

I schedule programs around easily observed events such as planetary conjunctions, eclipses, and meteor showers. Such milestones establish a theme. Historic dates in spaceflight or astronomical history offer additional topics. In 2011 we hosted a birthday party for Neptune to celebrate one Neptunian year since the planet's discovery in 1846. The party included a birthday cake and other treats. We gathered at a local restaurant for the 2012 transit of Venus. Cupcakes with yellow frosting topped with Red Hots candy representing the Sun and Venus were served along with "solar plasma" lemonade.

Failing any upcoming milestone celestial happenings, schedule your event around the first-quarter Moon, when Luna is an interesting early evening telescopic target that won't overwhelm the sky with glare. Don't forget important calendar dates such as the solstice or equinox and events like Astronomy Day or Globe at Night. Remember that the Sun is an interesting target with the proper equipment for daytime observation.

Promotion and Marketing

Promotion is an essential part of every successful event. A decade ago I began promoting via e-mail. In 2006 I developed a website and recently added a Facebook page. I also promote upcoming events through local radio, television, and newspapers. Write a press release and deliver it at least one month before your event. Six weeks out is even better. Contact your local newspaper and broadcast media outlets and find out who is responsible for public service, community bulletin board, or public-affairs programming. Cultivate a working relationship with each person.

Include the who, what, where, and when of your event. Designate someone in your group to be press secretary. That person should be knowledgeable, affable, and good at public relations. Be sure to include the person's contact information in the release.

Many radio stations air free public-service announcements of community events run by nonprofits. Most

TARGET VENUS **The author patiently guides a young boy as he looks at Venus through a 10-inch Dob.**

MARK STEVEN WILLIAMS

SOLAR VIEWING Observing the Sun with safe solar filters is a great daytime activity. This photo was taken at St. John's Lutheran School in Lanesville, Indiana.

stations update these every two to three weeks. Keeping that list current is usually about the last thing on the list of duties for the responsible staffer. If your press release arrives a week before your event, it probably will never get on the air. You also want the message to be broadcast as many times as possible and at different times of day.

Radio hosts are always seeking interesting guests for interviews. Contact the producers, send a press release to them personally, and follow up with a phone call. Be enthusiastic and give them something to work with. Talk about an upcoming meteor shower, a visible pass of the International Space Station, or which planets are currently visible. During an interview I might say "The ISS is traveling at 5 miles per second, which is Podunk to Green Acres along Highway 1 in ten seconds." Remember, this is showbiz!

Most stations also air public-affairs programming. These shows are usually broadcast on Sunday mornings and are generally produced by a member of the station's news staff. Arrange to do the interview so it airs the weekend before your event.

During their forecasts, the meteorologists at your local TV stations often mention celestial happenings such as eclipses, changes of season, and meteor showers. Become a resource for them. The weather guys and gals love showing interesting images of eclipses, unusual sunsets, and conjunctions. They'll probably be happy to announce your next star party and may even do a live shot there. After all, their job title begins with "meteor."

All of this extra effort pays off. We've had guests from 75 miles away attend our events.

Prepare the Show

Once you've arranged for a suitable venue, scheduled the event, and done your marketing, its time to organize the show. A two-part presentation, indoors and out, provides interactive activities and face time with your guests.

ADULT ACTIVITY The author demonstrates how to measure angular distances for star party guests.

MARK STEVEN WILLIAMS / SARA DEATRICK

Begin indoors with a *PowerPoint* presentation, which will go on regardless of the weather. Schedule your event to begin about 90 to 120 minutes before sunset depending on the program content and activities. Indoor meetings give me the opportunity for enjoyable one-on-one interaction with guests, which gives me a chance to do some audience research. I ask guests to leave their name, town, and e-mail address on a sign-up sheet. Prior to the next event, everyone on the list receives an invitation.

During introductions I hand out star charts for the date or month of the event. Download and print a quantity of the monthly map from **SkyMaps.com**. Anticipate the expected crowd and print a few more copies than you think you'll need.

Another handy tool is Kelly Beatty's monthly Sky Tour Podcast on **SkyandTelescope.com**. Download the podcast and embed it in a slide at the top of your presentation. *PowerPoint* can continuously repeat an audio file embedded in a slide. I set this feature up and start the podcast playing 30 minutes before showtime so early arrivals are entertained even if I'm away on a comfort break.

Include lots of graphics, images, and sounds in *PowerPoint*. I've used this program for years. *PowerPoint For Dummies* describes new techniques and enhancements you can use with each presentation.

Make your presentation fun, fast paced, interesting, and professional. Don't get too technical, "sciencey," or dry. Break the program into topical segments interspersed with quizzes, prize giveaways, and crafts activities.

I always include a segment on light pollution. I keep this brief and ask guests if they can think of a local place that's overlit. Usually there's at least one answer in the affirmative. Comparison images of an urban and dark sky, along with examples of retrofit shields and full-cutoff fixture products, make great examples. Demonstrate solutions. A little lighting education stimulates awareness.

Sound amplification is a valuable tool, especially in larger venues. I use two systems, a portable 150-watt P.A. system for outdoors and a smaller setup that I use indoors. My gear includes a quality wireless microphone and an audio mixer. With either system I can plug in audio from the laptop so everyone can hear the *PowerPoint* audio along with my narration. The wireless microphone enables me to roam the crowd and interact with guests.

Showtime!

Since I began doing shows with the local library branch, we've added crafts activities. They are fun for all ages. Designs for a planisphere, the "Star Clock" from Seattle's Pacific Science Center, or a simple paper sundial, are available online. We made shoebox pinhole cameras for our 2012 Transit of Venus party.

For a recent program we had a lot of fun with the "Best Kid's Planet Costume Contest." You could also try a "Strangest Alien" or other space theme. Promote the


MARK STEVEN WILLIAMS

TO THE NEXT LEVEL The author teaches local Boy Scouts how to use planispheres and sky maps so they can earn astronomy merit badges.

contest in your pre-event publicity. Children have a blast dressing up, winning prizes, and coming up with creative costumes.

Speaking of prizes, I try to bring inexpensive astronomy-related items to give away at each event. This might be a book, tickets to the local planetarium, or other such items. I barter with various organizations for these prizes.

Because I work for a large radio broadcasting company, I have become the unofficial staff astronomer at our stations. I sit in with the afternoon host on our news/information/talk station on a regular basis when there's something newsworthy and prior to a public event. Develop such relationships with the media folk in your area.

Finally, print quality business cards to circulate at your events and keep a supply with you at all times. Set up a website or Facebook account and be active on social media. Adopt a showbiz sensibility and become the neighborhood astronomer. Nowadays, folks contact me for help with their new telescope or ask about something they saw in the sky. We still don't have a local lighting ordinance, but hundreds of families have shared my love of the night sky at the eyepiece of my trusty Dob.

I'd love to hear the tales of your astronomy outreach adventures. For a sample *PowerPoint* presentation, sample press releases, tips on acquiring prizes, and information on sound reinforcement gear, please feel free to contact me at geezer@stargeezerastronomy.com. ✦

***Mark Steven Williams** began watching the sky when the Project Echo satellite went into orbit in 1960. Today he provides creative and technical services for a major broadcast media company in Louisville, Kentucky. His astronomy outreach includes public and private events, planetarium programs, and a radio feature* What's Up with The StarGeezer. *His website is **www.StarGeezerAstronomy.com**.*

Strong New Meteor Shower to Strike?

Joe Rao

Bright meteors could streak from the northern sky on the morning of May 24th.

Meteor observing is usually a slow and meditative pursuit, but occasionally it can turn dramatic. Most meteor showers are fairly predictable. But in addition to the occasional bright fireball blazing into view, there's always a chance you'll find yourself witnessing something truly new and unexpected — perhaps even when no shower was predicted at all.

Late this May things could turn exciting. A tiny periodic comet named 209P/LINEAR will make an unusually close pass by Earth. The comet should become no brighter than 10th to 12th magnitude despite its nearness. But there's excellent reason to think that for a few hours on the night of May 23–24, Earth will pass through thin trails of rubble running near the comet's orbit. We're fairly likely to experience a new meteor shower similar in intensity to the Perseids or Geminids, which are normally the richest of the year. We *may* receive the most dramatic meteor display since the spectacular Leonid showers of more than a decade ago, with a high proportion of the meteors being bright.

The United States and southern Canada are the only parts of the world well positioned for this event. The rest of the globe will either be facing away from the incoming meteors or bathed in daylight.

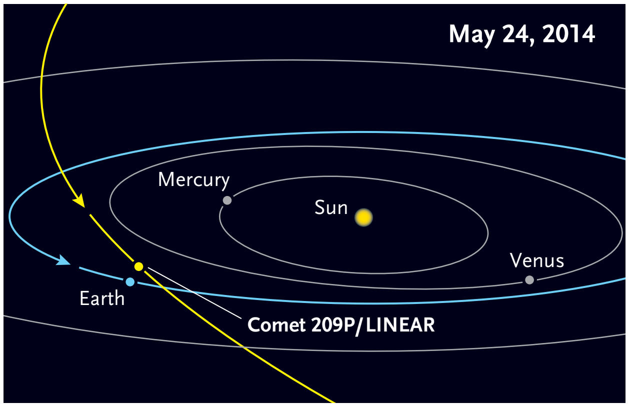
The Source

The body of origin for this potential display was discovered only a decade ago. Comet 209P/LINEAR is named for Lincoln Near-Earth Asteroid Research, an automated sky survey run by the U.S. Air Force, NASA, and MIT's Lincoln Laboratory that uses a 1-meter reflector. Its primary purpose is to discover and track near-Earth asteroids, but it finds lots of new comets too. It found the periodic comet now named 209P on February 3, 2004.

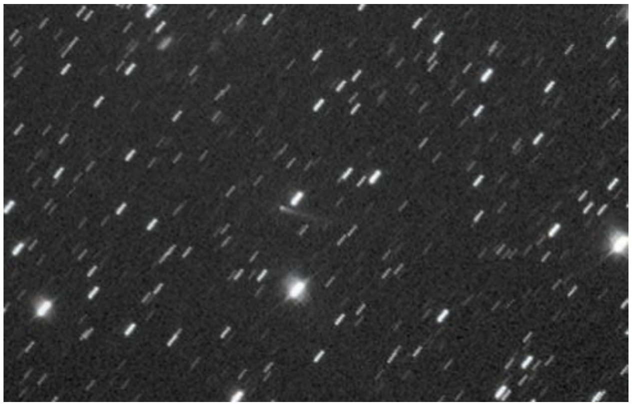
The comet is in a 5.04-year orbit with its aphelion (farthest point from the Sun) just inside the orbit of Jupiter. This flags it as a member of Jupiter's comet family. In fact, Jupiter's gravitational influence has herded about two-thirds of all short-period comets into orbits having aphelia near Jupiter's orbit.

Jupiter's gravity continues to perturb 209P/LINEAR a little bit this way or that. The comet's most recent Jupiter encounter, however, was unusually significant.

A SHOWER COMPRESSED To make this composite image of Perseid meteors last August 12–13, David Mayhew took many exposures continuously for hours, then composited those with meteors into a single frame containing clouds and the moonlit landscape of Colorado's Pawnee National Grassland. Don't expect to see several meteors at once!



S&T: LEAH TISCIONE; SOURCE: NASA / JPL-HORIZONS

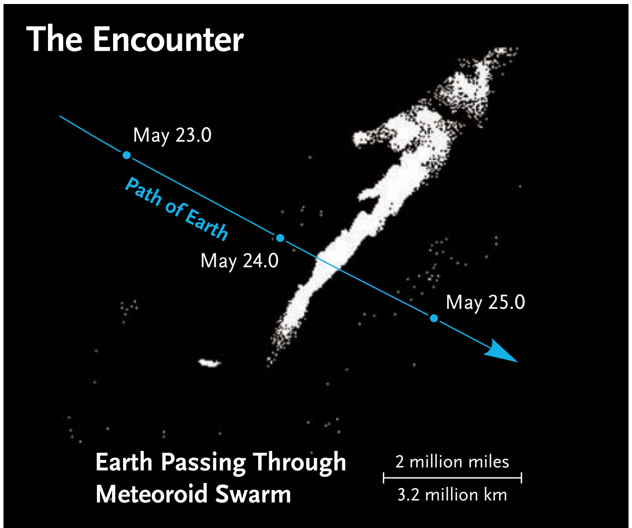


MICHAEL JÄGER

THE SITUATION ***Left:*** **On May 24th, Earth will be near both the comet's orbit (yellow line) and the comet itself. A comet's pebbly trail of debris spreads forward and backward along its orbit fairly quickly, then migrates away from the orbit more slowly, mostly still within the orbit's plane.** ***Right:*** **Comet 209P/LINEAR (centered) will be a visual challenge in amateur telescopes, only about 10th to 12th magnitude even when it's passing unusually close by Earth in late May. Michael Jäger in Austria imaged it one orbit ago on April 28, 2009. He used a 5.5-inch f/2.8 astrograph for this stack of four 2½-minute exposures.**

In February 2012 the little comet passed within 0.58 a.u. (54 million miles; 87 million kilometers) of Jupiter. This encounter perturbed the comet, and the debris presumably near it, into a new orbit that comes within just 0.003 a.u. (280,000 miles; 450,000 km) of Earth's orbit — creating prospects for a new meteor shower.

The first person to recognize this possibility was Peter Jenniskens of the SETI Institute and NASA's Ames Research Center. Jenniskens then asked Finnish celestial dynamicist Esko Lyytinen, a meteor-prediction expert, to check his calculations.



Each meteoroid follows its own slightly different orbit. Jérémie Vaubaillon modeled the orbits of swarms shed by Comet 209P/LINEAR during each of its passes by the Sun in recent centuries. Here, the paper is the plane of Earth's orbit; Earth's progress is marked at 0:00 UT for three days. The complex, 3-dimensional stream of debris intersects the paper at a low angle; the white dots mark the intersection points of individual test particles. Earth should pass through a thick part of the stream around 7ʰ UT May 24th.

S&T: LEAH TISCIONE; SOURCE: JÉRÉMIE VAUBAILLON

The meteoroid bits that crumble off a comet's nucleus spread along the orbit ahead of and behind the comet, and in time they widen into a thin, ribbonlike sheet mostly confined to the comet's orbital plane. So, whenever Earth cuts through this plane fairly close to the comet's path, we have a chance for a meteor shower.

Lyytinen calculated the evolution of a number of dust-and-rubble trails, each resulting from 209P shedding debris during a particular previous swing by the Sun. Many of these trails, he found, will be close to Earth on May 24, 2014. "Because the comet itself would be close to Earth at that time, and we pass not far from [the comet's] perihelion point," he says, "all those past dust trails would pile up on one another."

Two other proven meteor sleuths, Jérémie Vaubaillon (IMCCE, France) and Mikhail Maslov in Russia, independently reached the same conclusion. Vaubaillon notes, "All the trails ejected between 1803 and 1924 cross Earth's path in May 2014." That's 25 trails of comet rubble. Quite a pileup!

Maslov thinks the main sources of meteor activity should be the trails shed from 1898 to 1919. "However," he adds, "some meteors could be produced by earlier trails of the comet, down to the oldest computed trail from 1763, and even earlier."

The Initial Excitement

So, what might we see?

The first predictions, announced in October 2012, suggested a zenithal hourly rate (ZHR) as high as 1,000 meteors visible per hour. A shower's ZHR is the number of meteors you'd see per hour in a very dark sky if the shower's radiant, its perspective point of origin, were near the zenith. The rate you actually see is usually lower than this ideal: decreasing slowly as the radiant moves away from the zenith, then rapidly as it nears the horizon.

A ZHR of 1,000 per hour would qualify as a "meteor storm." But more recent considerations lead modelers to advise us to keep our expectations much lower.

The main uncertainty in the scenario stems from the comet itself. For a striking meteor display to take place, the comet needs to have shed copious amounts of stuff. But research recently published by Quanzhi Ye and Paul A. Wiegert (University of Western Ontario, Canada) finds that the comet's dust production is currently weak. This could be a bad sign about its past debris-shedding behavior. Or it could just indicate that 209P is now transitioning from a "typical" (dusty) comet to a dormant one resembling an asteroid.

We have no clue about 209P/LINEAR's activity before its 2004 discovery. Notes Vaubaillon, "What gives me confidence is that the orbit is very stable, so of whatever dust particles have been ejected in the last 150 years, many will encounter Earth on May 24th." Maslov agrees that what we will see depends on what happened many revolutions ago.

Moreover, the comet's production of fine dust might not correlate with its production of sand- and pebble-size meteoroids. Comet expert John Bortle says that even if Comet 209P has never been very dusty, it could have produced substantial sand and gravel, which are much less visible per unit mass than dust is.

How Many Meteors?

What are the best predictions for the meteor activity we may see on May 24th?

Ye and Wiegert derive a nominal ZHR of about 200, with a disclaimer that "given the current weak dust production of the comet, rates could be much lower." They conclude that a meteor storm is unlikely.

Vaubaillon thinks that a ZHR of 400 is "the best-case scenario," adding, "I would not bet on a meteor storm."

Maslov says, "Considering the high computed density and the high number of encountered trails, we can provide an approximate estimate for the ZHR of 100." But, he adds, "It's a very cautious estimation, and it is very possible that the real activity will turn out to be much higher; storm levels cannot be excluded."

Lyytinen's outlook: "The uncertainties are very wide in both directions. I would not be especially surprised by a ZHR of only 100; however it is my opinion that a storm-level outburst is also possible."

For comparison, the annual Perseids and Geminids typically produce a peak ZHR of about 100 or so.

IN PERSPECTIVE **Another composite image of the 2013 Perseids. Xiang Zhan took 10-second exposures continuously for four hours on August 12–13 using a wide-angle lens. He combined 68 frames showing meteors. A shower's meteors travel in parallel at the same speed. The radiant (in Perseus here) is the resulting far-off perspective point from where they appear to originate.**

XIANG ZHAN / BEIJING PLANETARIUM

The Timing

All the forecasters offer their likely peak times as well as intensities. These differ by hardly more than an hour, as listed in the table on the facing page.

The consensus peak time is about 7:10 UT May 24th plus or minus a half hour. This timing favors the U.S. and Canada except the far north.

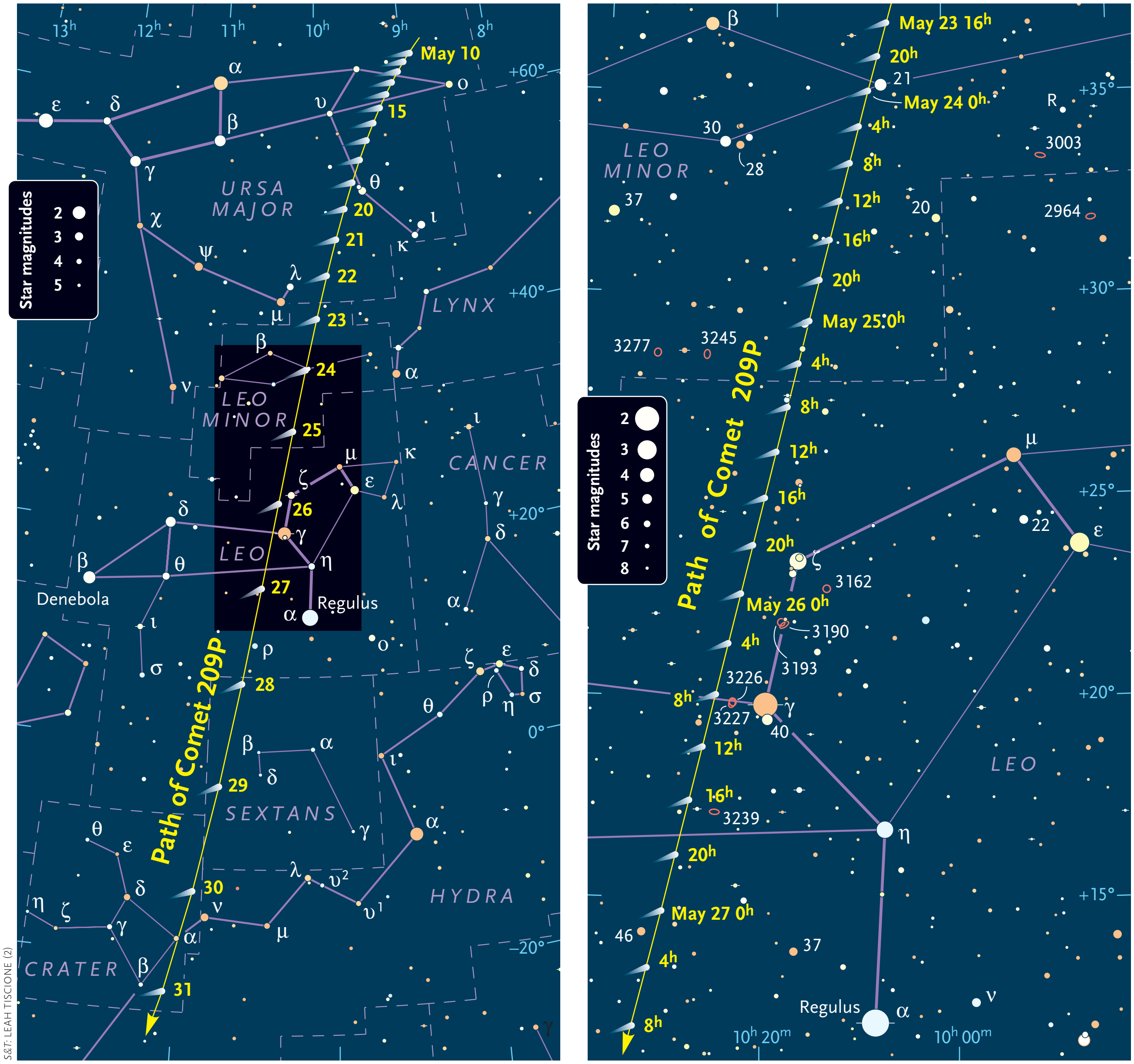
As for the shower's duration, Vaubaillon's model suggests that the first noticeable meteoroids will occur around 5:40 UT and the last ones by 8:50 UT. That's just three hours!

Vaubaillon says that the next showers from Comet 209P's debris trails are not expected until 2022 and 2045.

Viewing Circumstances

The shower's radiant is near Polaris: within a few degrees of right ascension 8^h 16^m, declination +79°, in Camelopardalis. That makes these meteors "Camelopardalids." The

SPOT THE CULPRIT! **Comet 209P/LINEAR passes closest to Earth, and moves fastest across the sky, on May 29th, just five days after we're predicted to pass through its debris. The black rectangle at the middle of the wide-field chart (*left*) shows the area of the second, close-up chart (including the Sickle of Leo), where stars are plotted to magnitude 8.0. The times and dates are Universal Time. The comet may be magnitude 10, 11, or 12. On the night of May 25–26 local date for North America, it passes through the interesting field near the bright binary star Gamma (γ) Leonis. This area includes the pair of 11th-magnitude galaxies NGC 3226 and 3227; think photo opportunity. For similarly deep charts all along the comet's track, enlargeable and printable, see skypub.com/209p.**



S&T: LEAH TISCIONE (2)

Plan Your Watch

To do a good meteor watch, you need only the simplest equipment: a reclining lawn chair, a heavy coat plus blankets or a sleeping bag (even in May!), insect repellent as needed, a notepad and pencils or a voice recorder, and a timepiece you can use in the dark.

Set up at a spot with a wide-open view of the sky and no glary lights. Give your eyes time to dark-adapt and then lie back and watch the stars. Gaze about halfway from the radiant to the zenith. Be patient.

Record the time when you start watching steadily. When you see a meteor that's flying in the direction away from the radiant, write or record "C" for Camelopardalid. For any other meteor, note "S" for sporadic. You can write with your hands in your sleeping bag and your eyes on the sky; you just have to be able to decipher your notes later.

Jot down the time about every 15 to 30 minutes, then turn the page. If you take a break, record its start and end times.

You'll also need to record the magnitude of the faintest stars you can see. Note too what percent of your working view is blocked by obstructions or clouds, and the star or constellation where your gaze is mostly directed.

Do not combine observations made by two or more people. Each person must make his or her own count completely independently, uninfluenced by anyone else.

Follow these procedures and you'll have a scientific meteor count worthy of reporting to the International Meteor Organization for tracking this new shower. Go to **www.imo.net/visual/major** to read more on how to observe, determine your limiting magnitude, and fill out the required report form.

—Alan MacRobert

Predicted Peak Time and Shower Intensity

Forecasters	Predicted Peak Time (UT)	Predicted ZHR	Remarks
Quanzhi Ye, Paul Wiegert	May 24, 6:29	<200	Actual rate could be much lower. Meteor storm is "unlikely."
Esko Lyytinen	May 24, 7:00	>100	"Storm-level outburst is possible."
Mikhail Maslov	May 24, 7:21	>100	"Very cautious estimation; storm levels cannot be excluded."
Jérémie Vaubaillon	May 24, 7:40	100 to 400	"I would not bet on a meteor storm."

radiant is a third of the way from Polaris to Ursa Major's nose (see the constellation map in the center spread). So the radiant stays up all night for the world's mid-northern latitudes, but the Southern Hemisphere loses out.

Remember that the possible ZHR values we're quoting assume not just a completely dark sky, with stars visible to magnitude 6.5, but that the radiant is overhead. No one will be blessed with that condition during nighttime. At places where the radiant will be about 30° above the horizon at the predicted peak time — for example New York, Chicago, Denver, and Los Angeles — the observed rate will be about half the ZHR by definition. Where the radiant is only about 20° up at the peak time — Miami, New Orleans, Austin, and Monterrey, Mexico — the observed rate will be about 35% of the ZHR. Near Seattle, Edmonton, and Winnipeg the radiant will be about 45° up, so the observed rate will be about 70% of the ZHR.

To sum up, the best viewing circumstances are for the Pacific Northwest and nearly as good for most of the rest of the northern U.S. and southern Canada. Farther north, twilight interferes. Much farther south, the radiant is low.

But the American South gets a consolation prize!

FOLLOW ALONG INDOORS

If you're outside watching, you'll know what's happening as soon as anyone on Earth! If it's cloudy, check the International Meteor Organization's site at **www.imo.net** for an activity graph growing in near real time as observers worldwide report in.

When a shower's radiant is low in your sky, the infrequent meteors that you do see are *earthgrazers,* skimming into the top of the atmosphere at a low angle. This means they are unusually long-lasting and run far across the sky.

Moonlight will be a minor hindrance at most. The Moon is a waning crescent 4½ days from new, just 20% illuminated, and it doesn't rise until around 3 a.m.

Bright and Slow (But Look Quick!)

There will be no mistaking this new meteor display if it shows up on schedule. The meteors are likely to be bright and unusually slow-moving. They'll be bright because the simulations suggest the debris trail should be skewed strongly toward relatively large particles, larger than 1 millimeter. We could be treated to some outstandingly bright fireballs. As for their apparent speed, the meteors will hit the atmosphere at a mere 18 km/second (40,000 miles per hour), far slower than those of any of the annual showers. The Geminids arrive at about twice that speed, the Perseids three times.

So hope for fair weather, plan your observing site, and be ready for whatever happens in the early hours of May 24th. Personally, as I noted earlier, I'm keeping my expectations low — maybe a handful of beautiful, slow-moving fireballs spread across a couple of hours. But nobody knows. We'll just have to wait and see. ✦

*Contributing editor **Joe Rao** is a five-time Emmy-nominated meteorologist for News 12 Westchester and a lecturer at New York's Hayden Planetarium. He has served as* S&T*'s chief meteor forecaster since 1993.*

HyperStar on the ISS

David H. Levy

An optical system developed for amateur astronomers goes to the International Space Station.

WE ALL KNOW that technology pioneered by professional astronomers has become commonplace in the arsenals of today's amateur astronomers. But did you know that the tables have turned, and that an off-the-shelf product created specifically for amateur astrophotographers is currently assisting with professional research aboard the International Space Station (ISS)?

Called HyperStar, it's an optical component for Schmidt-Cassegrain telescopes that transforms them into high-speed, wide-field imaging telescopes. It was developed by Dean Koenig of Starizona, an Arizona-based astronomy store, and it lies at the heart of the Pathfinder camera system officially known in NASA-speak as ISERV, an acronym for the International Space Station Environmental Research and Visualization System. The project is part of a larger NASA collaboration with the United States Agency for International Development known as SERVIR.

Unlike HyperStar's ground-based counterparts, the orbiting telescope is poised to look back at Earth rather than into space. Its mission is to provide urgently needed images for monitoring the impact of calamitous events such as tsunamis, hurricanes, earthquakes, volcanic eruptions, and great fires, and it's already helping countries respond to these natural disasters. It is also being used to monitor long-term environmental changes on the ground.

HyperStar on Earth

Koenig's idea for HyperStar dates back more than a decade to when he was discussing Celestron's Fastar imaging system with optical designer Richard Buchroeder. Developed in the late 1990s, the Fastar optical assembly was fitted in place of the secondary mirror on selected Celestron Schmidt-Cassegrain telescopes,

ALL IMAGES: NASA / SERVIR / ISERV UNLESS OTHERWISE CREDITED

Facing page: **Pathfinder's "first light" image was taken February 16, 2013, as the International Space Station passed over wetlands at the mouth of Panama's Rio San Pablo, where the river flows into the Golfo de Montijo. *Above right:* In the microgravity of ISS's Destiny module, Canadian astronaut Chris Hadfield readies Pathfinder for installation in the Earth-facing Window Observational Research Facility (*right*) in January 2013.**

transforming them into ultra-fast imaging systems. Buchroeder pointed out that the Fastar design was good, but could be improved. By 2003 Starizona introduced its HyperStar optics for several models of Celestron's Fastar-compatible telescopes, and soon after Celestron discontinued its Fastar accessory while continuing to make selected telescopes compatible with HyperStar. The optical system is now also available for several models of Meade Schmidt-Cassegrain telescopes. A review of HyperStar for deep-sky astrophotography appears in the February 2010 issue, page 34.

As an astronomical imaging system, HyperStar has racked up an impressive set of credentials. A HyperStar-equipped Celestron telescope helped celebrate the International Year of Astronomy at the White House in October 2009. American amateur Fred Bruenjes used a 14-inch Meade fitted with a HyperStar to discover Comet C/2012 C2 (Bruenjes) in February 2012. And Australian Terry Lovejoy used an 8-inch Celestron and HyperStar to discover the spectacular sungrazing Comet C/2011 W3 (Lovejoy) at the end of 2011.

HyperStar in Space

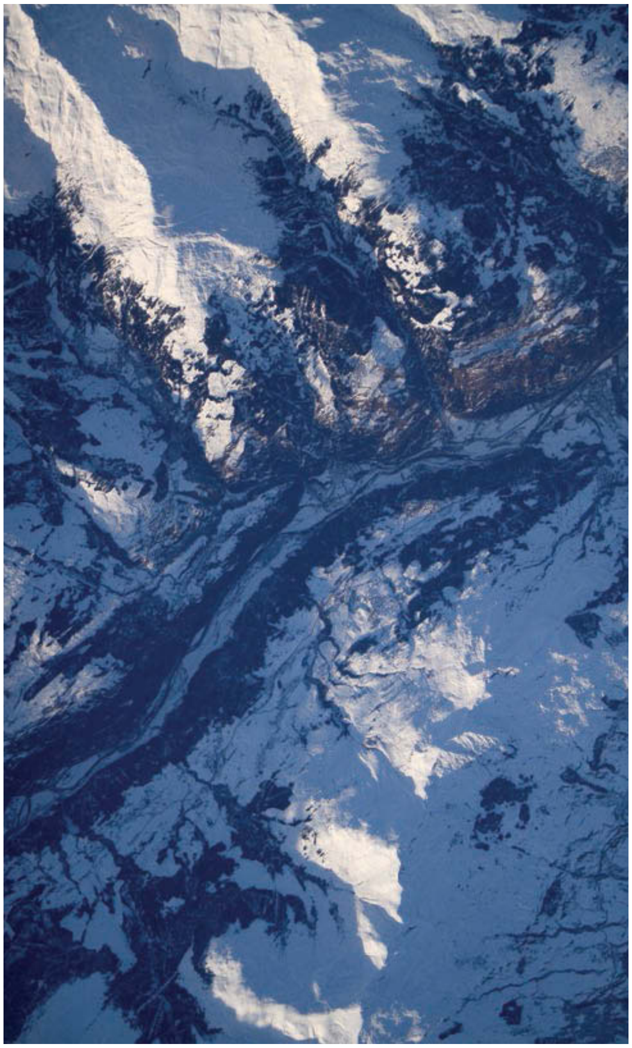
HyperStar's route to the ISS began with Burgess Howell, a scientist at NASA's Marshall Space Flight Center in Huntsville, Alabama. Howell is ISERV's principal investigator and payload developer. The project is a first step in giving scientists operational experience acquiring fully automated Earth-monitoring images from the observation window in the ISS's Destiny module. The experience and expertise gained from this relatively low-cost project will probably lead to the design and construction of a much more capable system that will be externally mounted on the ISS.

Howell says that his group "sought out equipment that was essentially off the shelf" for the Pathfinder system. A breakthrough occurred when he was talking to Starizona's Koenig at a recent Pacific Astronomy and

Below left: **Pathfinder views the rugged terrain on the eastern side of the Argolic Gulf near the Greek village of Kilada, seen at bottom center.** ***Below:*** **The snow-covered Swiss Alps were another target for Pathfinder's remotely controlled camera aboard the ISS.**

NASA / BURGESS HOWELL, ISERVIR

Above: **This pair of images captured the height of the flooding that inundated downtown Calgary, Alberta in June 2013. The pictures were quickly relayed to Canadian officials to improve the response to the natural disaster.**



Telescope Show in Pasadena, California. Howell asked Koenig about the possibility of imaging Earth with a HyperStar-equipped telescope on the ISS. “You have to be kidding!” was Koenig’s initial reaction of shock. But when Howell made it clear he was serious, Dean jumped aboard instantly. “Let’s do it!” he said, and a partnership was born.

The team had many issues to deal with once the project began. Their first decision was to determine the best telescope assembly that WORF (NASA’s acronym for the Window Observational Research Facility) aboard the ISS could support. At first they considered an 8-inch Celestron, but later opted for the increased aperture of Celestron’s 9.25-inch Schmidt-Cassegrain telescope. Because of WORF’s limited dimensions, however, the larger scope’s mount and fork arms were not the right size for aligning the telescope’s optical axis with the center of the window. Koenig suggested using smaller fork arms from an 8-inch Celestron as a support for the 9.25-inch telescope tube. Such a hybrid mounting would restrict vertical motion of the telescope for most astronomical applications, but there was still enough motion for the orbiting setup.

Another modification was to slide the telescope tube back between the fork arms. This would enable the telescope to pan around a larger field below the spacecraft when the front of the telescope was mounted as close as possible to the WORF window. Koenig noted that such a modification would not work efficiently on Earth because it would be difficult to balance the telescope, but this isn’t a problem for the microgravity conditions aboard the ISS. The motorized mount allows the telescope to pan up to about 20° from the point on Earth directly below the ISS. This gives a sweep of about 140 miles (225 km) to either side of the spacecraft’s ground track. Overall, the system will be able to image up to 70% of Earth’s surface where 95% of the world’s people live.

The Pathfinder images are captured with a Canon EOS 7D DSLR camera attached to the HyperStar in the same manor that amateurs use HyperStar for astronomical imaging. The system’s extremely fast focal ratio allows exposures of 1/8,000 second, which are necessary for freezing the apparent ground motion as the ISS orbits our planet at 17,000 miles per hour.

From the ISS’s nominal altitude of 220 miles, each Pathfinder image covers a relatively small 8-by-5½-mile footprint with a resolution of about 10 feet. The system can capture as many as three to seven high-resolution frames per second.

According to Howell, a big advantage of the Pathfinder images is that they can be transmitted in near real time, unlike traditional satellite imagery, which takes time to process. The rapid availability of Pathfinder’s images

This Pathfinder image captured small clouds drifting lazily above several lakes in the mountainous region near Valparaiso, Chile.

DEAN KOENIG

Above, left to right: **Starizona's Steve Koenig, Scott Tucker, and Donna and Dean Koenig show off the HyperStar-equipped Celestron telescopes they modified for Pathfinder. *Left:* The orbiting camera captured this unusual feature in the desert of central Algeria about 85 miles (135 km) south of the town In Salah.**

could make a big difference in determining how officials respond to natural disasters.

The Pathfinder headed to the ISS on July 20, 2012, 43 years to the day after Neil Armstrong first set foot on the Moon. It hitched a ride to the ISS aboard an HTV-3 supply rocket launched from a rain-soaked pad at Japan's Tanegashima Space Center. After a week of lazy travel, the rocket docked with the ISS, and its payload was transferred to the orbiting laboratory.

It wasn't until January 2013, however, that Canadian astronaut Chris Hadfield had the job of installing the telescope on its WORF perch. With everything installed and the camera accurately focused, first-light images from Pathfinder were made the following February 16th as the ISS passed over the mouth of the Rio San Pablo in Panama. A few months later the camera recorded two-dozen images of the flooding that ravaged parts of downtown Calgary, Alberta, forcing the evacuation of more than 100,000 people. Those images were quickly sent to Canadian officials to help them respond to the flooding. You can read more about this and other environmental events that Pathfinder's images are helping to monitor at the SERVIR Global website **www.servirglobal.net**.

According to Corey Lee, Celestron's vice president for product development, the company is "excited and proud that a Celestron telescope is in space assisting NASA's quest for knowledge." Although Celestron and HyperStar's many Earth-based users are happy to see this equipment being used on the ISS, the most animated person of all remains Koenig, who was included in a 2012 NASA Silver Achievement Medal presented to the ISERV team. Whenever the project is brought up in conversation, Koenig's eyes light up. After years developing ideas and equipment to benefit amateur observers and astrophotographers, to see one of his products orbiting in space is a sweet thrill indeed. ✦

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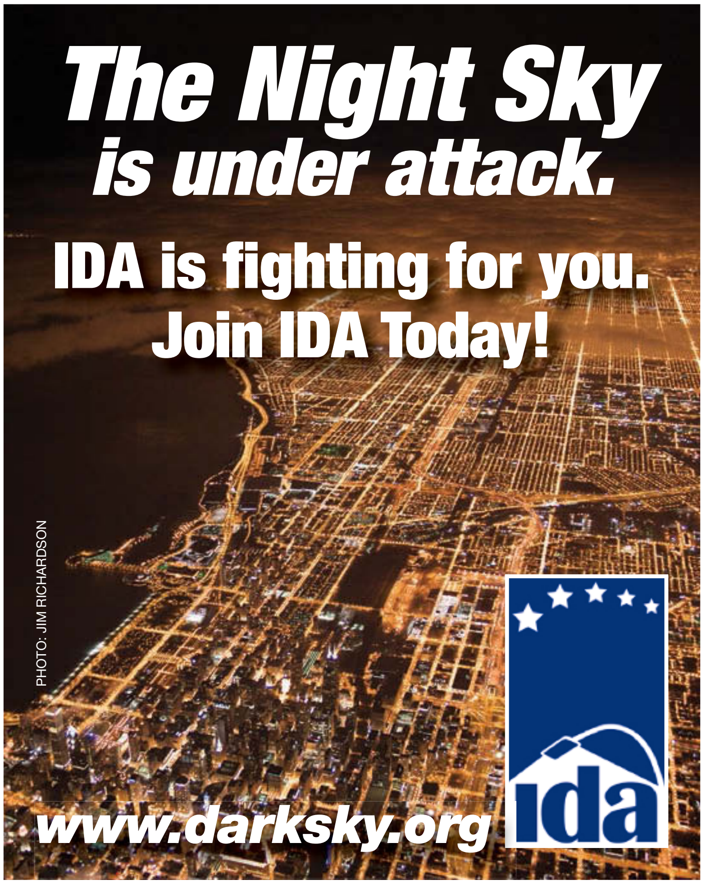
*Long-time amateur astronomer, comet discoverer, and author **David Levy** lives with his wife, Wendee, on the outskirts of Tucson, Arizona. They maintain the website **www.jarnac.org**.*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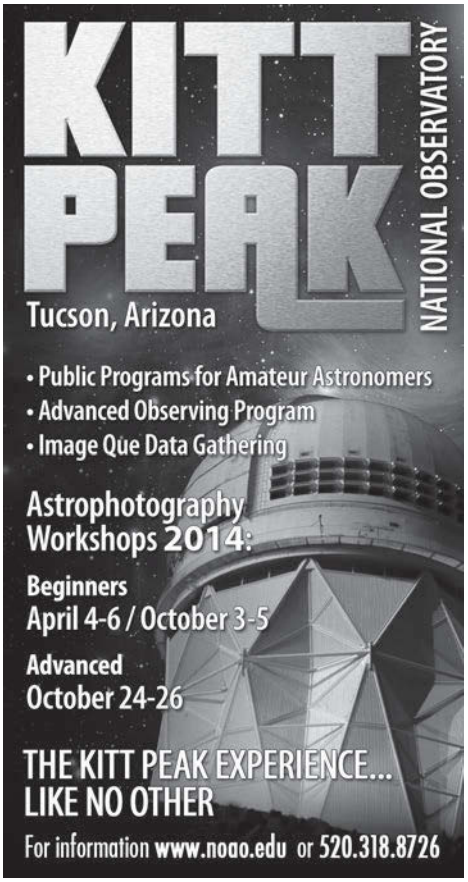
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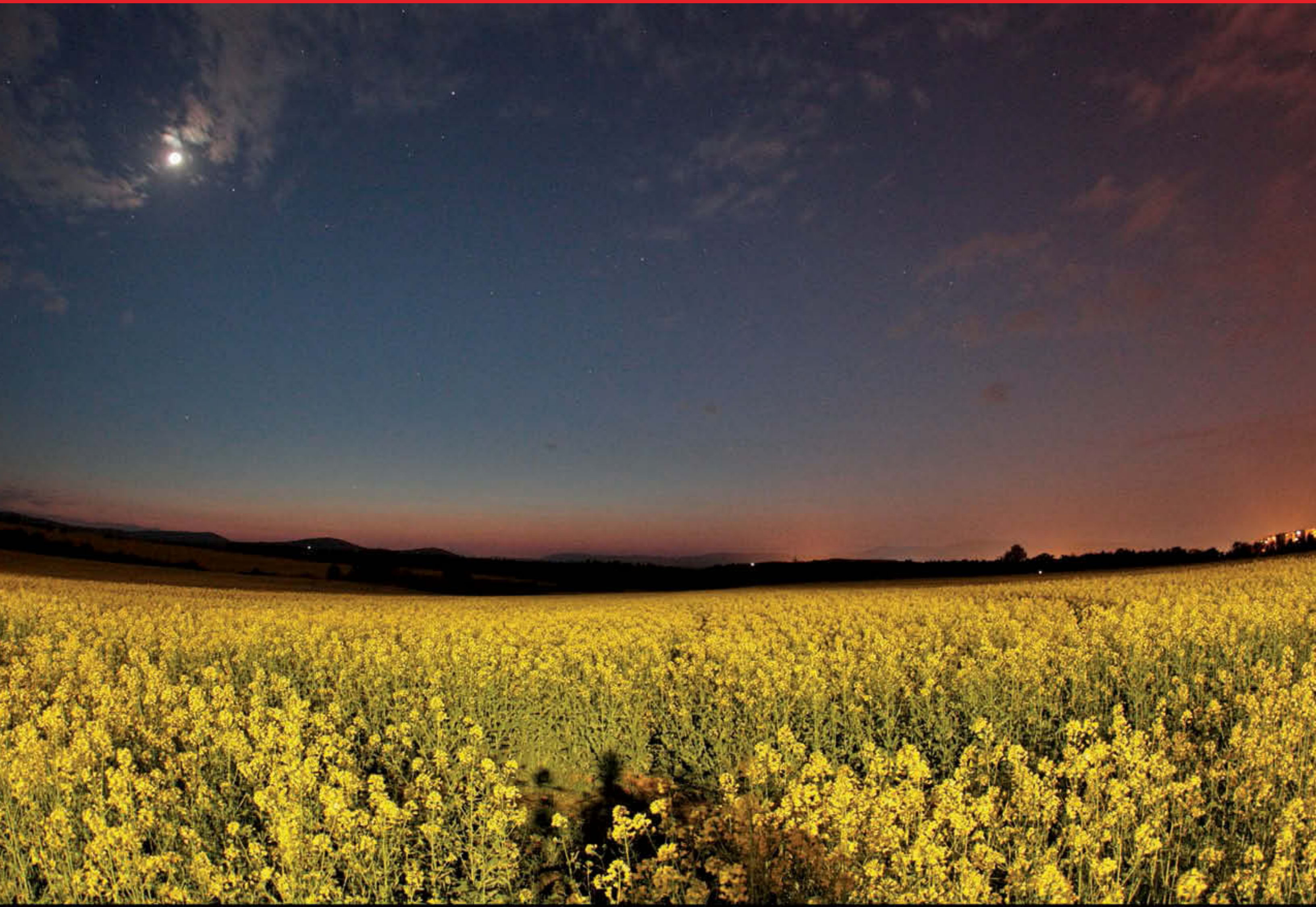


In This Section

PHOTOGRAPHER: TAMAS LADANYI

The Moon shines above a field of colza flowers in Hungary.

Additional Observing Articles:

Sky at a Glance

MAY 2014

3, 4 **EVENING:** The waxing crescent Moon shines below Jupiter on the 3rd and left of Jupiter on the 4th.

6 **PREDAWN:** The Eta Aquariid meteor shower peaks before dawn's first light. It is best observed from southerly latitudes; see page 52.

10 **EVENING:** Bright Mars shines left of the Moon.

10–11 **ALL NIGHT:** Saturn is at opposition to the Sun and closest to Earth for the year.

13–14 **ALL NIGHT:** The full Moon shines near Saturn, closing within 1° to 3° of it before dawn on the 14th in the Americas. The Moon occults (hides) Saturn for New Zealand and most of Australia.

15, 16 **EARLY DAWN:** Telescopes show Uranus less than 1.5° north of Venus, which is 9,000 times brighter.

16–28 **DUSK:** Look for Mercury above the west-northwest horizon, far lower right of Jupiter, as the sky darkens. This is Mercury's highest apparition in 2014 for observers at mid-northern latitudes.

23–24 **LATE NIGHT:** A new meteor shower, or conceivably even a meteor storm, may be visible, with observing circumstances favoring North America; see page 30.

25 **DAWN:** Venus shines beautifully just below the thin crescent Moon, as shown on page 49.

26–31 **EVENING:** Comet 209P/LINEAR, the parent body of the new meteor shower, passes less than 0.06 a.u. from Earth, one of the closest comet approaches in history. See skypub.com/209p for finder charts.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	NW	Visible May 3 through June 4	
Venus			E
Mars	SE	S	W
Jupiter	W	NW	
Saturn	SE	S	SW

Moon Phases

First Qtr May 6 11:15 p.m. EDT

Full May 14 3:16 p.m. EDT

Last Qtr May 21 8:59 a.m. EDT

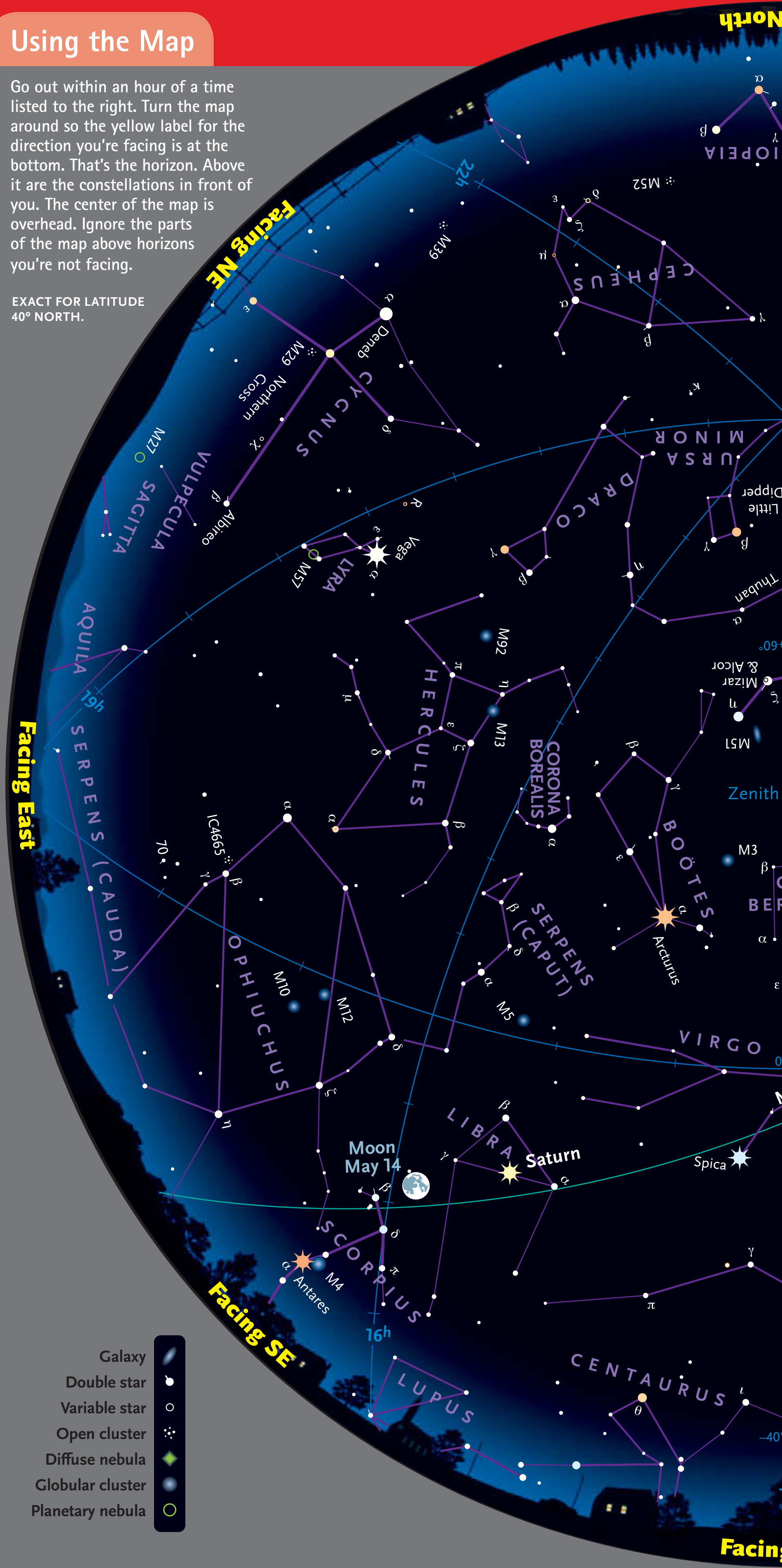
New May 28 2:40 p.m. EDT

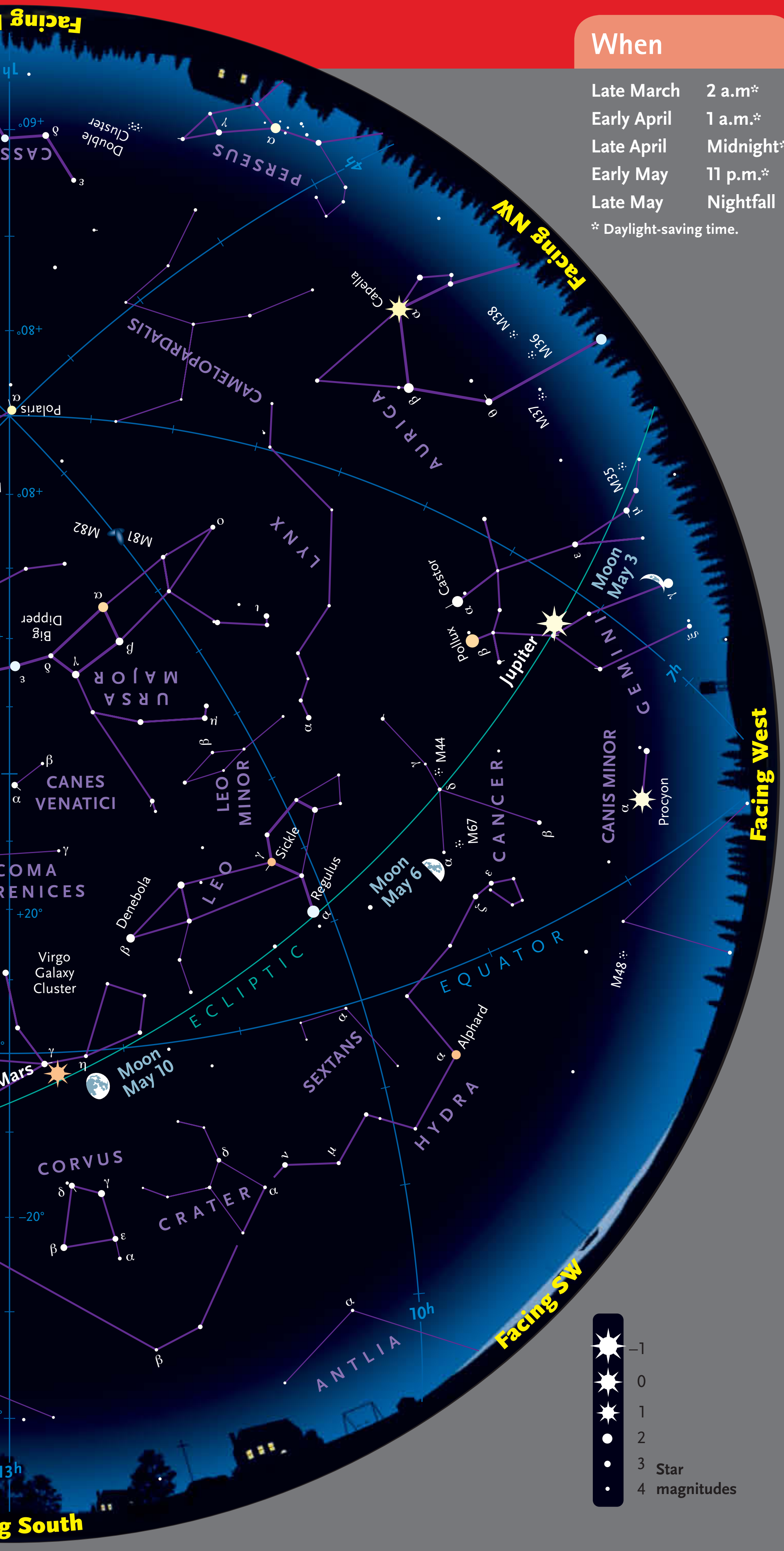
SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

Late March	2 a.m.*
Early April	1 a.m.*
Late April	Midnight*
Early May	11 p.m.*
Late May	Nightfall

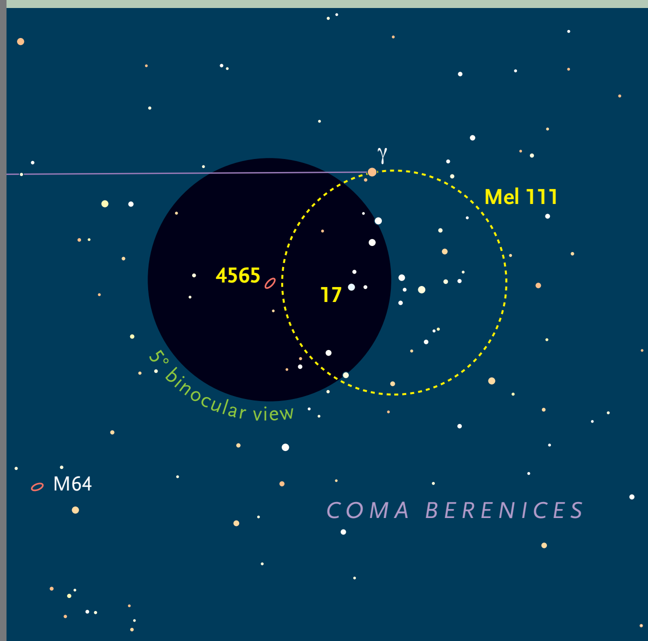
* Daylight-saving time.

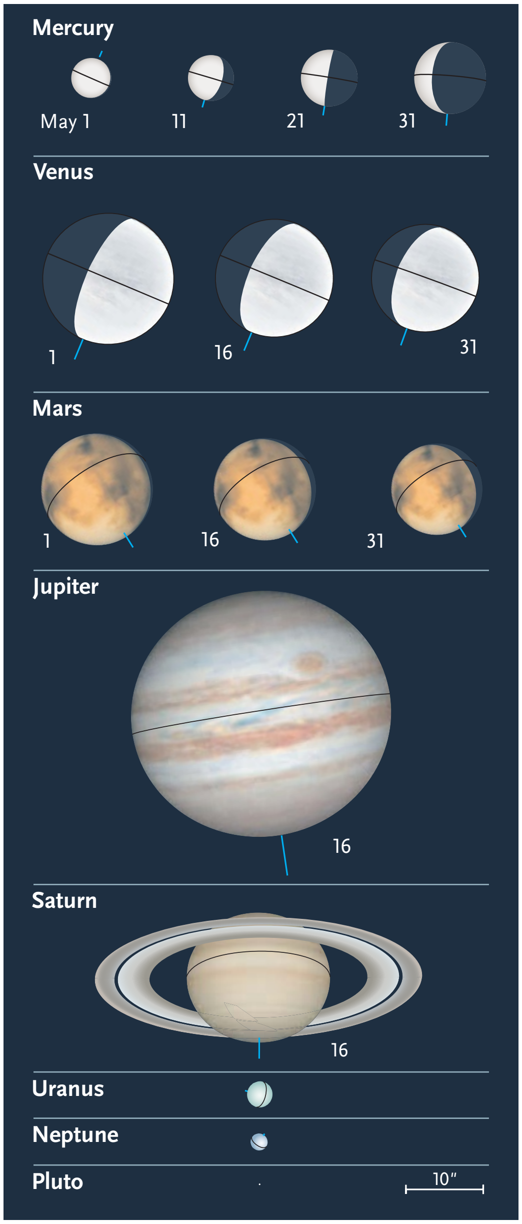
Near and Far in Coma

Like any tool, binoculars have their strengths and weaknesses. They excel at showing big swaths of sky but don't do as well with objects that are small and faint. One constellation that features both extremes is Coma Berenices.

Coma's binocular prize is the vast open cluster **Melotte 111**, often called the Coma Star Cluster. It's exactly the kind of object that binoculars show better than telescopes. It's so large that it seems to spill out of the field of view even in ordinary binos. One reason is because it's less than 300 light-years away, making it one of the nearest star clusters to our solar system. The grouping sparkles with the light from some two dozen stars brighter than magnitude 8. As an added bonus, on the eastern edge of the main clump of cluster stars, you'll find a nice, wide double: **17 Comae Berenices**. Its components shine at magnitude 5.3 and 6.6 and are separated by a generous 145″ — an easy split for any bino.

If Mel 111 plays to binocular strengths, then **NGC 4565** exposes their greatest weakness. This galaxy is situated just off the cluster's eastern edge. While relatively large for such an object, it appears tiny at the low magnification typical for binoculars. To make matters worse, the galaxy is also quite faint. Although it's listed at magnitude 9.5, NGC 4565's surface brightness is low. Indeed, 10×50 binoculars don't show it well even under dark skies. That's not surprising when you consider that NGC 4565 lies approximately 40 million light-years beyond the stars that make up Mel 111. It's truly a background object. ✦



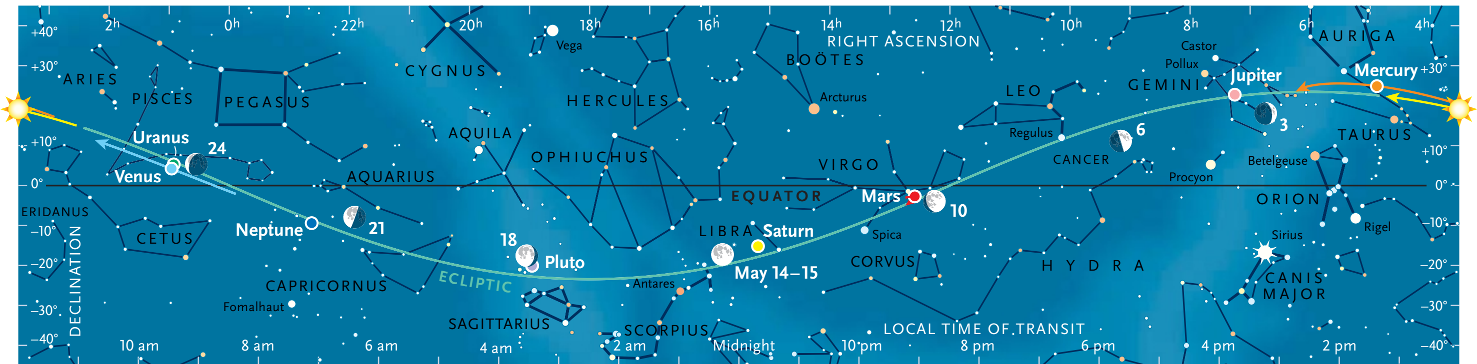


Sun and Planets, May 2014

	May	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	2^h 31.8^m	+14° 56′	—	–26.8	31′ 45″	—	1.007
	31	4^h 30.4^m	+21° 50′	—	–26.8	31′ 33″	—	1.014
Mercury	1	2^h 53.8^m	+17° 06′	6° Ev	–1.8	5.2″	97%	1.294
	11	4^h 15.9^m	+23° 17′	16° Ev	–0.9	5.9″	75%	1.132
	21	5^h 23.0^m	+25° 30′	22° Ev	0.0	7.3″	47%	0.916
	31	6^h 03.6^m	+24° 40′	22° Ev	+1.1	9.3″	25%	0.724
Venus	1	23^h 52.7^m	–2° 10′	43° Mo	–4.1	17.0″	67%	0.982
	11	0^h 35.2^m	+1° 58′	41° Mo	–4.1	15.8″	70%	1.056
	21	1^h 18.3^m	+6° 11′	39° Mo	–4.0	14.8″	74%	1.128
	31	2^h 02.3^m	+10° 18′	37° Mo	–4.0	13.9″	77%	1.197
Mars	1	12^h 43.7^m	–2° 57′	151° Ev	–1.2	14.5″	98%	0.644
	16	12^h 34.3^m	–2° 40′	134° Ev	–0.8	13.3″	94%	0.705
	31	12^h 35.7^m	–3° 26′	120° Ev	–0.5	11.9″	91%	0.788
Jupiter	1	7^h 04.3^m	+22° 55′	64° Ev	–2.0	35.3″	99%	5.592
	31	7^h 26.7^m	+22° 17′	41° Ev	–1.9	33.0″	100%	5.974
Saturn	1	15^h 15.1^m	–15° 29′	170° Mo	+0.1	18.6″	100%	8.914
	31	15^h 06.3^m	–14° 56′	159° Ev	+0.2	18.5″	100%	8.960
Uranus	16	0^h 54.8^m	+5° 09′	40° Mo	+5.9	3.4″	100%	20.785
Neptune	16	22^h 36.8^m	–9° 31′	78° Mo	+7.9	2.3″	100%	30.175
Pluto	16	18^h 56.0^m	–20° 09′	132° Mo	+14.1	0.1″	100%	31.971

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

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



The Sun and planets are positioned for mid-May; 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

Splendid Spica

There's more than meets the eye to Virgo's sole bright star.

One of my most cherished astronomical memories was formed on the night of April 12–13, 1968. I was 13 years old, and I had received my first really useful telescope a few months earlier. I had already seen a few total lunar eclipses, but that night was when I first viewed one through a telescope. And not just any total eclipse of the Moon — though all of them have their attractions. During this event, as the Moon dimmed and reddened, a 1st-magnitude star flamed into vastly greater splendor incredibly close to the Moon.

That star was Spica, and it has been one of my favorites ever since. Most of you are probably first reading these words in late March or early April and still have a chance to prepare for the total lunar eclipse of April 14–15, 2014. The Moon will be fairly close to Mars and quite close to Spica during this eclipse, though its separation from the star will be much greater than when I witnessed it all those years ago. Regardless of whether clouds let us see this eclipse, I want to share some facts and observations relating to spectacular Spica.

A spike to the ear of wheat. Most amateur astronomers have learned how to take the Big Dipper's handle and use it to make an arc (curved line) to Arcturus and then drive a spike (straight line) to Spica. I sometimes advise people to continue the curve to Corvus, the constellational crow whose compact and geometrically neat pattern lies not far to Spica's southwest.

Many amateur astronomers also know that the name Spica is Latin for "ear of wheat," a translation of the Greek name Stachys. That's because the star marks the ear (or spike) of wheat being held by Virgo when commonly imagined as Ceres, the ancient Roman goddess of agriculture and living things. The word "cereal" is derived from her name, and of course the goddess also gives her name to the largest asteroid, the so-called dwarf planet Ceres. It's interesting that the asteroids Ceres and Vesta are putting on a great show this spring and early summer right here in Virgo, just 15° north or northeast of Spica (see **skypub.com/asteroids** for a finder chart).

Spica's suns. Five of the sky's 20 brightest stars have spectral types between *B*0 and *B*3 — hotter than Rigel or Regulus. But of those, only Spica is visible from mid-northern latitudes. Actually, Spica consists of at least two extremely luminous blue stars, roughly seven and four times wider than the Sun. The brighter, larger Spica

JOHANNES HEVELIUS

Virgo is shown mirror-reversed in this 1687 chart, with the star Spica atop a sheaf of wheat. North is to the right.

component has a mass about 11 times the Sun's, and so it should someday go supernova. Spica's stars have an average separation of only 11 million miles, and they orbit each other in just over 4 days — during which the changing orientation of their ellipsoidal shapes cause the point of light we see as Spica to vary slightly in brightness. The larger component also pulsates, adding up to a net variation between magnitude 0.92 and 1.04.

Sun and Spica simultaneously. In years long after the 1968 lunar eclipse, I've twice seen the Moon occult Spica. The most memorable observation featured Spica emerging from behind the Moon just after sunrise. I was able to keep seeing Spica in an 8×50 finderscope for quite some time as the Sun grew higher. Spica's spark was visible in one eye while, at the same time, my other (unaided) eye beheld the Sun peeking through trees: two stars seen together in the daytime sky. ✦

Saturn All Night

The ringed planet is at opposition to the Sun this month.

At nightfall during most of May, the ecliptic is strung from horizon to horizon with four bright planets and four 1st-magnitude stars. From west-northwest to southeast, these are Mercury, Jupiter and Pollux, Regulus, Mars and Spica, Saturn, and rising Antares.

Mars is visible almost all night long. Saturn is at opposition on May 10th, so it *does* remain visible all night. But Venus doesn't rise in the east until just after dawn's first glimmer.

DUSK

Mercury has its highest apparition of the year for skywatchers at mid-northern latitudes. On May 1st Mercury is probably too low to see without optical aid, but it appears higher in twilight each successive evening. From May 16th to 28th, Mercury is more than 10° above the northwest horizon 45 minutes after sunset as seen from 40° north latitude. At the peak of its apparition on May 22nd, Mercury sets almost 2 hours after the Sun, just about the longest interval possible at that latitude.

As always when Mercury is visible in the evening, its brightness and phase decrease throughout the apparition. On May 25th, when Mercury is at greatest elongation 23° east of the Sun, it shines at magnitude +0.4, and telescopes show its 8″-long crescent less than 40% lit. As May ends, Mercury has faded to only about magnitude +1.2, but it's still more than 5° high an hour after sunset.

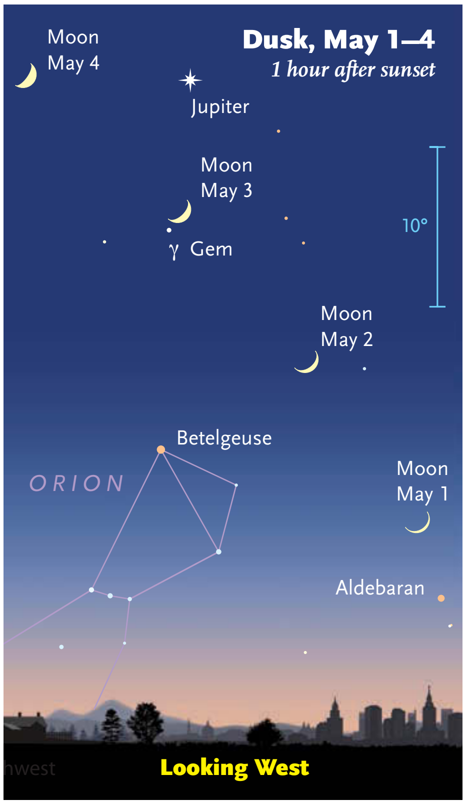
EVENING

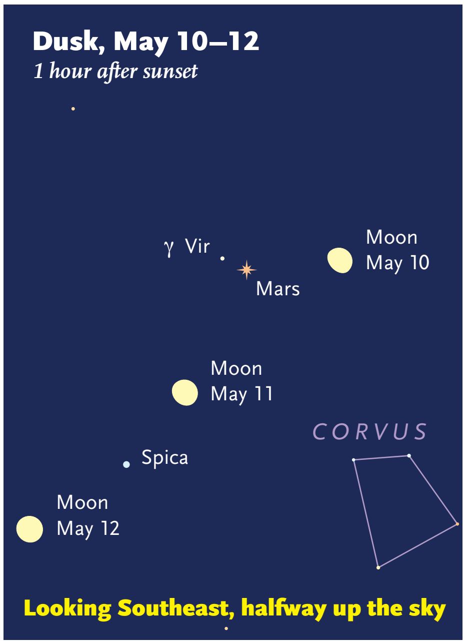
Jupiter fades slightly in May, from magnitude –2.0 to –1.9, and telescopes show its banded orb shrinking from 35″ to 33″. But it still appears much brighter and bigger than any other evening planet. As May begins, Jupiter stands about 45° high in the west an hour after sunset at mid-northern latitudes, but by month's end it's only half as high — and much less sharp in telescopes. Jupiter sets around 1 a.m. (daylight-saving time) as May opens, and around 11 p.m. as the month closes.

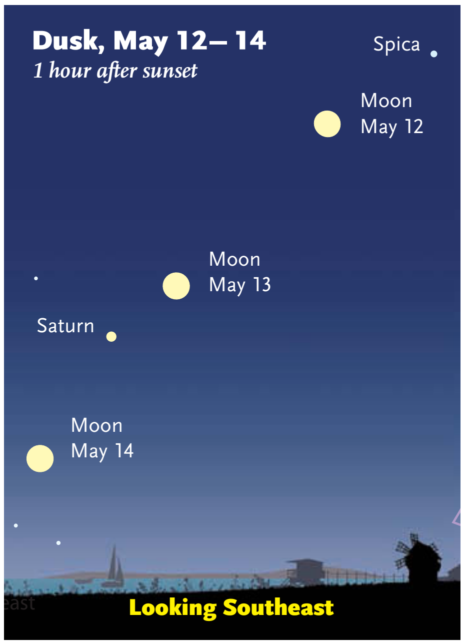
Jupiter moves through a lovely starscape this month. It starts May about 2° north of 4th-magnitude Zeta Geminorum (Mekbuda) and then treks slowly eastward, passing less than ½° north of 4th-magnitude Delta Geminorum (Wasat) on the American evening of May 22nd. This motion brings Jupiter steadily closer to bright Pollux and Castor, with which it forms a long triangle.

ALL NIGHT

Mars was closest to Earth in mid-April, but it's receding rapidly as faster-moving Earth speeds ahead of it around the Sun. So it dims from magnitude –1.2 to –0.5 in May, but that still leaves it much brighter

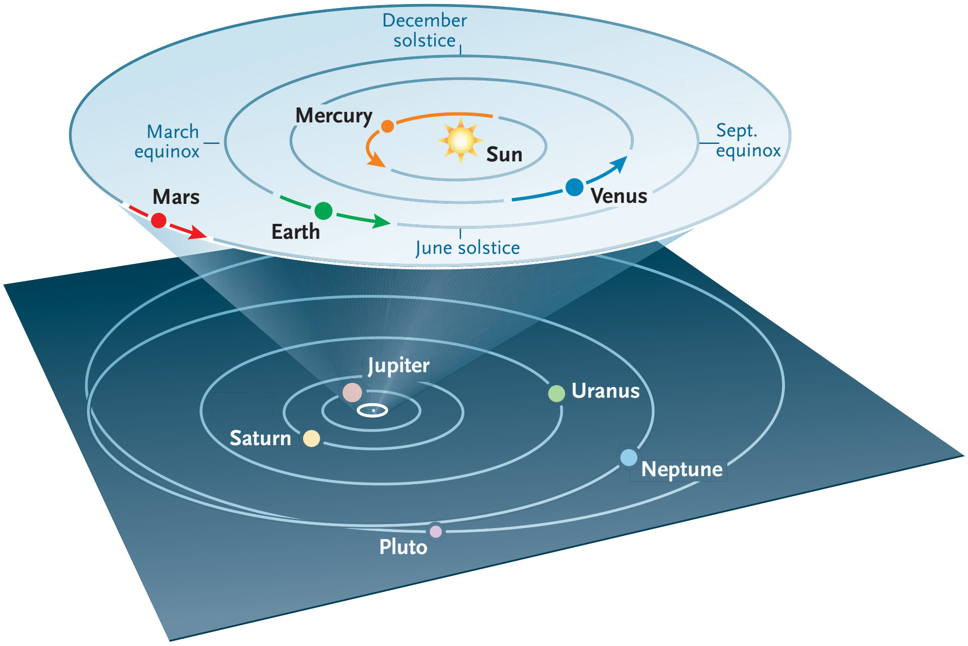






ORBITS OF THE PLANETS

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



than Arcturus to its upper left. Mars halts its retrograde (westward) motion on May 21st, so it lingers the whole month in a pretty region of western Virgo near the classic double star Gamma Virginis (Porrima), whose separation has widened in recent years to 2.2″.

Mars is highest in the south (and usually sharpest in a telescope) around 11 p.m. daylight-saving time as May begins, and in evening twilight as May ends. Mars's globe shrinks from 14.5″ to 11.8″ during the month, so get in as much telescopic observing as possible while Mars still appears relatively large.

Saturn comes to opposition on May 10th, when it rises just before sunset and sets just after sunrise. Saturn shines at or near magnitude +0.1, its peak brightness for 2014, throughout May.

Telescopes show that Saturn's apparent equatorial diameter is around 18.6″ while its rings span 42″. Saturn shines in Libra, far to the lower left of Mars and Spica after dusk. Watch it creep closer to Alpha Librae (Zubenelgenubi) week by week.

Pluto doesn't reach opposition until early July, so it's not highest until well after midnight. Next month's issue will contain a finder chart.

DAWN

Venus shines about 12° high in the east a half hour before sunrise nearly all May, as it traverses southern Pisces. The planet dims marginally, from magnitude –4.1 to magnitude –4.0, and its gibbous globe dwindles from 17″ to 14″ wide.

Telescopes show **Uranus** less than 1.5° north of Venus on May 15th and 16th. Venus shines 9,000 times brighter than 5.9-magnitude Uranus. **Neptune**, magnitude 7.9 in Aquarius, rises more than an hour before Uranus. But neither of the outermost planets is high enough yet for good telescopic views.

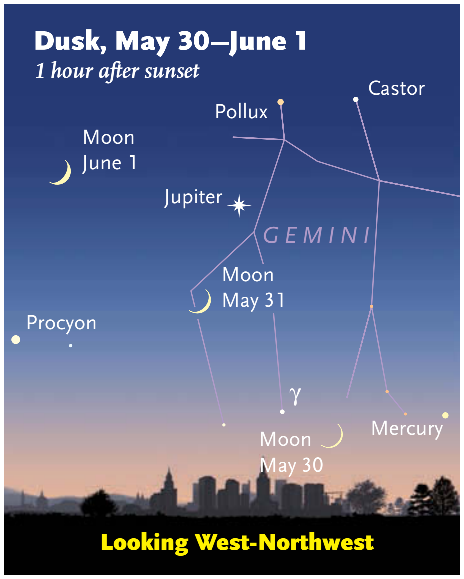
MOON PASSAGES

The **Moon** is a thin waxing crescent not far above Aldebaran on May 1st. On May 3rd it lies well below Jupiter and very close to Gamma Geminorum (Alhena), Gemini's third-brightest star. On May 4th the Moon is about midway between Jupiter and Procyon.

The Moon is waxing gibbous on May 10th, when it shines to the right of Mars. The nearly full Moon starts the American night of May 13–14 very near Alpha Librae and ends near Saturn. The Moon occults Saturn for viewers in New Zealand and most of Australia.

The waning lunar crescent shines spectacularly close above Venus before dawn on May 25th.

The second waxing crescent of the month hangs well to the left of Mercury at dusk on May 30th, and well below Jupiter on May 31st, as shown at left. ✦



A New Comet PanSTARRS

A comet sails by the Big Dipper, glowing at 7th or 8th magnitude. We think.

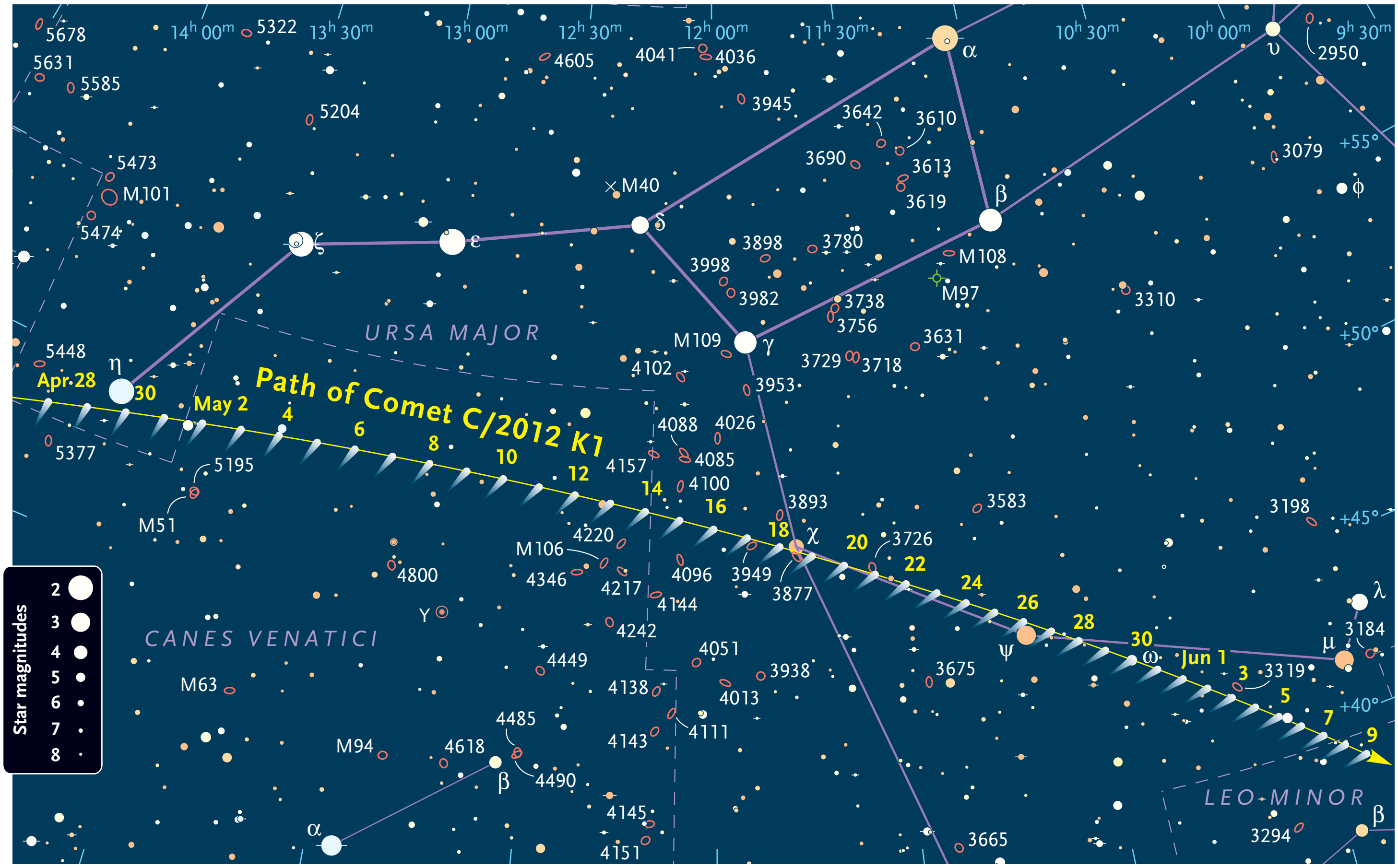
Mention "Comet PanSTARRS" and what we remember is the 3rd-magnitude comet low in the bright western twilight last March. It moved into a darker sky as it faded, and it turned to display an odd, fan-shaped tail that offered a striking shape-contrast with the Great Andromeda Galaxy when they were in the same binocular field of view.

That Comet PanSTARRS was designated C/2011 L4. There are others. They take their name from the Pan-STARRS sky-survey project growing on Hawaii's Mount Haleakalā and its 1.8-meter Pan-STARRS 1 telescope. One of these may make a nice evening target for small telescopes from late April through June.

This one is Comet C/2012 K1. Discovered at 20th magnitude two years ago, it is predicted to glow at 7th or 8th magnitude as it flies south of the Big Dipper high in the evening sky in May, then descends into the sunset in July.

That's if it behaves itself. Everyone is skittish about predicting comet brightnesses after Comet ISON's vanishing act last November. At least this one never comes close to the Sun (its perihelion is a wide 1.05 a.u. from the Sun on August 27th), but its orbit suggests that it's an untested newcomer to the inner solar system, as ISON was.

Use the map below to pinpoint where to look for it. The evening sky is mostly or entirely moonless in late April and into the first three days or so of May, and then from about May 17th through June 3rd.



The latest Comet PanSTARRS will be a high evening target south of the Big Dipper in May. The comet symbols are plotted at 0^h Universal Time on the dates indicated (which falls in late afternoon or evening of the previous date for North American time zones). The tails point away from the Sun. Stars are plotted to magnitude 8.0.

Phenomena of Jupiter's Moons, May 2014

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

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

Saturn Reaches Opposition

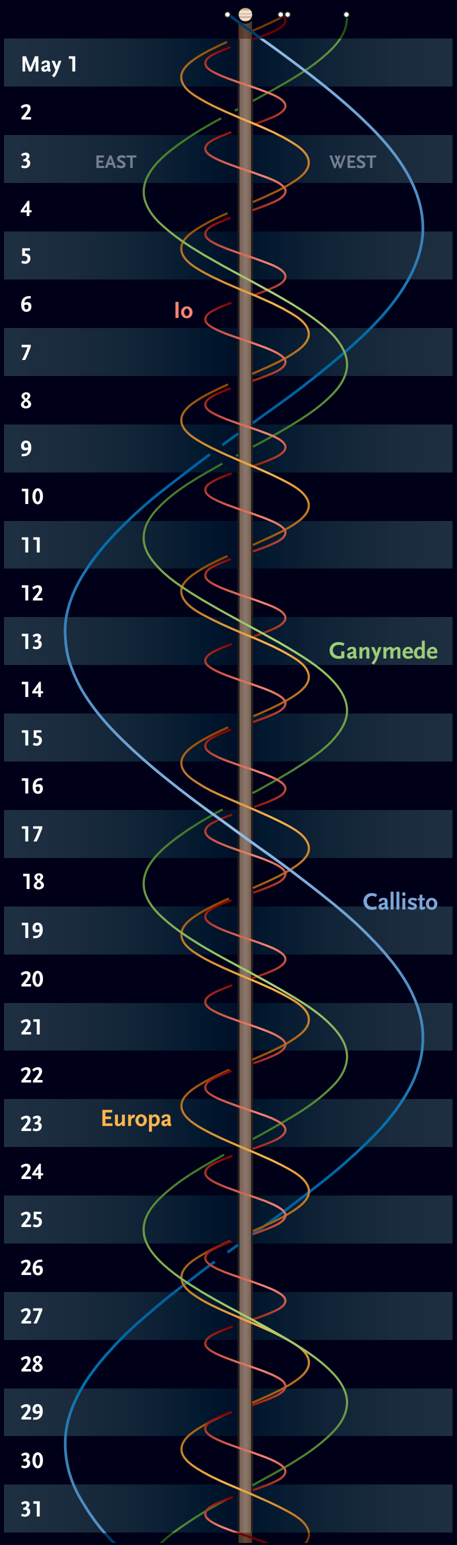
When Alan Friedman took this exquisite image in 2006, Saturn and its rings were tipped from our line of sight by about as much as they are now, but they were showing us their southern side rather than the northern. Friedman used a 10-inch Astro-Physics Maksutov scope and a planetary video camera.

Saturn comes to opposition on May 10th, glowing rather low in Libra even when it's highest in the middle of the night. Saturn is at its biggest and brightest for this year from mid-April all through May, and its rings are tipped a wide 21° or 22° to our line of sight.

Watch the thin black shadow of Saturn's globe on the rings diminishing just off the globe's celestial western side before opposition, then regrowing on the eastern side afterward. And watch for the Seeliger effect, a noticeable brightening of the rings for a few days around opposition. Read lots more about observing Saturn in the May 2013 issue, page 50.

Saturn has the best set of visible moons of any planet! A 60-mm scope will usually reveal Titan. A 4- or 6-inch adds Iapetus, Rhea, Dione, and (with a little difficulty) Tethys. A 10-inch may catch Enceladus. See just where to look for them, or identify the ones you see, with **skypub.com/satmoons** or by using our handy *SaturnMoons* app, available for $2.99 from the iTunes Store.

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.

Eta Aquariid Meteors

The big meteor excitement in May is the possible strong shower on the morning of the 24th visible from the U.S. and Canada; see page 30. But a more predictable shower, best for southerly skywatchers worldwide, should be at its peak before dawn on May 5th, 6th, and 7th.

The Eta Aquariid shower can sometimes be the year's best for the Southern Hemisphere. This year, expect a zenithal hourly rate of about 50 lasting for two or three days. Few of the meteors are seen from above north latitude 40°, since dawn begins earlier the farther north you are at this time of year. That doesn't give the shower's radiant in Aquarius time to rise very high.

However, the few Eta Aquariids that northerners do spot are long, graceful "earthgrazers," skimming the upper atmosphere far across the sky. They'll be coming out of the east-southeast, from the direction of the Aquarius Water Jar.

The Eta Aquariids are, like the Orionids of October, old debris from Halley's Comet. Earth intersects this same broad meteoroid stream at two different places in our orbit around the Sun.

Action at Jupiter

Jupiter still stands pretty high in the west at dusk in early May, in upright Gemini below Pollux and Castor, but it's moving lower each week. And it's nearly at its smallest now, shrinking from 35″ to 33″ wide during May. Examine it with a telescope early while it's still high, even before the end of twilight.

Any telescope shows Jupiter's four big Galilean satellites. Binoculars usually show two or three, occasionally all four. Identify them with the diagram at left.

The table on the previous page lists all the interactions in May between Jupiter, its shadow, and the satellites and their shadows. Don't be surprised if the satellites' shadows on the planet are harder to observe now that Jupiter is smaller and more distant.

Below are the times, in Universal Time, when Jupiter's Great Red Spot should cross the planet's central meridian. The dates, also in UT, are in bold. The Red Spot too will be less apparent with Jupiter on the far side of the Sun from us.

April 1, 2:52, 12:48, 22:44; **2**, 8:39, 18:35; **3**, 4:31, 14:27; **4**, 0:22, 10:18, 20:14; **5**, 6:10, 16:06; **6**, 2:01, 11:57, 21:53; **7**, 7:49, 17:45; **8**, 3:40, 13:36, 23:32; **9**, 9:28, 19:24; **10**, 5:19, 15:15; **11**, 1:11, 11:07, 21:03; **12**, 6:59, 16:54; **13**, 2:50, 12:46, 22:42; **14**, 8:38, 18:33; **15**, 4:29, 14:25; **16**, 0:21, 10:17, 20:12; **17**, 6:08, 16:04; **18**, 2:00, 11:56, 21:51; **19**, 7:47, 17:43; **20**, 3:39, 13:35, 23:31; **21**, 9:26, 19:22; **22**, 5:18, 15:14; **23**, 1:10, 11:05, 21:01; **24**, 6:57, 16:53; **25**, 2:49, 12:45, 22:40; **26**, 8:36, 18:32; **27**, 4:28, 14:24; **28**, 0:20, 10:15, 20:11; **29**, 6:07, 16:03; **30**, 1:59, 11:54, 21:50.

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

These times assume that the spot is centered at about System II longitude 210°. If it's elsewhere, it will transit 1⅔ minutes early for every degree of longitude less, or 1⅔ minutes later for every degree more.

Any feature on Jupiter appears closer to the central meridian than to the limb for 50 minutes before and after transiting. A light blue or green filter helps the contrast of Jupiter's reddish, orange, and tan markings. ✦

When Seeing Isn't Believing

This bright feature in Saturn's rings is merely an illusion.

Visual observers are not alone in recording illusory features such as the Terby White Spot, seen in this January 30, 2011 webcam image of the "Dragon Storm" on Saturn by Don Parker.

On March 14, 1889, an intriguing announcement was issued by the *Central Bureau for Astronomical Telegrams* in Kiel, Germany, the international clearing house for announcing discoveries and transient events. It reported that Belgian astronomer François Terby had detected a strange new feature in the rings of Saturn.

An experienced planetary observer, Terby was widely admired for his studies of Mars and Jupiter. On the evening of March 6th that year, he was observing Saturn through the 8-inch refractor at his private observatory in the city of Louvain. Using magnifications of 150× to 280×, he noticed a white region bordering the black shadow cast on the rings by Saturn's globe. Extending across the bright A and B rings, this feature remained stationary for more than an hour until clouds intervened. Six nights later Terby saw the bright boundary again in precisely the same location.

A flurry of confirming observations were soon reported, some by astronomers using telescopes of only 3 or 4 inches aperture. Many observers saw Terby's spot as a bright strip with parallel edges, while to others it looked elliptical or D-shaped, with the flat side of the D's semicircle defined by the shadow's edge.

William Brooks, the director of the Smith Observatory in Geneva, New York, reported that Terby's spot "comes out almost conspicuously in the 10-inch equatorial [refractor] at times." Visible with all magnifying powers from 80× to 450×, it was usually most conspicuous with

Although the luminance within each of these rectangles is uniform, it seems to vary across the width of each one. Look carefully at the rectangles near the middle and you will see a darker region just to the left (on the darker side) of the edge between two adjacent rectangles and a lighter region just to the right of the same edge. These are Mach bands. If you hold a pencil over any of the boundaries, the apparent difference in the brightness of adjacent rectangles will diminish dramatically.

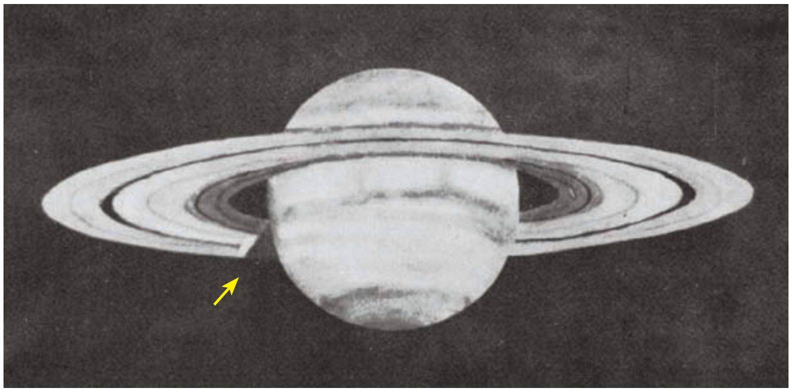
a power of 150×. "To me the brilliancy of the white region appears variable," Brooks wrote. "Fluctuations of light at irregular intervals of a few minutes have been detected by careful scrutiny."

Despite such corroborating testimony, the Terby White Spot's lack of motion caused many to immediately question its reality. British amateur astronomer William Noble argued that "the white spot on Saturn's ring can have no objective existence," because "the rotation of the ring must carry the luminous patch round and, instead of remaining persistently in contact with the shadow of the ball, it must travel right round the planet."

Andrew Ainslie Common presented compelling evidence that the Terby White Spot is an optical illusion. He reported that when he used a wedge-shaped neutral density filter to gradually attenuate the brightness of Saturn's image, "the ring disappears at the same time all round, whereas if the white spot had any real existence (i.e. if it were really brighter than other parts of the ring), it would have remained visible after the other portions of the ring had been cut out by the dark wedge."

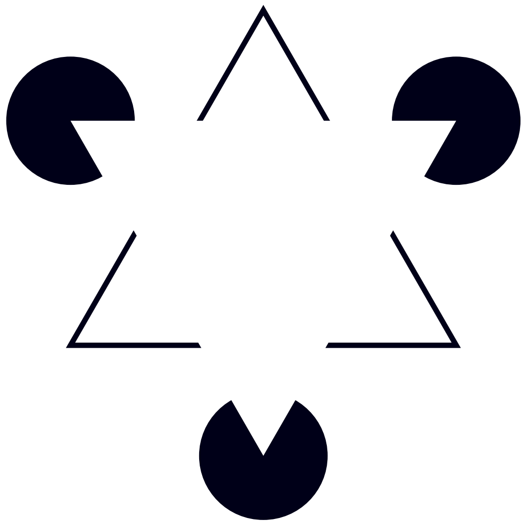
Common attributed the Terby White Spot to an effect of the stark contrast between the sunlit surface of the rings and the adjacent black shadow of the globe. He noted that an observer can create a spurious, narrow band of increased brightness on any part of the rings (or even the globe itself) simply by placing Saturn partially out of the field of view so that its image is in contact with the eyepiece's field stop.

Another British amateur, J. E. Drower, offered further damning evidence. "I have got a precisely similar appearance to that described by Dr. Terby," he wrote, "by making a small model of Saturn with a ball and cardboard ring. The latter I nicked on the edge and bent slightly convex until I got a shadow of the ball projected upon it by a strong light."



THOMAS A. DOBBINS COLLECTION

The Terby White Spot appears in this 1954 drawing by Thomas R. Cave, who used the Griffith Observatory's 12-inch Zeiss refractor on a night of excellent seeing.



GEORGIE FIBONACCI

We are hardwired to "see" borders even where no contrast exists. Stare at this figure and you will perceive a white triangle delineated by a well-defined but illusory boundary.

The Terby White Spot is a striking example of an optical phenomenon first described by the Austrian physicist and empirical philosopher Ernst Mach in 1865. Mach noted that the human eye-brain combination exaggerates the contrast between light or dark areas at the borders of adjacent extended surfaces of differing brightness. Contours and borders dominate human visual perception because edges are accentuated by these features, known as "Mach bands."

In recent years I've encountered remarks posted in online discussion groups alleging that the Terby White Spot must have some basis in reality because it appears in many webcam images of Saturn, often with an uncanny similarity to its appearance in sketches by visual observers. Nothing could be further from the truth. The unsharp masking and wavelet sharpening image-processing algorithms mimic very closely the edge enhancement that occurs in the eye-brain's neural network.

Saturn will reach opposition on May 10th this year. For about 10 days before and after that date, the shadow cast by the globe on the rings will disappear as the Sun, Earth, and Saturn line up. The globe's shadow will reappear on the following (eastern) side of the ring in late May, and will be widest at quadrature on August 9th, when Saturn is 90° from the Sun. On late spring and early summer evenings Saturn will be well placed in the southwestern sky, affording an opportunity to see the Terby White Spot and answer the old question: "Who are you going to believe, me or your own lyin' eyes?" ✦

For our monthly lunar libration table, visit skypub.com/librations.

Galaxy Time

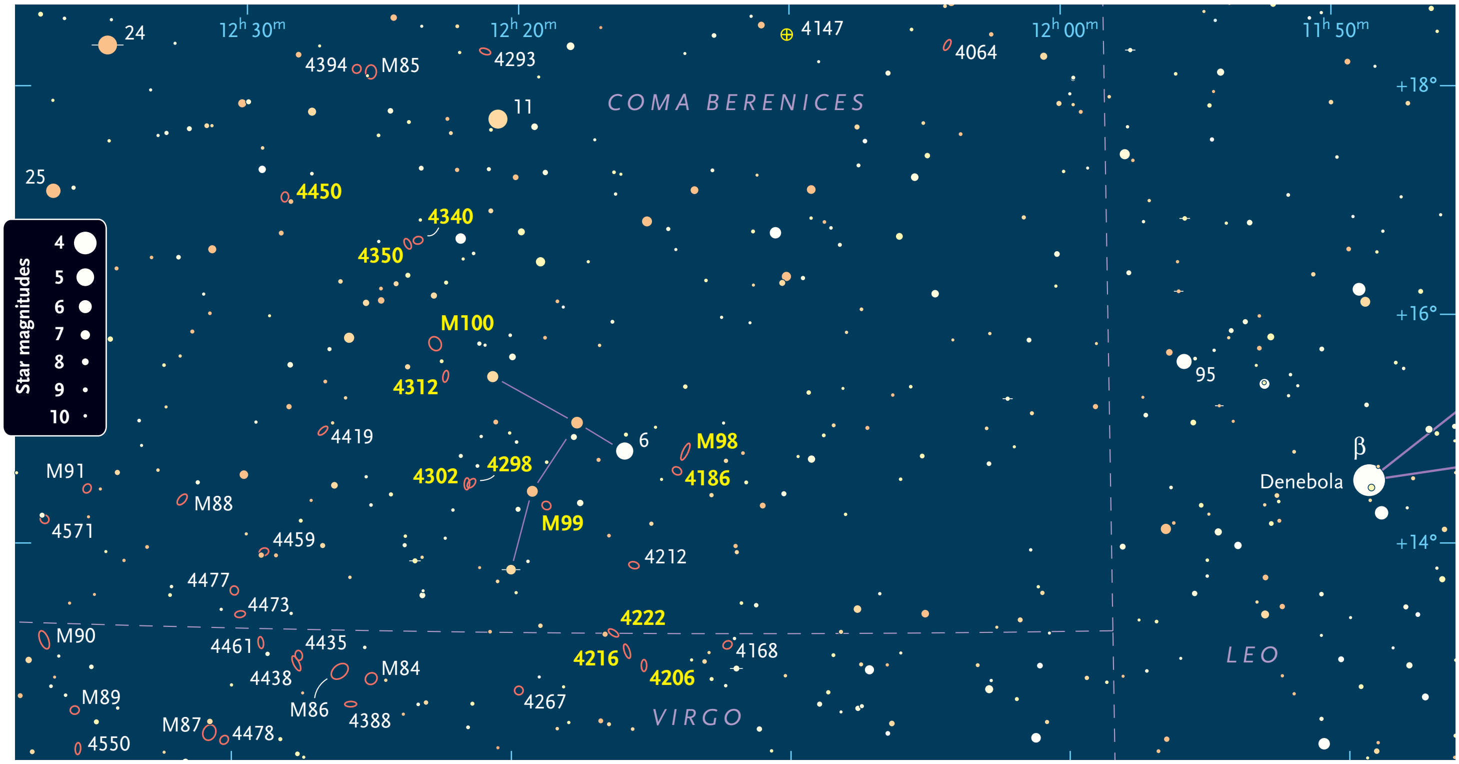
Some remarkable spiral galaxies swarm around the star 6 Comae.

Spring evenings are galaxy time. The misty river of the Milky Way, rich in nebulae and star clusters, hugs our horizon. As compensation for the Milky Way's poor placement in our sky, freedom from its obscuring dust clouds grants us the privilege of gazing deep into space, where lie the distant star cities known as galaxies. The Virgo Cluster of galaxies is conveniently located in one of the least obstructed areas of the sky, its members strewn across the Virgo-Coma constellation border.

Let's visit some of the modestly bright Virgo Cluster galaxies found near the star 6 Comae. At magnitude 5.1, this star is visible to the unaided eye in a fairly dark sky. Otherwise, sweeping 6.5° eastward from the star Denebola in Leo will take you to it. Through a finderscope, you can see that 6 Comae and four other stars form the 1.4°-tall T outlined on the star chart below. This star-studded T will help us find three galaxies from Charles Messier's 18th-century catalog.

The middle and eastern stars of the T's top point directly to **Messier 100**, the brightest of the three. From my semirural home, through 18×50 image-stabilized binoculars, M100 is sizable and relatively easy to see compared to other galaxies in the area. It appears roundish and grows slightly brighter toward the center. My 105-mm refractor at 87× shows a small, round, bright center and a fairly bright, oval halo enwrapped in the filmy gray mantle of a round outer halo. These halos of light are made up of the gracefully winding arms of this face-on spiral galaxy. **NGC 4312** shares the field of view. It's very faint, quite elongated, and leans a bit west of north. A dim star watching the galaxy's eastern flank looks as if it might be double, which is confirmed at 122×.

My 10-inch reflector at 115× shows off more of M100's outer halo. It's perpendicular to the inner halo and covers about 5′ × 4′. Faint stars dot M100's edge southeast and west of the galaxy's center. I can faintly trace a pair of spiral arms unwinding clockwise in the inner halo, and they show nicely at 187×. Viewed at 115×, NGC 4312 reveals a bright, elongated core with ashen extensions that shift the galaxy's tilt a shade farther to the west. NGC 4312 appears



CURT AND SALLY KING / ADAM BLOCK / NOAO / AURA / NSF

ADAM BLOCK / NOAO / AURA / NSF

roughly 3½′ long and one-quarter as wide.

NGC 4340 and **NGC 4350** are perched 55′ north-northeast of M100. The latter is easier to see, but it's just a ghostly little spot through my 105-mm scope at 28×. NGC 4340 makes an appearance at 47× as a soft, round glow with uniform brightness. NGC 4350 now shows a bright core and appears elongated north-northeast to south-southwest. At 87× NGC 4340 sports a bright core and a faint halo that gives the galaxy approximately the same tilt as its neighbor.

My 10-inch scope at 213× shows that this apparent slope is due to brighter patches in NGC 4340's extended halo, which now covers 2½′ × 1½′ and runs east-southeast to west-northwest. NGC 4350 appears about 2′ long and one-third as wide. Each galaxy harbors a tiny, bright nucleus. Although I used high magnification to glean details, I found the most aesthetically pleasing view at 115× — and most of the same features were visible.

Climbing 1.1° east-northeast from NGC 4350 brings us to a 9th-magnitude star, with **NGC 4450** close by to its northeast. I can detect the galaxy's oval glow through my 18×50 binoculars, but the star is quite distracting. It's much easier to sort out with my 105-mm refractor at 47×. The galaxy looks fairly bright, and it intensifies toward the center. At 87× it boasts a small, slightly brighter core.

In my 10-inch reflector at 187×, NGC 4450's faint, 3½′ × 1½′ halo is tipped a bit west of north. The core is perhaps half those dimensions, irregular in brightness, and tipped a little east of north. The galaxy's starlike nucleus is offset to the east of the core's center, and the core grows much brighter toward it.

The next brightest of our Messier-object trio is **Messier 99**, handily located 10.6′ southwest of the middle star in our T's stem. In 18×50 binoculars, M99 is small, fairly easy to see, and roundish with a brighter center. Through my 10-inch scope at 68×, it becomes oval and tips toward the star that we used to find it. The outer halo gives a vague impression of two opposed arms unwinding counterclockwise. At 115× the arm at the southwestern end of the galaxy is more obvious. The galaxy is about 4¼′ × 2½′, with a star at the edge of its southeastern flank. At 213× I noticed a small spot in the halo 1.2′ north of this star. Images show that this is a star-forming region within M99.

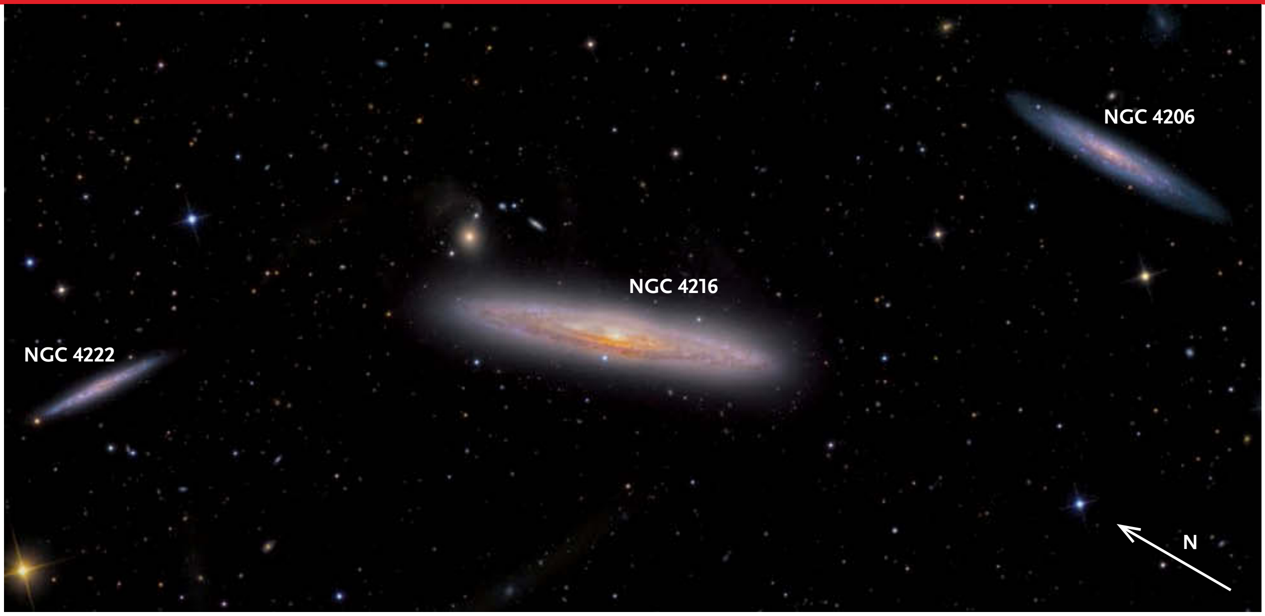
In 1848, M99 became the second "nebula" identified as a spiral by Lord Rosse, the first being the Whirlpool Galaxy (M51) in Canes Venatici.

NGC 4298 and **NGC 4302** share the field with M99 through my 105-mm scope at 47×, but I only see a single

Galaxies in the Virgo Cluster's Northwest Quadrant

Galaxy	Mag(v)	Size	RA	Dec.
Messier 100	9.4	7.4′ × 6.3′	12^h 22.9^m	+15° 49′
NGC 4312	11.7	4.6′ × 1.1′	12^h 22.5^m	+15° 32′
NGC 4340	11.2	3.5′ × 2.8′	12^h 23.6^m	+16° 43′
NGC 4350	11.0	3.0′ × 1.4′	12^h 24.0^m	+16° 42′
NGC 4450	10.1	5.2′ × 3.9′	12^h 28.5^m	+17° 05′
Messier 99	9.9	5.4′ × 4.7′	12^h 18.8^m	+14° 25′
NGC 4298	11.3	3.3′ × 1.2′	12^h 21.5^m	+14° 36′
NGC 4302	11.6	5.5′ × 1.0′	12^h 21.7^m	+14° 36′
Messier 98	10.1	9.8′ × 2.8′	12^h 13.8^m	+14° 54′
NGC 4186	13.8	1.0′ × 0.8′	12^h 14.1^m	+14° 44′
NGC 4216	10.0	8.1′ × 1.8′	12^h 15.9^m	+13° 09′
NGC 4206	12.2	5.2′ × 0.8′	12^h 15.3^m	+13° 01′
NGC 4222	13.3	3.3′ × 0.5′	12^h 16.4^m	+13° 18′

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.

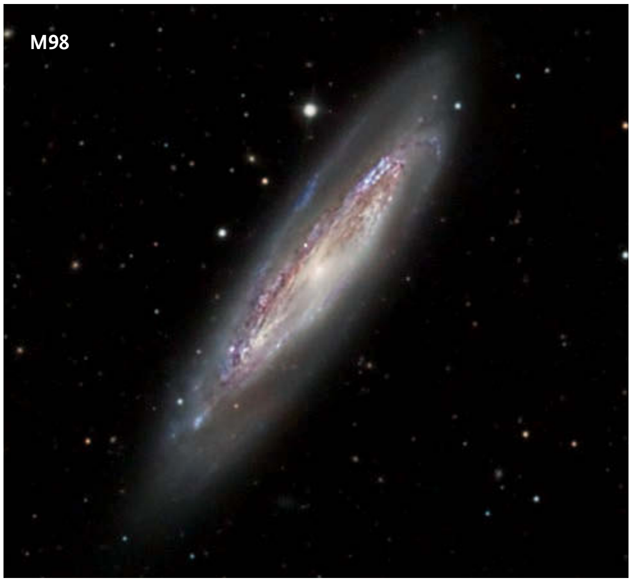


KEN CRAWFORD / DAVID MARTINEZ-DELGADO

smudge. At 87× I can tell that I've only nabbed NGC 4298, which is oval with a very faint star on its northeastern flank. At 122× the galaxy grows a little brighter toward the center, and its northeast-southwest profile appears two-thirds as wide as it is long. With averted vision, I can glimpse NGC 4302's slim streak just east of its companion.

This is a nifty pair in my 10-inch scope at 115×. NGC 4302's north-south ribbon spans 4′ and is brighter for the central half of its length. A 13th-magnitude star rests 1.6′ east of the northern tip. Cozily close NGC 4298 is about 2′ long and holds a large, bright core offset northwest of center. Brightness variations and the extent of the galaxies are better appreciated at 213×, and NGC 4302 wears a faint star on the western edge of its northern tip.

The dimmest of the three Messier galaxies is **Messier 98**, located 32′ west of 6 Comae. It's rather gauzy through the 18×50 binoculars, but fairly long and tipped north-northwest. With my 105-mm refractor at 87×, I see a brighter elongated core within a diaphanous 8′ × 2′ halo. The galaxy is much improved at 122×. There's a petite nucleus and a very faint star 2.6′ to its north-northeast, near the galaxy's flank. M98 points toward little **NGC 4186**, a phantom smudge that makes a nearly equilateral triangle with 11th- and 12th-magnitude stars about 4½′ east-southeast and east-northeast, respectively.



BOB AND JANICE FERA

M98 is lovely through my 10-inch reflector. At 115× the patchy core embraces a small, bright nucleus that's slightly offset from the galaxy's center. NGC 4168 is a fat oval that grows brighter toward the center. It's major axis is about ¾′ long and points at the east-northeastern triangle star.

We'll end our tour with an amazing trio of spiral galaxies nearly edge on to our line of sight. The brightest one is **NGC 4216**, dangling 1.7° south of 6 Comae in the constellation Virgo. I see this galaxy in 18×50 binoculars as a feeble band of light, tipped north-northeast, that grows a little brighter toward the middle. It's easily visible through my 105-mm scope at 28× and shows a small, bright core. At 87× NGC 4216 covers about 7′ × 1¼′, and its core enfolds a bright, starlike nucleus. **NGC 4206** and **NGC 4222** share the field of view. The former is a dim, north-south streak, and the latter is terribly elusive. With averted vision, and perhaps averted imagination, I only suspect a fuzzy spot where the center of NGC 4222 should be.

The trio neatly fits in the field of view through my 10-inch scope when I use a wide-angle eyepiece that gives 115×. NGC 4206 is about 4′ long and displays a slightly brighter elongated core. Gossamer NGC 4222 is a super-thin, 2½′-long slash slanted east-northeast. This rare arrangement of slender galaxies will fit within the field of any eyepiece that gives your telescope a true field of ½° or more. Give it a try! ✦

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Digging Deep in Messier 83

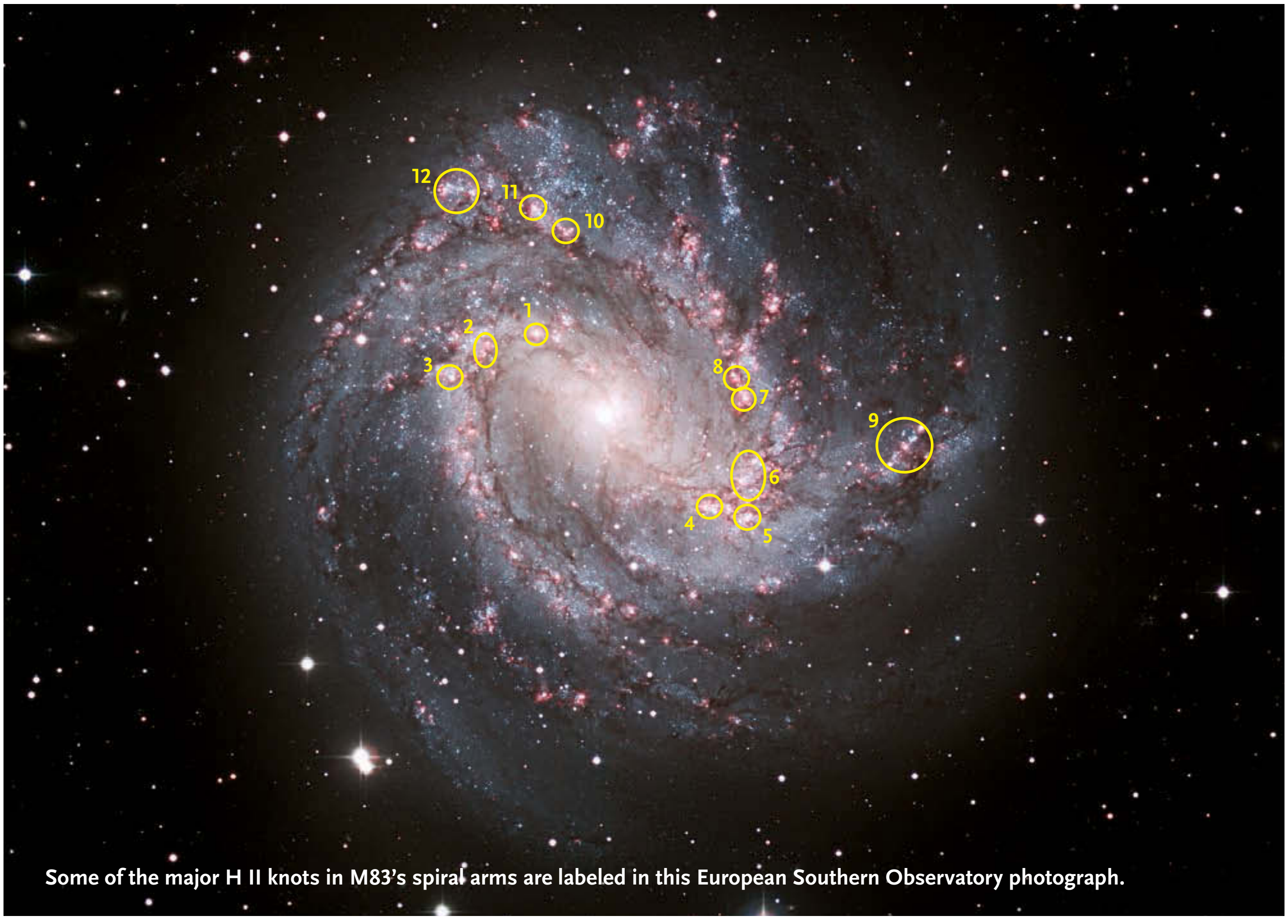
This magnificent spiral galaxy is best observed from southerly latitudes.

M83, THE GORGEOUS Southern Pinwheel, ranks high on my all-time favorites list. Shining at magnitude 7.5, M83 is the 4th-brightest Messier galaxy after M31, M33, and M81. And at a distance of 15 million light-years, it's one of the nearest "grand-design" barred spirals.

M83's spiral arms are bursting with pink star-forming regions and recently minted blue star clusters. A 1983 catalog in the *Astrophysical Journal* lists 298 H II regions — sites where young, massive stars have ionized nearby gas clouds. M83's central bar funnels gas into a starburst nucleus, which harbors numerous massive stars. This activity has produced six supernovae in the past 90 years, a record only surpassed by NGC 6946.

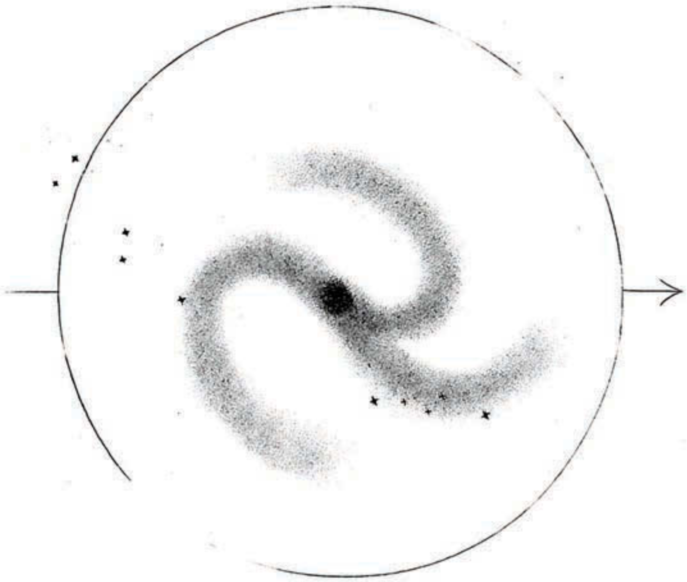
French astronomer Nicolas-Louis de Lacaille discovered M83 during his expedition to the Cape of Good Hope in 1751–1752. Using just a half-inch refractor at 8×, Lacaille cataloged 9,766 southern stars along with 42 nonstellar objects (mostly clusters). He logged M83 as a "small, shapeless nebula" and included it in his list of nebulae "not accompanied by any star."

In 1787 William Herschel trained his 18.7-inch speculum-metal reflector on M83 from his garden in Slough, England. Although the galaxy was just 10° above the horizon, he noted "faint branches about 5′ or 6′ long, elongated southwest to northeast." Searching for clear, transparent skies, British amateur astronomer William



Some of the major H II knots in M83's spiral arms are labeled in this European Southern Observatory photograph.

ESO



A 48-inch reflector and an observing site at latitude 35° north enabled William Lassell to discern M83's spiral structure in 1862.

Lassell shipped his 48-inch equatorial reflector to the island of Malta in 1861. Lassell observed M83 the following spring, describing it as a "three-branched spiral" and producing the sketch shown above.

M83 is buried in southern Hydra, 19° south of Spica, at declination –30°. So mid-northerners often observe M83 through the haze and light pollution that tend to hug the horizon, making it tough to see more than its bright core. But given the right conditions, M83 is rich in detail, with 8- to 10-inch scopes revealing the central bar and spiral arms, and larger apertures resolving multiple H II knots and dark rifts.

I first observed M83's spiral structure through my 13-inch solid-tube reflector in the early 1980s. I saw a weak central bar running northeast to southwest, punctuated by a small, bright core. The two principal arms weren't easy, but they nearly merged to form the Greek letter theta (θ). Not bad from Northern California, but I knew I was missing out on the real deal.

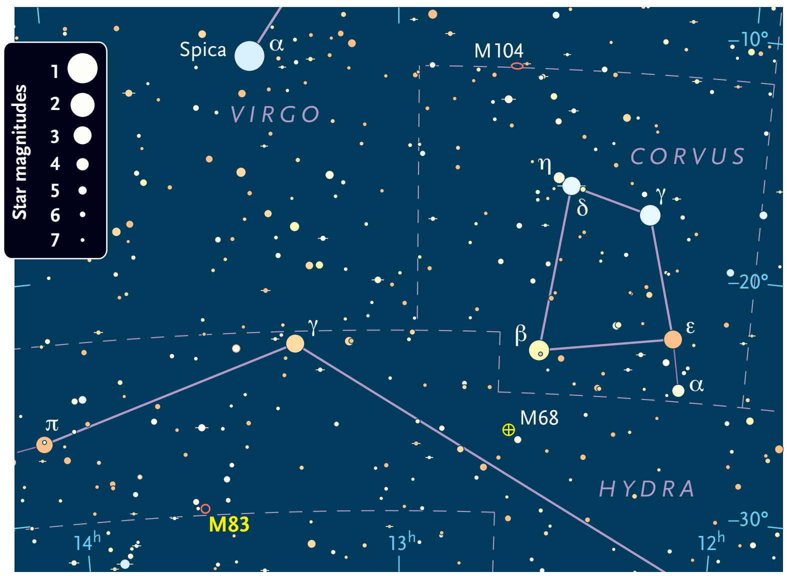
In February 2004, I lugged a 13-inch airline-portable travelscope to the Costa Rica Southern Sky Party, which is held annually at a dark site along the Gulf of Nicoya. From a latitude of +10° north, M83 rose 50° above the horizon, and the detail now popped! Three spiral arms were separated by darker ribbons of dust and embedded within an 8′ × 6′ halo. The arm attached to the northeast side of the bar unfurls counterclockwise around the south side of the galaxy. Its counterpart begins on the bar's southwest end and shoots north before curling eastward along the north side. The third arm branches outside to the south and curves west.

In 2008 I traveled to Zane Hammond's Magellan Observatory in Australia and viewed M83 in his 24-inch f/3.7 scope while it was directly overhead. At 200× the bar extended 3′ × 1′ and enclosed a bright circular nucleus. The two prominent arms appeared chiseled with high contrast by dust lanes at their edges. The longer northern arm winds roughly 270°, merging into the halo on the southeast side near the 8″-wide double star h4599, whose components shine at magnitude 10.5 and 11.5. The southern arm attaches at the northeast side of the bar, sweeps south and west, and peters out 3′ south of center. When I increased the magnification to 375×, several small knots sparkled near the inner ends of both arms, and darker veins of dust sliced across the arms.

Last spring I scrutinized M83 in Texas through Jimi Lowrey's 48-inch jumbo-sized Dob, and the arms were chock-full of glowing H II regions. The brightest of these are marked on the photograph on the facing page. At 488× I saw three prominent knots (#1–3), varying in size from 10″ to 20″, at the northeast end of the central bar. A series of fuzzy splotches was symmetrically placed on the opposite side (#4–8), with the largest splotch extending 25″. And I saw additional bright clumps at the southwest (#9) and northeast (#10–12) sides of the halo.

To view M83 in its full glory — along with the many other showpieces of the far-southern sky — I highly recommend adding a Southern Hemisphere trip to your bucket list. But from any location, your best view will be on a dark, transparent night when M83 is at its highest on the meridian. ✦

S&T *contributing editor* ***Steve Gottlieb*** *has made several trips to the Southern Hemisphere to complete his observations of the* New General Catalogue of Nebulae and Star Clusters.



Dennis di Cicco

Takahashi's New ε-130D Astrograph

A premier astrograph from the days of film-based photography gets an update for the digital age.

ε-130D Astrograph

U.S. price: $2,995.

As tested with Micro Edge Focuser, tube rings, dovetail mounting plate, and Nikon camera adapter: $4,095.

www.takahashiamerica.com

Takahashi has re-engineered its legendary 130-mm f/3.3 Epsilon astrograph for digital imaging. The ε-130D's massive focuser easily handled the 5½-pound (2.5-kg) load of the camera pictured on page 65. It is shown above with the optional 10:1 Micro Edge Focuser, which the author considers a must-have accessory for such a fast optical system. The focuser doesn't have a provision for squaring a camera body to the optical axis — something rarely needed for DSLRs, but it can be required for optimum performance of astronomical CCD cameras, especially at f/3.3.

ALL PHOTOS BY THE AUTHOR

It was a little like dealing with Russian nested matryoshka dolls as my colleague Sean Walker and I worked our way through yet a third inner shipping box on our way to the new Takahashi ε-130D astrograph. But when we opened the last box and brushed aside a layer of packing peanuts to reveal the gleaming yellow telescope, it was if we had just stepped out of Mr. Peabody's Wayback Machine and into astrophotography's dream world of 30 years ago. And unless you've been photographing the night sky since well before the digital age, then that flashback may require a bit of explanation.

Unlike today, in the mid-1980s there were very few commercial astrographs — telescopes made specifically for astrophotography. The Epsilon hyperbolic astrographs from Takahashi were one of the few exceptions. There were five models ranging from a 130-mm (5.1-inch) f/3.3 up to a special-order 300-mm f/3.8. Relatively speaking, they were expensive and rare, even among advanced astrophotographers. But they produced incredible wide-field photographs that elevated their status to that of "dream machines" for many of us diehard sky shooters.

Now Takahashi has reintroduced the smallest member of the Epsilon series specially designed for digital cameras. The main difference involves the multi-element corrector lens that screws into the telescope's focuser (and it is sold separately for $699 for use with the original ε-130 astrographs). The new corrector is spec'd with a slightly smaller 44-mm-diameter imaging circle covering 5.9°, rather than the original's 48-mm, but it offers tighter star images and less field distortion. To check it out, we borrowed the ε-130D from Texas Nautical Repair, Takahashi's exclusive North American distributor.

Pure Takahashi

The moment I lifted the ε-130D from its box I could tell it was pure Takahashi. Built like a battleship with flawless fit and finish, the scope has the immediate look and feel of quality. The tube, which is made of steel, has heavy cast-aluminum end rings and an exceptionally solidly made spider assembly for the large secondary mirror.

The rack-and-pinion focuser is massive, with silky-smooth motions for the drawtube and rotating base, which turns 360° and makes it easy to frame celestial targets. I was surprised to find that the focuser comes with only standard hand knobs. The 10:1 Micro Edge Focuser, which is really a must-have accessory for an f/3.3 instrument, is a $299 option. Fortunately, the user can easily install the Micro Edge Focuser at any time without modifying the original.

The ε-130D's primary *and* secondary mirrors have precision centering marks to aid in optical collimation, which is critical for an f/3.3 system. The scope, however, arrived in perfect collimation, and it's difficult to imagine how much abuse it would take to knock it out of optical alignment.

Another Takahashi feature of the ε-130D is its robust line of accessories, including tube rings, mounting plates, and, especially, a plethora of bits and pieces for adapting various cameras to the scope. These include adapters for popular DSLR and astronomical CCD cameras. For optimum optical performance, a camera's focal plane needs to be 56 mm from the corrector's mounting flange. This is sufficient back focus for all DSLR cameras compatible with T mounts, as well as many astronomical CCD cameras and filter wheels, including SBIG's STT-8300 with its thick, self-guiding filter wheel (*S&T:* July 2013, page 62).

The ε-130D is very compact with an overall tube length of just 18 inches. On paper, its 10.8-pound (4.9-kg) weight makes it sound like a good match for relatively small German equatorial mounts, but there's more to the story. The large focuser, especially when fitted with a heavy astronomical camera, places a significant load well off to the side of the scope's optical axis. As such, a lot of counterweight is typically needed on the tube end of the declina-

As explained in the text, the 10.8-pound astrograph is a challenge to properly balance, especially on small equatorial mounts. This picture does not include the large additional counterweight that was needed to achieve perfect balance for this setup.

The author took this view of the Pleiades in a moonlit sky with a full-frame DSLR camera. It shows only moderate vignetting in the corners of the frame due to the ε-130D's optics, but the camera adapter and camera body itself caused significant light-loss around the edges of the frame.

Suburban skies limited the author's unfiltered exposures, but they were less of a problem for images made with a narrowband hydrogen-alpha filter. This view of the Rosette Nebula is a full-frame image made with the setup shown on the facing page.

tion shaft to balance the system. This, in turn, calls for more counterweight on the other end of the declination shaft, and a small mount can quickly approach its weight limit for a properly balanced ε-130D.

There are various ways to tackle the balance issue. The easiest is to use a heavy-duty mount and let the telescope-side of the system be out of balance. That's what I did for the setup shown on the facing page with the ε-130D on an Astro-Physics Mach 1 GTO mount. Another approach is to place the focuser and camera on the "top" side of the tube as shown on page 63 (most set-ups don't have adequate clearance to have the camera on the bottom of the tube). Putting the camera on top of the tube places it far from the polar axis and thus requires some extra counterweight on the other end of the declination shaft, but at least the system will be balanced. (What's not shown in that photograph is the big, ugly counter-weight I really used on the iOptron iEQ30 mount to make the pictured setup balance.)

WHAT WE LIKE:

Excellent image quality

Solid construction

High-quality focuser

WHAT WE DON'T LIKE:

10:1 fine-focus accessory not standard

Focuser has no provision for squaring cameras to the focal plane

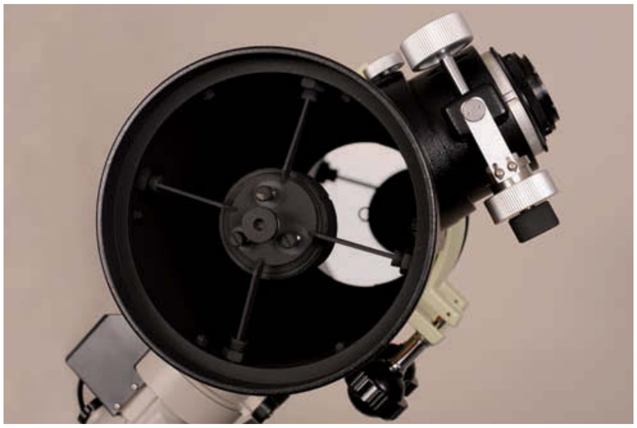
Optical Performance

Given the reputation of the original Epsilon astrographs, I wasn't surprised that the ε-130D delivered excellent optical performance. The 44-mm-diameter imaging circle is large enough to cover the 24-by-36-mm detector in a full-frame DSLR camera as well as the popular Truesense Imaging (formerly Kodak) KAF-11000 CCD used in many high-end astronomical cameras. Star images were indeed tiny, round pinpoints in the corners of this detector's frame, which covers a 3.2° × 4.8° field. There was, however, some

***Right top:* The corrector lens at the heart of the ε-130D's digital upgrade is available separately for use with the original ε-130 astrographs introduced in the mid-1980s.**

***Right center:* The primary and secondary mirrors have accurate centering marks that aid in collimating the system.**

***Right bottom:* With careful balancing, the ε-130D and a DSLR camera worked well on the iOptron iEQ30 mount shown on page 63. Less care was needed for this setup due to the greater load capacity of the Astro-Physics Mach 1 GTO mount despite the heavier SBIG STT-8300 camera and self-guiding filter wheel.**



vignetting in the corners of the field, especially in the case of DSLRs attached to the scope with T-mount hardware. Takahashi's wide-mouth Nikon adapter helped, but some vignetting remained in addition to that due to the inherent light falloff of the telescope's optics.

In my opinion, where the ε-130D really struts its stuff is when the scope is fitted to an astronomical camera having a KAF-8300 CCD. Such a setup covers a 2.4° × 1.8° field with an image scale of 2.6 arcseconds per pixel — great for wide-field deep-sky work. And while I don't recommend that people dispense with flat-field calibration frames, the ε-130D shows such modest vignetting on the KAF-8300 chip that I could process many images without them, as was the case for my shot of the Rosette Nebula on the facing page. The ε-130D will also perform well with smaller chips in APS-format DSLR cameras.

Although my testing was done under very cold winter conditions, I didn't have the wide swings in nighttime temperature that often occur during the rest of the year here in New England. As such, I didn't experience any significant temperature-induced focus change. But that's not to say it isn't likely to be an issue with the ε-130D. Conventional wisdom holds that an f/3.3 optical system has a focusing tolerance of approximately 27-microns, which is the amount that the ε-130D's steel tube will expand or contract with a 9°F (5°C) temperature change. But if you adopt the more-stringent focusing tolerance given by Don Goldman and Barry Megdal (*S&T:* August 2010, page 72), the value drops to a mere 5 microns and about a 2°F temperature change. I certainly experienced this much change on the nights I was shooting, but I didn't notice any softening of star images due to a focus shift, at least not one I could separate from my images being naturally softened by atmospheric seeing as my targets dropped in altitude.

The Takahashi ε-130D astrograph continues the reputation established by its predecessors in the age of film-based astrophotography. For its aperture and focal length it remains one of the world's premier astrographs for DSLR and astronomical CCD cameras. ✦

Senior editor ***Dennis di Cicco*** *vividly recalls early photographs made with Takahashi's Epsilon astrographs that began appearing in Japanese magazines in the mid-1980s.*

◂ MERCURY GLOBE *Sky & Telescope*, in cooperation with NASA and the U.S. Geological Survey, unveils the first-ever complete photographic Mercury globe ($99.95). This 12-inch globe of the innermost planet in our solar system is based on thousands of images recorded by NASA's Messenger spacecraft. The globe includes the names of nearly 400 features (craters, mountains, valleys, etc.) named after famous artists, musicians, and other contributors to the humanities. Each globe comes with a clear plastic stand and a fact sheet that provides more details about the Messenger mission and how we produced the globe.

Sky & Telescope 90 Sherman St., Cambridge, MA 02140
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▸ PORTABLE TRACKER iOptron unveils the SkyGuider Equatorial Mount ($578), an ultra-portable mount for wide-field astrophotography. The SkyGuider is a compact German equatorial mount with a single-axis drive to enable precise tracking of the stars using the same RA gear and worm as the company's ZEQ25GT mount (reviewed in the March issue, page 60). It can also accept autoguiding corrections via a standard ST-4 port. The unit can sturdily bear a load of up to 11 pounds (5 kg) and accepts the company's ball head to attach your camera or telescope via a standard ⅜-16 mounting screw. The unit is powered by an included cigarette-lighter adapter and includes a removable counterweight shaft with 3.3-pound counterweight that can be replaced with an additional ball head for dual camera operation. The SkyGuider includes an Accu-Aligning polar scope, a stainless-steel field tripod, and a soft carrying case. See the manufacturer's website for additional details.

iOptron 6F Gill St., Woburn, MA 01801
866-399-4587; www.ioptron.com

DOB PLATFORM Alien Platforms now offers tracking for your Dobsonian telescope. The new Alien Platform Single-Axis Model ($319) can accommodate a Dobsonian-mounted Newtonian up to 12 inches and weighing as much as 85 pounds (39 kg). The platform includes three non-slip footpads for aligning your Dob on the platform, each of which glows in the dark to make setup after dark a hassle-free endeavor. Each platform is handcrafted from superior-grade maple and birch plywood. The motor tracks for one hour before requiring a reset, and is powered by a single 9-volt battery.

Alien Platforms 1863 Ridge Rd., Champlain, NY 12919
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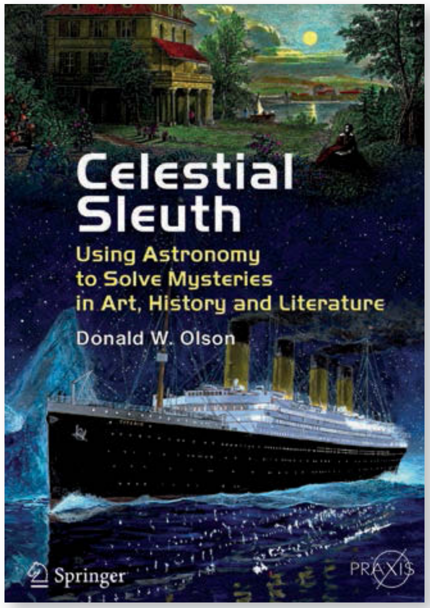
History Mysteries

Celestial Sleuth: Using Astronomy to Solve Mysteries in Art, History, and Literature



Donald W. Olson
Springer, 2014
355 pages, ISBN 978-1-4614-8402-8, $39.99, softcover.

TEXAS STATE UNIVERSITY astronomer Donald Olson has just come out with a book that is perfectly suited for *S&T* readers with a wide interest in astronomy in a popular context. Like an astronomical Sherlock Holmes, Olson has combined astronomy with history, art, and literature to solve a variety of past mysteries.

Olson tells detective stories that cover an incredibly wide range of topics and well-known cases. He repeatedly comes up with surprising and evocative solutions, all with convincing proofs that scholars should have picked up decades or centuries earlier. The exciting revelations on famous cases make *Celestial Sleuth* a unique book.

Many of these cases have been previously solved in *S&T* feature articles coauthored by Olson. For the past two decades, the monthly arrival of a new issue of *S&T* always had me first looking with joyful anticipation for the latest article by Olson. This book weaves these cases together as a consistent story, and with new material.

I can vouch for the technical accuracy of Olson's calculations. And I am impressed by the wide variety of evidence he brings to bear on astronomical questions. A hallmark of his work is to visit the site, find the exact place where the event took place, and to measure the angles and directions involved (with theodolites, star trails, and such) to determine the astronomical conditions. He and his colleagues then re-create the exact conditions, whether it is drifting with the tides in the English Channel or photographing moonbows in Yosemite National Park.

Part I of the book covers "Astronomy in Art." Olson solves the riddle of why the sky is frighteningly red in Edvard Munch's iconic painting *The Scream*, making a convincing connection to a catastrophic event on the other side of the world. The celestial sleuth also makes cases of famous works by Claude Monet, Vincent van Gogh, J. M. W. Turner, Ansel Adams, and Frederic Church.

Part II discusses "Astronomy in History." Olson solves the mystery of why the predicted high tide failed to rise during the November 20, 1943 landing of U.S. Marines on Tarawa in World War II, which resulted in more than 1,000 casualties as the men waded ashore under heavy machine gun and artillery fire. He also solves mysteries on the death of Stonewall Jackson, the Pearl Harbor attack, D-Day, the *USS Indianapolis*, Abraham Lincoln, the Battle of Marathon, Julius Caesar, the Boston Tea Party, Paul Revere's ride, and the *Titanic*.

Part III covers "Astronomy in Literature." As an astrophysicist working on historical supernovae, I am convinced that Olson has correctly identified the appearance of Tycho's 1572 supernova as being accurately reported in Shakespeare's *Hamlet*. Olson's literary casebook includes Omar Khayyam's *Rubaiyat*, Chaucer's *Canterbury Tales*, William Blake's *The Tyger*, Mary Shelley's *Frankenstein*, James Joyce's *Ulysses*, and Walt Whitman's *Leaves of Grass*.

Don Olson's *Celestial Sleuth* has become my all-time favorite astronomy book because of its beauty and fun, as well as its many startling and convincing new results. ✦

***Bradley E. Schaefer** is a professor in the Department of Physics and Astronomy at Louisiana State University and is on the board of advisors for both the* Journal for the History of Astronomy *and* Archaeoastronomy. *An* S&T *subscriber since 1969, he has read all issues back to volume 1.*

A Featherweight Front End

Innovative materials and a clever design stretch this scope's limited "weight budget."

ONE OF THE MOST important components of a successful Dobsonian telescope is a lightweight front end. In general, every ounce added there will require five times as much weight (or more) added to the scope's back end to ensure the tube assembly balances. The situation is even more challenging with ball-and-socket-type reflectors. By their nature, these scopes require an even lower center of mass, so keeping weight off the front end becomes doubly crucial. Just ask Oregon ATM Jerry Oltion.

IMAGES COURTESY JERRY OLTION

Below left: **Oregonian ATM and science fiction writer Jerry Oltion made this striking 12-inch ball-and-socket telescope.** ***Above:*** **Crucial to the instrument's success is a lightweight front end and secondary-mirror support cage, which allowed him to dispense with the counterweights normally used behind the primary mirror to balance a scope of this design. The ball is made from an acrylic lighting-fixture globe available from www.1000bulbs.com.**

Jerry's original 10-inch Trackball scope was featured in our August 2006 issue, page 100. It's a clever design, but when Jerry wanted to build an even larger version with an aperture of 12½ inches, he decided to try something a little bit different. "For this scope I used a full-thickness mirror that weighs 18 pounds (8.2 kg), and I wanted to see if I could make the scope without the usual counter-weights inside the ball," he says. "The short f/4.6 focal ratio, and the requirement that the center of gravity be at the center of the ball, meant the scope's upper end could weigh only 40 ounces (1.1 kg), including the eyepiece!"

Clearly his choice of materials for the secondary cage was important. After a couple of false starts, he discovered Duraplast — a rigid, lightweight, reinforced foam-board that comes in sheets of various thicknesses. It's available in flat black.

"It's beautiful stuff to work with," Jerry says. "It cuts smoothly with a circular saw, and glues well with epoxy. It's also sturdy enough that I could bolt the truss poles directly to the secondary cage by using nylon sleeves in the Duraplast bolt holes for the bolts to tighten against."

Even after making the Duraplast secondary cage, Jerry still had an uphill fight to stay within his weight budget. Subtracting the 6-ounce weight of the scope's secondary mirror and another 7 to 8 ounces for the eyepieces he wanted to use, he had only 4 or 5 ounces left for the spider, finder, and a 2-inch focuser.

Ingenuity was needed to make a focuser light enough. Jerry's solution was to start with a section of 2-inch plastic ABS pipe, a piece of aluminum angle stock, and a set of "perfect" miniature bearings mounted on 1-inch-long shafts that he purchased from Surplus Shed (**www.surplusshed.com**). The focuser's drive is a size-2 knitting needle (donated by his wife Kathy) inserted into a length of plastic tubing for extra traction. "A piece of high-density plastic made a good tensioner bearing, and I used parts made from a file-folder hanger to support the drive shaft," Jerry adds. And with that the focuser was done — all 5 ounces of it.

That left next to nothing in Jerry's weight budget for the finder and spider. For the spider, he says, "I used as close to nothing as I could get away with: a plastic vitamin bottle cut at an angle and suspended by "vanes" made of 24-gauge wire." The finder is a minimalist "stick" finder like the one he described in the June 2013 issue, page 66.

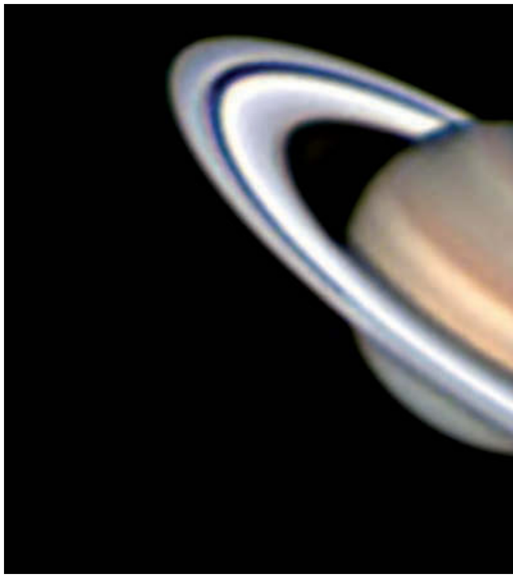
When everything was ready, it was time for the moment of truth. Would the scope balance? "I assembled the scope, set it on its ball end, and let go," Jerry recalls. "I was afraid the top end would plummet to the floor, but it balanced!" Furthermore, because his calculations and weight estimates had been conservative, the scope was slightly back-end heavy. This proved a good thing, since it enabled him to use all but the heaviest eyepieces in his collection. Remarkably, the entire telescope weighs just 35 pounds — only 17 pounds more than the primary mirror alone.

One key to keeping the scope's front end lightweight is this home-built, Crayford-style focuser. Its main components are a short length of aluminum angle, a piece of PVC pipe, a knitting needle, and surplus bearings described in the accompanying text.

"I've been insanely happy with the scope out under the stars," Jerry says. "The focuser has no backlash or image shift, and the secondary cage is as stiff as can be, adding no vibration that I can detect."

Readers wishing to learn more about this telescope can visit **www.sff.net/people/j.oltion**. ✦

Contributing editor ***Gary Seronik*** *is an experienced telescope maker who has made several lightweight travelscopes. He can be contacted through his website,* ***www.garyseronik.com***.



Redeeming Color

Dan Llewellyn

Advances in imaging technology should make amateurs give these cameras a second look.

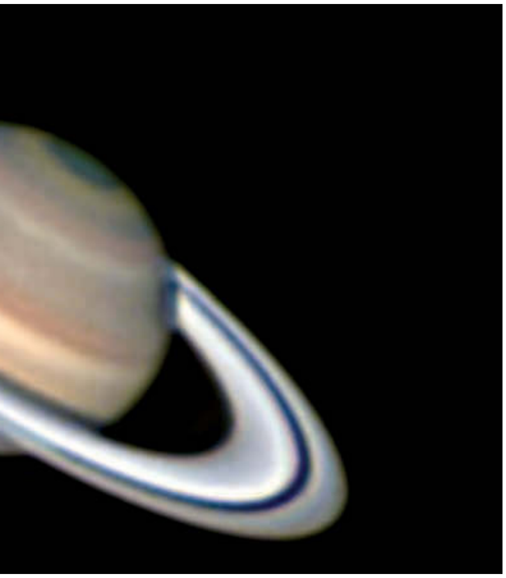
PLANETARY IMAGERS these days routinely produce high-resolution photos of the Sun, Moon, and planets with high-speed video cameras. Most use a monochrome camera with individual color filters to record videos that then are stacked, sharpened, and combined into the final color image. But depending on your interests, you can eliminate the monochrome camera — with its complex filter wheels and expensive filters — and use a color video camera to record some of the highest-quality planetary images around.

Online imaging forums are almost universal in their recommendation to use a monochrome camera with separate red, green, and blue filters instead of a one-shot color (OSC) camera. That's because color cameras are reputed to produce inherently lower-resolution images due to their filter matrix, known as the Bayer filter. That may have been true a few years ago, but changes in interpolation algorithms, chip sensitivity, and stacking software have made this problem a thing of the past.

Understanding Color Cameras

Both CCDs and CMOS sensors in all digital cameras start their lives as monochrome sensors. In order for a monochrome sensor to produce a color image, two things are necessary: a color filter array (CFA) permanently affixed over the sensor, and software to re-interpret the images as individual color channels. The vast majority of OSC cameras use the Bayer filter, named for its inventor, Bryce Bayer. This 4-pixel block of tiny color filters, arranged in a repeating grid of one red, two green, and one blue pixel over the entire sensor, was designed to mimic the human eye's response to color and luminosity. The result is an image where 50% of the pixels are recorded though the green filters, 25% are red, and 25% are blue-filtered, all on the same grayscale image.

Your camera's control software (or your preferred planetary stacking program) then separates the pixels into the three respective color channels and interpolates the "gaps" between the missing pixels on each channel to



Planetary Cameras

make a color image. This is where a popular misconception comes into play. A 4-pixel block that only samples one pixel in red should have the red information reduced by 75%, right? Wrong! Each pixel in an OSC camera reports information in all three color channels, regardless of which filter is over the pixel, when the image is run through an advanced debayering algorithm.

Color through Debayering

A debayering (or demosaicing) algorithm interprets the color information from an OSC camera to reproduce the luminance and chrominance of the imaged target. The oldest, fastest, and worst debayering algorithm for planetary imaging is known as nearest neighbor. It simply takes the missing pixel values from its adjacent pixels. So in a 4-pixel block (2×2 array), the green-filter pixels will copy the red and blue pixels' luminance values next to it and mix them together to make an RGB value for each green pixel. This is repeated on the red and blue pixels. The process has the unfortunate side effect of producing color fringing, which is enhanced when you sharpen the image.

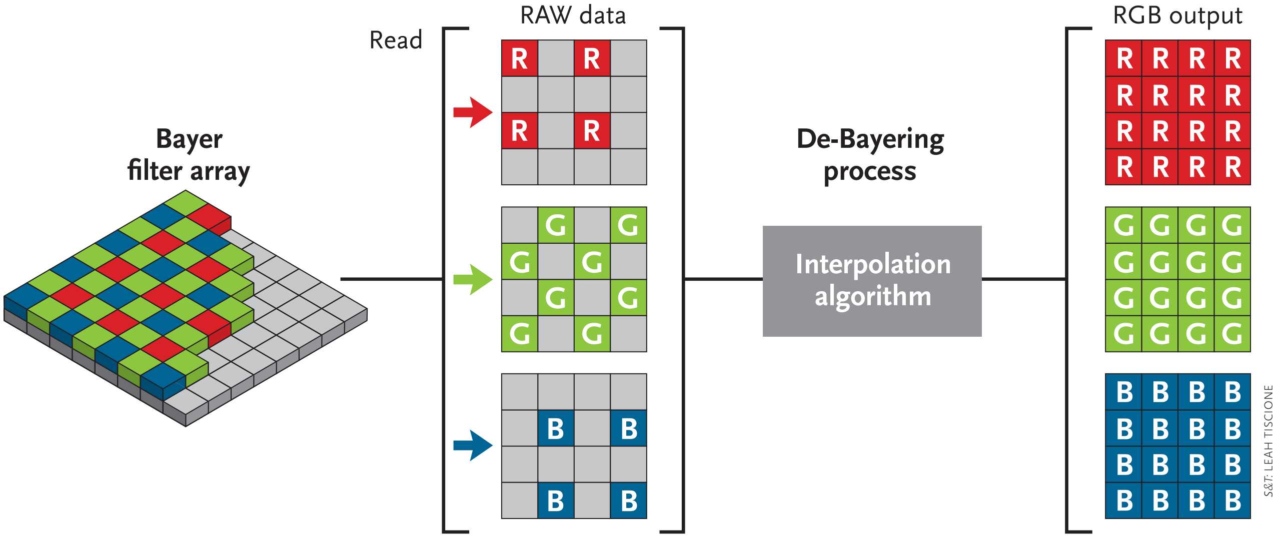
Fortunately, today's high-speed color planetary cameras allow us to avoid the problems of nearest neighbor debayering. The easiest option is to record raw video files and then debayer them later during post-processing. Nothing is done to the values but a straight capture. On most models, this is done by recording using the Y800, Y1600, or FORMAT 7 video codecs.

Another option is to record in raw debayered mode.

Digital imaging of the planets burst onto the scene in the early 21st century. Although most practitioners recommend using a high-speed monochrome video camera to take multiple images through color filters in a mechanical filter wheel, few realize it's easier than ever to take great planetary images. Modern processing algorithms have caught up to color camera technology, enabling you to take images of Jupiter, Saturn, and Mars like the ones shown above without the need of additional equipment besides your telescope, a camera, and your PC computer. All images are courtesy of the author unless otherwise credited.

This feature debayers the video frames directly in your camera, which then streams a color video to your computer's hard drive. Although this method enables you to use more advanced debayering before stacking, the option produces color video files that are much larger than a raw video and requires that you have a high-speed camera interface and a fast computer processor with lots of memory. (Roughly speaking, you'll download three times as much data in debayered mode than in raw.)

Finally, most color camera models offer the option to record videos in "color space debayered" mode. This is done using the codecs RGB, YUV411, 422, or 444. This mode enables you to use a predetermined color space applied to the video stream. I prefer to apply the RGB color space to my videos, although YUV options allow for better separation of luminance and color information in the recorded video. Regardless of the color space you use, each requires adjustment to achieve a neutral color balance, and you must change the debayering method from



Because all images and videos recorded with a color camera are recorded through tiny color filters placed over each pixel (left), a special computer program known as a debayer filter must separate the individually filtered pixels into their respective color channels (center), and then fill in the missing pixels in each color using an interpolation algorithm to create the final color result (right).

nearest neighbor before you start recording.

When processing raw bayer-filtered video files, you need a stacking program that gives you options to utilize the newer debayering algorithms, specifically High Quality Linear and Directional Filter. Algorithms such as these are much more effective because they examine both larger blocks (8×8 and larger), rows, and columns of pixels to derive a more accurate trichromatic representation.

It should be noted that *RegiStax* (**www.astronomie.be/registax**), the venerable go-to program for stacking since the dawn of planetary video stacking, uses the nearest neighbor algorithm exclusively. So if you prefer to stack color videos using *RegiStax*, you'll need to debayer the data before stacking. The free camera control software *FireCapture* (**http://firecapture.wonderplanets.de**) comes with a stand-alone program called *Debayer.exe* that rewrites your raw video file using a selection of advanced debayer algorithms. Additionally, the program *PIPP* (**https://sites.google.com/site/astropipp**) offers multiple debayer options. For best results, use either of these programs before stacking your video in *RegiStax*.

Another option for stacking raw videos is the program *AutoStakkert!2* (**www.autostakkert.com**). This program uses the advanced algorithm Bayer drizzle, which doesn't interpolate at all. Instead, it takes advantage of the drift in planetary videos to fill in the missing spaces between pixels with real data. This method undermines the myth of color cameras producing inherently lower resolution.

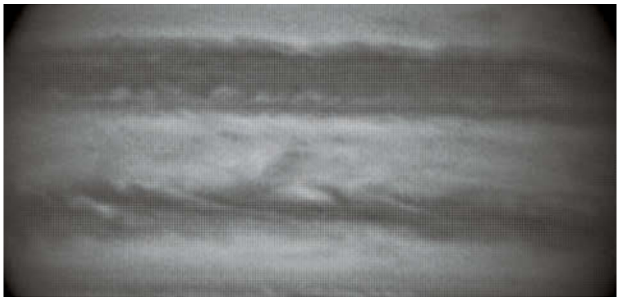
The oldest debayer algorithm, known as nearest neighbor, simply looks at the closest adjacent pixels to fill in the missing information. This leads to color artifacts that can significantly degrade your final image (*top*). Sophisticated newer debayer algorithms, such as HQ Linear, examine a large radius of pixels to more precisely fill in the missing information, which produces a sharper, cleaner result (*bottom*).

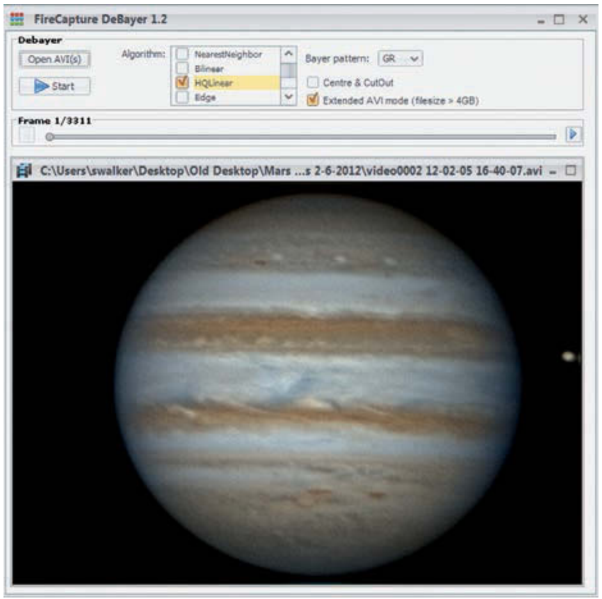
At the Telescope: Using the Histogram

If you decide to image with a color camera, make sure you use the histogram tool when recording your videos. This feature displays a linear measurement of the signal in your video, enabling you to avoid overexposing the brightest regions. The histogram tool is critical for achieving color balance and exposure. If the control software that came with your camera does not have a live histogram tool, I recommend using *FireCapture*, which supports most popular camera models.

The benefit of using the live histogram is to let you adjust all three color channels to roughly equal levels, so that you can achieve a natural color balance. You'll thereby set your white point, or color balance, for capture and ultimately produce more natural color-balanced images right from the start.

The histogram tools in *FireCapture, IC Capture.AS,* and *FlyCap* display the histogram as the 256 levels of gray on a standard 8-bit video display. Using this scale, I prefer to expose my videos to peak between roughly 64 and 96, or about 25–33% of the histogram. Exposing to much higher levels can lead to overexposure of the brightest areas of your target, which is impossible to recover during post-processing. In order to get the histogram within this range, you need to adjust your exposure. The image will look dim on your laptop monitor, but this is inconsequential: you can brighten the image during stacking.



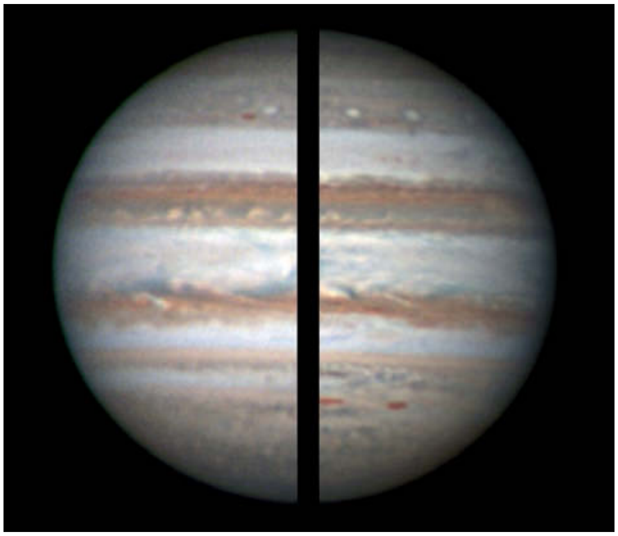


Above: **Most amateurs using color cameras opt to record their videos in "raw" mode, which simply records the video as if it were a monochrome detector. The resulting image looks like the target was captured through a window screen. Although this option produces the smallest file size, it still requires debayering to convert into a color image. *Right:* If you keep your older raw color video files recorded using the Y800 video codec, you can debayer it using one of the many pre-processing programs such as *Debayer.exe* and then re-stack the result in *RegiStax*. The resulting image is almost always better than your previous attempts.**

Exposure, Gain, and Frame Rate

Here's where it's important to understand the relationship between exposure, gain, and frame rate. You adjust the maximum intensity of the image by varying the exposure of your camera, which is the time the electronic shutter in your camera is exposing each frame. Frame rate is defined as how many pictures the camera can take in a second (fps). So there is an inverse relationship between the camera frame rate and exposure — the higher the frame rate used, the quicker the shutter has to be. This means if you're using a high frame rate, you'll need to increase the electronic gain to boost the image signal to keep it properly exposed.

But be warned: gain adds electronic noise. For a color camera, you should limit the gain increase to as little as possible. I suggest using a modest frame rate to keep the gain settings low. When imaging through my Celestron C14 and my Point Grey Research Flea3 video camera, I use 15 fps when imaging Saturn, 20 to 30 fps for Jupiter, and 30 to 40 fps when shooting Mars. It's much easier to stack 1,000 properly exposed video frames with low noise levels than 3,000 noisy, gain-amplified frames.



Although *RegiStax* has long been the go-to program for planetary video stacking, it exclusively uses the nearest neighbor algorithm to debayer raw video files. The result at left is a *RegiStax* result, whereas the right-half image was debayered using the HQ Linear algorithm found in the program *Debayer.exe* that comes with *FireCapture*. Nearly all the small-scale detail is noticeably sharper in the HQ Linear-processed image.

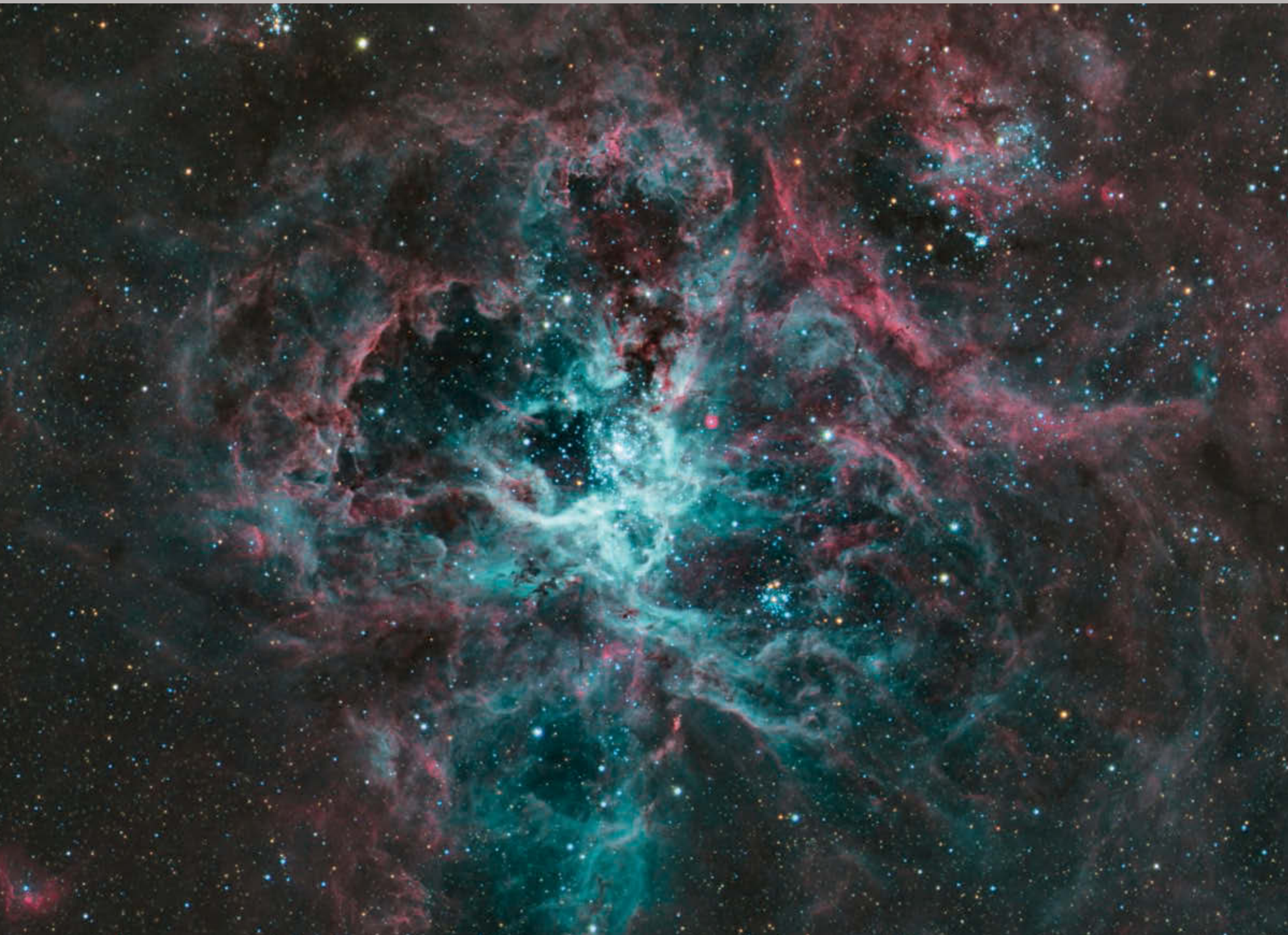
Additional Benefits

Perhaps the biggest advantage to using a color camera is that all the color channels are in focus. There is no need to waste time refocusing each filter, as you must when imaging with monochrome cameras. This is a major advantage when imaging Jupiter, because the planet's rapid rotation limits you to about 2 minutes of capture — longer, and you'll lose fine detail in your image due to motion blur.

Color cameras also provide a relatively easy learning curve compared with tri-color imaging, not to mention they avoid the expense of purchasing a filter wheel and a set of color filters. Unless you're interested in isolating the near-infrared wavelength of methane in Jupiter's atmosphere, a monochrome camera is simply unnecessary for capturing excellent photos of the planets.

So whether you're about to try your hand at planetary imaging or you're contemplating a camera upgrade, consider testing a new color planetary camera yourself. You may find the benefits outweigh any perceived drawbacks. ✦

***Dan Llewellyn** observes and images the planets from his home in Decatur, Georgia.*



▲ **GASEOUS ARACHNID**
José Joaquín Pérez
The cluster of vibrant, young, blue stars known as R136 provides much of the energy that illuminates NGC 2070, the Tarantula Nebula in the Large Magellanic Cloud.
Details: *RCOS 16-inch Ritchey-Chrétien telescope with an Apogee Alta U9 CCD camera. Total exposure was 5⅕ hours through color and narrowband filters recorded using the SSRO Prompt Observatory in Chile.*

► **THE SEVEN SISTERS**
André van der Hoeven
Located roughly 440 light-years away, the Pleiades' stars span approximately the same amount of sky as the full Moon as seen from Earth.
Details: *TEC APO140ED refractor with QSI 583wsg CCD camera. Total exposure was 14⅕ hours through Astrodon color filters.*

▲ **PERFECT LAUNCH**
David Kodama
A cloudless blue sky frames the path of the SpaceX rocket Falcon 9 on its way out of Earth's atmosphere.
Details: *Nikon D700 DSLR camera with Sigma 15-mm lens. Composite image of multiple exposures.*

◄ **ORION SOUTH**
Jimmy Walker
A deep look into Orion's famous sword reveals a cascade of deep-sky targets from top to bottom, including the reflection nebulae NGC 1973/75/77, the bright emission nebulae M43 and M42, and tiny NGC 1999 at center, as well as many large, undesignated bands of gas and dust.
Details: *Takahashi FSQ-106EDX III astrograph with FLI ML11002C CCD camera. Two panel mosaic, each totaling 2½ hours of exposure.*

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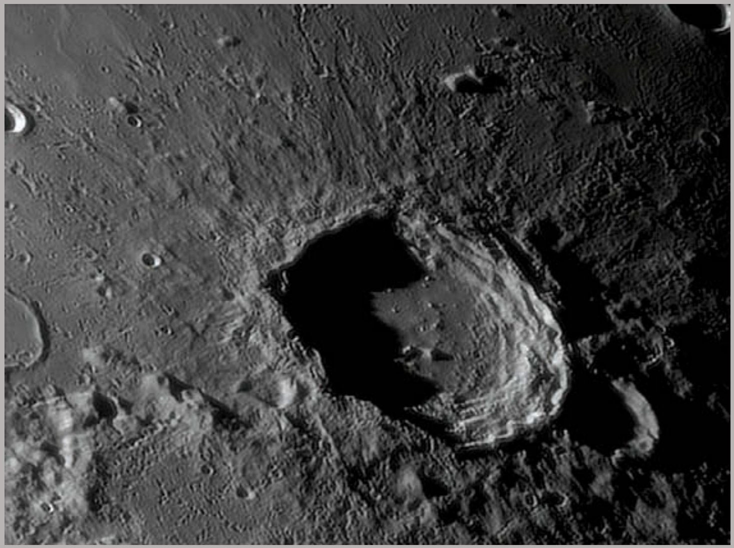
▲ **THE STAR QUEEN**

Geoffrey Heller

The Eagle Nebula, M16, is the brightest part of a large complex of gas and dust in Serpens Cauda that includes the famous "Pillars of Creation" imaged by NASA's Hubble Space Telescope.

Details: *AstroTech AT10RC Ritchey-Chrétien with QSI 583wsg CCD camera. Total exposure was more than 100 hours through Astrodon narrowband filters.*



► **SUNSET CRATER**

Alessandro Bianconi

Shadows deepen within the rim of the lunar impact crater Aristoteles, located on the southern side of Mare Frigoris.

Details: *Celestron EdgeHD14 Schmidt-Cassegrain telescope with QHY5L-II video camera. Stack of multiple video frames.* ✦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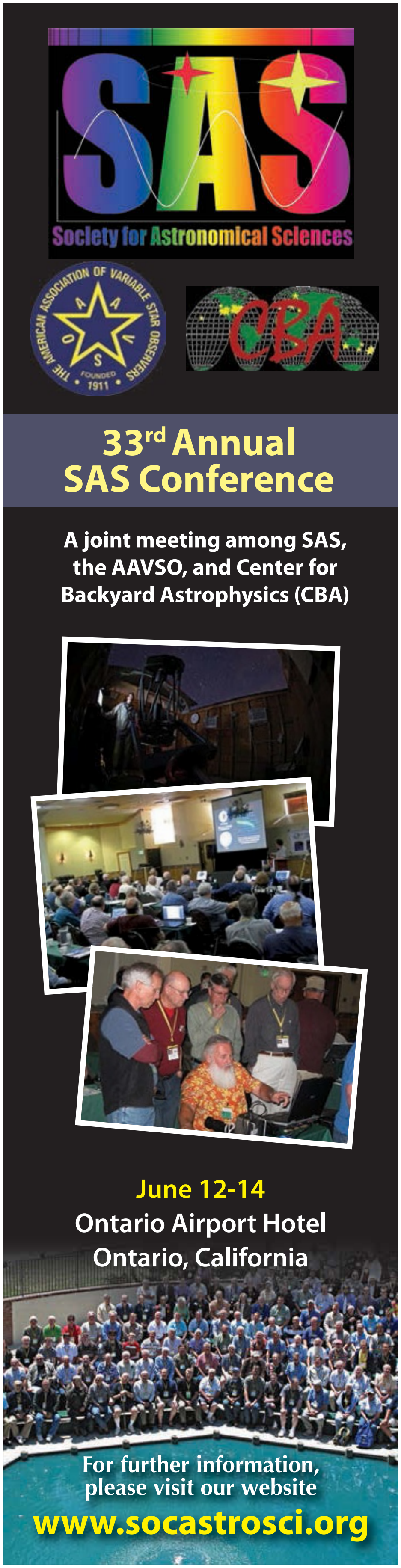
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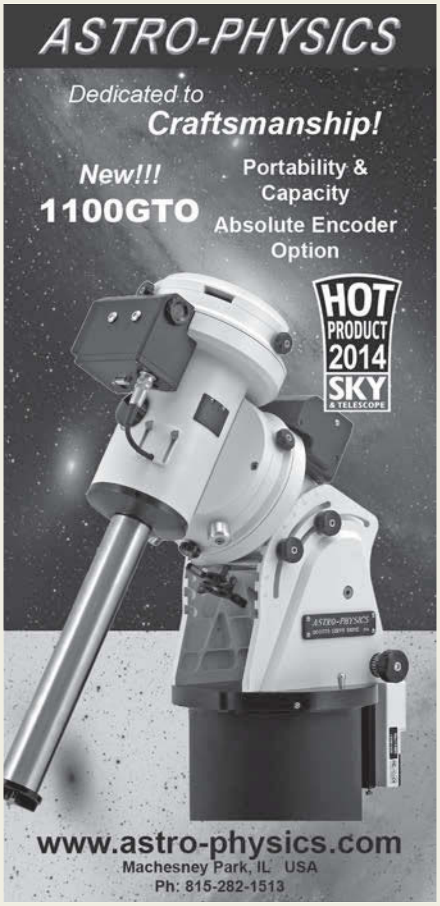

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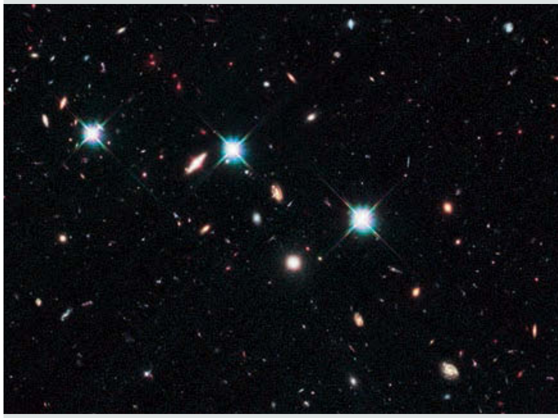

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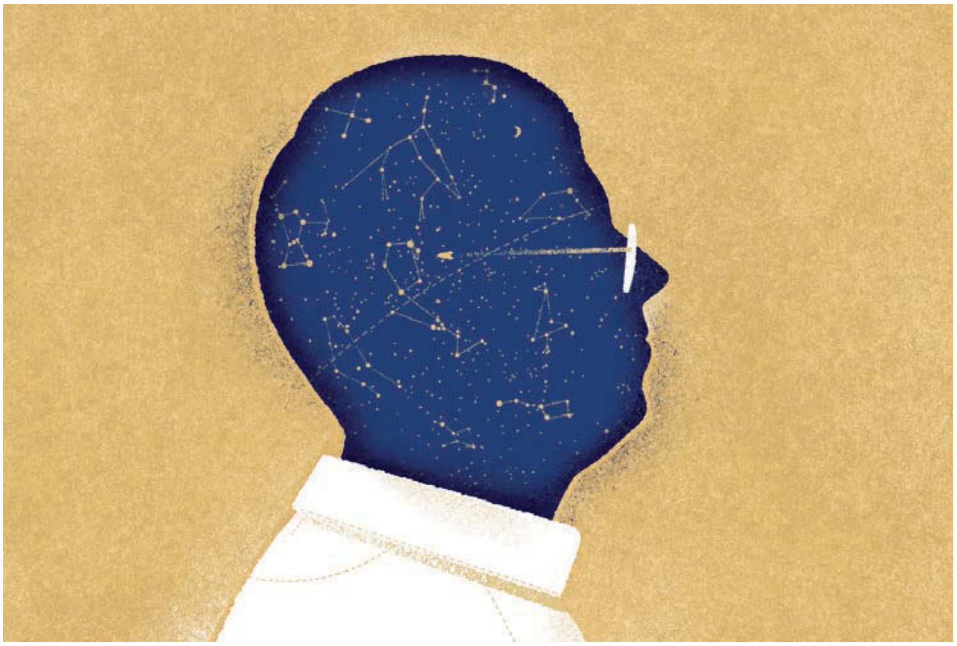

KAROLIS STRAUTNIEKAS

I'm sitting in my hotel room 240 miles from home. Traveling here was challenging, even though the journey itself was uneventful. I have Asperger syndrome, and for all "aspies," changes of routine, in fact changes of any kind, can be fraught with anxiety. But tonight, I see Jupiter sparkling in the western sky — the same Jupiter I saw from my front porch last night. And that continuity will help me reorient myself and fall asleep.

Asperger syndrome (AS) is a form of autism, which according to the Centers for Disease Control is now the fastest growing developmental disability in the U.S., affecting 1 in 50 children aged 6 to 17. AS impacts the way a person processes information, comprehends the world, and relates to others. Unlike those with classic autism, however, "aspies" do not usually have learning difficulties and often they have above-average intelligence. The long list of high achievers who have (or are speculated to have had) Asperger syndrome includes Albert Einstein, Isaac Asimov, and Carl Sagan.

Because people with AS often feel they've come from another planet, it's not surprising that many are drawn to astronomy and science fiction. Time spent with the stars can be deeply beneficial to those with AS, as well as others on the autism spectrum. Parents of autistic children have often reported a seemingly miraculous transformation once a map of the stars was put on their child's bedroom ceiling. Previously, the youngster would not settle at night and ended up disrupting the entire household; now he or she will fall asleep quickly, awake refreshed, and have improved behavior.

There was no star map on my bedroom ceiling when I was growing up in the 1950s. In fact, the syndrome did not become a standard diagnosis until 1992. But from my earliest days, I insisted on having my bedroom curtains drawn back at night so I could see the sky, and even when the stars were obscured, I would still imagine them there. For a chronically anxious boy given to frequent panic attacks, the stars had a calming influence — as they do to this day.

Many people find starwatching a relaxing antidote to the pressures of modern-day life. For those of us with AS, these interludes can be especially therapeutic. In contrast with a world that regularly overwhelms us with its jumble of noise and activity, the night sky is a haven of peace, simplicity, and order. Against a uniformly black background, points of light in fixed relationship to one another slowly orbit the celestial pole or rise and set with clockwork regularity. On any given night, we know exactly where the Moon and planets will be. No jarring sounds or clashing colors befuddle the mind. Even the Moon is restfully monochrome and reassuringly changeless.

Some autistic children find rest by memorizing the names of the stars, others by counting them. I've always found the mosaic of constellations to be harmonious — joining the dots of light in my mind somehow helps it to de-clutter and heal. So if you know someone with autism who hasn't spent time with the stars, why not introduce them? For those inspired by your love and knowledge of the heavens, the benefits could be truly life-changing. ✦

***Paul Greenewich** is a data analyst from Suffolk, England. He was diagnosed with Asperger syndrome in 2012. A longer version of this article appeared in the November-December 2013 issue of* Popular Astronomy.