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SKY & TELESCOPE

MAY 2016

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One Perfect Night

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M24 region imaged by Tony Hallas using a Tele Vue-NP101is refractor.

Tony Hallas, Renowned Astrophotographer, Returns to the Eyepiece

(from an unsolicited e-mail to David Nagler)

Hi David and Al,

Although I am still active in imaging, I have decided to go back to viewing and have taken possession of a new 24" f/3.85 Slipstream telescope from Tom Osypowski. You will be happy to know that I have acquired a treasure trove of Tele Vue eyepieces to complement this telescope, specifically: 26 and 20mm Nagler Type 5, 17.3, 14, 10, 6, 4.5mm Delos, Paracorr Type 2, and 24mm Panoptics for binocular viewing. After using a Delos, "that was all she wrote;" you have created the perfect eyepiece. The Delos eyepieces are a joy to use and sharp, sharp, sharp! I wanted to thank you for continuing your quest to make the best eyepieces for the amateur community. I am very glad that you don't compromise ... in this world there are many who appreciate this and appreciate what you and Al have done for our avocation. Hard to imagine what viewing would be like without your creations.

Best,
Tony Hallas

Tony with his Tele Vue eyepiece collection awaits a night of great observing at his dark-sky site.

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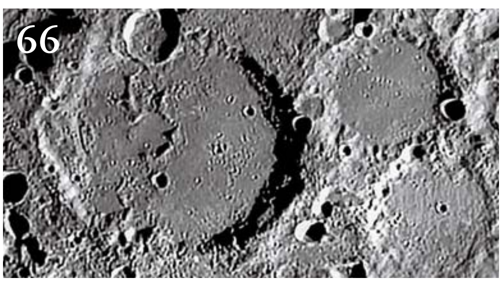
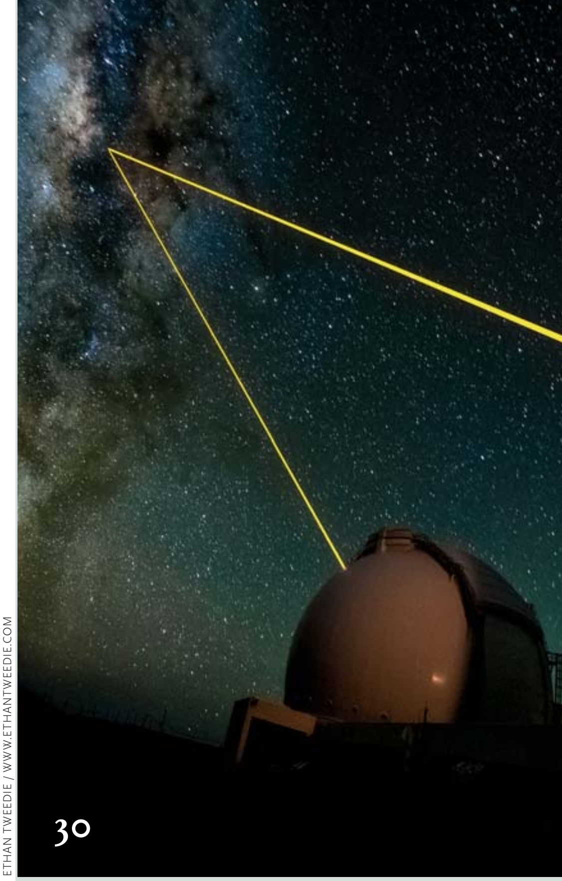
May 2016 VOL. 131, NO. 5

On the cover:
The spiral M81 is one of the brightest galaxies visible from Earth, thanks in part to its young, hot stars.

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



ROBERT REEVES



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May 2016 Digital Extra

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- **Two Cool Galaxies: M81 and M82**
  Test yourself — how many details can you spot in M81 and M82?

- **Adaptive Optics: Before and After**
  See how adaptive optics changed astronomy in this image gallery.

- **Gravitational Wave**
  Get the story on LIGO's first-ever direct detection of spacetime ripples.

Photo Gallery

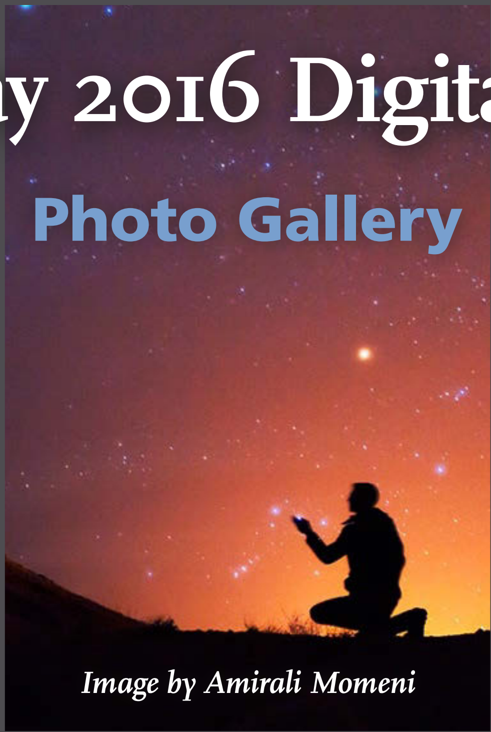

Image by Amirali Momeni

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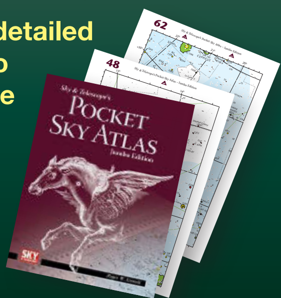

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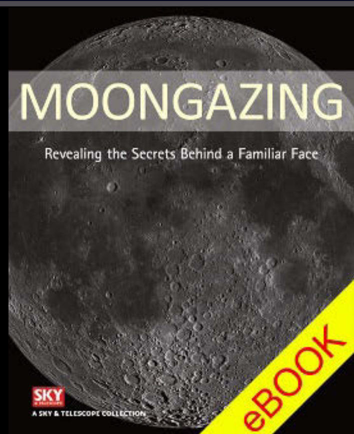

DIGITAL BACK ISSUES:
February, March, and April

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ONLINE PHOTO GALLERY

Giuseppe Petricca captured the full Moon on Christmas in 2015 in this 30-panel mosaic.

Goodbye, Hello

WITH THIS ISSUE we bid a fond farewell to Gary Seronik, whose articles on observing and telescope making have appeared in *S&T* for 20 years. Gary recently became editor of *SkyNews*, the highly regarded Canadian astronomy magazine. We wish him the very best in this new endeavor.

But we can't say goodbye without a quick look back at his substantial contributions to *S&T*. A subscriber since age 12, Gary started writing for us in 1996 and joined the staff as an associate editor in 1998.

Gary Seronik

He quickly took on the amateur telescope-making (ATM) and observing columns, and he began helping Dennis di Cicco with test reports. He launched two new columns, Lunar Notebook and Deep-Sky Notebook, which survive today as Chuck Wood's Explore the Moon and our Going Deep columns, respectively.

Gary also worked on books for Sky Publishing. He edited a new edition of Antonín Rükl's classic *Atlas of the Moon* and Chuck Wood's *The Modern Moon*. He came up with the idea for our bestselling *Pocket Sky Atlas*. And he oversaw the publication of *Binocular Highlights*, a compilation of his *S&T* columns of that name.

In 2006, Gary and his wife, Ellen Rooney — they met here at *S&T* — moved back to Gary's home province of British Columbia. But he remained on the *S&T* staff, continuing to write Binocular Highlights, Telescope Workshop (TW), and occasional test reports.

Beginning with the June issue, two new Contributing Editors will take over Gary's columns.

Mathew Wedel will write Binocular Highlights. By day, Matt is a paleontologist and Associate Professor of Anatomy at Western University of Health Sciences in Pomona, California. By night, as he wrote in his "Binocular Holiday" feature (*S&T:* Dec. 2015, p. 32), he is an "adventurous stargazer." See his blog at **10minuteastronomy.wordpress.com**.

Matt Wedel

Jerry Oltion will write a recasting of TW that we're calling Astronomer's Workbench. A science-fiction author of 15 novels and more than 150 short stories, Jerry is also an accomplished ATM, whose work Gary has featured several times in TW. See more on Jerry at **sff.net/people/j.oltion**.

Jerry Oltion

To appeal to a wider audience of do-it-yourselfers, Astronomer's Workbench will broaden beyond TW to include homemade astro gear of all sorts, from laser collimators to custom eyepieces. If you've got ideas for projects to showcase in this new column, email Jerry at **j.oltion@sff.net**.

A final thanks from all of us to Gary. "I was fortunate to have tremendous teachers," he says. "But it's the friendships with staff and contributors that I'll carry with me as I go forward. It's been a helluva ride." ✦

Peter

Editor in Chief

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GOTO

Again and Again

Some years ago, an advertisement similar to this one announced installation of the world's first GOTO CHRONOS HYBRID planetarium, at the College of San Mateo near San Francisco, California. It was a fantastic system that for the first time, brought the perfect synchronization of a state of the art opto-mechanical planetarium projector with a fulldome digital video system. Instructors Darryl Stanford, Mohsen Janatpour and astronomy technician Dean Drumheller loved working with the system to teach college astronomy courses and to inspire visiting school students.

Then the unthinkable happened. Only a few weeks after the planetarium's dedication, the fire suppression sprinkler system in the new building accidentally went off, flooding the entire planetarium with water! The CHRONOS HYBRID equipment was ruined. But Darryl, Mohsen, Dean had enjoyed working with the system so much that they immediately ordered another one.

Fast forward to today, when funding became available to add upgrades to many of the college's science facilities. Since the planetarium was so tremendously successful in not only educating but also inspiring current and future students, the decision was made to once again continue investment in the planetarium. And once again, the choice was GOTO.

So in January 2016, Darryl, Mohsen, and new astronomy technician Justin Stevick began using a brand new system. The new system includes a second generation CHRONOS II, which replaces earlier incandescent lamps with new high-output, high-efficiency LED illumination, and brings even more reliability. Dean says that the new CHRONOS II stars, sun, moon, and planets are so much brighter he actually has to dim them down a bit for some scenes. And Justin will never have to replace another burned-out lamp.

The fulldome video system was updated with new computers and software, and video projector resolution was improved from 2K to 4K. The full, synchronized system continues to be controlled by the HYBRID manual control console, which makes teaching live lessons easy, accurate, and fun.

So yet again, a new GOTO state-of-the art planetarium is in place, and ready to go. And the College of San Mateo becomes the first planetarium in the world to have had three (3!) GOTO HYBRID systems installed!

"Planetarium Tech Justin Stevick and instructors Darryl Sanford and Mohsen Janatpour (l. to r.) beam almost as brightly as their CHRONOS II HYBRID."

"After with CHRONOS II"

"Before, with CHRONOS"

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Pierre Paquette's brass astrolabes are highly detailed and accurately represent the sky.

General Relativity 101

I very much enjoyed the articles about General Relativity (*S&T:* Dec. 2015, p. 18 and p. 26). I've read many papers and articles about GR over the years but have never seen the basic concept laid out so clearly. I actually feel that I understand it slightly better now, and this is no mean feat! I especially liked Alan MacRobert's sidebar in Pedro Ferreira's article (p. 20) explaining how the curved path of a tossed ball reduces to a nearly straight line in 4D spacetime. I'm not sure that I completely understand this concept yet — who does? — but he definitely got me visualizing something in a new way. I also like the idea of comparing gravity waves to ripples in a beaten rug!

Tom Sales
Somerset, New Jersey

Double-Duty Stars

There are two stars in Auriga labeled "β" in the center star charts of the December, January, and February issues. Will the real Beta Aurigae please stand up?

Dick Jacobson
Cottage Grove, Minnesota

Kelly Beatty replies: *There are a couple of situations in the sky where a bright star is shared by two constellations, and this is one of them. Elnath, the star labeled β in the corner of Auriga closest to Taurus, is in fact Beta Tauri. The broken purple lines leading up to it indicate that it's not part of Auriga. Another case occurs in the Great Square of Pegasus. Do you see the two "α" labels? One of these, Alpheratz, is Alpha Andromedae.*

Modern-Day Astrolabes

Bruce Watson's article about astrolabes (*S&T:* Feb. 2016, p. 24) got my immediate and full attention. It so happens that I actually make astrolabes, mainly of brass. The unit shown above is what I've been working on lately.

While Watson is, strictly speaking, correct in noting that you can buy a modern brass astrolabe on eBay or Amazon for about $200 or a plastic one for $75, these are small and often minimally useful. In comparison, my 10-inch model is precise to the minute, after taking into account the equation of time and making a correction for longitude (both of which are engraved on the back).

Watson also mentions a "craftsman in Germany" who can make you a "stunning brass replica." I also found a source in France. We three seem to be the only brass astrolabe makers in the world.

Pierre Paquette
Pierrefonds, Québec

The "Power" of Saturn

Dean Regas's Focal Point about how a first view of Saturn through a small telescope can be life-changing (*S&T:* Feb. 2016, p. 76) is right on the mark. I felt as if Regas were describing my own experience as a 12-year-old boy, back in the late 1970s, when I first marveled at the "cartoon" that was Saturn through a friend's 60-mm department-store refractor.

That event hooked me — in fact, having since pursued an education in astrophysics and employment with NASA, I'd say that night certainly changed my life. Regas's experience and mine (as well as those of countless others) serve to highlight the importance of ongoing educational outreach to today's kids. You never know what a simple look through a telescope can do.

Gary Minarich
Phoenix, Arizona

Since 1977, when I joined the astronomy group of the Physics Association in Frankfurt, Germany, I have been privileged to show the wonders of the universe to visitors at the group's historic observatory with an old, 8-inch refracting telescope. When the group's size is not too big, I show off some other nice astronomy objects — but the last target, if it's in view, is always Saturn. When people look through the telescope and see this planet for the first time, the reaction is always overwhelming. You can see this in their eyes and faces! They don't expect to see such a wonderful natural object. It even fascinates our young visitors — to the point that they forget to play with their mobile phones!

So, to all astronomers out there: if Saturn is available to observe, please show it to people!

Alois Juli
Frankfurt am Main, Germany

Fear of the Night

Alas! How true Tony Flanders's "Night Fright" (*S&T:* Jan. 2016, p. 84) rings in South Africa. My humble garden has the misfortune to be invaded by streetlights on three sides. Worse still, two neighbors on opposite sides of me have blinding security lights that trespass almost everywhere. By huddling under a tree and using my roof's shadow, I can make out 16 to 20 stars. The Milky Way is exiled. So the weekly meetings of the Cape Centre of the Astronomical Society of Southern Africa, the pages of *Sky & Telescope*, and NASA's Astronomy Picture of the Day are my only windows to the sky.

Keith Gottschalk
Claremont, South Africa

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The Spirit Is Willing

After many years as a subscriber to *S&T,* regretfully I have to cancel. At 91, it is no longer safe for me to use my observatory. For more than 22 years I wrote a weekly article, "Celestial Exploring," for the *Wet Mountain Tribune* in Westcliffe, and I relied on *S&T* for accurate information on coming sky events. Keep up the good work, and continue being the top magazine on astronomy.

John Boucek
Pueblo West, Colorado

Editor's note: *Boucek was one of several local volunteers, led by Jim Bradburn of Wet Mountain Valley Dark Skies, who last year succeeded in getting Westcliffe and Silver Cliff, Colorado, certified as IDA Dark Sky Communities; see* ***wetmtndarkskies.org****.*

More Praise for John Brashear

I read Al Paslow's article regarding the demolition of the old Brashear building and finding its time capsule (*S&T:* Jan. 2016, p. 68) with particular interest. I have a background in restoring old telescopes, and when tackling a Brashear 6-inch f/15 refractor I was amazed and awed by the quality of materials and workmanship throughout the instrument. The mechanical complexity and precision machining were especially impressive. In spite of likely being more than 100 years old (and having suffered some neglect), this instrument required little more than cleaning, lubricating, and refinishing. Except for the missing finderscope, the only unworkable part was a badly corroded worm gear, the bracket for which was stamped *W&S* and thus presumably from Warner & Swasey.

Admittedly, these were not mass-market instruments. Still, the words written by Brashear in the time capsule's letter ("every piece of work shall be made as perfect as human hands and human brains can make it") ring true throughout the instrument.

John F. Rusho
Fulton, New York

Star Trails: A Long Story

The caption for the photograph of circumpolar stars (*S&T:* Feb. 2016, p. 37) states that the total exposure time was 6 hours. But the arcs sure don't look to be quarters of a circle.

Ron Adams
Rochester, New York

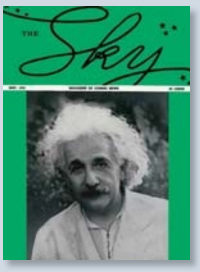
Jeremy Gray replies: *My apologies, Ron! The original images did indeed span 6 hours, but I must have stacked fewer than that to achieve the desired final image. Sometimes I process fewer images than I shoot if the ambient sky changes or if the Sun or Moon moves into a significantly different position. This was one of those cases.*

For the Record

- *Mars will have an apparent diameter of 18.4″ (not 22″) when at opposition on May 22, 2016 (*S&T: *Jan. 2016, p. 54).*
- *Renowned telescope maker John Alfred Brashear was born in 1840, not 1849 (*S&T: *Jan. 2016, p. 70).*

75, 50 & 25 Years Ago

Roger W. Sinnott



May 1941

Wartime Optics "[Given] our country's defense program . . . Eastman Kodak is searching for men to make optical instruments on a production basis, and has communicated with several amateur groups. . . . Undoubtedly, there are amateur telescope makers who could easily qualify for such work, but the problem is to find those who wish to do it, and who are not already so employed. . . .

"To go to Springfield, Vt., the cradle of amateur telescope-making, would do little good, for in that booming town . . . all amateurs are busily engaged in the machine tool trades so vital to defense.

"As for amateur observers — constellation, variable star, meteor, and aurora students — would they not form an excellent nucleus for a civilian night patrol? If for no other reason than their being used to long hours of observing, amateurs ought to make good sky watchers."

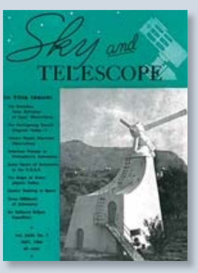
Editorials like this one, penned by Editor Charles A. Federer Jr., reflected growing concerns during the early days of World War II.

May 1966

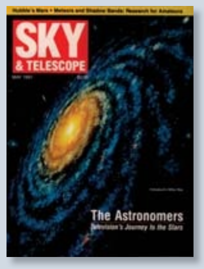
Cloud Satellites "In 1961, the Polish astronomer [Kazimierz] Kordylewski reported his discovery of two large, faint patches of light moving around the earth in the same path as the moon, one of them 60 degrees ahead of it, the other 60 degrees behind. . . . A particle at either of these two points would continue in stable orbital motion, forming an equilateral triangle with the earth and moon.

"Kordylewski described the cloud satellites as several degrees in diameter . . . resembling the gegenschein, but fainter.

"J. Wesley Simpson, of Lockheed Missiles and Space Co., now reports that he and R. G. Miller have made repeated observations of the cloud satellites from Locksley Observatory, in the Santa Cruz Mountains of California. . . .



"On several dates when one of the cloud satellites was favorably placed, visitors to Locksley Observatory were asked to scan the appropriate area of the sky, without being told what to expect. According to Mr. Simpson, in every case the visitor detected a patch of light."



Despite such seeming confirmations, astronomers have never fully embraced Kordylewski's cloud satellites.

May 1991

Buckyballs in Space "Does interstellar space abound with carbon-60 molecules shaped like soccer balls? [Their crystals, recently made in a lab,] represent a new, third kind of solid carbon (in addition to graphite and diamond). . . . Soccer balls and the geodesic domes of R. Buckminster Fuller have the same geometry, leading scientists to refer to C60 as 'buckminsterfullerene' or 'bucky balls.'. . .

"Surprisingly, tests on the spectrum of C60 . . . have so far failed to match astronomical observations. But the chemists haven't given up yet. 'There is still a possibility that some of the unidentified interstellar bands might arise from ionized C60' [reports Donald R. Huffman, University of Arizona]."

*That linkage finally succeeded last year (*S&T: *Nov. 2015, p. 14).*

Learn more about the discovery and watch videos explaining gravitational waves at http://is.gd/gravitationalwaves.

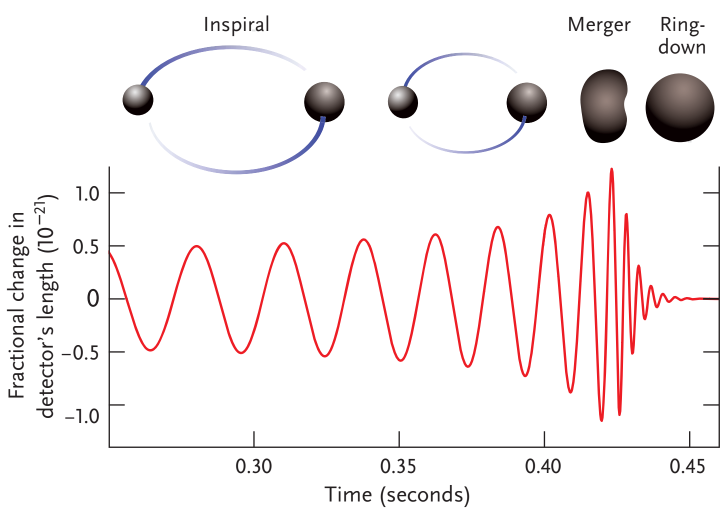
PHYSICS I Gravitational Waves Detected, Discovery Heralds New Era of Astronomy

On February 11th LIGO scientists announced the direct detection of gravitational waves, a discovery that will smash wide open a new door on the cosmos.

Gravitational waves are ripples in the fabric of spacetime, predicted by Einstein's general theory of relativity (*S&T*: Dec. 2015, p. 26). They're created by accelerating masses, much as paddles sweeping through water spur vibrations in a pond. Previously, astronomers only had indirect evidence of their existence. But at 9:50:45 Universal Time on September 14, 2015, LIGO's two L-shaped labs — one near Hanford, Washington, and the other in Livingston, Louisiana — caught the gravitational-wave signature of two colliding black holes.

LIGO detected the signal shortly after both its facilities turned back on following five years of intensive upgrades. The instruments shoot infrared lasers through 4-kilometer-long arms of near-perfect vacuum. The laser light reflects off ultrapure, superpolished, and seismically isolated quartz mirrors. The passing gravitational waves slightly altered the path lengths in the arms of both detectors, by about 1/1000 the width of a proton. That slight change created an interference pattern in the laser light, which LIGO scientists detected as an "event." They've dubbed the event GW150914.

Vibrations as Gravitational Waves Passed



This reconstructed signal from LIGO shows the last few orbits of the black hole duo's dance of death, the merger itself, and the "ringdown" as the newly formed black hole settled down.

S&T: GREGG DINDERMAN / SOURCE: LIGO SCIENTIFIC COLLABORATION AND VIRGO COLLABORATION / *PHYSICAL REVIEW LETTERS* 2016 (DOI10.1103/PHYSREVLETT.116.061102)

Based on the gravitational waves' frequency, team members estimate that the colliding black holes had the masses of about 36 and 29 Suns, respectively. LIGO watched all three predicted phases of the collision: the black holes' death spiral, the ensuing merger, and the "ringing" of the merged object as it settled into its new form. The newly created black hole contains about 62 solar masses; the gravitational waves carried away three solar masses' worth of energy, just as predicted.

With only two detectors, LIGO can't pinpoint the source's exact location — it could come from anywhere within about 600 square degrees of sky near the Large Magellanic Cloud in the Southern Hemisphere sky. The source has a redshift between 0.05 and 0.12, meaning the waves traveled between 700 million and 1.5 billion years before reaching us.

The team claims a 5.1-sigma detection, meaning the odds of the signal occurring by chance are about one in 3.5 million. The result appears in *Physical Review Letters*.

The direct detection of gravitational waves opens up an entirely new spectrum that doesn't involve any form of light. As LIGO member Eric Katsavounidis (MIT) puts it, "This is the end of the silent-movie era in astronomy."

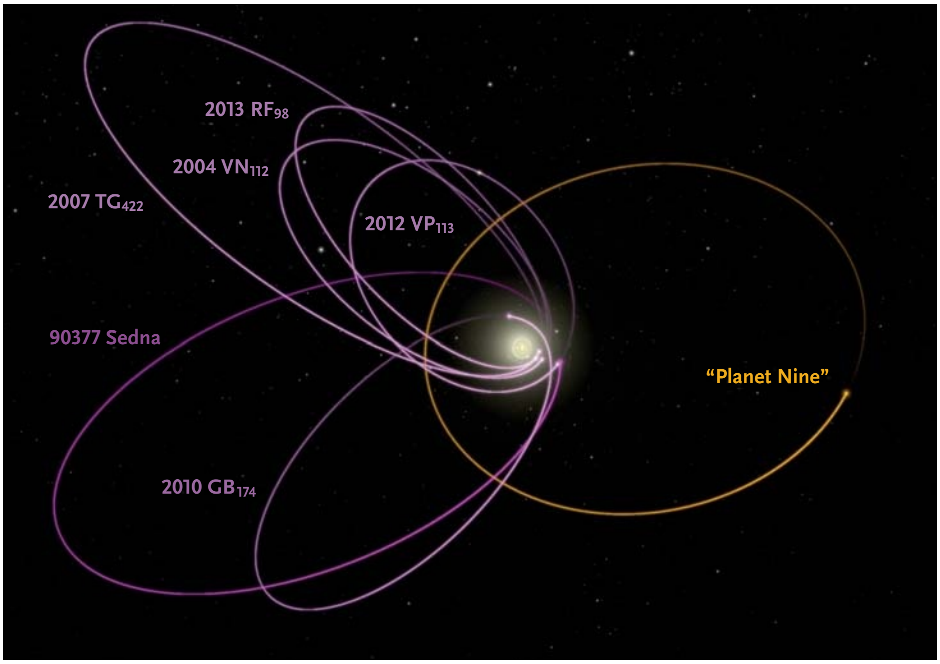
Gravitational waves are incredibly difficult to detect, for three main reasons: (1) gravity is the weakest of the four known forces of nature, (2) the strength of the waves falls off sharply as they traverse space, and (3) matter barely feels their presence. "The gravitational waves from a distant galaxy that are detectable to LIGO are squeezing and stretching the Milky Way Galaxy by the width of your thumb," says science team member Chad Hanna (Penn State University).

LIGO began its first "advanced" observing run last fall, but improvements continue and future runs will have at least twice the sensitivity and enable LIGO to survey 10 times the volume of space. Theorists predict Advanced LIGO should catch an additional five binary black hole mergers in its next observing run. They also expect roughly 40 binary neutron star mergers every year it runs, and an unknown number of black hole-neutron star mergers and supernovae.

Although the detected merger went entirely according to predictions, scientists hope to eventually see discrepancies that could provide vital clues to new physics, potentially reconciling contradictions between relativity and quantum theory.

■ **ROBERT NAEYE**

SOLAR SYSTEM | Is There a Ninth Planet?



The six most distant known objects in the solar system have orbits (shown in purple) that remain beyond Neptune and which align in one direction. A hypothesized massive planet (orange orbit) could be maintaining this perplexing alignment.

Does a massive, extremely distant planet orbit the Sun? A new analysis of distant solar system orbits argues that it should exist. Writing in February's *Astronomical Journal*, Konstantin Batygin and Michael Brown (Caltech) describe how Kuiper Belt objects that average at least 150 astronomical units from the Sun and never come closer than about 50 a.u. share an interesting dynamical property. Their perihelia all cluster near the ecliptic plane — and they're all moving south to north when they pass through perihelion.

This orbital clustering started to draw attention after the discovery of the object 2012 VP_{113} a few years ago. In announcing that find, Chadwick Trujillo (Gemini Observatory) and Scott Sheppard (Carnegie Institution for Science) noted the perihelic similarity of 2012 VP_{113}, 90377 Sedna, and 10 other bodies (*S&T:* July 2014, p. 14). Moreover, these objects occupy a dynamical "no man's land" that defies easy explanation for how they got there. Trujillo and Sheppard concluded that a massive planet, even farther out, might be responsible.

Batygin and Brown have taken this idea to the next level. Their analysis shows that the solar system's six most distant objects not only have clustered *arguments of perihelion* (as it's known technically) but also follow elliptical orbits oriented the same way in space, angled below the ecliptic plane by about 30°. There's only a 0.007% chance of this having occurred by chance. Moreover, these copycat orbits couldn't simply be a holdover from the solar system's formation — over time, subtle perturbations from the giant planets would cause them to slowly drift apart.

Instead, something must be actively imposing this orbital order. Batygin and Brown invoke a massive hypothetical body, which they've dubbed "Planet Nine," with at least 10 times Earth's mass (two to four times its diameter). It would occupy a highly elongated orbit that averages about 700 a.u. from the Sun and never comes nearer than roughly 300 a.u. Such an object would naturally explain not only the clustered perihelia but also the dynamically puzzling orbits of Sedna and its kin.

So where is this putative planet? Actually, a wide range of orbits is possible, with periods ranging from 10,000 to 20,000 years. The Batygin-Brown prediction requires a highly elongated orbit, which means that most of the time the object lingers near aphelion. So it should be no brighter than roughly magnitude 22 — beyond the range of most ground- and space-based surveys to date.

Even if the proposed "Planet Nine" is never seen directly, the circumstantial case for its existence might be strengthened once observers discover more very distant Kuiper Belt objects and assess their orbital distribution.

■ **J. KELLY BEATTY**

IN BRIEF

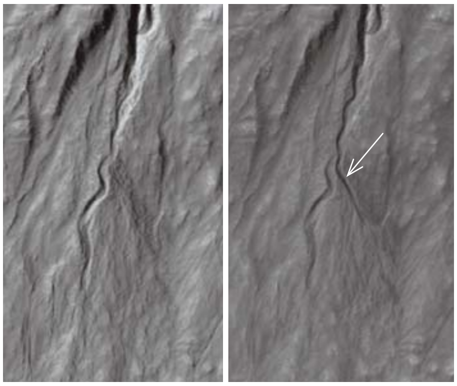
Hunting for Planets Around Proxima Centauri. Astronomers are ramping up their search for exoplanets orbiting the nearest star to our solar system. The Pale Red Dot initiative, led by the European Southern Observatory, is a campaign to examine the red dwarf star Proxima Centauri for exoplanets using the *radial velocity* method, which teases out the signal of a planet tugging on its host star. You can follow the Pale Red Dot campaign on the project's website, palereddot.org, or by following the Twitter hashtag #PaleRedDot. Meanwhile, Proxima Centauri's passage in front of a background star in February gave the Hubble Space Telescope an opportunity to look for *microlensing events*. These are small spikes in the background star's brightness that a planet orbiting the red dwarf could produce as it passes in front of the star, magnifying the starlight as a lens would. Read more about the endeavors at http://is.gd/proxcen2016.

■ **DAVID DICKINSON**

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

MARS | Gullies Triggered by Dry Ice?

Researchers are circling back to the idea that carbon dioxide ice might be responsible for some or all of the gullies on Mars. In 2000, images from NASA's Mars Global Surveyor revealed hundreds of these features, trailing down crater rims all over the Red Planet (*S&T:* Sept. 2000, p. 56). They looked geologically fresh, cut into older terrain yet largely free of erosion.



NASA / JPL / UNIV. OF ARIZONA

Images taken in 2010 *(left)* and again in 2013 by NASA's Mars Reconnaissance Orbiter show that an existing gully recently formed a new branch (indicated by the arrow).

These gullies are different from (and much larger than) the occasional, seasonal trickles of salt-infused water seen elsewhere on the surface, which create the so-called *recurrent slope lineae* (*S&T:* Jan. 2016, p. 14).

Initial speculations focused on the idea that water was seeping out onto the surface and cutting little channels as it flowed downslope. Yet many gullies occur in frigid polar regions or on heavily shadowed slopes facing toward the poles.

The "gully debate" reignited last year when images from NASA's Mars Reconnaissance Orbiter showed that many gullies are evolving *right now* — cutting more deeply into their surroundings and creating aprons of debris farther downslope, sometimes more than once. Modern-day Mars is far too cold and dry to harbor the substantial near-surface reservoirs of liquid water that could explain this behavior.

In the January *Nature Geoscience*, researchers Cedric Pilorget (IAS/CNRS, France) and François Forget (LMD/CNRS, France) suggest a formation scenario that involves no water at all. Instead, they invoke frozen carbon dioxide ("dry ice"), which coats all of the Martian polar terrain each winter and even extends to poleward-facing slopes at lower latitudes. This explanation builds on a dry-ice-powered process first proffered by University of Melbourne researcher Nick Hoffman in 2002.

Careful modeling by Pilorget and Forget shows that the annual frosting of dry ice can become transparent enough to allow sunlight to pass through to ground level. Ice in contact with the Sun-warmed soil sublimates into gas but remains trapped under the overlying slab. Gas pressure builds and eventually lifts and cracks the slab, causing the trapped gas (along with entrained dust) to cascade downslope, forming or enlarging a gully.

■ **J. KELLY BEATTY**

MILKY WAY | Galactic Hit-and-Run

A few hundred million years ago, a small galaxy had a fender-bender with the Milky Way. Even as it fled the crime scene, it sent ripples coursing through the Milky Way's disk. Now with the help of a trio of brightly pulsating stars, Sukanya Chakrabarti (Rochester Institute of Technology) and colleagues say they have found the fugitive dwarf galaxy.

Last year, Chakrabarti and her team found four stars located toward the Norma constellation — the exact spot where, back in 2009, she and Leo Blitz (University of California, Berkeley) had predicted the runaway galaxy is hiding. The astronomers hoped the four stars were Cepheids, standard candles that regularly expand and contract at a rate directly related to their intrinsic brightness. If so, the team would be able to use the stars' variations to confirm their distances.

But since then, a debate between Chakrabarti's team and that of Pawel Pietrukowicz (Warsaw University Observatory, Poland) has arisen over whether the stars are true Cepheids. Due to the Polish team's work, three of the four stars were rejected.

Chakrabarti's new study, announced January 7th at the winter American Astronomical Society meeting in Kissimmee, Florida, adds two new stars to the list of potential members of the sought galaxy. But it's still unclear whether these three candidates are Cepheids; they could be binaries or stars with dark spots only mimicking a Cepheid's pulsation.

Whether or not the trio prove to be Cepheids, Chakrabarti does think they are a good starting point. Follow-up observations of the shift in the stars' spectral lines reveal velocities that all clock in at roughly 156 km/s (349,000 mph) — an order of magnitude larger than typical velocities of stars in the disk of our galaxy. So they clearly don't belong to the Milky Way.

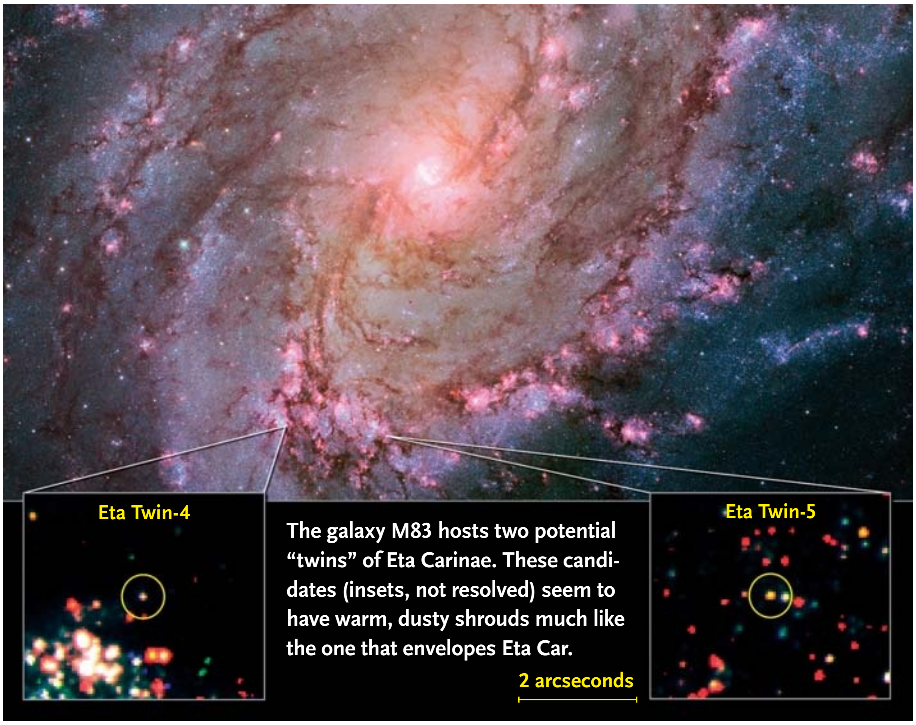
■ **SHANNON HALL**

IN BRIEF

Limit on Black Hole Gluttony. Once a black hole reaches about 50 billion times the mass of the Sun, the disk of gas that acted as its dinner buffet begins to crumble apart. Andrew King (University of Leicester, UK) presents this conclusion in the February 11th *Monthly Notices Letters of the Royal Astronomical Society*. A more massive black hole will have a larger disk feeding it than a smaller hole will. But King calculates that, above the limit, the disk's gas will collapse into clumps, forming stars. To continue growing, the black hole would need to swallow clumps (or stars) whole. Since the glow from accretion disks is what enables observers to "see" these dark objects, more massive black holes might be truly invisible: astronomers would need to turn to more indirect means, such as gravitational lensing, to find the biggest behemoths. Gas disks have revealed black holes up to around 10 billion solar masses.

■ **ALLEN ZEYHER**

STELLAR | Spotting "Twins" of Eta Carinae



The galaxy M83 hosts two potential "twins" of Eta Carinae. These candidates (insets, not resolved) seem to have warm, dusty shrouds much like the one that envelopes Eta Car.

NASA / ESA / HUBBLE HERITAGE TEAM / R. KHAN (GSFC AND ORAU)

Astronomers looking for clones of the huge, unstable star Eta (η) Carinae have potentially found five in other galaxies.

Eta Car is one of the most massive stars in the Milky Way, estimated to have 120 Suns' worth of material. It pumps out more than 5 million times the energy than the Sun does, but it and its companion star hide inside a double-dumbbell of dust and gas called the Homunculus Nebula.

Astronomers haven't seen any stars quite like Eta Car, but they want to. Such massive, evolved stars created many of our galaxy's heavy elements, and these megastars might also be the culprits behind what are called *superluminous supernovae*, stellar explosions that are strangely bright compared with their kin.

Observers haven't had much luck looking for Eta Carinae's twins, though they've turned up several candidates. Rubab Khan (NASA Goddard) and his team are narrowing the search by looking in other galaxies for dust-enshrouded stars whose visible and infrared light closely matches Eta Car's.

The team looked at four bright, star-forming spiral galaxies that lie 15 to 26 million light-years away: M51, M83, M101, and NGC 6943. Together, these galaxies produced 20 of the Type II (core-collapsing, big-star-killing) supernovae seen in the last century. And here is where the astronomers found five objects that look just like Eta Car.

"Look just like" is used loosely, Khan explained January 6th during a press conference at the American Astronomical Society's biannual meeting. The five objects are too distant to be resolved. But the light coming from these sources behaves just like that from Eta Car. The sources are relatively faint in near-infrared and visible light, as seen by the Hubble Space Telescope, but they're bright at mid-infrared wavelengths, as seen with the Spitzer Space Telescope. Moreover, their brightness "flattens out" in this mid-infrared range, in a manner that's a spot-on match for star-enveloping dust that's been warmed to between 400 and 600 kelvin. Thus, the team members are pretty sure they're seeing light from massive, evolved stars, as they also explain in the December 20th *Astrophysical Journal Letters*.

■ **CAMILLE M. CARLISLE**

BLACK HOLES | The Disappearing Quasar

Astronomers tracking a distant quasar over a span of 13 years reported January 8th at the American Astronomical Society meeting in Kissimmee, Florida, that all signs of the quasar have disappeared.

The quasar, known as SDSS J1011+5442, was first detected in 2002. A follow-up spectrum collected the next year showed all the signs of hot gas feeding a typical, ferociously gobbling supermassive black hole sitting at the center of a galaxy.

The quasar's brightness declined steadily over the next decade, far more systematically than usually happens with such objects. When Jessie Runnoe (Penn State University) and colleagues observed the quasar again as part of the Time Domain Spectroscopic Survey in 2015, they took a visible-light spectrum of the beast's disk of gas. They found nothing — almost all signs of the quasar had vanished. Instead, they saw only a relatively ordinary galaxy. The team published its results in the January 11th *Monthly Notices of the Royal Astronomical Society*.

This isn't the first case of a disappearing quasar; astronomers now know of several "changing look" active galaxies (as they're collectively known).

The best explanation for J1011+5442's disappearance is a diet, in which the black hole cut its feeding rate by a factor of 10. The accretion disk should still surround it, though. The outermost part of the disk, which is responsible for the light, would normally take 800 years to gradually empty out and fade, Runnoe says. Instead, she suggests that rather than clear its plate completely in the few short years they've been observing, the quasar swallowed the nearest, hottest gas from the inner accretion disk. This could happen quickly, in a month or two. The hot, inner gas would have emitted ultraviolet light as it swirled toward the black hole, irradiating the outer disk to make it glow. So when the ultraviolet beacon near the black hole went dark, the outer disk would have lost its visible-light shine as well. ✦

■ **MONICA YOUNG**

Our Year In Space

ISS astronauts are reviving our passion for space travel in novel ways.

I'M WRITING THIS near the end of Astronaut Scott Kelly and Cosmonaut Mikhail Kornienko's "Year in Space." Since March 2015, these men have orbited our planet in the International Space Station. It's easy to take the ISS for granted. I'll admit at times I've grumbled about its share of the NASA budget compared with that of my own pet planetary probes. But the Year in Space has rekindled the idealistic and romantic excitement, fueled by the Apollo missions and science fiction, which as a kid had me imagining we would soon be widely inhabiting the solar system.

Kelly and Kornienko have been using themselves as experimental subjects, gathering valuable data on human responses and adaptations to long-duration spaceflight that will be key for missions to Mars or elsewhere. Life has evolved for 4 billion years in close concert with the Earth, and today we humans are perfectly attuned to its surface environment, in ways that become obvious when we leave it.

Space changes us physically, with the lack of gravity especially taking its toll. Space also affects people psychologically and spiritually. Those who have seen Earth from above report a sense of profound communion with all of humanity and with the biosphere, and a feeling that our global conflicts would ease if more people could gain that perspective. Unfortunately, only a small number of individuals have been in orbit and experienced this "overview effect."

Yet something has changed in the way we are now experiencing space. The Year in Space is part of a delightful trend of astronauts taking advantage of social media and other tools to share their experiences in new and more direct ways. The connection with people on the ground has become deeper and livelier.

Commander Chris Hadfield made Earth's first astronaut music video: David Bowie's "Space Oddity," actually performed while floating in a tin can far above the world. It was an inspired choice. Bowie, who was 10 years old during Sputnik, poetically explored space travel as a metaphor for risk and transcendence.

Art helps us connect with and process the universe that science reveals. And now, by showing their artistic sides, astronauts are sharing more broadly the inspiring, transformational potential of the space experience.

Scott Kelly aboard the International Space Station, July 2015

NASA

Scott Kelly has used social media artfully to communicate both daily details and moments of insight. With his #EarthArt series he shares stunning images of our planetary home presented with casual but sharp descriptions, curating in real time an awe-inspiring art project for the growing number of Earth's inhabitants who have an internet connection. He often wishes us good morning or good night from space with a stirring view of a crescent Earth, an iridescent thin band of blue shining against the great darkness.

Yes, we humans are well adapted to Earth's land surfaces but deeper in our history was a time when life was confined to the oceans. The move to the harsh environs of the land was difficult but ultimately worth it. Perhaps the halting beginning of our extraterrestrial stage is a moment of similar evolutionary potential. Our planet as it really is — indivisible, beautiful, and precious — is revealed to us through the space perspective. The more people who see it, the better equipped we'll be to meet the global challenges of the coming century. ✦

David Grinspoon *is an astrobiologist, author, and senior scientist at the Planetary Science Institute. Follow him on Twitter at @DrFunkySpoon.*

Two Cool Galaxies

The Incomparable M81 and M82

Howard Banich

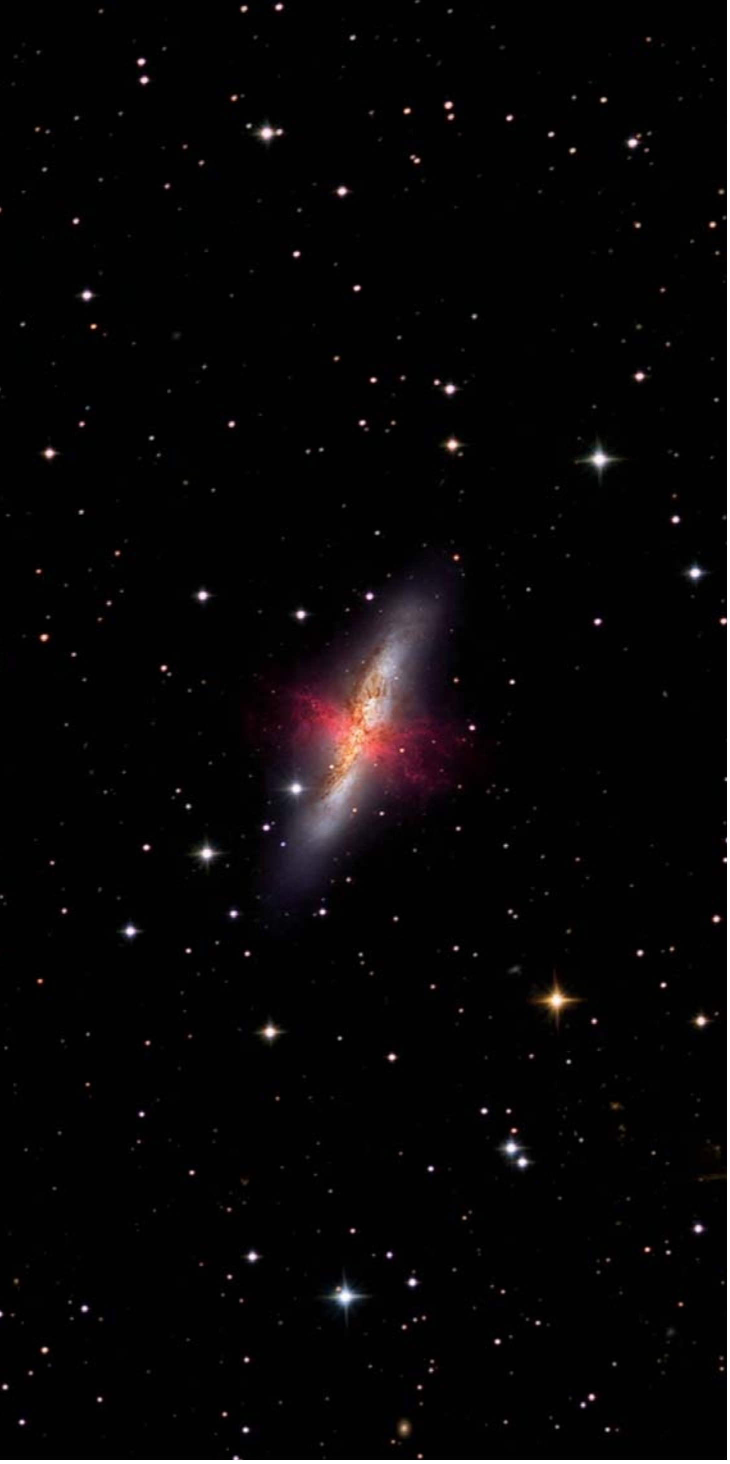
Sometimes, during a great night, the atmosphere will get out of the way for a while. The early morning hours of October 13, 2015, produced one of these extraordinary moments while I was observing from Steens Mountain in southeastern Oregon.

The sky had been exceptionally transparent all night, and by 4:30 a.m. an intense zodiacal light was well up in the east. My observing buddy, Rod Shea, had already hit the sack.

The seeing had been a mess all night but was quickly sharpening as the temperature stabilized around 40°F. Dawn was an hour away, the air perfectly still. Conditions were superb.

Orion was nearing the meridian when it occurred to me to turn around and have a look at M81 and M82, which had risen in the northeast and were now level with Polaris.

I'd been working on detailed drawings of both galaxies since 2011, and while pushing my 28-inch telescope to their position, I remember thinking the view might be pretty good. Little did I know M82 was about to blow me away.



JOHANNES SCHEDLER

CLOSE COMPANIONS Can you think of one without the other? M81 (left) and M82 (right) have been gravitationally interacting for approximately 500 million years, along with galaxy NGC 3077 (not shown).

M82 is different

A starburst galaxy, M82 is the closest, brightest, and most active of its kind. Its most recent encounter with M81, about 200 million years ago, sparked its intense star formation. The ongoing starburst not only makes M82 the brightest external galaxy in infrared light, it's been a major factor in shaping it into the highly disturbed object we see today.

Even at low power in a small scope a good deal of chaotic mottling can be seen along the central half of its edge-on profile. In progressively larger scopes this mottling resolves into a fascinating jumble of dark lanes and bright splotches.

This untidy appearance is M82's defining visual characteristic and is the reason for its alternative designation as Arp 337. It really does look peculiar — and so distinctly appealing.

Superwind

Although there's a 30 million-solar-mass supermassive black hole (SMBH) in the center of M82, it's the ongoing starburst activity and subsequent supernovae in and around the core that create its famous bi-polar superwind. The superwind is the outflow extending north and south from the center of M82 and forming the lacy red wings seen in the image to the left.

The southern superwind is the easiest to see in a telescope and extends farthest from the core, but the northern superwind is often impossible to detect with any certainty. They're both brightest near the ends of the central dark lane.

The filamentary nature of the superwind creates the random-looking dark areas that crisscross the central profile of the galaxy. However, some of these dark lanes are interstellar dust, raw material for future star formation. It's fascinating that this pre-stellar dust looks so similar to the post-stellar outflow.

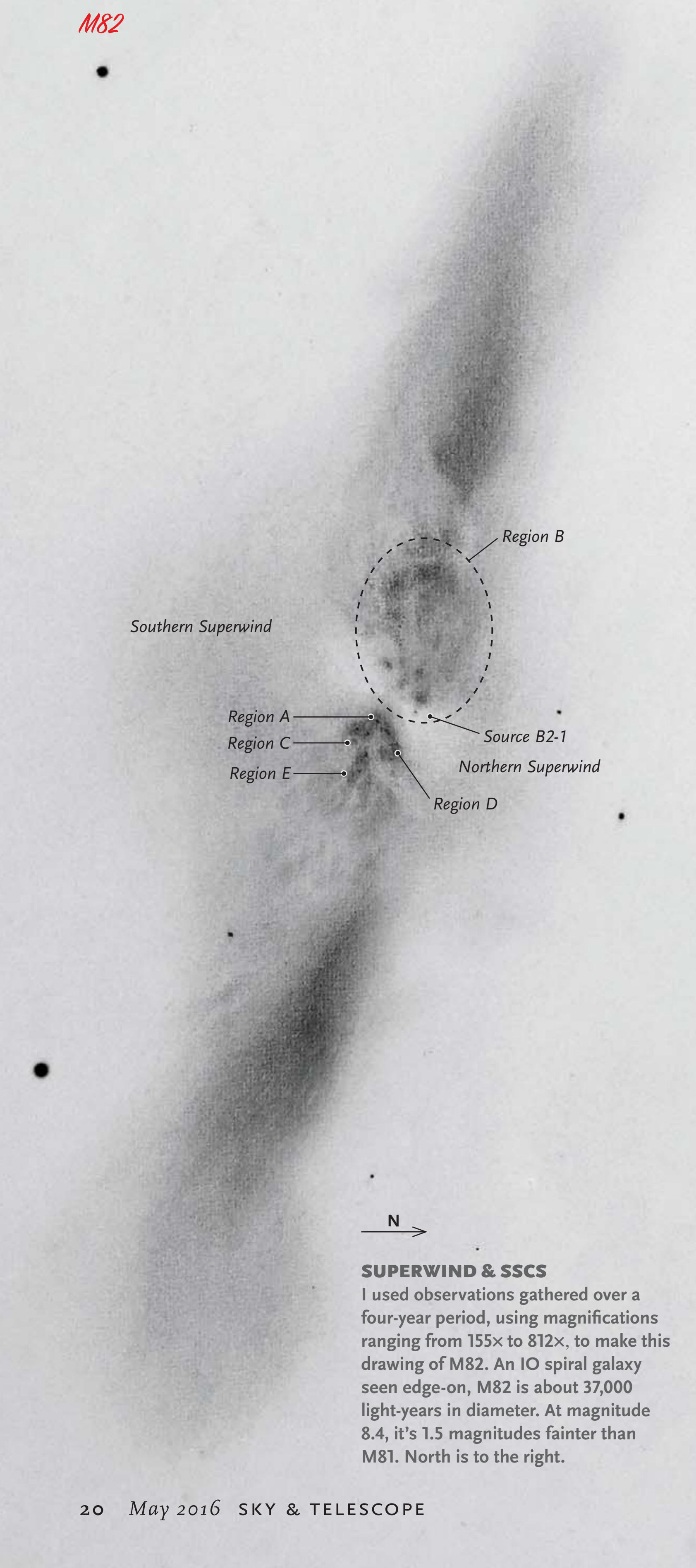
The superwind wings are an obvious part of M82's photographic appearance, but visually they rest on the far side of subtle. That makes objectivity during an observation especially important because our brains are wired to expect them after seeing so many detailed photos of M82.

Super Star Clusters

On both sides of the central dark lane are massive star-forming regions in the core, shining through the outflows and dust. These areas are Super Star Clusters (SSCs). These SSCs formed 4 to 6 million years ago in the latest surge of star formation. They are confined to the central 1,600 light-years of the galaxy and define the starburst region in optical wavelengths.

The most obvious of these relatively young clusters are labeled A, C, D, and E in the annotated drawing on the next page (these designations follow from O'Connell and Mangano's paper on the central regions of M82 in *Astrophysical Journal*, 1978). Together, they make up the arrow-shaped area just west of the central dark lane.

I first saw them on a night of superbly steady seeing at Chuck and Judy Dethloff's property in the Oregon



SUPERWIND & SSCS
I used observations gathered over a four-year period, using magnifications ranging from 155× to 812×, to make this drawing of M82. An IO spiral galaxy seen edge-on, M82 is about 37,000 light-years in diameter. At magnitude 8.4, it's 1.5 magnitudes fainter than M81. North is to the right.

ALL SKETCHES BY THE AUTHOR

Coast Range Mountains in 2011. They looked best at 812×. At this magnification the SSCs sparkled with tiny, star-like knots in the 28-inch scope — a fantastic sight!

Shapes

The superwind and dust overlay of the central area creates some intriguing features, the most prominent of which is the hourglass-shaped dark lane cutting M82 in half. This is the most reliable dark feature for observation along M82's length. All the other dark and bright features are smaller, and can seem tossed together willy-nilly at low power.

The eastern core — Region B — can be particularly uncertain. A major starburst area about 100 million years ago, it's now settled down. The tiny bright spot labeled B2-1 can only be seen at high magnification with steady seeing.

More generally, the eastern half of the galaxy appears fairly straight, while subtle curves embellish the western half. The brightest arc begins with a slight northeast twist then gracefully turns west while fading into the blackness of intergalactic space.

So what blew me away at Steens Mountain?

After centering M82 in my low-power eyepiece I bumped up the magnification to 408×. I was immediately stunned to see — easily see — the highly complex superwind and dust lanes silhouetted against the central portion of the galaxy in exquisite detail. Wow!!

It was simply beyond expectation to see this extravagant level of resolution. I was astonished and completely surprised by this intricately woven veil of black lace — it was a fantastically delicate and awesome sight. This gave the central area of M82 an appearance reminiscent of a naked-eye view of the summer Milky Way, which is a remarkable comparison to make with a galaxy 11.8 million light-years away.

There are faint details in many deep-sky objects that force me to check my preconceptions to make sure what I'm seeing is real, usually because I'm putting a great deal of effort into seeing them. This was the opposite of that, and remains one of the most memorable sights I've seen through any telescope.

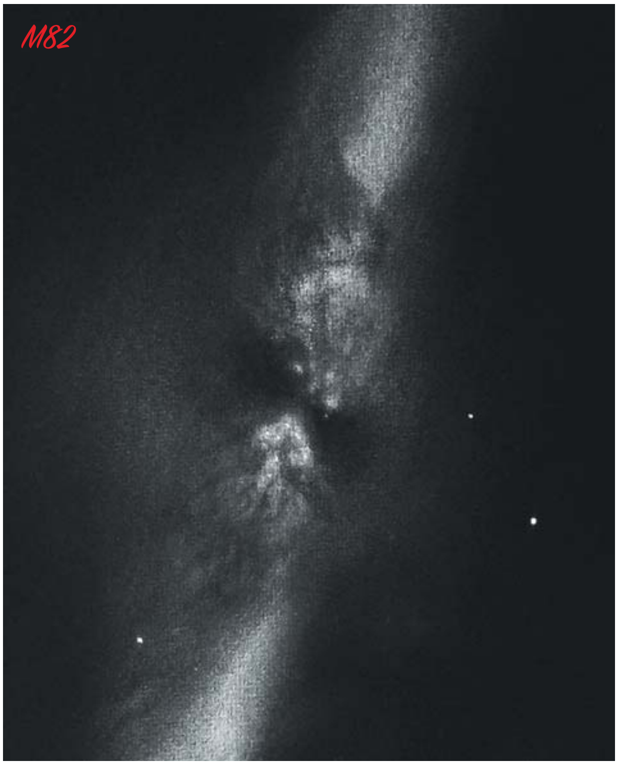
M81 is beautiful

The view of M81 from Steens Mountain was also the most gorgeously detailed I've ever seen — it just wasn't as staggering a sight as M82.

M81 looked magnificent, though, with a fully realized view of its grand design spiral features, sprinkled with a handful of details I hadn't been able to see before.

A classic SA(s)ab spiral, M81 is the epitome of a beautifully symmetrical and serene-looking two-arm galaxy, and a perfect contrast to the apparent chaos of M82. Unfortunately, many of M81's features are difficult to see

SPIRAL SPECTACULAR My drawing of M81 is based on four years of observations using magnifications from 155× to 408×. Each of the labeled regions is an assortment of many objects, with details of each posted at http://is.gd/coolgalaxies. Note the dwarf irregular galaxy Holmberg IX at upper center as a faint, diffuse area — it was formed 200 million years ago during a close encounter between M81 and M82. It's nearly as faint as the spiral disk area of M81. North is to the right.



DARK AND DUSTY Inverted close-up showing the intricate dark lanes of the superwind and interstellar dust — this is a close representation of what I saw at Steens Mountain. The magnification was 408×, producing a 2-mm exit pupil in my 28-inch scope.

A CLOSER LOOK This inverted close-up illustrates how M81 looked at Steens Mountain through my 28-inch scope. Both this and my M82 drawing above show the averted vision view built up over 4 years of sketching.

well even though it's 1.5 magnitudes brighter than M82. Larger and more spread out, its visibility depends highly on sky conditions and the experience of the observer.

It's startling how much can be seen through a great high altitude sky, yet even when conditions aren't top notch, M81 is a remarkable place to explore.

The Core

Any telescope will show the bright, oval core, which is the easiest part of M81 to see. Along with its even brighter nucleus, they're the first things you'll notice. Sometimes they're the only things visible if the sky is too bright to reveal the spiral arms, or if your scope isn't large enough to show them.

Either way, as you get accustomed to the view you may begin to see more.

The major axis of the core is slightly offset from that of the spiral arms — an interesting feature to look for because it doesn't show up in photographs.

The core builds in brightness toward the center and is suddenly punctuated by the bright nucleus. This is M81's active galactic nucleus (AGN). At its center, a massive amount of energy is coming from the compact region around its 70 million-solar-mass SMBH. That's pretty big for a galaxy approximately 90,000 light-years across with nearly the same mass as the Milky Way. (For comparison, the Milky Way's SMBH contains about 4 million solar masses.)

The outer and less bright part of the core is slightly fainter on the northern side, throwing off its symmetry. It's also attended by several foreground stars, the three brightest of which form a nearly straight line on the core's southern side. You may also spot several fainter stars superimposed on the core, but they need steady seeing and decent magnification. For instance, look just a few arcseconds south of the AGN for a star that's nearly overwhelmed by the core's brilliance.

Along the western border of the AGN is a thin, curved dark lane that shows up nicely in most photos. It's not easy to see telescopically, though — the first time I saw it was at Steens Mountain. It was dimly visible with direct vision at 408× but averted vision really made it pop.

Spiral Arms

Close encounters with M82 probably gravitationally enhanced M81's spiral arms, but they're still understated, low-contrast features. They also compete with the bright core, making them a difficult target in less than optimal observing conditions.

In my experience, they're best seen with medium magnifications. I used 120× with my old 12.5-inch Dob, and 253× with my 28-inch. In my 8-inch scope I've seen a suggestion of the arms at 69×.

On the best nights my 28-inch shows each arm nearly wrapping completely around the core, but they're still subtle. The southern arm is slightly easier to see, especially along its most highly curved outer edge. The ends of each arm taper and blend into a larger oval glow that defines the complete spiral disk.

This glow is the dimmest part of M81's structure, extending the galaxy's shape and filling the area between the arms. It's much fainter than the arms and is best detected by looking for a subtle decrease in sky brightness beyond the disk.

M81's apparent size nearly doubles when this soft glow is detected. The arms look longer and the symmetrical beauty of the galaxy becomes more apparent. This can be a hard-won sight though, and another one where objectivity is needed.

H II Regions and Star Clouds

I've often been able to detect subtle mottling along the brightest and highest contrast portion of the southern arm through my 28-inch while using averted vision. This corresponds to some of M81's H II regions and star clouds. However, until this past October I hadn't seen any of the brighter patches individually.

It took Steens Mountain's transparent, high-altitude skies, and 408×, to pull them out. Surprisingly, these small, faint, and fuzzy patches were visible even when the seeing was poor.

I noted the most distinct group of H II regions A and B on my sketch. Along with C, the faintest region, they're equally spaced starting just south of a superimposed foreground star along the most defined edge of the southern arm. Region D is the easiest to see, appearing as a faint star-like object on the east side of the southern spiral arm. It might look slightly fuzzy on the best nights. The northern arm yielded three regions. Along with starlike E, the small condensations of F and G were found in the barely undulating fog of this somewhat featureless area.

By the way, each region is a conglomeration of many objects — H II and star clusters, X-ray, UV, infrared, and SNR sources — making their barely seen glow even more exotic.

Although these details give M81 added depth and character, the galaxy is more than the sum of its parts. It's the combination of its classic grand design shape and synergetic relationship with M82 that ultimately makes it — and them — so captivating.

Together

These two galaxies have profoundly reshaped each other. Observing them together is not only one of astronomy's great sights, it helps convey the reality of their connection.

A telescopic view large enough to see the apparently serene M81 and the obviously agitated M82 in context to each other, and to intergalactic space, is a big part of what makes observing them so extraordinary.

The scene looks tranquil at first. Majestically tilted toward each other, the galaxies' vast and breathtaking dynamism becomes apparent with even a little familiarity of their long history.

We're seeing just the latest frame of a 500 million-year-long movie. Now 300,000 light-years apart, M81 and M82 are still roiling from their latest encounter, only seemingly suspended in their grand and inexorable gravitational ballet. ✦

Howard Banich *lives in Portland, a long but scenic drive from Steens Mountain in southeastern Oregon. He can be reached at* ***howard.banich@nike.com***.

IN THE BEGINNING This was the wide-angle view through my homemade 8-inch f/4 Newtonian from my suburban front yard in 1975. The streak in the upper left corner was a telescopic meteor.

Our Surprisingly Ancient "Greek" Constellations

BALAGE BALOGH

Perseus the Wizard, Ursa Major the Dragon-Wagon — many of the classical Greek constellations were revamped from ages much earlier.

CRAIG CROSSEN

The standard versions of our familiar constellations, with their Greco-Roman mythologies that most skygazers learn early in their starry pursuits, aren't half the story. The ancient Greeks gave us our 48 "classical" constellations, but many of these were already extremely old, inherited and adapted from very different societies long extinct.

Modern scholarship has traced many of our Greek constellations to prototypes in cultures of Mesopotamia (modern Iraq) that were about as distant in time from the ancient Greeks as we are from them. Some constellations date back at least to the origin of writing, which seems to have happened in Sumeria, just north of the Persian Gulf, around 3200 BC. This suggests that these

SUMERIAN ORIGINS The ancient city of Uruk, in the marshy waterways of Sumeria north of Eridu, grew to become the world's largest city by the late 4th millennium BC, with an estimated 50,000 residents. Invented here were the wheeled wagon and its constellation counterpart, as well as the plow, the cylinder seal, the first true writing, and monumental architecture — such as the White Temple of Anu, the sky god. In this illustration, the temple's design and that of the surrounding neighborhoods are based on excavations and mapping of what are now crumbling bricks in the desert.

constellations may be older still: literally prehistoric.

In an earlier issue, I described the Sumero-Babylonian prototypes of the Greek "water" constellations that fill our southern sky in autumn (*S&T:* March 2015, p. 36). Now let's look to the northern side of the sky. While the ultimate origins of the "water" constellations are lost in the prehistory of far-southern Mesopotamia (in particular the city ruined of Eridu), the birth dates of some of our northern constellations can be estimated more accurately.

One of them, for instance, had to follow the invention of the wheel.

Wagon of the North

The most conspicuous star pattern in the northern heavens is the Big Dipper, which marks the hindquarters and surrealistically long tail of the classical Great Bear. Originally, however, the Big Dipper itself seems to have been the entire Bear, because in both the *Iliad* and the *Odyssey* (approximately 8th century BC), Homer says the Bear is also called the Wagon (in Greek, *Hamaxa*) — a shape that's suggested by just the Dipper itself.

The Greek celestial Wagon is a direct borrowing from ancient Mesopotamia, where it was called *Margidda,* the "Long [i.e., four-wheeled] Wagon." But the word *margidda* is Sumerian, implying that the Dipper stars took this identity before 2000 BC, when Sumerian ceased to be a living language. This is confirmed by its appearance in Sumerian star-name lists written around 2000 BC and by its mention in an old Sumerian myth called (by modern scholars) "Enki and the World Order," which seems to have been composed around 2500 BC.

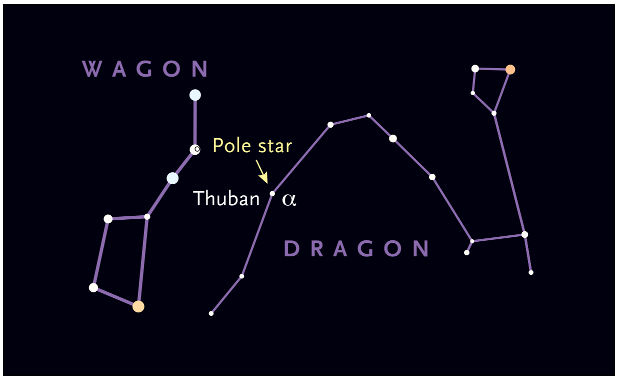
The Mesopotamians declared that the Wagon was circumpolar, but in a way that at first seems unrealistically exaggerated. A late (1st millennium BC) astrological text calls it the "Axle of the Sky," and another states that it "stands" the entire year. Were the skywatchers of the time really so unobservant? Or does putting the celestial pole in the middle of the scene correctly describe a larger tableau? Indeed it does, as we shall see.

Babylonian and Assyrian astronomical texts of the last two millennia BC associate the northern heavens with the air- and weather-god Enlil, an older Sumerian deity. This suggests a special relationship between Enlil and the prominent celestial Wagon. And indeed, cylinder-seal designs from as far back as the mid-3rd millennium BC show Enlil standing in his wagon. The wagon has a long, arched draft-pole in front, corresponding to the Dipper's handle. The drawing below is from a cylinder seal of the Akkadian Period, around 2300 BC. It shows Enlil, whip in hand, in his Wagon. It's being pulled by a winged lion-griffin, its head down and its gaping jaws spewing flame or venom. Enlil's consort Ninlil, the "goddess of the wind" with thunderbolts in each hand, stands on the creature's back.

Enlil's Lion-Griffin carried into Greek astronomy as the constellation Draco the Dragon, which stands in front of the Dipper/Wagon. Today the Wagon seems to precede the Dragon around the celestial pole as the sky turns, but during the 3rd millennium BC the north celestial pole was near Alpha Draconis (Thuban), so the Wagon and most of the Dragon pivoted closely around the pole opposite each other. The arrangement is seen on the next page, with the dots connected as they appear on *Sky & Telescope*'s star charts. The complete scene

THE DIPPER STARTS HERE **Enlil, the god of the northern constellations, rides his celestial Wagon (*Margidda,* our Big Dipper), pulled by a celestial griffin, probably Draco the Dragon. This is a drawing of the impression from a cylinder seal of the Akkadian Period around 2300 BC.**

W. H. WARD, *THE SEAL CYLINDERS OF WESTERN ASIA* (CARNEGIE INSTITUTE, 1910)



SKY & TELESCOPE

AROUND THE FORMER POLE Enlil's wagon and its draft-beast appear in their modern versions on *Sky & Telescope*'s sky charts. They revolved as a pair around the north celestial pole, which was near Thuban at the time.

therefore "stood" all year on the axis of the sky, as the later Babylonian texts reported.

There's a popular notion that most or all of the classical constellations come from religious mythology, but that's not correct. Sumeria's humble Wagon constellation is a case in point. The four-wheeled wagon seems to have been invented at the southern Mesopotamian city of Uruk around 3200 BC — at least the earliest known picture of one is on a cylinder-seal impression found in a stratum in the ruins of Uruk dating to about that time. Given the resemblance of the Big Dipper to the profile of the Sumerian wagon with its arched draft-pole, it's safe to say that the constellation *Margidda* was invented after the wagon itself: in other words, after about 3200 BC. It's still sometimes called the Wain or Wagon in England.

A half-dozen archaic Sumerian constellations were named for what were then newfangled inventions. Thus we find in the Sumerian heavens a celestial Bow (in Sumerian, *Ban*) formed by the star-pattern of Kappa-Epsilon-Sigma-Delta-Tau Canis Majoris and Xi-Rho Puppis, with Sirius as the copper-headed arrow (*Kaksisa*) shot from it along the Eta-Delta-Alpha Canis line. (Copper was the most advanced material in military technology at that time, as emphasized by Sirius's brightness.) In the northern celestial hemisphere the Sumerians placed a celestial Plow, *Apin*, which apparently consisted of Gamma Andromedae plus our classical Triangulum, with the plow's narrow tip at Alpha Trianguli. The deep-tilling Sumerian plow with a seeder funnel (depicted below) was invented, like the four-wheeled wagon, around 3200 BC. In fact, there was a burst of creativity at Uruk in the late 4th millennium BC, when the wagon, the plow, the cylinder seal, monumental architecture, the potter's wheel, and true writing were all invented.

H. FRANKFORT, *CYLINDER SEALS FROM THE DIYALA REGION* (UNIV. OF CHICAGO, 1955)

TAMING OF BEASTS Hydra, with a roaring lion, pulls a Sumerian plow equipped with a narrow funnel-seeder as two deities guide it. One of them goads Hydra with a scorpion. The pointed plowshare end of the Sumerian constellation *Apin*, the Plow, later became the Greeks' narrow Triangulum. The serpent creature here, with its long, scaled body, upraised head, and horned crown of godhood, is identical to later Mesopotamian portrayals of Hydra the constellation.

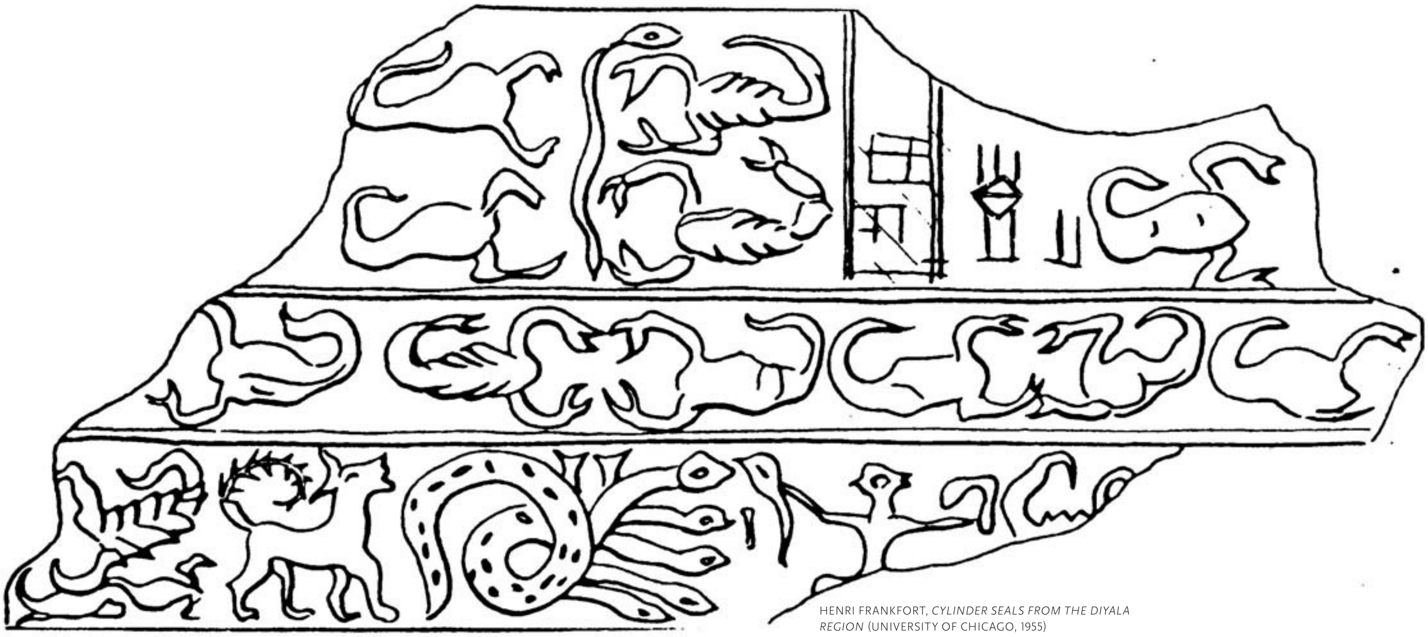
The Saga of the Kneeler

Concerning the star pattern we know as Hercules, the Greek astronomical poet Aratos wrote in his *Phaenomena* of 270 BC, "That sign no man knows how to read clearly, nor on what task he is bent, but men simply call him On His Knees [Greek: *Engonasin*]." The constellation was not known as "Hercules" until at least the late 2nd century AD, when the cult of Hercules grew increasingly popular in the Roman Empire. All the early Greek and Roman writers on astronomy — Aratos, Hipparchus, Geminos, Vitruvius, Manilius — refer to this star-pattern simply as The Kneeler.

No Sumerian, Babylonian, or Assyrian astronomical or astrological text mentions a celestial Kneeler. In fact, *MUL.APIN,* the great Assyrian astronomical work compiled before 1000 BC, calls the stars of our Hercules *Urku,* the Dog. Worse, images of kneelers are so frequent in ancient Near Eastern art that it would appear hopeless to identify a celestial Kneeler among them.

But during the Old Babylonian period of the early 2nd millennium BC, a cylinder-seal design featuring a particular kneeler happened to be especially popular. It shows him being attacked by a rampant lion or a rampant lion-griffin, sometimes both. The Kneeler is almost always accompanied by a seated goat likewise attacked by a lion-griffin and/or a lion, as shown on page 28. Several decades ago the assyriologists Edith Porada and Briggs Buchanan recognized this seal design as astronomical, pointing out that the Goat and the Lion-Griffin were neighboring Sumerian constellations, occupying the stars of Lyra and Cygnus-Cepheus, respectively.

What they overlooked was that our Hercules is right there next to them, just west of the Goat, our Lyra. Moreover, in the sky the Kneeler is upside-down with respect to the Lion-Griffin — in a vanquished position, as is shown in the cylinder-seal design. So I think we do indeed find the celestial Kneeler in Mesopotamia, occupying the correct area of sky, 1,500 years before Aratos.



NINURTA AND THE HYDRA A drawing of a cylinder-seal design from the mid-3rd millennium BC, found on a number of pieces of clay excavated at Tell Asmar northeast of Baghdad. The bottom row shows a kneeling Ninurta fighting a seven-headed snake. Two heads have been cut off at the neck; the figure holds at least one of them.

But this does not put a name on him. However, about a millennium earlier in Mesopotamia, another Kneeler figured prominently in cylinder-seal designs, and this one can be identified. He is fighting an assortment of mythological monsters, including serpents, caducei, spread-eagles, and — most importantly — seven-headed snakes or dragons. In all cases the Kneeler is the Vanquisher, not the Vanquished.

And he is named. According to the Sumerian myth *Lugal-e* of the late 3rd millennium BC, the Vanquisher of the Seven-Headed Serpent was the war-god Ninurta. Here then we seem to have the origin of both the Greek celestial Kneeler and the Greek myth of Hercules tackling the multi-headed Hydra.

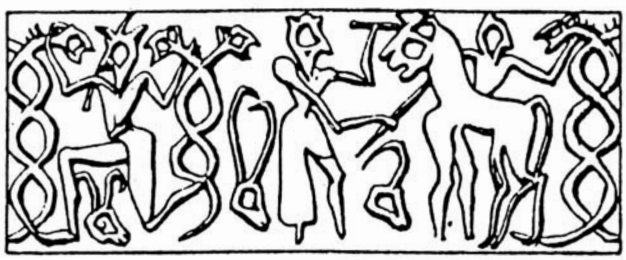
This role of the celestial Kneeler seems supported by the fact that his upright foot is always shown on the head of Draco. Indeed, in the early 3rd millennium BC when the north celestial pole was near Alpha Draconis, if you looked high in the north from Mesopotamian latitudes when the Kneeler's head (Alpha Herculis, Rasalgethi) was near the zenith, you would have seen Draco curved out beneath his feet. The classical Hercules is portrayed with his club raised as if to pound his victim. Vanquisher indeed.

This also helps explain why *MUL.APIN* called this star-pattern *Urku*, the Dog. Ninurka's consort was the goddess Bau, and her sacred animal was the dog. Vega, far and away the brightest star in this part of the sky, was Bau's star. Apparently her icon, the dog, was transferred late in Mesopotamian history to the sky-image of her husband one constellation over.

Nor was the association of dogs with Bau and Ninurta arbitrary: these were war deities, and on Sumerian cylinder-seal designs and steles, dogs are shown following war-wagons into battle and feeding upon the battle-dead.

How did the Heroic Kneeler of the early 3rd millennium become the Vanquished Kneeler of the early 2nd millennium? Perhaps the change was another consequence of the severe cultural dislocations in Mesopotamia after the collapse of the Sumerian Ur III Dynasty around 2000 BC. For the next two centuries Mesopotamia was in social, political, and economic chaos. It was during this time that Sumerian ceased to be a living language. Much of the high culture of the Sumerian 3rd millennium was lost, or misunderstood by the invading nomadic tribes. Thus the star-figure of the Kneeler remained in the sky, but perhaps his identification and mythological associations were forgotten.

Similarly, as told in my previous article, the Water-Pourer (our Aquarius) remained in the sky but on



HEROIC KNEELER A kneeling figure (left) seizes two caduceus-snakes by their necks in this drawing from a cylinder seal dating to around 2700 BC.

VANQUISHED KNEELER After the fall of Sumeria, the Kneeler was not so heroic. A winged griffin chomps on a powerless figure, and a lion seems to have bitten a weapon from his upraised hand, in this cylinder-seal impression from the Old Babylonian period around 1700 BC. On the left a similar creature attacks a goat, whose constellation was positioned next to the Kneeler in the Mesopotamian sky.

W. H. WARD, *THE SEAL CYLINDERS OF WESTERN ASIA* (CARNEGIE INSTITUTE, 1910)

later cylinder seals was often shown as one of the gods themselves rather than as a mere human priest of Enki, which he had been originally.

Perseus the Sumerian

The best-known Greek sky legend is the tale of Perseus and Andromeda. The Greeks elevated all its major players to the heavens: Perseus with his scimitar and Medusa's head; Andromeda, the chained maiden; Cepheus, the King; Cassiopeia, the Queen; Pegasus, the Winged Horse; and Cetus, the Sea Monster. The story is such an excellent example of ancient Greek myth-making — an art at which that people excelled — that it's hard to believe that most of its constellations have Sumero-Babylonian roots.

This is immediately clear from the objects Perseus himself carries: the Head of the Medusa and the Scimitar with which he cut it off. The Greek Medusa head — a

BRITISH MUSEUM

PROTO-MEDUSA for a proto-Perseus. Masks of Humbaba (or Huwawa) the Terrible, a demon-monster whose very look brought death, were tools of the trade for Mesopotamian exorcists and magicians. This one was used during animal-entrail divination around 2000 BC or a bit later. Humbaba stars in the epic of Gilgamesh and Enkidu, dated to about 2100 BC. His face was made of serpentine lines representing intestines; they squirmed and coiled like the later Medusa's living hair-snakes. Enkidu cut off Humbaba's horrible head and carried it in a leather sack, as did Perseus with the head of Medusa. Humbaba and the early Greek representations of Medusa displayed similar grimaced mouths. The Babylonians placed their demon-head and another wizard's tool, the curved staff, into the northern sky with *Shugi*, the Old Man, likely the pre-Perseus.

frequent motif in Greek art — is practically identical to earlier Mesopotamian demons' heads made of terracotta that were used in magic, exorcism, and divination. An example is pictured at the bottom of the facing page.

And in Mesopotamia, Perseus' Scimitar (*Harpe* in Greek) was named *Gam,* though assyriologists disagree about which stars represented it. In Sumerian the word *gam* referred not only to a curved weapon, but also to the curved staff used by magicians and exorcists. Moreover, in this same region of the sky the Sumerians placed a constellation called *Shugi,* the "Old Man." A better translation, given the presence here of a celestial magician's Staff and Demon's Head, might be "Exorcist" or "Diviner." Thus it would seem that the athletic superhero Perseus, carrying a scimitar and the severed head of the dreaded Medusa, descended from a Sumerian celestial wizard holding two tools of his trade.

The celestial Andromeda and her parents Cepheus and Cassiopeia seem to be purely Greek innovations. In Mesopotamia the Cepheus stars were the hindquarters of a large celestial Lion-Griffin that included Cygnus. Cassiopeia was the Stag. Andromeda is made of stars from three Mesopotamian constellations: the Plow, the Northern Fish of the Mesopotamian predecessor of Pisces, and the northeast-corner star of the Sumerians' Irrigated Field, which was our Great Square of Pegasus.

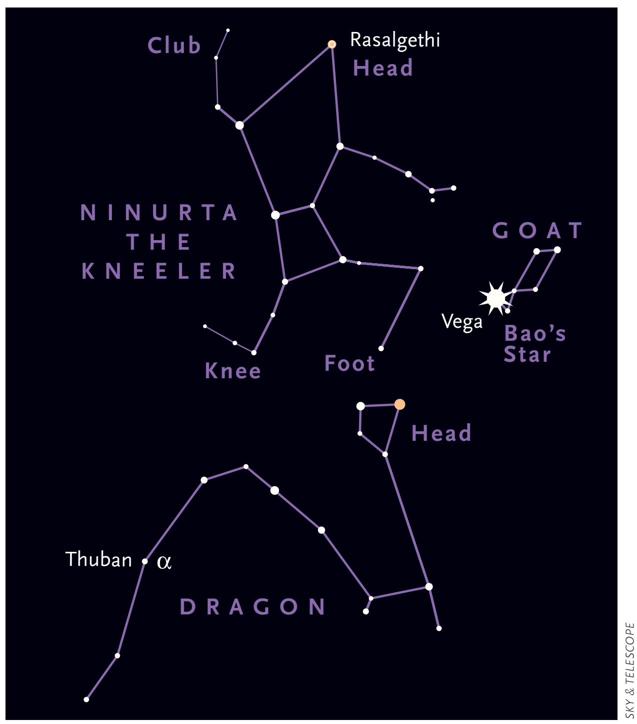
But the Greek Pegasus was not a totally new sky-figure: *MUL.APIN* lists a "Horse Star" between the celestial Eagle (Aquila) and the Irrigated Field. Only one bright star matches this placement: Epsilon Pegasi (Enif), the Nose of Pegasus according to the Greeks.

However, this could not date to the Sumerian 3rd millennium BC because horses were not used in Mesopotamia, and virtually never shown in Mesopotamian art, before 2000 BC. Indeed, the image of a celestial *winged* horse only appears in Mesopotamia in the Middle Assyrian Period around 1200 BC. Its presence in the sky by that time no doubt gave rise to our Pegasus.

Historians have known for two centuries that some constellations we inherited from the Greeks have Mesopotamian roots. What's surprising, however, is the extent of the Greek debt to the Sumerians, Babylonians, and Assyrians for constellation figures we would have assumed were Greek innovations, such as the Winged Horse, the Medusa's Head, and the Hydra. Even more surprising, perhaps, is that entire Greek myths were based on Mesopotamian originals, such as the battle of Hercules with the many-headed Hydra snake.

But the Greek genius was in how they used the images and themes they inherited: they turned it all into poetry. Literally so, in the case of Aratos and his flowery enumeration of the classical 48. And that surely has helped preserve them ever since. ✦

Craig Crossen *is a freelance writer, editor, and traveler who calls Minnesota home base. He co-authored* Sky Vistas *(2004) and is completing books on the history of all the classical constellations and on the history of archaeology in Iraq.*



HEROIC ONCE AGAIN From the Roman era to ours, Hercules wields a club as he kneels with his foot over the head of Draco. This is their portrayal on *Sky & Telescope*'s star charts.

Untwinkling the Stars

How did the world's largest telescopes conquer the tempestuous atmosphere?

SHANNON HALL

ETHAN TWEEDIE / WWW.ETHANTWEEDIE.COM

ARTIFICIAL STARS Twin laser beams from the Keck telescopes atop Mauna Kea, Hawai'i, create artificial guide stars to aid adaptive optics observations of our galaxy's center.

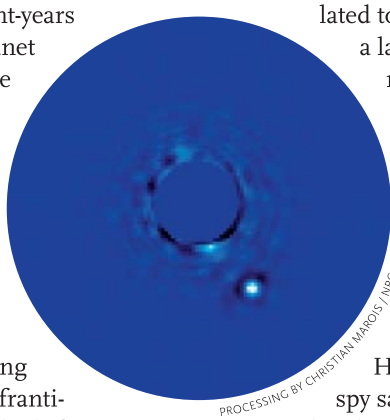
The first few days of an observing run can be enchanting: the night sky so dark that familiar constellations are hard to find, the landscape typically barren and far from city lights, and the array of mirrors and instruments finally catching beams of light from the distant universe.

But on one such evening in November 2013, high in the remote Chilean Andes, Bruce Macintosh was bored.

Macintosh (Stanford University) led the team that built the Gemini Planet Imager (GPI), the first in its class of next-generation adaptive optics instruments. The team had mounted GPI on the immense 8.1-meter mirror of the Gemini South telescope, and the instrument would finally begin its planet search during this observing run. But it still had to go through an extended testing sequence, and Macintosh was finding the work tedious — he was anxious to "get on sky."

So on the fourth night, after the team of engineers responsible for the tests headed to bed, Macintosh took matters into his own hands. “That was the night where we said, ‘y’know, let’s just point it at a damn planet and see what it looks like.’” The team slewed the telescope toward Beta Pictoris, a star 63 light-years from Earth with a hot, young giant planet that orbits its star at almost twice the distance that Jupiter orbits the Sun. Then they waited — but not for long. Within 60 seconds a lump had materialized on the screen before them.

The same detection prior to GPI would have taken an hour to image and days to process. Could the new instrument capture an exoplanet in only a minute? The astronomers filling the room remained skeptical. They frantically grabbed their laptops and searched for any papers that might show an image of the planet Beta Pictoris b. They then scrutinized the screens, holding their laptops sideways to better match the image’s orientation on the observatory’s computer screen. Sure enough, the images aligned. Before their eyes was a newborn gas giant, seen more clearly than ever before.



PROCESSING BY CHRISTIAN MAROIS / NRC CANADA

Spotting the exoplanet right off the bat was an incredible feat, says GPI chief scientist James Graham (University of California, Berkeley). “It doesn’t require any detailed analysis. It doesn’t require crunching the numbers. It’s just completely evident in the raw data that an exoplanet is there.”

But the basis of GPI’s success was decades in the making. Even 2,700 meters (8,900 feet) above sea level, Gemini South still sits beneath an ocean of air. So the telescope uses adaptive optics (AO) to correct for the turbulent atmosphere. In GPI, more than 4,000 actuators spaced just 400 microns apart deform the instrument’s secondary mirror to exactly match and cancel out atmospheric distortion. Without AO, light from planets, stars, and galaxies would dance and distort, like pebbles seen beneath a flowing stream. The colossal observatory wouldn’t see any sharper than a backyard scope. But with AO, images steady themselves, allowing astronomers to pick out fine details.

The technology that makes this feat possible was born in the 1970s in classified government meetings. A few select Air Force scientists and astronomers worked together to design early versions of laser guide-star systems before the project was declassified in 1991. After several decades of innovation, AO is still improving with each new generation. Today, ground-based telescopes such as Gemini South can exceed the clarity of the Hubble Space Telescope. And the next generation of AO-equipped mega-telescopes will push the boundaries of sight even further.

Deep (and Classified) Roots

Many early scientists, even Isaac Newton, wrestled with the problem of atmospheric distortion, but the real advances didn’t begin until the 1970s. That’s when the Pentagon was working on something seemingly unrelated to astronomy: it needed a way to focus a laser beam on a distant target, which meant protecting the beam from choppy wind. At the same time, DARPA, an agency within the Department of Defense, wanted to identify satellites launched by the Soviet Union.

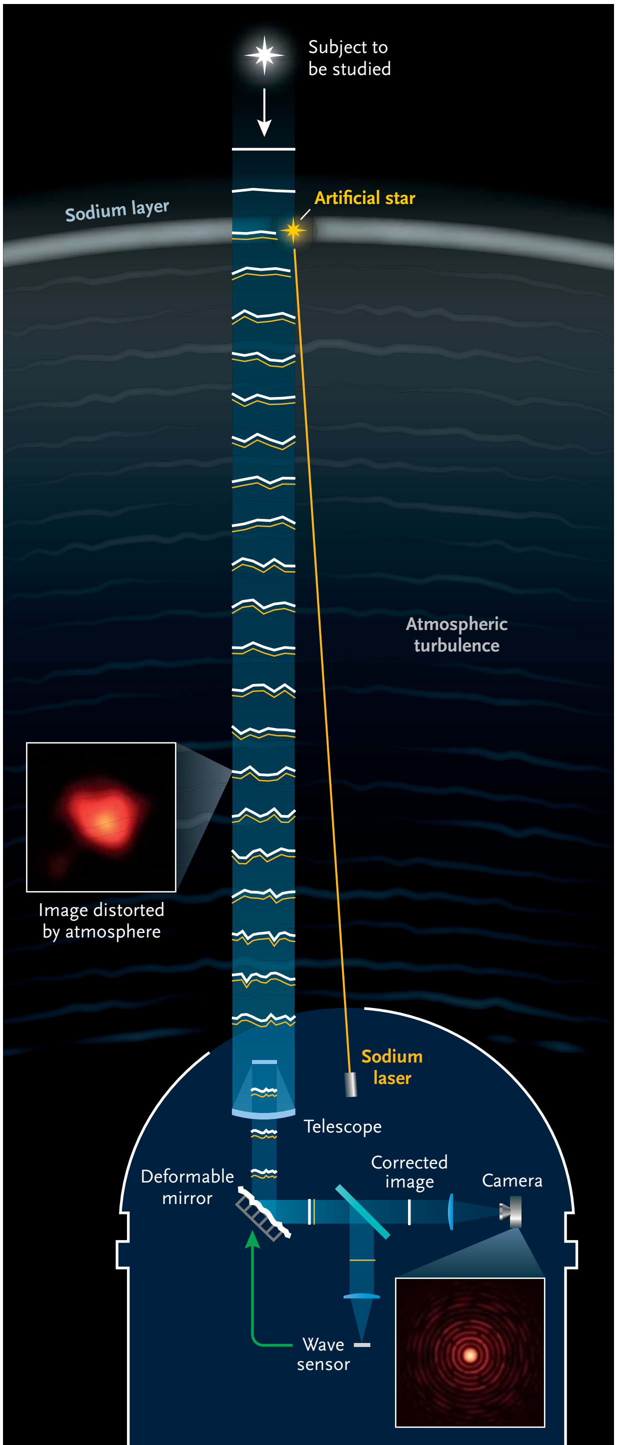
Even at a good location, atmospheric turbulence smears out details smaller than 1 arcsecond across. That’s good enough to see the cylinder-shaped Hubble, which is similar in size to most spy satellites, but not good enough to make out details. The military needed a way to do better.

If scientists could accurately measure how the atmosphere is moving, they could send that information along to a flexible secondary (or tertiary) mirror. In principle, this deformable mirror would exactly cancel distortions introduced by the atmosphere into the primary mirror’s image, sculpting the rays of light (from a satellite or any other target) back to near-perfect alignment.

One of the first AO demonstrations was installed in 1980 on DARPA’s 1.6-meter telescope in Maui. It used 168 piezoelectric actuators, which expand or contract in response to applied voltage, to very slightly bend a deformable mirror. Today, AO systems might contain many thousands of these mirror movers, thanks to improvements in their manufacturing, positioning,

GEMINI OBSERVATORY

BETA PIC ***Top:*** **One of the first images the Gemini Planet Imager took was of the disk around Beta Pictoris, a star known to host a planet. With just a minute-long exposure, the newborn gas giant appeared on screens in the control room.** ***Above:*** **The Gemini Planet Imager’s first-light images brought elation to the team in the control room at the Gemini South telescope in Chile.**



S&T: GREGG DINDERMAN

HOW ADAPTIVE OPTICS WORKS As starlight shines through Earth's atmosphere, turbulent air distorts its wavefront. A blurry image results. In a laser guide-star AO system, a sodium laser shoots up to the mesosphere, scattering among the sodium atoms there to create what appears to be a bright yellow star. Computer algorithms measure this artificial star's wavefront, which is similarly jangled by the time it reaches the ground. The computer then deforms a flexible mirror to return both wavefronts to their undisturbed forms.

and mounting.

But even with the best deformable mirrors, compensating for the atmosphere is no easy task. The simplest method calls for a star in the field of view, which would look like a small point if its light could travel undisturbed to the telescope. The atmosphere introduces any extra blur. So keeping a telescopic eye on the star gives a measure of atmospheric turbulence.

But there's a catch: in order to measure the rapidly changing atmosphere, astronomers need to catch a lot of photons quickly, so the star has to be pretty bright. No star fainter than 10th magnitude would do, and even if stars were evenly distributed, only 15 stars this bright would be found in each square-degree patch of the sky.

This limitation wouldn't be so bad if it weren't for a second one: only a very tiny area of the sky around the star — up to about 30 arcseconds wide for images at near-infrared wavelengths — will have similar atmospheric turbulence. The two conditions leave only 1% of the sky available for AO observations. There had to be another way.

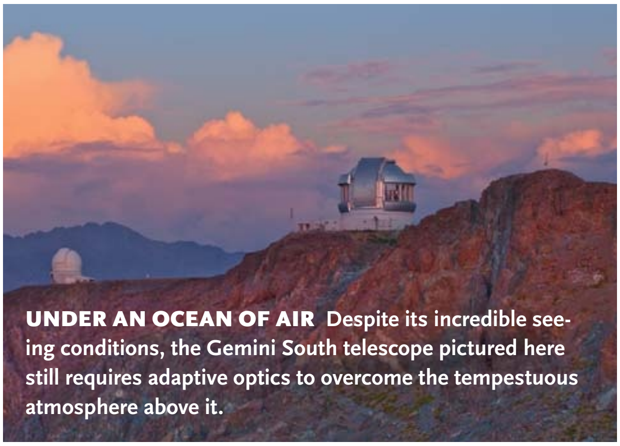
So in the late spring of 1982, the military called on the Jasons — a group of scientists who meet once a year to give technical advice on issues of national security — to help solve the problem. In that classified think tank, scientists came up with a potential solution: shine a laser upward along a telescope's axis and you can create a bright artificial star wherever you like.

With that in mind, Air Force scientist Robert Fugate and colleagues created a Rayleigh laser guide-star system at the Kirtland Air Force Base in Albuquerque, New Mexico. Molecules in the lower atmosphere such as oxygen, nitrogen, and aerosols reflect the laser beam, creating a green-colored spot of light in the sky. Fugate and his colleagues pointed their system toward a pair of stars in Ursa Major, capturing an image 25 times clearer than previous work. The researchers were well on their way to conquering the age-old problem of turbulence.

Declassifying AO

But at the time fewer than 100 people in the world knew about it. Many Jasons spent years lobbying the military to take the wraps off, but it wasn't until the Soviet Union fell apart (and spy satellites became less of a threat) that the military considered declassifying the information. Scientists around the world had started to catch up anyway — two French astronomers published a paper describing the technique in 1985. Finally, in 1991 Fugate was allowed to describe the research at a meeting of the American Astronomical Society in Seattle, Washington.

"Prior to that meeting I had never talked about this with more than 10 people in the room," Fugate recalls more than 20 years later. But by the start of his talk, the room had filled up with nearly 400 people, some of whom were standing three to five deep all around the



GEMINI OBSERVATORY

UNDER AN OCEAN OF AIR Despite its incredible seeing conditions, the Gemini South telescope pictured here still requires adaptive optics to overcome the tempestuous atmosphere above it.

walls. “I was as nervous as I could be,” Fugate says. But he did not disappoint. Utter silence followed his announcement, then noisy chatter filled the room.

Although it was clear that adaptive optics was the tool astronomers needed, the current system was far from perfect. Take Fugate’s laser system. Because it used Rayleigh scattering in the lower atmosphere, it could only shine up to about 20 kilometers above Earth’s surface. Still more air above this layer remained unmeasured.

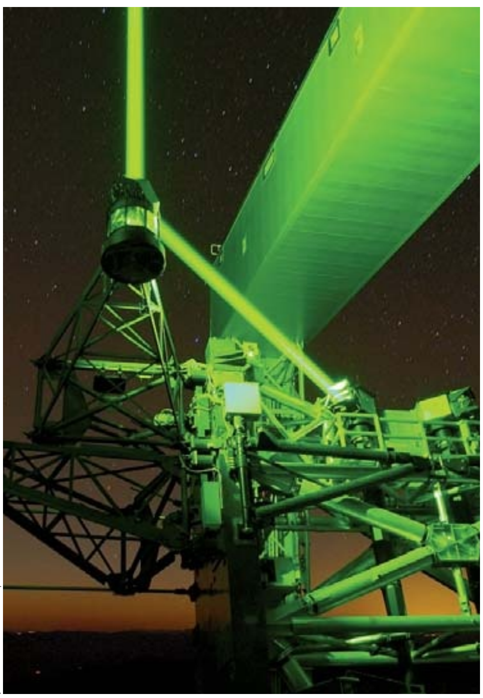
So another Jason involved with the project, Claire Max (then at Lawrence Livermore National Laboratory), worked on a better solution: if a laser is tuned to a specific wavelength (589 nanometers), it will excite a layer of neutral sodium atoms floating about 90 kilometers above Earth’s surface. Initially deposited by meteors passing through the atmosphere, these sodium atoms will fluoresce in response to the laser’s light — an effect visible from the ground.

By the early 1990s a few sodium lasers had been built, but none powerful enough to do the job. It was over lunch one day that Max and a colleague realized the necessary laser was sitting beneath their feet. Livermore Laboratory had an enormous underground laser that was normally used to separate isotopes but could be tuned to sodium wavelengths. So one night Max set up a mirror to bounce the horizontal laser beam up into the sky. She then pointed a small telescope at the guide star and measured the atmosphere’s disturbances. It was proof that she could improve upon Fugate’s existing system, and by 1996 Max and colleagues had deployed a prototype at Lick Observatory’s 3-meter telescope. But even then most observatories failed to embrace the technology — it was too expensive.

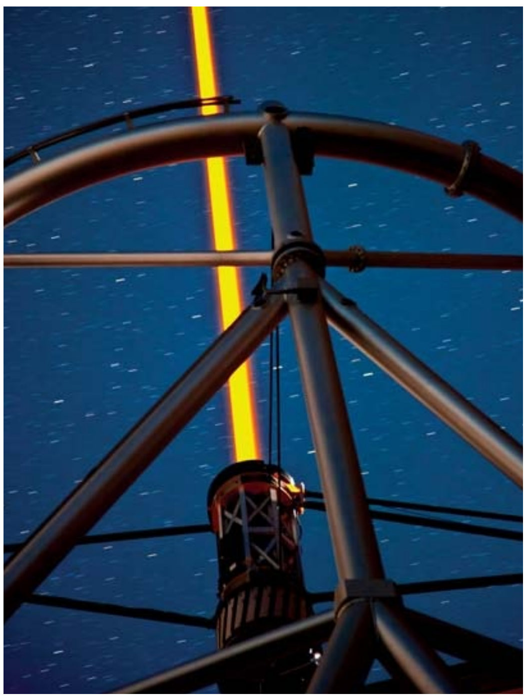
In 1999 a $20 million grant from the National Science Foundation kick-started the Center for Adaptive Optics. Astronomers from the University of California and Livermore continue to work together to improve upon existing technology and further develop the techniques necessary to use it. Now, even though laser-assisted AO systems still have to be custom-built for every observatory, most large telescopes have joined the game.

Outshining Hubble

In optics the motto is generally, “the bigger, the better.” A larger primary mirror captures more photons and enables astronomers to see fainter and farther objects. It also determines the level of detail the telescope can pick out, as long as atmosphere isn’t an issue. The Hubble’s 2.4-meter mirror can resolve objects 0.1 arcsecond apart

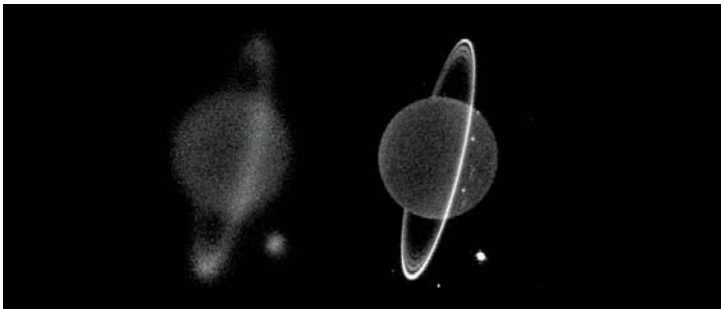


JULIAN ZIEGLEDER / MAX PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS



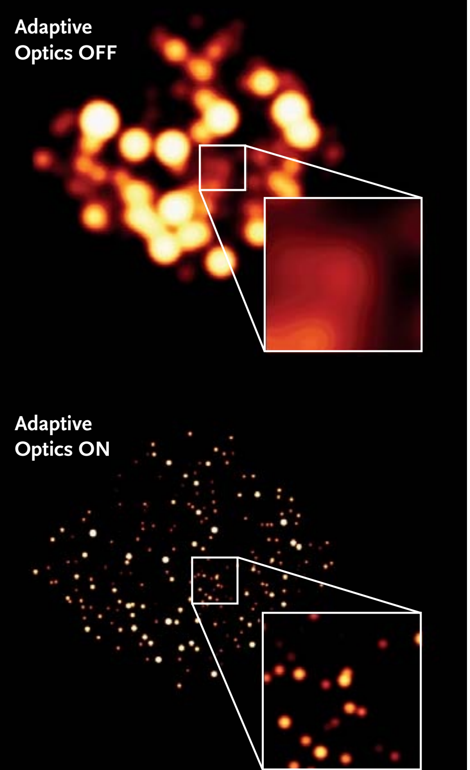
GEMINI OBSERVATORY

GREEN VS. YELLOW Green-tinted Rayleigh lasers, such as the ones being installed at the Large Binocular Telescope *(left)*, are commercially available and therefore cheaper. They reflect off a lower layer of the atmosphere and account for distortion nearer the ground. Lasers tuned to 589 nanometers, such as the one employed by the Gemini South telescope *(right)*, reflect off the higher-altitude sodium layer about 90 kilometers above the ground.



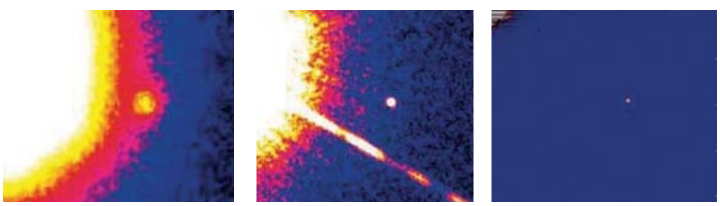
HEIDI B. HAMMEL AND IMKE DE PATER / WMKO

BEFORE AND AFTER Without adaptive optics, a near-infrared image of Uranus appears blurry *(left)*. When the same image is taken with AO technology turned on *(right)*, the faint and fuzzy ring resolves into several distinct rings, and small storms within the atmosphere are revealed.



UCLA GALACTIC CENTER GROUP / W.M. KECK OBSERVATORY LASER TEAM (2)

TUNING IN TO SGR A* Astronomers used complex techniques to reveal action in our galaxy's center before adaptive optics *(top)*. With the advent of AO *(bottom)*, astronomers have pinpointed and tracked the minute motions of individual stars as they careen around Sgr A*, our galaxy's supermassive black hole. The larger square fields are 6″ on a side, insets span 1″, and all images were taken at wavelengths near 2.2 microns.



T. NAKAJIMA / S. DURRANCE; S. KULKARNI / D. GOLIMOWSKI / NASA; M. CHUN / NICI TEAM

ADAPTIVE OPTICS REVOLUTION The AO-enabled Palomar Observatory discovered the first brown dwarf, Gliese 229B, tucked within the glare of its companion star *(left)*. Hubble followed up a year later *(center)* to help pin down its orbit. After a decade, an image captured by the Near-Infrared Coronagraph and AO system on the Gemini North telescope (*right*, in a slightly larger field of view) shows how far the technology has come.

Find a full gallery of before-and-after images at http://is.gd/adaptiveoptics.

at 1 micron, but only because it flies about 350 miles above Earth's surface. With the advent of adaptive optics, one of Keck's 10-meter telescopes (among the largest observatories in the world) can resolve details as fine as 0.04 arcsecond — producing images more than twice as crisp as Hubble's.

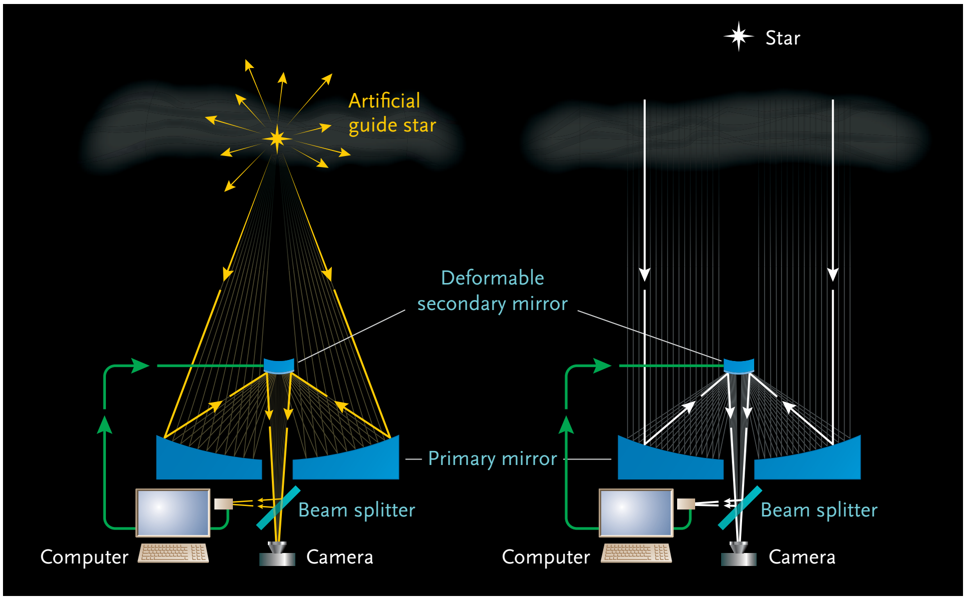
In 1999, the Keck Observatory placed its first natural guide-star system on Keck II and a year later on Keck I. With better deformable mirrors and even the ability to separate light into its constituent wavelengths, this system was radically improved in comparison to earlier AO counterparts.

Such razor-sharp vision enabled astronomers to peer into the crowded environment at the center of the Milky Way Galaxy. Before getting access to Keck's adaptive optics, Andrea Ghez (University of California, Los Angeles) and her team had used a camera that took exposures every few milliseconds to create stacked images of this region. But from 1995 to the present day, Ghez's team has been able to watch stars orbiting the Milky Way's center at closer distances than ever before. These previously hidden stars whip as close as 45 astronomical units to the center, at speeds up to 12,000 kilometers per second (roughly 4% the speed of light). Yet the center appears empty. The source of gravity that's flinging the stars in their speedy orbits can't be anything but a supermassive black hole.

Although Ghez herself is modest about this achievement, other astronomers think her research is without a doubt the best example of AO's successes. "I don't have words to express how stunning that is," says GPI's Macintosh. "It's both just visually stunning to watch as a human, and scientifically it's really, really important."

Then in 2003, Keck II upgraded its AO system to use a sodium laser sent from Max's team at Livermore (Keck I followed suit a few years later). Peter Wizinowich, who leads AO development at Keck, has spent the past two decades improving the technology. He has commissioned new lasers, better deformable mirrors, and faster code to work seamlessly between the two. As such, Keck's AO system is the most productive one in astrophysics: to date, it's responsible for roughly 70% of refereed-science papers that use adaptive optics.

Orbits seem to be the theme of Keck's first AO results. A couple years after Ghez's work, a team including Macintosh used the Keck II and Gemini North telescopes to directly image three pinpricks of infrared light around HR 8799, a 6th-magnitude star in the constellation Pegasus. In theory such direct images of exoplanets could reveal their composition, climate, and even possibilities for life. Though this first image wasn't yet up to that task, the discovery laid the groundwork for direct-imaging systems (*S&T:* Oct. 2015, p. 16).



S&T: GREGG DINDERMAN

TO INFINITY A laser guide star shines down from a layer in Earth's atmosphere — a lot closer than real stars, which might as well be infinitely far away. As a result, artificial starlight shines down in a cone *(left)*, rather than in the cylindrical shape of real starlight *(right)*. So atmospheric turbulence won't affect light from an artificial star in the exact same way as light from a real star. Future AO systems will use multiple laser beams to correct for turbulence within a larger area of the sky.

The Next Generation: Megascopes

But the most expensive and ambitious spree of telescopes — and their accompanying adaptive optics — has only just begun. Giant observatories currently under development include the Thirty Meter Telescope on Mauna Kea, the European Extremely Large Telescope in Chile, and the Giant Magellan Telescope also in Chile.

When it comes to building billion-dollar behemoths, adaptive optics is a must. Increasing the size of these telescopes' primary mirrors would mean nothing if the atmosphere were to limit their resolution to 1 arcsecond. But cancel out the atmosphere, and a 30-meter telescope could spot objects as small as 0.008 arcsecond across.

Megascopes will need improvements in laser technology if they're to implement AO. While the light from a star infinitely far away will fall through the atmosphere in a cylinder — its rays of light perfectly parallel — a sodium laser guide star's light falls through a tall cone that peaks at the sodium layer. Since its rays aren't perfectly parallel, a single sodium guide star can't perfectly mimic a star. The larger the telescope, the more that difference begins to matter.

"The 30-meter telescopes are going to require not a single laser but a grid of laser beacons, each of them with their own cone, to try to reconstruct the atmospheric turbulence in three dimensions," Macintosh says. Demonstration systems have been deployed at the Gemini South telescope and the Very Large Telescope. A similar system is being readied for the Keck II telescope. Ghez can't wait because she expects to see 10 times the number of stars in the galactic center as she's seen before.

Even space-based telescopes will one day utilize a form of adaptive optics. Though they fly high above the atmosphere, their AO will correct imperfections in the optics themselves. Hubble, for example, slips between day and night roughly every 45 minutes. This change warms and cools the spacecraft and changes its focus. Although the beloved space telescope doesn't have AO, its successor, the James Webb Space Telescope, will launch with a built-in AO system.

Stumbling Blocks

It's safe to say that laser adaptive optics has revolutionized astronomy, but it does present several observing challenges. Contrary to popular belief, artificial laser guide stars don't allow astronomers to see any celestial object on any clear night of the year. Astronomers still need a second (real) guide star — albeit very faint — to make a few basic corrections. With this restriction, laser guide-star AO currently covers 70% of the sky, largely in the galactic plane where there are more stars.

Also, sodium beacons don't work perfectly every day of the year. The blanket of sodium in the upper atmosphere thickens every time Earth tumbles into a stream of meteors. So the sodium layer will be densest September through December, after the brightest meteor showers of the year (namely the Perseids, Geminids, and Orionids) deliver their bits of sodium. Unfortunately, this is when the weather is often poorer. During the optimum observing conditions of summer, astronomers may struggle to produce a bright-enough beacon of light.

Finally, there's one more minor — and sometimes amusing — issue: local aviation. "Small private planes are like moths," says Marshall Perrin (Space Telescope Science Institute). "They're drawn to the light." When Perrin was at Lick Observatory over a decade ago, his team wouldn't operate the laser until 11 p.m., when most of the general aviation was done. So-called "aircraft spotters" still work today at the largest telescopes to search for planes.

ESO / L. CALÇADA / N. RISINGER (SKYSURVEY.ORG)

THE FUTURE OF AO This artist's conception shows multiple lasers being deployed as part of the adaptive optics system planned for the European Extremely Large Telescope, which is currently under construction on Cerro Armazones in Chile.

Because of these limitations some astronomers prefer using bright stars where available. Macintosh and his colleagues, for example, only search for young planets near relatively close stars, side-stepping any issues with artificial guide stars. But not everyone is as lucky as Macintosh's team. For those who don't have a bright star handy, an artificial beacon, albeit an imperfect one, opens a new window into the universe.

So, shortly after the Sun sets, most of the biggest optical telescopes around the world begin the night's observations by firing out a laser beam the color of sodium street lamps. The laser itself can be seen from several kilometers away, an eerie beam in the encompassing darkness.

Fugate likes to look at it philosophically. "We're using the remnants of our solar system — these meteors — as a mechanism to investigate the edge of the universe," he says. "I mean, it's just amazing when you think about how it all kind of comes together that way." ✦

As a freelance science journalist and former S&T *intern,* ***Shannon Hall*** *spends her days pondering the wonders of the universe from a local coffee shop.*

AO Spin-offs

The ongoing quest for the perfect image doesn't stop with astronomy. Adaptive optics has also been applied to microscopy, ophthalmology and — perhaps back into — the military.

Microscopy: Biological samples bend a microscope's beam of light in unpredictable ways. By first focusing the light into a glowing point, scientists can see how it warps as it passes through intervening tissues and correct for the distortion.

Ophthalmology: Ophthalmologists struggle to see past the fluid inside the eye to make out minute details in the retina. But with adaptive optics, they're able to see the finer features, allowing them to diagnose potential eye diseases early enough to prevent them.

Military: It took more than 25 years, but it seems the military's goal to utilize laser weapons has finally left the realm of science fiction. Engineers can now pre-distort a laser beam to cancel out atmospheric turbulence and focus with precision on a target.

Thomas Dobbins

Anomalous Appearances

How will your observations of the Mercury transit stack up to the historical record?

Transit of Mercury

FRED ESPENAK

Amateur astronomers around the globe are making preparations to observe this month's transit of Mercury (see p. 48, this issue). Passages of the tiny planet across the face of the Sun have never stirred as much popular interest as the far rarer transits of Venus, those spectacular events that have inspired expeditions to far-flung corners of the globe for several centuries. However, sufficient attention has been paid to transits of Mercury that many anomalous appearances have been reported over the years.

These oddities have long been the subject of speculation and even heated debate. Many astronomers have tried to explain the mysterious "black-drop effect" frequently seen when Mercury's disc touches the inner edge of the Sun at second contact (near the beginning of a transit) or at third contact (near the end of a transit). (See *S&T*: Jan. 2012, p. 73.) But other strange visual effects have sparked interest as well. For example, the anomalies observed during the Mercury transit on November 5, 1868, were the subject of a detailed account in the *Monthly Notices of the Royal Astronomical Society* written by the celebrated British amateur astronomer William Huggins, who is chiefly remembered today for using a spectroscope to determine the chemical composition of stars and nebulae. A wealthy dealer in silks and linen with a keen interest in the sciences, Huggins used the proceeds from the sale of his family's lucrative textile business to build a well-equipped observatory on Upper Tulse Hill in south London. Its centerpiece was a telescope that would still be the envy of most amateur astronomers a century and a half later — an 8-inch refractor featuring a superb objective lens made by the renowned American optician Alvan Clark.

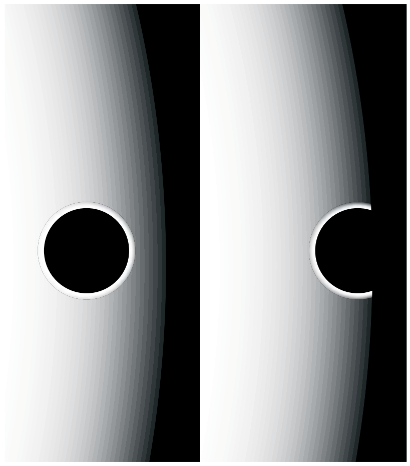
Huggins enjoyed decent daytime seeing during the November 1868 transit. "The Sun's edge was a little tremulous from atmospheric agitation," he recounted in his notes, "but the solar surface was so well defined that the bright granules of which it is composed could be distinctly seen."

Shortly after the entire disc of Mercury was silhouetted against the brilliant backdrop of the Sun's surface, Huggins noticed an even brighter, sharp-edged halo surrounding the black dot:

> The breadth of the luminous annulus was about one-third of the planet's apparent diameter. The aureola did not fade off at the outer margin, but remained of about the same intensity throughout, with a defined boundary. The aureola was not sensibly coloured, and was only to be distinguished from the solar surface by a very small increase of brilliancy.

There were a few corroborating observations of the bright halo surrounding miniscule Mercury that day. Observing with the 12.7-inch refractor at the Royal Observatory at Greenwich, E. J. Stone reported: "With power 137, a ring of light was clearly visible around the disc of Mercury. It extended to a distance of nearly a semi-diameter." But scores of other observers failed to see any trace of the halo, and even Stone was cautiously skeptical, writing: "I am of the opinion that it arose from mere contrast."

Similar effects had been reported for more than a century. First described by the French astronomer François de Plantade in 1736, the luminous ring was documented again by his countryman Honoré Flaugergues during the transits of 1786, 1789, and 1799. To the German astronomer Johann Hieronymus Schröter, the halo was a pale, almost ghostly, object that was "scarcely brighter than the surface of the Sun."



S&T: LEAH TISCIONE

CLEARLY VISIBLE British observer V. A. Firsoff detected a narrow but brilliant ring around Mercury during the November 7, 1960, transit. He projected the solar image from a 6.5-inch reflector onto a piece of white cardboard.

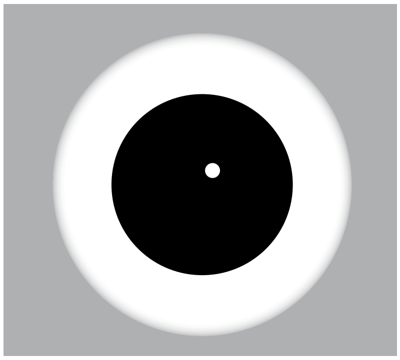
A few observers interpreted the halo as sunlight refracted by a dense, distended atmosphere surrounding Mercury. Most, however, compared it to the bright band bordering the limb of the airless Moon that had been reported during the partial phases of solar eclipses, a phenomenon that Astronomer Royal George Biddell Airy had dismissed in 1864 as "strictly an ocular nervous phenomenon." In the 1881 edition of his classic observing handbook *Celestial Objects for Common Telescopes*, the Reverend Thomas William Webb wrote off the halos as "deceptions from the violent contrast and the fatigue of the eye." To the French astronomer Camille Flammarion, they called to mind the illusory bright aura that he repeatedly saw surrounding the shadow cast by a hot air balloon onto sunlit prairies during his many ascents.

The halo is a striking example of a phenomenon first described by the Austrian physicist Ernst Mach in 1865. Mach noted that the eye-brain combination invariably exaggerates contrasts at the borders of adjacent extended surfaces of differing brightness. Observational astronomy is rife with examples of these "Mach bands," notably the "Terby White Spot," a spurious bright feature often seen bordering the intensely black shadow cast by Saturn's globe across the planet's rings (*S&T*: May 2014, p. 54).

But in addition to the bright halo, Huggins witnessed an even more curious phenomenon:

> Almost at the same moment that I first perceived the surrounding annulus of light, I noticed a point of light nearly in the centre of the planet. This spot had no sensible diameter with the powers employed [120× and 240×], but appeared as a luminous point... I kept it steadily in view until that part of the planetary disc, where the point of light was situated reached the Sun's limb, I then ceased to see it.

LUMINOUS ANNULUS British astronomer William Huggins reported a bright halo surrounding the disc of Mercury and a luminous spot on the planet during the transit of November 5, 1868.



S&T: LEAH TISCIONE

COURTESY OF THE SCIENTIFIC PAPERS OF WILLIAM HUGGINS

WORKING FROM HOME Huggins poses inside his observatory at Upper Tulse Hill next to the 8-inch Clark refractor kitted out for spectroscopic observations.

Like the bright halo, points of light and diffuse bright patches were frequently reported during transit events. Most dispatches described features that were centrally located, although in some instances they were offset towards the edge of the planet's tiny black disc.

The fact that a host of observers, generally of equal skill and experience, and equipped with telescopes of comparable size and quality, saw nothing unusual while their colleagues were reporting these curious appearances was certainly troubling, and a matter of much discussion. Suggestions that erupting volcanoes or intense auroral displays might account for lights rivaling the solar photosphere in brightness were deservedly taken with a grain of salt. Far more plausible were the explanations involving internal "ghost" reflections from the surfaces of the telescopes' objective and eyepiece lenses, which lacked modern antireflection coatings.

In 1850, the Reverend Baden Powell, Professor of Geometry at Oxford University and father of the founder of the Boy Scouts, suggested that optical diffraction was responsible. Eighty years later the French astronomer and optician André Couder was able to reproduce the luminous spot in his laboratory at Meudon Observatory in Paris. While photographing black circles projected against a brilliant background, Couder was able to record the bulls-eye pattern of the bright Airy disc at the center of the circle, surrounded by faint diffraction rings. A slight misalignment of the optical elements displaced the spot toward the edge of the circle. Even with perfectly aligned lenses, when the background was not uniformly illuminated (to mimic the darkening that occurs near the limb of the Sun), the spot was not concentric.

Despite Couder's convincing experiments, more than mere optical effects seemed to be at play. Observing the November 8, 1881, transit of Mercury through a 4.75-inch refractor equipped with a Herschel wedge at the Sydney Observatory, Australian astronomer Lawrence Hargrave saw a central bright spot very distinctly three minutes after ingress. However, he soon realized that it would disappear "on looking steadily at it." Reports like Hargrave's led the late William Corliss, who compiled several catalogs of astronomical anomalies, to conclude that "something akin to those optical illusions where grey images appear out of nowhere amid geometrical designs" might be involved.

The upcoming transit of Mercury will be an opportunity to glimpse these strange, elusive anomalies once again. The knowledge that they're strictly in the eye of the beholder shouldn't rob them entirely of the ability to evoke a sense of wonder. Through them, we're visually connected to our observing forebears. ✦

*Contributing Editor **Thomas A. Dobbins** has observed most reported phenomena on the planets, both real and illusory.*

In This Section

This January 19, 2016 self-portrait of NASA's Curiosity Mars rover shows the vehicle at Namib Dune. While it looks like the rover's enjoying a day off playing in the dirt, it's actually collecting sand samples for laboratory analysis.

PHOTOGRAPH: NASA / JPL-CALTECH / MSSS

OBSERVING

Sky at a Glance

MAY 2016

5 **PREDAWN:** The Eta Aquariid meteor shower peaks before dawn, but meteors should be visible for several mornings before and after. This is often the best shower of the year from the Southern Hemisphere; see page 51.

6 **NIGHT:** A double shadow transit occurs on Jupiter from 9:39 to 10:42 p.m. Pacific Daylight Time.

7 **EVENING:** As twilight deepens, catch the thin waxing crescent Moon as it sets. Aldebaran gleams about 6° upper left of the Moon.

9 **DAY:** North Americans can use a telescope and solar filter to watch the tiny dark dot of Mercury cross the Sun today. The transit is visible to observers across the globe, with the exceptions of Australia and easternmost Asia; see page 48.

13 **EVENING:** Spot Regulus 3–4° above the first-quarter Moon. Brighter Jupiter blazes some 15° to their upper left.

14 **EVENING:** Jupiter continues to reign in Leo. Find the bright planet about 4° upper left of the waxing gibbous Moon.

21–22 **NIGHT:** Mars reaches opposition this night in Scorpius. The full Moon beams about 7° upper left of the planet.

22 **NIGHT:** The Moon rises in twilight. Look for the modest light of Saturn about 4° to its right.

30 **NIGHT:** Mars is closest to Earth (0.503 a.u.) and 18.6″ across, the closest and largest it has been for the last 10½ years.

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

	◄SUNSET	MIDNIGHT	SUNRISE►
Mercury	Hidden in the Sun's glare all month		
Venus	Hidden in the Sun's glare all month		
Mars	SE	S	SW
Jupiter	S	W	
Saturn	SE	S	SW

Moon Phases

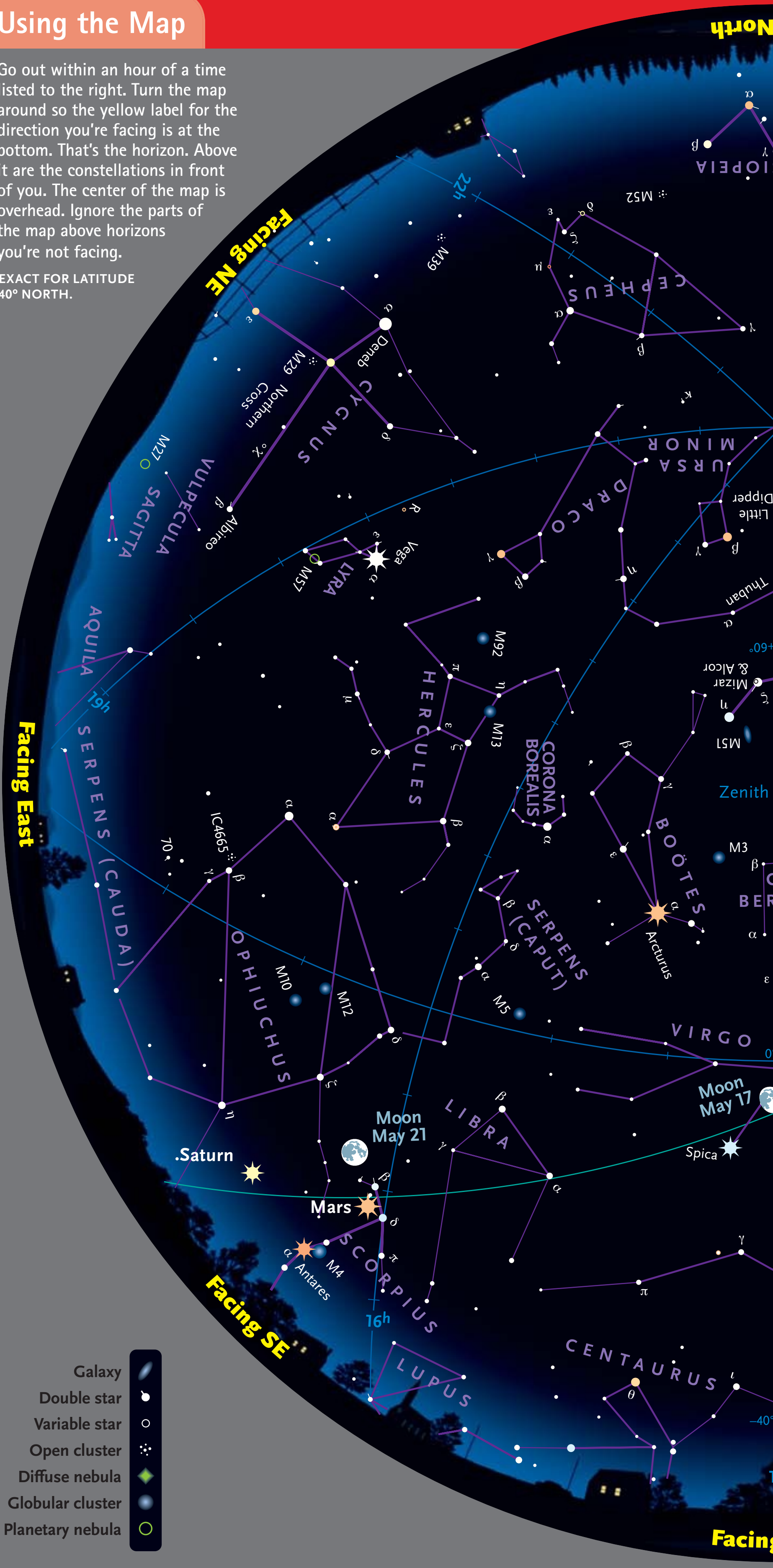
New	May 6	3:29 p.m. EDT	
First Qtr	May 13	1:02 p.m. EDT	
Full	May 21	5:14 p.m. EDT	
Last Qtr	May 29	8:12 a.m. EDT	

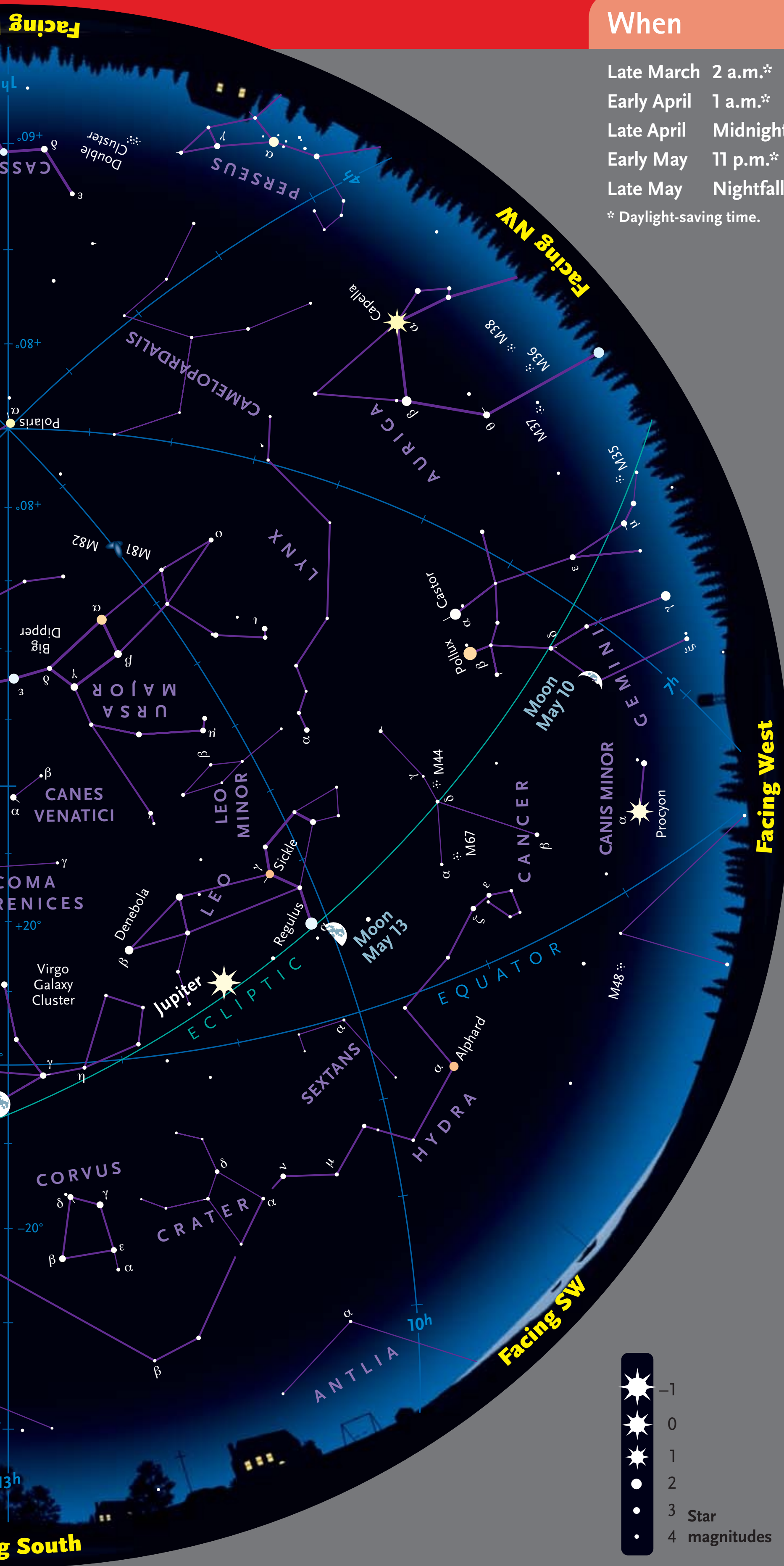
SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

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

* Daylight-saving time.

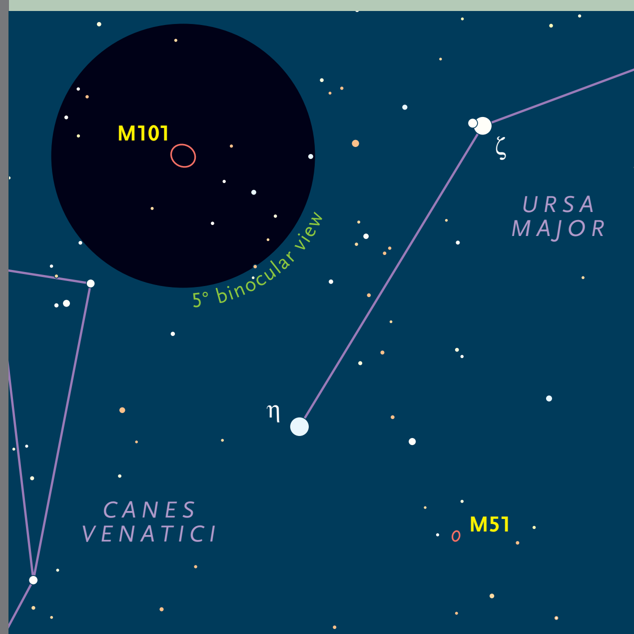
Two in the Dipper's Handle

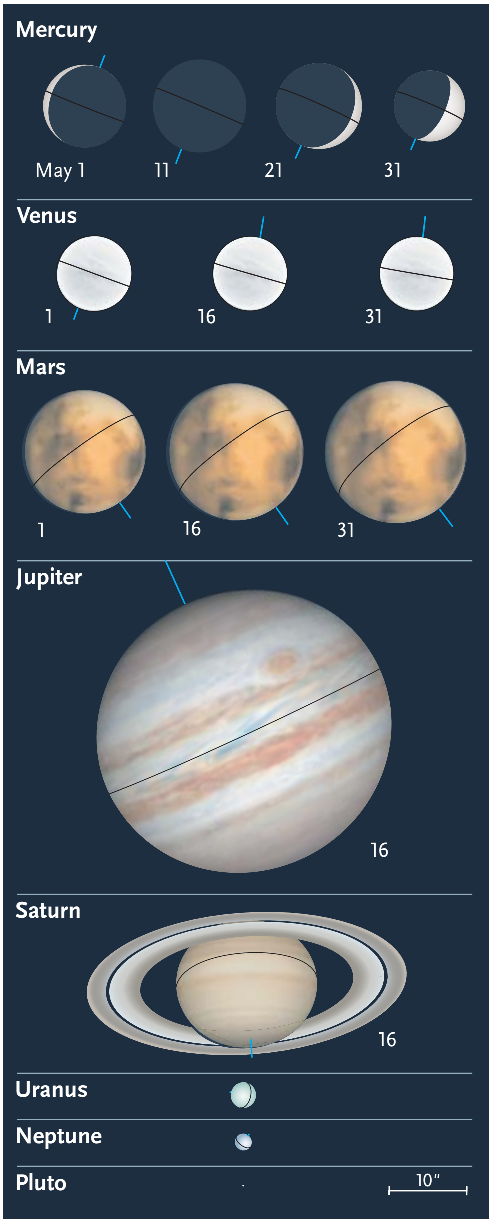
Spring is galaxy season — hurrah! But if you're a binocular user, your excitement is probably tempered by the knowledge that most galaxies are bit disappointing visually. Modest aperture and low power are not the ideal combination for small, dim targets. And yet, even if only a few galaxies show up reasonably well in binoculars, each is worthy of appreciation. They are, after all, magnificent conglomerations of millions of stars and an unknowable number of planets. All those suns and worlds are concentrated into a tiny fuzz of dim, ancient light — each one an "island universe," as philosopher Immanuel Kant put it. Pretty impressive when you think about it.

Two fine island universes are located close to the handle of the Big Dipper: **M51** and **M101**. M101 is found just above a distinctive string of stars trailing eastward from Mizar, Zeta (ζ) Ursae Majoris. Glowing at magnitude 7.5, M101 is readily visible in my 15×45 image-stabilized binoculars, but it's a real challenge in 10×30s.

Nearby M51 is situated in Canes Venatici and roughly one binocular field southwest of Alkaid, Eta (η) Ursae Majoris — the end of the Dipper's handle. Listed at magnitude 8.5, you might expect it to be tougher to pick up than M101, and yet it's not. I've even glimpsed it in 8×25 binoculars. How can that be? It's a question of surface brightness.

Both objects are face-on galaxies, which means they have low surface brightness. M101 spans roughly 28 arcminutes, while M51's light is packed into a relatively compact 11-by-8-arcminute oval. That gives it significantly greater surface brightness — magnitude 13.1, verses 14.6 for M101. As a result, M51 stands out better against the background glow of the night sky. ✦



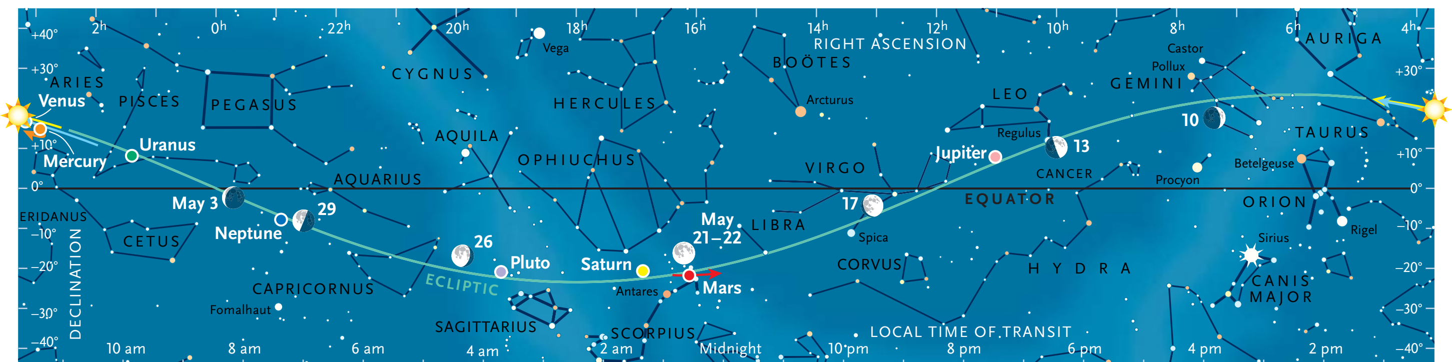


Sun and Planets, May 2016

	May	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$2^h\ 33.6^m$	+15° 04′	—	–26.8	31′ 45″	—	1.008
	31	$4^h\ 32.4^m$	+21° 55′	—	–26.8	31′ 33″	—	1.014
Mercury	1	$3^h\ 20.8^m$	+20° 34′	12° Ev	+3.0	10.8″	7%	0.625
	11	$3^h\ 04.2^m$	+16° 49′	2° Mo	—	12.1″	0%	0.555
	21	$2^h\ 50.6^m$	+13° 17′	16° Mo	+2.6	11.2″	10%	0.601
	31	$3^h\ 01.6^m$	+13° 13′	23° Mo	+0.9	9.2″	27%	0.729
Venus	1	$1^h\ 57.2^m$	+10° 39′	10° Mo	–3.9	9.8″	99%	1.697
	11	$2^h\ 44.6^m$	+14° 53′	7° Mo	–3.9	9.7″	99%	1.715
	21	$3^h\ 33.7^m$	+18° 31′	5° Mo	–3.9	9.7″	100%	1.727
	31	$4^h\ 24.6^m$	+21° 21′	2° Mo	–4.0	9.6″	100%	1.734
Mars	1	$16^h\ 22.9^m$	–21° 39′	153° Mo	–1.5	16.1″	98%	0.582
	16	$16^h\ 06.2^m$	–21° 42′	172° Mo	–1.9	17.9″	100%	0.523
	31	$15^h\ 43.9^m$	–21° 23′	169° Ev	–2.0	18.6″	100%	0.503
Jupiter	1	$11^h\ 00.0^m$	+7° 55′	122° Ev	–2.3	40.8″	99%	4.830
	31	$11^h\ 02.0^m$	+7° 36′	94° Ev	–2.1	37.4″	99%	5.275
Saturn	1	$16^h\ 56.3^m$	–20° 49′	146° Mo	+0.2	18.1″	100%	9.177
	31	$16^h\ 47.8^m$	–20° 35′	176° Mo	0.0	18.4″	100%	9.017
Uranus	16	$1^h\ 23.0^m$	+8° 06′	33° Mo	+5.9	3.4″	100%	20.802
Neptune	16	$22^h\ 53.3^m$	–7° 59′	74° Mo	+7.9	2.3″	100%	30.224
Pluto	16	$19^h\ 13.2^m$	–20° 55′	128° Mo	+14.2	0.1″	100%	32.463

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

The Tale of All Tails

From comets to constellations, May is the month for celestial tails.

May is a month for tails — and tales about them — in the sky. I'll start with comet tails, but our main topic this month is the many constellation tails that appear on the May meridian.

Did you see a long tail on Halley's Comet 30 springs ago? In early May, 30 and 33 years ago, I glimpsed two of the most amazing long comet tails of my life. One belonged to the closest comet to pass Earth in more than 200 years, Comet IRAS-Araki-Alcock. The other belonged to the most famous of all comets, Halley. I have a request: if you saw or photographed a great length of Halley's tail in late April or early May 1986, please share your tale about it by contacting me.

Seven tails on the May meridian. Those 1983 and 1986 comet tails were incredibly rare sights. But every year, we have the opportunity to observe the starry tails of the May evening sky. No less than seven tails are poised right on the sky's meridian at the time of the all-sky map at the center of this magazine, and two more are rising. Several of these tails offer very special sights for amateur astronomers.

Tails of the bears, hunting dogs, and dragon. The most prominent tail on the May meridian is the long one of Ursa Major, the Great Bear. Bears don't have long tails. How Ursa Major — and Ursa Minor — got one remains something of a mystery. One mythic explanation is that the tails got elongated when the bears were hurled into the heavens by them.

The tail of Ursa Major — which is also the handle of the Big Dipper, Great Plough, and Celestial Wagon (see page 24) — serves as the "arc to Arcturus."

But the tail of Ursa Major is a fascinating sight in itself. Test on any given night whether your naked eyes can see the faint star Alcor perched near the bright star that forms the bend or crook in the Great Bear's tail — Mizar, itself a fine double star in almost any telescope.

To one side of the Great Bear's tail is the sometimes visually elusive M101, one of the truly classic face-on spiral galaxies. To the other side (south) of the Ursa Major tail is another such galaxy, this one very prominent indeed. I'm referring to M51, which is actually not in the bounds of Ursa Major, but rather in mostly faint Canes Venatici the Hunting Dogs — a pair of constellational creatures with tails (see page 43).

The May meridian also has the tail of Ursa Minor


Comet Halley, 1986

AKIRA FUJII

standing vertically beside it. But there is a less frequently noticed tail that sticks right between the two Bears, or Dippers. It's the tail of Draco, the Dragon. Most of the famous stars and other deep-sky objects of Draco are in the dragon's head and coils. But between Mizar, at the middle of the Great Bear's tail, and the "Guardians of the Pole," the two rather bright stars in the Little Bear's body (Little Dipper's bowl), shines Alpha (α) Draconis, the star also known as Thuban. Thuban was the North Star of the earliest days of Egyptian civilization — a mere 4½ thousand years ago.

Many more tails for May evenings. Before the big, loose naked-eye Coma Star Cluster was turned into the hair of Queen Berenices in later Classical times, the cluster represented the tuft of the tail of Leo. It's right on the meridian this time of year. So, more or less, is the tail of long, long Hydra, the Sea-Serpent.

And there are two newly arrived tails in this month's sky. The front half of Scorpius, featuring Antares (and, this May, blazing Mars!) is all that's up at our map time. But look what's just risen in the northeast and east: Cygnus, the Swan, with its first-magnitude tail star, Deneb (the name Deneb even means "tail"), and Serpens Cauda, the tail section of the expansive two-part constellation Serpens, the Serpent. ✦

Mars Comes Close

Mars gives us our closest look in a decade, while Mercury puts on a show.

This month offers two remarkable planetary sights that no one has seen in ten years. On May 9th Mercury passes across the face of the Sun; the transit is visible across all of North America. In addition, Mars is coming close to Earth again. We've waited a decade for it to blaze brighter than magnitude –2 and appear more than 18″ across in telescopes, and the time is finally here.

In early May, brilliant Jupiter is the only planet visible at dusk. But as the month progresses, fiery Mars rises earlier and earlier after sunset, until it finally shines as twilight falls, rivaling Jupiter in brightness. Zero-magnitude Saturn comes up soon after Mars, sharing its company with 1st-magnitude Antares in Scorpius. Mercury is only easily visible this month on May 9th, when it transits the Sun. Venus is lost in the solar glare all month.

DUSK TO DAWN

Jupiter shines at its highest in the south, coming into view not far from the meridian at nightfall in May. The gas giant dims from magnitude –2.3 to –2.1. Its width shrinks from 41″ to 37″ but still displays elaborate telescopic detail in its clouds during good seeing. On May 9th Jupiter halts its retrograde (westward) motion against the starry background and begins to move eastward below the hindquarters of Leo. Jupiter sets around 4 a.m. on May 1st but about 2 a.m. on May 31st, so it's no longer a dusk-to-dawn attraction at the end of the month.

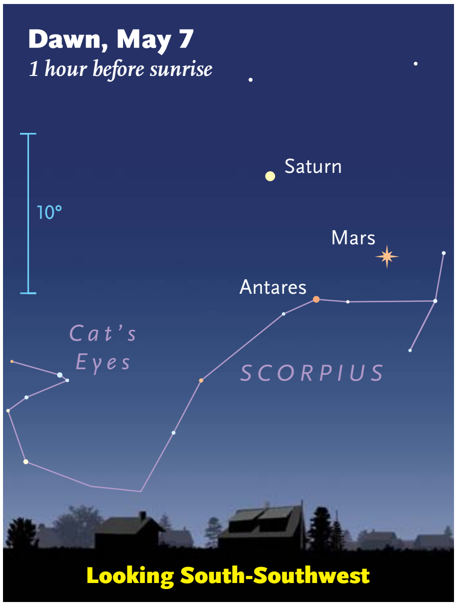
Mars arrives at its best opposition in 11 years on May 22nd. Due to the considerable ellipticity of its orbit, Mars can reach its closest approach to Earth quite a few days before or after opposition. This year is a case in point, as closest approach doesn't happen until May 30th.

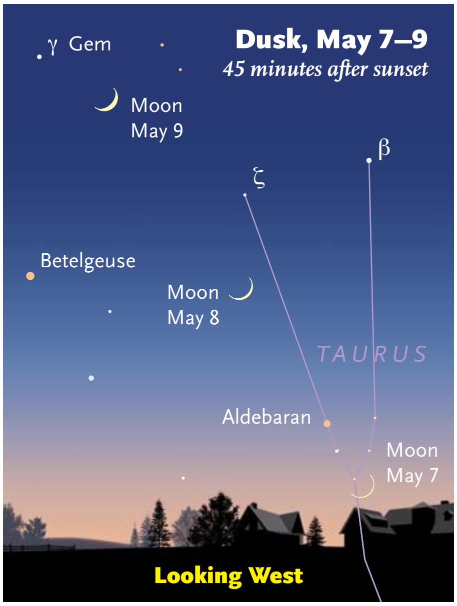
Fire-colored Mars rises two hours after sunset as May opens, but its rapid retrograde motion brings it up right at sunset by May 22nd. On May 1st, the Red Planet shines highest after 2:30 a.m. daylight-saving time. As it begins to rise earlier, so too does it reach its highest altitude sooner; by the end of the month, it transits the meridian around midnight.

Mars starts the month at magnitude –1.5 and brightens until it peaks at a marvelous –2.1, equaling the magnitude of Jupiter, for a few days late in the month. Variations in atmospheric activity on either planet (such as planetwide dust storms on Mars) can alter brightness by as much as a few tenths of a magnitude, so compare the two planets when they're at similar altitudes.

The view of Mars with the naked eye or in binoculars this month is captivating. In a telescope, it appears just 16″ wide as the month opens, but reaches a maximum angular diameter of 18.6″ at the end of May. That's large enough to reveal numerous surface markings with a good telescope under good seeing conditions. To determine which side of Mars and which surface features face you at any given time, use the *S&T* Mars Profiler (**http://is.gd/marsprofiler**). See our Mars observing guide in last month's issue, page 48, as well.

Mars spends the month retrograding across the narrow, northward-extending strip of western Scorpius. It begins May some 5° north of Antares and threads the gap between Beta (β) and Delta (δ) Scorpii on the 19th. At opposition on the 22nd, it comes very close to Delta. But rapid retrograde motion simultaneously carries Mars toward Libra, away from the

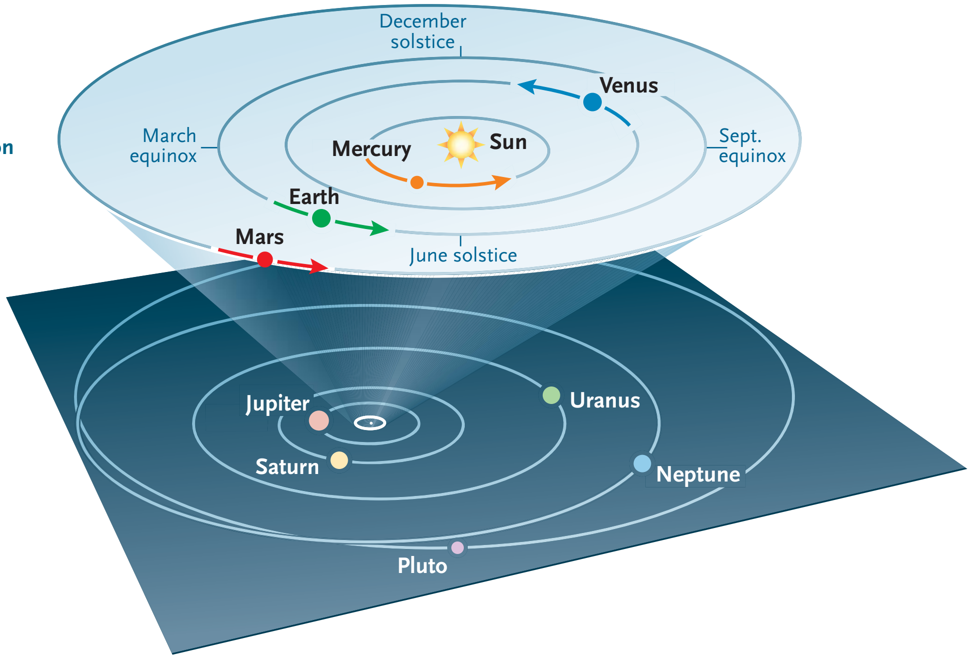




These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist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

ORBITS OF THE PLANETS

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



much more slowly retrograding planet just over the border in Ophiuchus — ringed Saturn.

Saturn rises about 30 minutes after Mars on May 1st but trails its planetary neighbor by about an hour at month's end. While Mars brightens by more than half a magnitude over the course of the month, Saturn's radiance improves only slightly, from +0.2 to 0.0. As May ends, when Mars is closest to Earth, the equatorial diameter of Saturn's globe has grown to 18.4″ — almost exactly the same size as Mars in your telescope! But the surface of Saturn is much dimmer, due to its 7 times greater distance from the Sun.

The rings of Saturn, tilted 26° from edge-on, span an even greater length: 42″ this month. The ringed world is headed for opposition on the night of June 2nd.

Saturn forms a triangle with Mars and Antares all month. Watch the triangle elongate as time passes. May begins with Mars and Saturn 8° apart and ends with them separated by 15°. Meanwhile slow, distant Saturn stays nearly on station with fixed Antares.

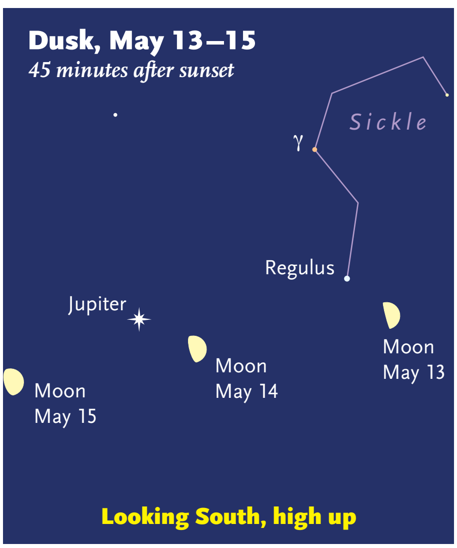
DAWN

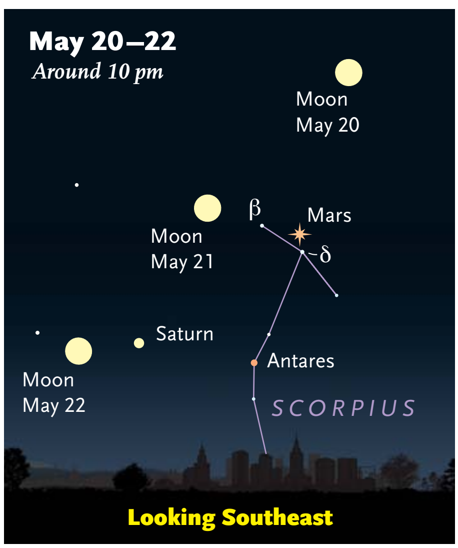
Mercury transits the Sun on May 9th; see page 48. Other than this, the tiny planet remains almost too dim and low to see emerging before sunrise even at month's end. **Venus** is headed for superior conjunction on June 6th and is not visible in May.

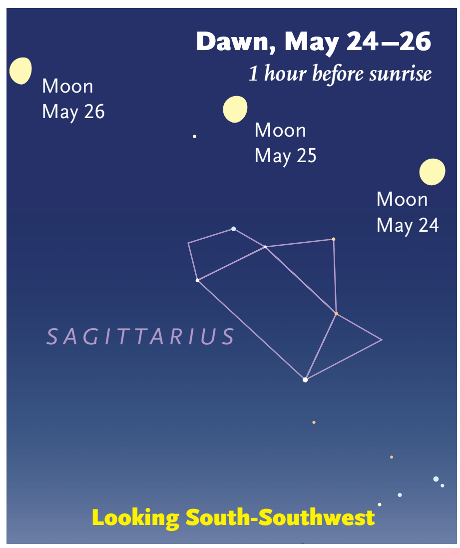
Pluto, in northern Sagittarius, reaches the meridian before dawn begins. **Neptune** and **Uranus** are poorly placed for observation this month.

MOON PASSAGES

At dusk on May 7th, the thin crescent **Moon** appears very low with Aldebaran above it. The waxing gibbous Moon shines near Regulus on the evening of May 13th and near Jupiter on the 14th. On the night of May 21st, the full Moon forms a near-rectangle 10° long with Mars, Saturn, and Antares. The next evening, the Moon rises left of Saturn. On the morning of 25th, the Moon poses above the teapot of Sagittarius. ✦

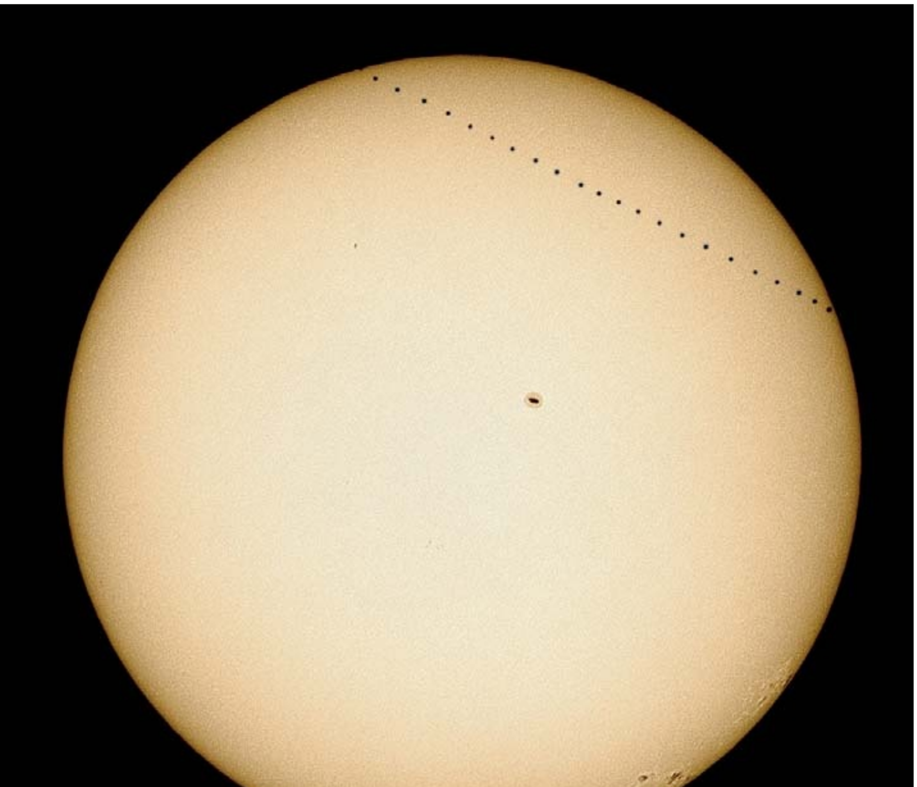






The May 9th Transit of Mercury

The littlest planet will cross the enormous Sun for viewers in most of the world.



Mercury in transit appears tiny, but unlike sunspots, it's round and has no penumbra. It moves noticeably in 15 minutes, the average time between these exposures taken by Dominique Dierick during the transit of May 7, 2003.

DOMINIQUE DIERICK

Transit Timetable

Time Zone	Transit Begins	Transit Midpoint	Transit Ends
Universal (GMT)	11:12	14:58	18:42
Eastern (EDT)	7:12 a.m.	10:58 a.m.	2:42 p.m.
Central (CDT)	6:12 a.m.	9:58 a.m.	1:42 p.m.
Mountain (MDT)	5:12 a.m.	8:58 a.m.	12:42 p.m.
Pacific (PDT)*	—	7:58 a.m.	11:42 a.m.
Alaskan (AKDT)*	—	6:58 a.m.	10:42 a.m.
Hawai'ian (HST)*	—	—	8:42 a.m.

Times for your location may differ by several minutes. *Transit begins before sunrise.

Mark Monday May 9th on your calendar. As the Sun crosses the sky that day, Mercury will cross the face of the Sun for the first time since 2006.

If you're in western North America, the rising Sun will already display Mercury's telltale black dot, as indicated on the world map at right. Easterners and many Western Europeans will be able to watch the entire transit, weather permitting, from Mercury's first nudge into the Sun's face to its final slide-away 7½ hours later.

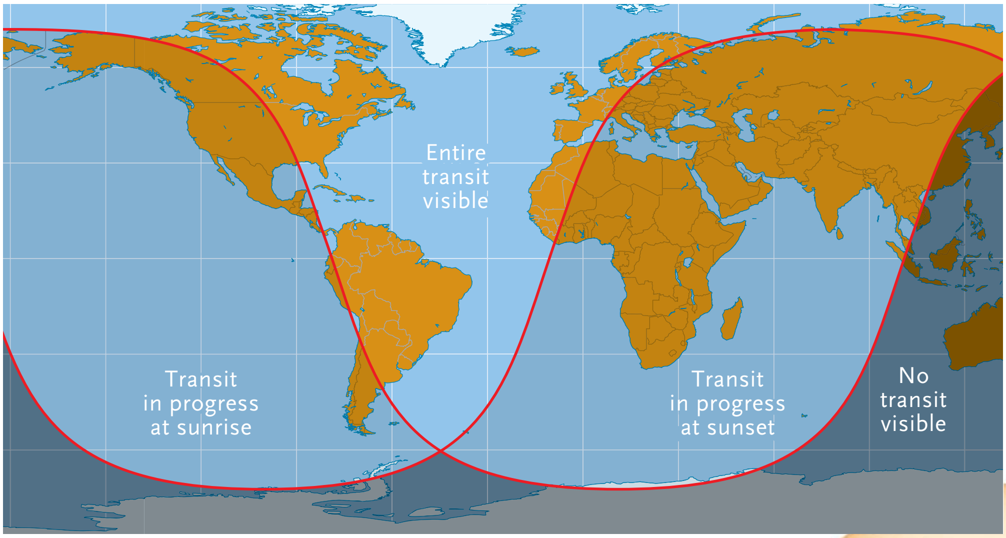
For the rest of Europe, Africa, and most of Asia, the transit also begins in the daytime but will still be underway when the Sun sets. Folks in Australia and eastern Asia will just have to watch online.

The timetable below tells when the first edge of Mercury enters the Sun and the last edge leaves (first and last contact), in Universal Time and in civil daylight-saving times for North America. Times of the events will differ by a few minutes as seen from various locations on Earth.

If you don't have a safe white-light solar filter that mounts over the front of your telescope, now's the time to get one. They're available from astronomy dealers in many sizes and fits. When we reviewed them, we liked the ones made with Baader AstroSolar aluminized polyester the best (*S&T*: Feb. 2005, p. 102, and July 1999, p. 63). This material is optically superb despite its wrinkly appearance, and it leaves the Sun a fairly natural color.

Alternatively, you can use an unfiltered telescope with your lowest-power eyepiece to project an image of the Sun's disk onto white paper a foot or two behind the eyepiece, and watch the events transpire on the paper. But a direct view through a solar filter shows the scene better. (Of course, never look directly at the Sun without a proper filter.)

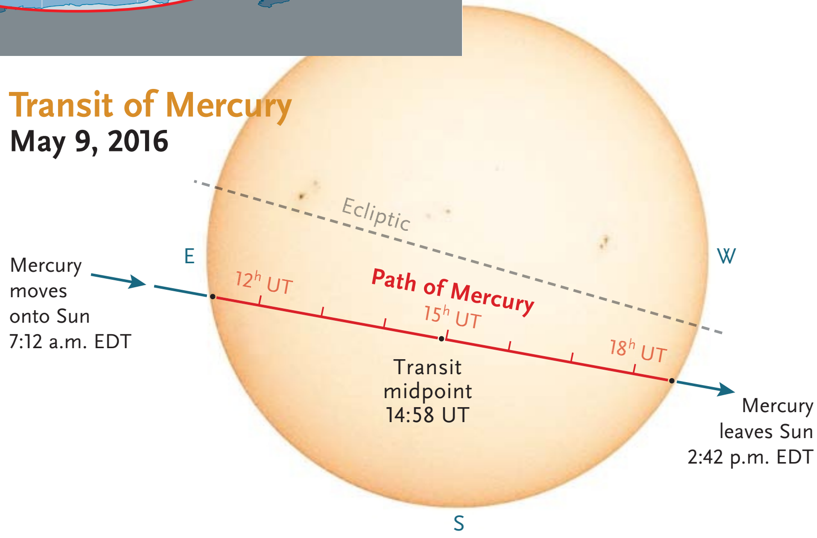
And yes, you do need the telescope. Mercury is the smallest planet. Its black silhouette will appear only 10 arcseconds wide even though Mercury is at inferior conjunction. That's about 1⁄200 of the Sun's width, and only a sixth the diameter (and 3% of the area) of Venus's dramatic black disk during the rare transits of Venus. At first glance you might mistake Mercury for a small sunspot — but look again. It's precisely round and lacks a gray penumbra.



Most of the inhabited world will be able to see at least part of the transit, weather permitting. Observers in eastern North America and western Europe can watch both the entry and exit of Mercury across the Sun's edges.

If you're in the Americas, don't miss the chance to watch tiny Mercury slip off the Sun. Be watching by about 18:35 UT (2:35 p.m. Eastern Daylight Time). Can you see anything of the black drop effect as Mercury begins to contact the Sun's limb?

FRED ESPENAK



And it moves! The most interesting aspects to watch will be Mercury making its entrance and/or exit across the Sun's limb. The planet will take 3 minutes and 12 seconds to do so. If you can watch at the time of ingress, keep your eye on the limb barely south of due east for the first detectable sign of a tiny dent. Use high power. You can tell which limb is celestial east by turning off your telescope's drive if it has one; the Sun will drift across the eyepiece view from east to west.

At second contact — when Mercury's trailing edge comes onto the Sun — watch for any sign of the *black drop effect*: the illusory appearance of a tiny black line still connecting the planet to the outer darkness. And does the black disk show a central point of light? More about such anomalous appearances begins on page 38.

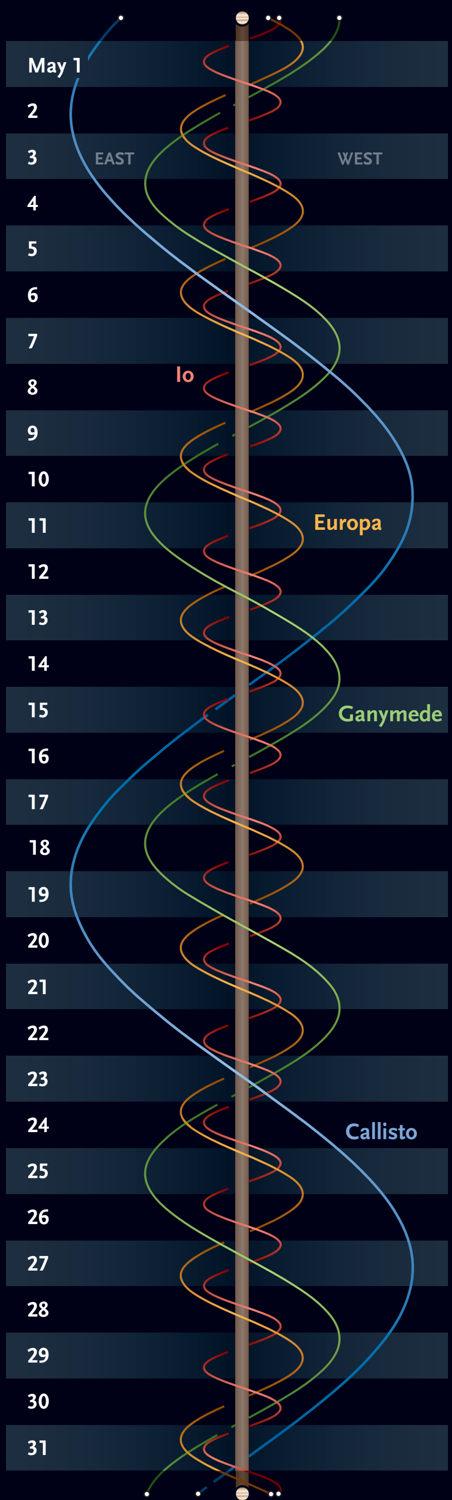
As Mercury travels across the Sun's vast expanse, how readily can you see its motion? If it passes near a sunspot, can you see that it's darker than even the sunspot's umbra? When Mercury departs at egress, the sequence of phenomena at ingress unwinds in reverse order.

Although transits of Mercury are less dramatic than those of Venus, they come more often. The last two Venus transits happened in 2004 and 2012 after a gap since 1882, and not until 2117 will the world see another. But Mercury passes between the Earth and Sun about 13 or 14 times every century. It will next do so on November 11, 2019 — again visible from the Americas and Europe.

There are a couple of reasons for the difference. Mercury rounds the Sun more frequently than Venus does and passes through inferior conjunction five times as often. And Mercury is also closer to the Sun, so from Mercury, the Sun presents a larger target for a line of sight from Earth through the planet to hit.

As you're watching the transit, imagine a copy of Earth replacing Mercury. It would look only 2.6 times wider than the tiny dot — a reminder of how insignificant the terrestrial worlds appear next to the awesome scale of our home star.

Jupiter's Moons



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

Daily Jupiter Events

Jupiter's Great Red Spot is living up to its name better than at any time in memory. In a small telescope, it's much less difficult to see now. Christopher Go shot this stacked-video image on January 4th using a 14-inch scope. South is up.

CHRISTOPHER GO

Telescope users in May should plan to catch Jupiter right around the end of twilight, while it's still high on the meridian or just past it.

Jupiter's four big Galilean moons are visible in any scope. Binoculars usually show at least two or three. Identify them using the diagram at left.

All of May's interactions between Jupiter and its satellites and their shadows are listed on the facing page. On Friday night May 6–7, North Americans can watch a **double shadow transit:** both Callisto and Io are casting their tiny black shadows onto Jupiter from 4:39 to 5:42 May 7th UT. (To get Eastern Daylight Time, subtract 4 hours from UT.)

And here are all the times, in Universal Time, when Jupiter's Great Red Spot — unusually vivid this year! — should cross the planet's central meridian. The dates, also in UT, are in bold.

April 1, 3:56, 13:51, 23:47; **2,** 9:42, 19:38; **3,** 5:34, 15:29; **4,** 1:25, 11:21, 21:16; **5,** 7:12, 17:08; **6,** 3:03, 12:59, 22:54; **7,** 8:50, 18:46; **8,** 4:41, 14:37; **9,** 0:33, 10:28, 20:24; **10,** 6:20, 16:15; **11,** 2:11, 12:07, 22:02; **12,** 7:58, 17:54; **13,** 3:49, 13:45, 23:41; **14,** 9:36, 19:32; **15,** 5:28, 15:23; **16,** 1:19, 11:15, 21:10; **17,** 7:06, 17:02; **18,** 2:57, 12:53, 22:49; **19,** 8:44, 18:40; **20,** 4:36, 14:31; **21,** 0:27, 10:23, 20:18; **22,** 6:14, 16:10; **23,** 2:05, 12:01, 21:57; **24,** 7:52, 17:48; **25,** 3:44, 13:39, 23:35; **26,** 9:31, 19:27; **27,** 5:22, 15:18; **28,** 1:14, 11:09, 21:05; **29,** 7:01, 16:56; **30,** 2:52, 12:48, 22:44.

May 1, 8:39, 18:35; **2,** 4:31, 14:26; **3,** 0:22, 10:18, 20:14; **4,** 6:09, 16:05; **5,** 2:01, 11:56, 21:52; **6,** 7:48, 17:44; **7,** 3:39, 13:35, 23:31; **8,** 9:26, 19:22; **9,** 5:18, 15:14; **10,** 1:09, 11:05, 21:01; **11,** 6:57, 16:52; **12,** 2:48, 12:44, 22:39; **13,** 8:35, 18:31; **14,** 4:27, 14:22; **15,** 0:18, 10:14, 20:10; **16,** 6:05, 16:01; **17,** 1:57, 11:53, 21:48; **18,** 7:44, 17:40; **19,** 3:36, 13:31, 23:27; **20,** 9:23, 19:19; **21,** 5:14, 15:10; **22,** 1:06, 11:02, 20:57; **23,** 6:53, 16:49; **24,** 2:45, 12:40, 22:36; **25,** 8:32, 18:28; **26,** 4:23, 14:19; **27,** 0:15, 10:11, 20:07; **28,** 6:02, 15:58; **29,** 1:54, 11:50, 21:45; **30,** 7:41, 17:37; **31,** 3:33, 13:29, 23:24.

These times assume that the Great Red Spot is centered at System II longitude 234°. It will transit $1\frac{2}{3}$ minutes earlier for each degree less than 234°, and $1\frac{2}{3}$ minutes later for each degree greater than 234°. Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting.

A light blue or green filter slightly increases the contrast and visibility of Jupiter's reddish and brownish markings. An orange filter helps to darken the blues.

For how to make a scientific meteor count, see imo.net/visual/major.

May Meteors

Only one major meteor stream, the one shed by Halley's Comet, intersects Earth's orbit in two places with both of the resulting showers being visible at night. In October we call them the Orionids, and in May they're the Eta Aquariids.

Both showers run for several days and have a reputation for meteors that are swift and relatively faint. But in May we apparently pass nearer to the center of the stream; the Eta Aquariid shower is roughly three times as strong as the Orionid shower, and it lasts longer too.

This year the Eta Aquariids should peak on the mornings of May 5th and 6th, when they will be untroubled by moonlight. This is usually the best shower of the year for the Southern Hemisphere, with perhaps 60 meteors visible per hour before dawn to an observer under ideal conditions. Meteor watchers in northern latitudes see fewer, and those north of 40° or 45° see hardly any, because the shower's radiant (at the Water Jar, the head of Aquarius) is still low in the east-southeast as dawn brightens.

On the other hand, when a shower's radiant is low, the few meteors that do appear will be long, dramatic Earthgrazers, sometimes flying far across the sky (*S&T:* Aug. 2014, p. 64). ✦

Lunar Occultation

If you're out observing the Moon with a telescope late on the night of May 17–18, you may notice that its dark limb is creeping toward a 4.4-magnitude star: Theta Virginis. The Moon will go on to occult the star for viewers all across North America, although for easterners the Moon and star will be getting low in the west.

Some disappearance times: at **Washington, DC,** 3:23 a.m. EDT; **Chicago,** 2:10 a.m. CDT; **Denver,** 12:51 a.m. MDT; **Los Angeles,** 11:36 p.m. PDT. Detailed local timetables for both the disappearance and reappearance of the star are at **is.gd/ThetaVirMay2016**.

Phenomena of Jupiter's Moons, May 2016

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

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 by IMCCE / Paris Observatory.

Let's Shoot the Moon!

It's easy to take high-quality images of the lunar disk.

The digital imaging revolution has taken astronomy by storm. Spectacular images recorded by amateurs using digital single-lens reflex (DSLR) cameras, specialized planetary cameras, and large-format CCDs dominate the pages of this magazine. But the imaging devices you *most likely* own are smartphones, tablets, and compact "point-and-shoot" cameras. Surprisingly, these simple devices are capable of producing pretty, even stunning images of our nearest neighbor, the Moon. It's not quite as easy as just walking up to the eyepiece and snapping away — but that's the general idea.

Whether you have a smartphone or tablet (which usually have small, fixed-focus lenses) or a much more versatile compact camera or DSLR, all employ a similar set of operational modes. Some have a "manual" setting, and that's preferable to the "automatic" mode, which tends to overexpose lunar images. Apps like *NightCap Pro* can add these features to your smartphone. Using the manual setting, you can adjust the shutter speed, exposure, aperture, and ISO (or at least your phone's brightness setting) to control the amount of light reaching the camera's detector. A fast shutter speed helps minimize blurriness due to atmospheric turbulence, wind, a nontracking mount, or an unsteady hand holding the camera up to the eyepiece.

HARRISON MCGAHA

Equipped with only a 4½-inch reflector and modest Canon PowerShot A530 camera, 13-year-old Harrison McGaha snapped this excellent view of a gibbous Moon last August from his home in Chelsea, Alabama.

Perhaps the most important setting is ISO. Basically, the higher the ISO value, the greater the detector's sensitivity to light. Typical smartphones or compact cameras have an ISO range of 100 to 1600, while new "low-light" models can reach 6400, 12,800, or higher. The tradeoff is that higher ISOs add more noise or "graininess" in the image. Try using 200 or 400, at least to start, for the greatest dynamic range and lowest image noise.

The beauty of lunar imaging is that even a small 60-mm refractor or 4-inch reflector can produce stunning images. Aperture isn't a major factor, as the camera is using the telescope as a giant telephoto lens. This optical arrangement — telescope, eyepiece, and a camera with an attached lens — is called *afocal photography*.

While unguided telescopes can produce nice results, a telescope that's tracking the Moon will generally produce better, less blurry images. If you have a steady hand, then just center the camera's lens over the eyepiece and use the self-timer function to secure decent images.

However, to get the sharpest images and best resolution, some mechanical help will come in handy. Almost indispensable for basic astro-imaging is a good photo tripod. Most cameras have a ¼-20 threaded hole for attaching it, or you can purchase an inexpensive tripod adapter for your smartphone. (In fact, most "selfie sticks" employ a simple yet effective tripod adapter.) If tripods aren't your style, then get a smartphone or compact-camera adapter that clamps onto the focusing tube and positions the camera lens directly over the eyepiece.

Technology offers alternatives to using the self-timer approach. Perhaps your camera can be used with a mechanical or electronic remote release. With some cameras a wireless Bluetooth controller can "trip" the shutter from up to 30 feet away.

Now Let's Go Image!

It's time to put your equipment and technique to practice by doing some lunar imaging. Before you head outside,

*Frequent contributor **Richard Jakiel** observes everything from the nearby Moon to distant galaxies.*

Richard Jakiel

S&T: SEAN WALKER (2)

RICHARD JAKIEL (2)

Left: **By purchasing an adjustable adapter, you can attach a smartphone or small digital camera directly to a telescope's eyepiece.** ***Right:*** **Compare the detail and contrast in these lunar images taken with a smartphone *(left)* and a point-and-shoot digital camera *(right)*.**

however, make sure the camera lens is clean and that the largest possible image file is selected. Make sure your battery is charged — and turn off the flash!

Point your telescope at the Moon, focus the eyepiece, and then position the camera lens directly over the eyepiece. Make sure it's pointing straight in, not tilted, to minimize distortion. Now use the telescope's focuser to produce a crisp image onto the camera's display. Go with low-power eyepieces, which tend to have larger field lenses and good eye relief. This makes centering the Moon easier and reduces vignetting (reduced image brightness) around the frame's periphery.

If possible, try not to use the automatic-exposure mode, as this tends to under- or overexpose the image. (That said, it's easier to bring out detail in an under-exposed image via computer processing.) A technique called *bracketing* works particularly well with lunar imaging. By shooting many images over a wide range of exposures and ISOs, you can accommodate the huge brightness range of lunar features and work around any blurring induced by atmospheric turbulence.

While capturing images, use the smartphone's display or the camera's "live-screen view" to check your framing and focus. You can experiment with the camera's optical zoom, if it's got one, to capture the smallest surface details, though changing to a higher-power eyepiece can work just as well. But don't use the *digital* zoom — smartphone users, take note! — because that doesn't actually record finer details.

Finally, shooting lots of images is a good hedge against "things that go bump in the night." Almost anything that can go wrong often will — ranging from knocking the telescope off target to losing focus, vignetting, weird internal reflections, power loss, and unexpected weather changes.

Even a basic camera is capable of shooting the Moon in a wide variety of situations. For example, you can capture faint Earthshine on the darkened lunar disk when the Moon is near new. Or record its sequence of phases over an entire lunar cycle. Not only will you learn how the surface brightness changes with phase, but you'll also have an impressive photo mosaic once the project is completed. The bottom line: don't be afraid to experiment, have fun, and go shoot lots of images! ✦

MORE LUNAR-IMAGING TIPS

For an expanded version of this article, go to **http://is.gd/basic_lunar_imaging**. To learn about advanced lunar-imaging techniques, see Robert Reeves' guide on page 66.

The Moon • May 2016

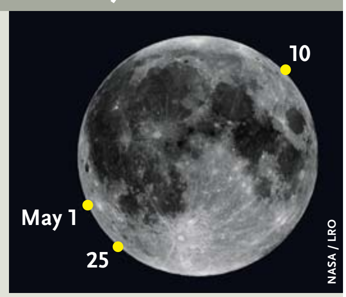
Phases

NEW MOON
May 6, 19:30 UT

FIRST QUARTER
May 13, 17:02 UT

FULL MOON
May 21, 21:14 UT

LAST QUARTER
May 29, 12:12 UT



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

Distances

Perigee 357,827 km	**May 6, 4^h UT** diam. 33′ 23″
Apogee 405,933 km	**May 18, 22^h UT** diam. 29′ 26″

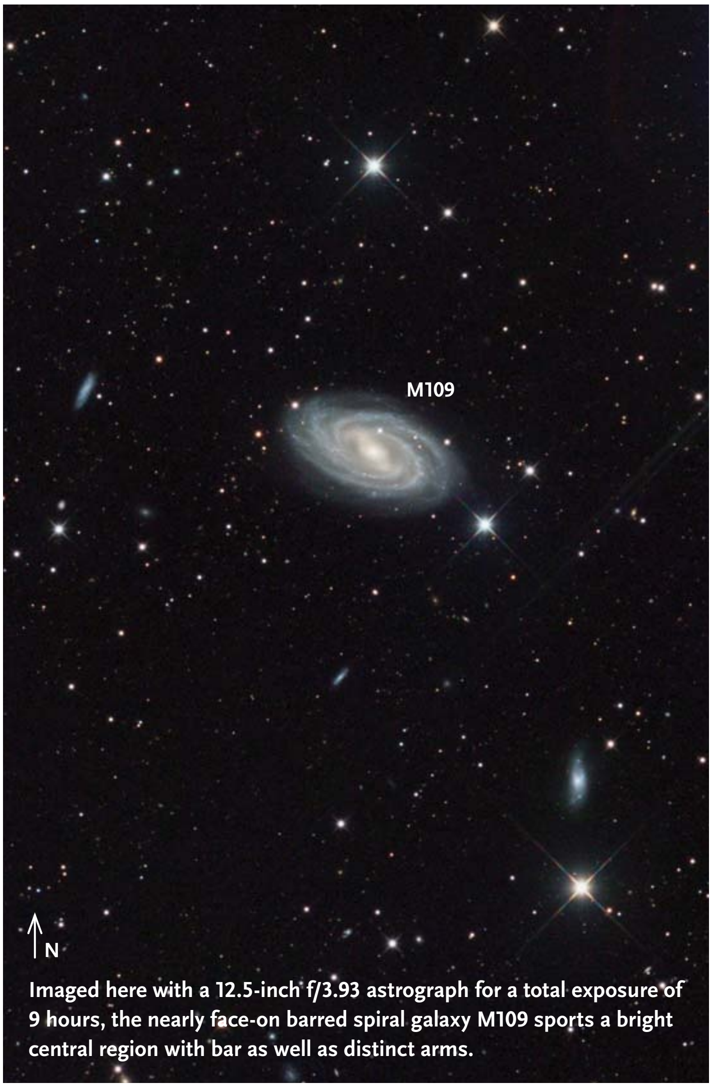
Favorable Librations

Lacus Veris	May 1
Hayn (crater)	May 10
Montes Rook	May 25

Get a Leg Up on Ursa Major!

Take advantage of the Big Bear's wealth of galaxies this month.

Ursa Major, the Big Bear, is the third largest constellation in the sky, surpassed only by Hydra and Virgo. Because it also offers us a clear window to the universe beyond our Milky Way, Ursa Major is home to a mind-boggling number of galaxies. In the *New General Catalogue* (NGC) alone, there are 394 galaxies that call the constellation home. Observing them all is a daunting task for backyard stargazers, so let's embark on a more casual exploration, limiting ourselves to a few in the region of the Big Bear's hindmost leg.



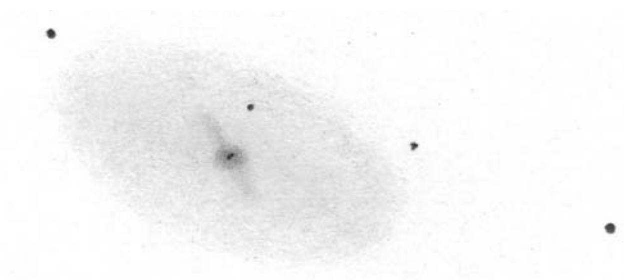
MASIL IMAGING TEAM

Imaged here with a 12.5-inch f/3.93 astrograph for a total exposure of 9 hours, the nearly face-on barred spiral galaxy M109 sports a bright central region with bar as well as distinct arms.

Ursa Major's "last leg" is rooted to her body at the star Gamma (γ) Ursae Majoris, commonly known as Phecda or Phad, meaning "thigh." From there the leg stretches through Chi (χ) to the Bear's toes at Nu (ν) and Xi (ξ).

The spiral galaxy **Messier 109** dwells 39′ east-southeast of Phecda within a distinctive trapezoid of stars, magnitudes 8.6 to 9.7. The trapezoid's three-star base is 25′ west of its two-star top. With 15×45 binoculars and averted vision, I can make out a very faint, oval glow cuddled up to the middle star in the base. M109 reveals a small, brighter center and tiny core through my 130-mm refractor at 63×. The middle star and a dimmer companion watch over the galaxy's west-southwestern end, while a faint star closely guards the opposite tip. Two faint stars pop out along M109's north-northwestern side at 117×, and the galaxy's bright center is elongated and skewed with respect to its halo. Through my 10-inch scope at 166×, M109 segregates into halo, bar, core, and nucleus as captured on my pencil sketch below.

Although this galaxy is accorded the designation M109, Charles Messier's last published catalog (1781) listed only 103 objects. Seven were later added by others, based on evidence that either Charles Messier or his friend and colleague Pierre Méchain observed them. By 1947 the list had grown to include M107. Then Owen Gingerich of Harvard College Observatory proposed two new candidates from objects briefly mentioned in Messier's description of M97 (*S&T:* Sept. 1953, p. 288). From the description and Gingerich's study of the region, he unambiguously identified one as NGC 3556, now dubbed M108. With the addition of a personal notation penned by Messier, the other was shown to be NGC 3992, now M109.



Modest aperture displays M109 as an oblong fuzzy spot, but the author was able to resolve the galaxy's halo, bar, core, and nucleus with her 10-inch reflector at 166×.

Sweeping 1.5° east-southeast from M109 carries us to **NGC 4102**. Through my 130-mm scope at 23×, this spiral galaxy is small but easily visible southeast of an 8.0-magnitude star. Using averted vision I can spot the irregular galaxy **NGC 4068** in the same field of view, 23′ west-southwest of its neighbor, with two faint yet distracting stars to its west. NGC 4068 shows well at 37×, its pale countenance tipped northeast. The glint of a nearly central, superimposed star smartens the galaxy, and the western stars are joined by a third to form a shallow arc. NGC 4102 appears oval and leans in the same direction as its companion. It harbors a bright, oval core and wears a faint star on its west-southwestern fringe. At 63× NGC 4102 covers about 2′ × 1′. Roughly one-third those dimensions, the galaxy's luminous core intensifies toward its center.

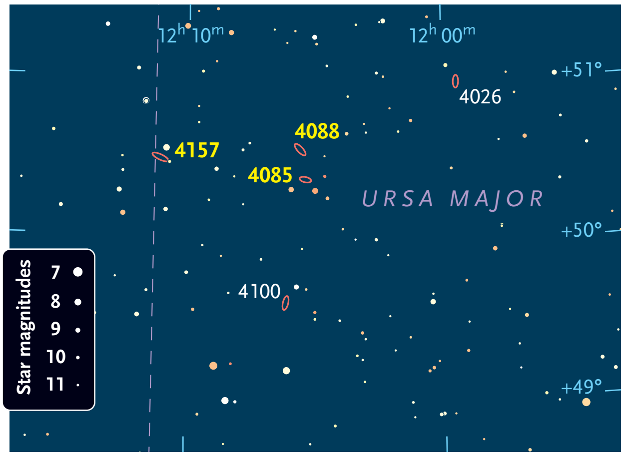
Although these galaxies look about the same size on the sky, NGC 4068 is a dwarf galaxy that's much closer to us than NGC 4102, shining at us from distances of approximately 15 million and 62 million light-years, respectively. Perhaps we should refer to NGC 4068 as a Starbird, for its inclusion in the panchromatic **STAR**-Burst **IR**regular **D**warf **S**urvey (STARBIRDS), introduced by Kristen McQuinn and colleagues in a 2015 paper in the *Astrophysical Journal Supplement Series.* The multi-wavelength study seeks to shed light on star formation in these galaxies, which occurs in intense episodes that can last more than a hundred million years.

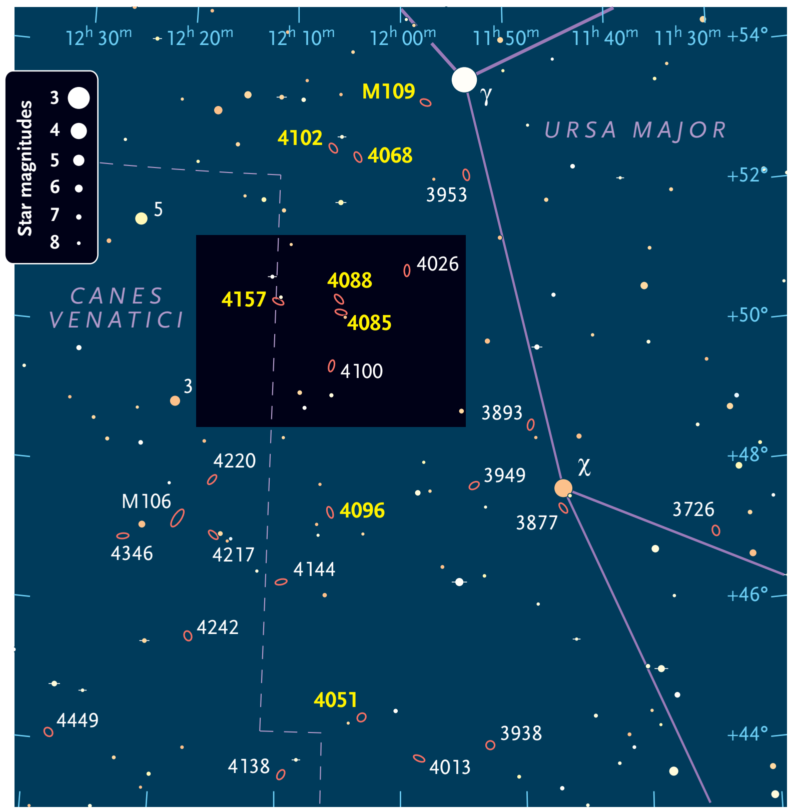
Now we'll drop south to the spiral-galaxy trio **NGC 4088**, **NGC 4085**, and **NGC 4157**. NGC 4088 is bright even in my 130-mm refractor at 23×. It extends northeast-southwest and hosts a brighter center. At 63× NGC 4085 joins the scene, faintly visible 11′ south of its partner as a slender, ashen glow that leans a bit north of east. Pushing the telescope 53′ east brings NGC 4157 into the field of view. This moderately faint but pretty galaxy is long and svelte, with a 10th-magnitude star punctuating its west-southwestern tip. The galaxy brightens toward its center and its long axis, a trait NGC 4085 shares when I boost the magnification to 91×. NGC 4085 then appears about 2′ long and one-fourth as wide, but its eastern end is wider than its western end. NGC 4088 measures about 3½′ long and one-third as wide, with a brighter, elongated center. To me, the galaxy seems rather pointy at its northeastern end. At 117× NGC 4088 shows hints of spiral structure forming a pattern like a Z or S that someone stepped on.

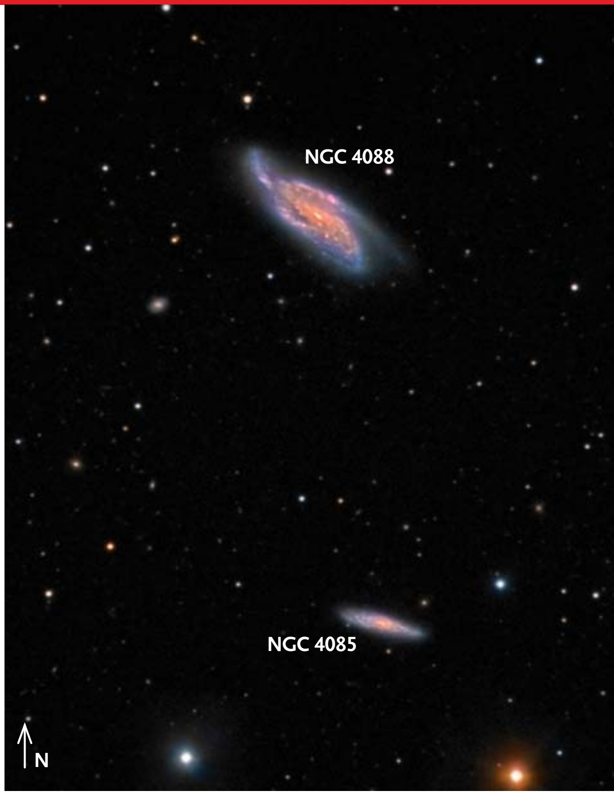
The shape of NGC 4088 is quite remarkable through my 10-inch scope at 187×, as seen on my sketch on the next page. The starlike spot close to the galaxy's center is SN 2009dd, a supernova that was visible at the time. At the same magnification, NGC 4157 is splendid. The most prominent part is irregular in brightness and spans 4′. Averted vision makes the galaxy's faint tips stand out well, drawing this milky splinter of light out to nearly 6½′. NGC 4085 also takes on character, becoming a junior version of the Whale Galaxy (NGC 4631 in Canes Venatici).

This trio of galaxies, as well as M109 and NGC 4102, are all members of the M109 Group, centered about 60 million light-years away from us.

NGC 4085 hovers a few arcminutes north of an east-west pair of stars, magnitudes 8.2 and 8.6. If we plunge 2.8° due south from the eastern star, we'll come to **NGC**







JIM THOMMES

Halton Arp included NGC 4088 in his 1966 *Atlas of Peculiar Galaxies* because one of its arms appears to be partially disconnected from the main structure, as shown in this LGRB image.

At 187×, the author's 10-inch reflector revealed the somewhat peculiar structure of spiral galaxy NGC 4088. The starlike dot near the galaxy's core is SN 2009dd, a supernova that was visible at the time of observation.

4096. This spiral galaxy is pretty even at 37× through my 130-mm scope, with a fairly slim profile that's faint at the tips and canted north-northeast. At 63× I estimate a tip-to-tip length of 5′. It's fairly bright for about 4′, within which the north-northeastern half is brightest, lending the galaxy a lopsided look. In my 10-inch reflector at 213×, NGC 4096 is a lovely sight, showing a mottled face that suggests the presence of spiral arms unwinding clockwise.

NGC 4096 is some 43 million light-years away. It belongs to a galaxy group dominated by M106, lodged next door in Canes Venatici, the Hunting Dogs.

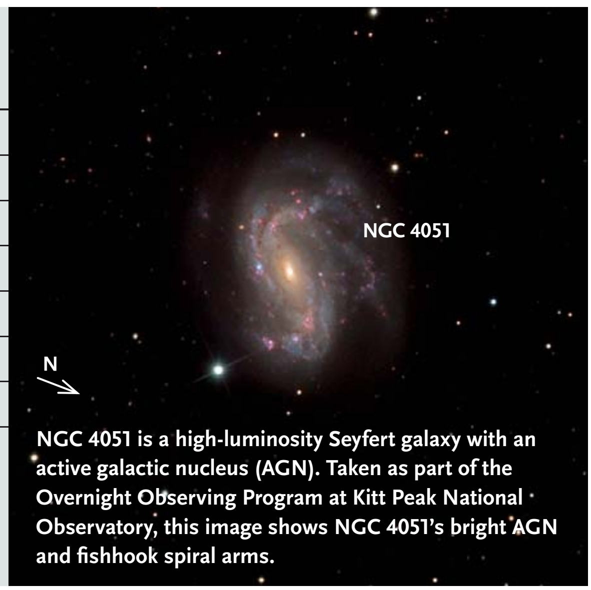
The final galaxy in our tour is **NGC 4051**, which floats 1.5° north of the 5th-magnitude star 67 Ursae Majoris. At 23× my 130-mm refractor discloses only a fairly small, fuzzy spot with a star at its western edge. At 63× I can tell that this spiral galaxy is elongated northwest-southeast. Upping the power to 91× unveils a small core and starlike nucleus cloaked in a smoky grey mantle about 2½′ long and half as wide. My 10-inch scope at 166× shows a 3¼′ × 1¼′ oval with brighter tips. A gauzy halo spreads mainly off the oval's northeastern flank, widening the galaxy to 2¼′. The nucleus remains starlike in a very small, round core. At 213× the core grows brighter toward the center, and the asymmetry of the halo is easier to perceive.

The small but conspicuous core of NGC 4051 greets our eyes thanks to this Seyfert galaxy's active galactic nucleus, powered by a black hole weighing in at about 1.7 million solar masses. The galaxy is about 47 million light-years distant and belongs to a group whose brightest member is NGC 4111, another resident of nearby Canes Venatici. ✦

Riding the Big Bear

Object	Mag(v)	Size/Sep	RA	Dec.
M109	9.8	7.6′ × 4.7′	11^h 57.6^m	+53° 22′
NGC 4102	11.2	2.8′ × 1.2′	12^h 06.4^m	+52° 43′
NGC 4068	12.4	2.5′ × 1.6′	12^h 04.0^m	+52° 35′
NGC 4088	10.6	5.8′ × 2.2′	12^h 05.6^m	+50° 32′
NGC 4085	12.4	2.8′ × 0.8′	12^h 05.4^m	+50° 21′
NGC 4157	11.4	8.0′ × 1.1′	12^h 11.1^m	+50° 29′
NGC 4096	10.9	5.6′ × 1.4′	12^h 06.0^m	+47° 29′
NGC 4051	10.2	5.2′ × 3.9′	12^h 03.2^m	+44° 32′

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.



NGC 4051 is a high-luminosity Seyfert galaxy with an active galactic nucleus (AGN). Taken as part of the Overnight Observing Program at Kitt Peak National Observatory, this image shows NGC 4051's bright AGN and fishhook spiral arms.

GEORGE SEITZ / ADAM BLOCK / NOAO / AURA / NSF

 Dennis di Cicco

Meade's 10-inch LX600-ACF Telescope

The value of the LX600 comes as much from its timing as from its advanced technology.

FORK-MOUNTED Schmidt-Cassegrain telescopes have been around for more than half a century. That's a sobering thought for those of us who vividly remember the first advertisements for them appearing in the pages of this magazine in the 1960s and their popularity growing almost explosively after Celestron introduced an attractively priced 8-inch model a few years later. By the early '80s Meade too was building Schmidt-Cassegrains, and the familiar silhouettes of stubby-tube, fork-mounted telescopes were ubiquitous along the skyline at every star party large and small. Schmidt-Cassegrains were the telescope to own whether your interests lay in visual observing, astrophotography, or both.

Frequent improvements, especially ones made for astrophotographers, occurred as Celestron and Meade volleyed design tweaks back and forth vying for market share, all the while keeping the telescopes priced within the reach of many amateurs. Nevertheless,

Meade 10-inch LX600-ACF Telescope

U.S. price: Telescope & tripod, $4,699; X-Wedge, $699

While it has the outward appearance of the fork-mounted Schmidt-Cassegrain telescopes that have served several generations of amateur astronomers, Meade's new LX600-ACF line has state-of-the-art optics and electronics in a newly engineered telescope and mount that have been designed for deep-sky astrophotography. For several months last year the author tested this 10-inch LX600-ACF from the drive-way of his suburban-Boston home.

ALL PHOTOS BY THE AUTHOR

as the 20th century drew to a close and digital imaging replaced traditional film-based astrophotography, Schmidt-Cassegrains surrendered much of their dominance to optical designs, albeit expensive ones, better able to cover large digital sensors corner to corner with quality star images.

Economics played a role, since astrophotographers able to afford large-format CCD cameras were also the ones able to afford expensive telescopes. High-end astrophotography was shifting to an elite group of individuals who had significant sums to spend on their hobbies. At first blush, it looked like deep-sky astrophotography's love affair with Schmidt-Cassegrains was ending.

But times change, and now there are moderately priced DSLR cameras that perform exceptionally well under the night sky. As such, these cameras are making top-notch, long-exposure astrophotography once again something that falls within the budgets of many amateurs. And that's fueling a market for reasonably priced telescopes that work well for deep-sky photography.

Enter Meade's new line of 10- to 16-inch LX600 telescopes. Designed specifically for deep-sky imaging, the LX600 series is everything that the previous generation of Schmidt-Cassegrain astrophotographers dreamed about and then some. And after months of testing a 10-inch model that we borrowed from the manufacturer for this review, I can confidently say that it's the best telescope of its type that I've yet tested for astrophotography.

First the Basics

Meade touts "revolutionary new technology" for its LX600 scopes, but even the newest technology involved — StarLock's automatic, full-time autoguiding — is a few years old. But that's a good thing, since it means that it's innovation that's already survived the test of time. What is new, however, is how all this technology is wrapped in updated hardware designed from the get-go as a platform for long-exposure astrophotography. Here's a quick look at the LX600's major features.

Optics. Meade avoids calling the LX600 a Schmidt-Cassegrain, using instead the acronym ACF for Advanced Coma-Free optics after a change the company introduced to the traditional Schmidt-Cassegrain optical design more than a decade ago. In addition to being photographically faster than the original f/10 Schmidt-Cassegrain design (which Meade still offers in its other telescope lines), the f/8 ACF produces nice, round star images across full-frame DSLR cameras. My review of Meade's then-new design, which was introduced under the moniker RCX but later changed to ACF, appears in this magazine's February 2006 issue (page 78), and includes side-by-side comparison images made with 12-inch versions of the original f/10 and new f/8 optical systems. There's no question that the ACF optics perform better for deep-sky photography.

The LX600 optical-tube assembly (OTA) has an improved mounting system for the primary mirror that virtually eliminates image shift as you focus the instrument. And there's now a very smooth, dual-speed focuser that aids with critical focusing. But achieving precise focus, which is paramount for maximum imaging performance, still requires a delicate touch on the fine-focus knob, and many astrophotographers will want to use an optional electric focuser (models are available from Meade and other manufacturers).

Tripod, X-Wedge, and mount. While outwardly similar to other Meade scopes, especially the LX200 line, the LX600 is substantially more robust. Simply put, the 10-inch model I tested is the most stable 10- to 12-inch fork-mounted scope I've yet reviewed, with the possible exception of Meade's long-discontinued 12-inch RCX400. And stability is what helps make the LX600 such a successful imaging platform.

But there's a price to pay for this — weight. The complete telescope setup weighs more than 160 pounds

The telescope breaks down into four major components: a 44-pound tripod, the optional 28-pound X-Wedge (shown here attached to the tripod), a 34-pound base with fork arms, and a 55-pound optical tube assembly (OTA). Stripping the OTA of its finder, counterweights, and StarLock guide scope reduces its weight to 44 pounds, but the author still found it difficult to safely assemble the telescope in equatorial mode by himself.

WHAT WE LIKE:

Solid fork mounting designed for astrophotography

Automatic full-time autoguiding (StarLock)

The Autostar II control system's myriad time-tested features

WHAT WE DON'T LIKE:

Weight requires two people to set up safely

Documentation possibly confusing for beginners

The heavy-duty X-Wedge gets a thumbs up for its design and construction. Ball-bearings and large hand knobs on the azimuth and elevation adjustments make easy work of precisely moving the heavy telescope during polar alignment.

In addition to the scope's 10-inch main aperture and 50-mm finder pointing skyward, there's StarLock's 80-mm f/5 guide refractor and a small-aperture, wide-field camera, which together perform a variety of important tasks beyond just autoguiding the main telescope for astrophotography. These include precision centering of celestial objects in the field of a camera or eyepiece, and helping refine the telescope's polar alignment.

(73 kg), including the 44-pound tripod and optional 28-pound X-Wedge (a must-have accessory for long-exposure astrophotography). The OTA and fork mount, without the StarLock guide scope and tube counterweights, tips the scales at almost 80 pounds. This makes it about 30% heavier than Meade's corresponding 10-inch LX200 and almost 60% heavier than its 10-inch LX90. With StarLock and counterweights, the assembled scope weighs close to 90 pounds. Furthermore, it is an awkward scope for one person to set up despite four handles and two handholds on the fork and a single handle on the back end of the OTA.

To make assembling the scope more manageable, Meade has designed a nice system for separating the OTA and fork arms into pieces that, for the 10-inch, weigh 44 and 34 pounds, respectively. This helps, but it still makes assembly challenging for one person. Indeed, rather than getting bogged down with details, and despite the fact that I set the scope up by myself nearly two dozen times, I will just say that I don't recommend it as a safe process for one person. Even with the OTA stripped to its minimum configuration (no finder, StarLock guide scope, or counterweights), I struggled to align the safety catches on the OTA's declination trunnions with their mating pieces on the fork tines. It would be easier to do this with the scope set up for altazimuth operation, but with the fork tilted for astrophotography on the wedge, it's an intimidating operation for one person. The real solution is to have a friend lend a hand when setting up the scope.

Autostar II. The brains for the LX600's GoTo pointing (including catalogs containing more than 145,000 celestial objects), tracking, and a host of other advanced features are in the Autostar II control system, which has been on Meade's high-end scopes for more than a decade. It is a mature system that works exceptionally well.

Despite its sophistication, Autostar II is relatively intuitive and easy to operate in the dark with the hand control. You don't need to keep a printed manual at hand, since even rarely used features are typically accompanied by instructions that scroll across the hand control's 2-line LED display. There are far too many Autostar II features to write about here, but you can find many of the details in the 72-page LX600 instruction manual, which can be downloaded as a PDF file for free from Meade's website (**meade.com**).

StarLock. This is really amazing technology, and it sets the LX600 apart from any other fork-mounted telescope on the market, bar none. In a nutshell, every time you slew the LX600 to a new target, StarLock automatically acquires a suitable guide star and begins guiding the telescope accurately enough for astrophotography. There is no need for an external computer or even so much as a button push of input from the user. The system is 100% autonomous. And it's also non-intrusive, meaning you can go about using the telescope any way you want without interference from StarLock. The autoguiding begins within about a minute of the scope being moved to a new location (by either GoTo slewing or the observer pressing the direction buttons on the hand control), and it's instantly overridden whenever the scope is moved to a new position by any means. A single red LED on the StarLock guide scope indicates when the system is autoguiding and you can begin shooting pictures.

StarLock also performs a variety of other tasks, including the precision centering of targets in the field

As expected, with the telescope only crudely polar aligned, an unguided exposure *(left)* shows significant image trailing. But with StarLock turned on *(right)*, the tracking was picture perfect. These back-to-back 5-minute exposures of the globular star cluster M13 in Hercules are with a Nikon D700 camera and Barlow lens.

of an eyepiece or camera; training the periodic error correction (PEC) of the scope's motor drive; and refining the telescope's polar alignment. I detailed StarLock's performance in a review of Meade's LX850 German equatorial telescopes in this magazine's December 2013 issue, page 60, so I won't rehash that material here other than to say I remain extremely impressed with the system.

I did, however, encounter a few differences this time. Most notably, unlike my previous experience, StarLock did not autoguide flawlessly "out of the box." I first had to train the PEC and perform what Meade calls an Automatic Rate Calibration (ARC). These steps are highly automated, involving only a few button presses on the hand control and about 15 minutes of time. And since the PEC information is stored in the scope's memory, you only need spend a couple of minutes running the ARC during subsequent observing sessions. In hindsight, it was my experience with the LX850 that was unusual, since Meade clearly states in the LX600 manual that these steps are "an essential procedure to obtain peak tracking accuracy."

My original StarLock testing with the LX850 was under tranquil summer skies. Under similar conditions

Left: The Autostar II hand control operates every feature of the LX600 from GoTo pointing to the advanced functions of StarLock. *Below:* The LX600 telescopes can be powered by a set of eight C batteries (four housed in each fork arm) as well as via a conventional 12-volt DC input jack on the scope's base. A set of fresh batteries will last for about two nights of observing.

StarLock performed equally well with the LX600, but when the frequently turbulent seeing conditions of our New England winters eventually rolled around, StarLock had a good, but not perfect, track record autoguiding. To be fair, any autoguider will struggle under crummy seeing conditions, so I wasn't surprised to have a few guiding failures now and then.

The Takeaway

Overall I was very impressed with the LX600. As someone who started doing deep-sky photography with an 8-inch Schmidt-Cassegrain in 1972, I can tell you that back then the LX600 is what we all dreamed a "perfect" astrophotography setup would be like, except we never imagined computers controlling the telescope's pointing and digital eyes doing the guiding!

I can certainly recommend the LX600 for anyone who has experience with a fork-mounted Schmidt-Cassegrain telescope, especially one polar-aligned for astrophotography. You'll be right at home with the LX600. And because Meade still includes accurate setting circles on the LX600, virtually any method you want to use to polar align the scope will work (something that can't be said for any of today's scopes that have dispensed with mechanical setting circles).

I'd be equally enthusiastic about endorsing the LX600 for beginning astrophotographers if the scope's documentation was a little better. For example, the all-important polar-alignment instructions that are mandatory when setting up for astrophotography (the ones that scroll across the hand control), while technically correct, are almost physically impossible to do — you can't point the OTA to declination 90° and look through the eyepiece while spinning the telescope "rapidly" on its polar axis. My neck hurts just thinking about it. Nevertheless, beginners have surmounted these obstacles in the past with fork-mounted scopes, and I'm sure they will with the LX600. And when they do, they will be amply rewarded with a robust astrophotography setup that is incredibly powerful. ✦

Dennis di Cicco has been writing about equipment in the pages of Sky & Telescope *for more than 40 years.*

New Product Showcase

▶ **GUIDESCOPE** Orion Telescopes & Binoculars introduces the 60mm Multi-Use Guide Scope with Helical Focuser ($219.99). This compact 2-inch f/4 guide scope is designed to make autoguiding deep-sky astrophotos easy and intuitive. The scope includes heavy-duty tube rings and a 3½-inch mounting bar that is compatible with all Orion quick-release finder brackets, and is threaded for additional mounting options. Its helical focuser has 10-mm of travel and can accept most autoguiding cameras that connect via a 1¼-inch nosepiece or a T-thread interface. Six nylon-tipped thumbscrews allow precise aiming when choosing guide stars.

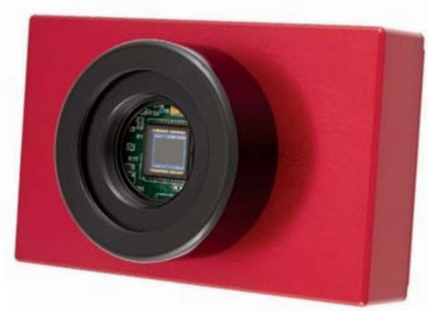
Orion Telescopes & Binoculars
89 Hangar Way; Watsonville, CA 95076
800-447-1001; oriontelescopes.com

◀ **SKYSAFARI UPDATE** One of the most popular planetarium apps for Apple devices gets a complete makeover. *SkySafari 5* (starting at $2.99) changes the look and feel of this popular app, and adds many new features. *SkySafari 5* includes up-to-date ISS and bright satellite pass notifications, expanded object descriptions, and a new "Tonight at a Glance" feature with notifications of solar system and bright satellite events. Available in basic, Plus, and Pro versions, each requires a device running iOS 8 or later, and includes support for the new Apple Watch. The Plus and Pro versions also incorporate WiFi Go To telescope control, expanded deep-sky catalogs, and iCloud synchronization. See the manufacturer's website for a complete listing of features.

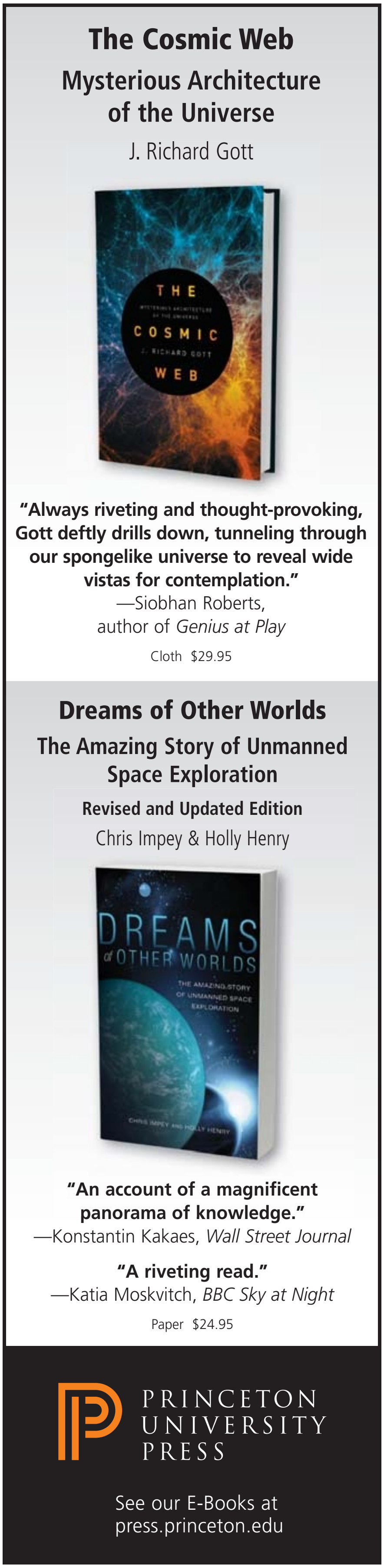
Simulation Curriculum (available on the App Store)
11900 Wayzata Blvd., Suite 126, Minnetonka, MN 55305;
1-877-290-8256; simulationcurriculum.com

▶ **VIDEO KIT** Atik Cameras enters the world of video observing with its Atik Infinity ($1,000). The camera features the highly sensitive and extremely low-noise Sony ICX825 sensor with a 1,392-by-1,040 array of 6.45-micron pixels to produce smooth, high-resolution views of deep-sky targets. This USB-2.0 camera can record up to 3 frames per second at full resolution, which are continually stacked on your PC computer with the included proprietary control software. The camera can also operate in 16-bit format and function as an autoguider for your deep-sky imaging needs with its built-in ST-4 autoguider port. The camera comes complete with a 3-meter USB-2.0 cable, 1.8-meter cigarette-lighter style power connector, 1¼-inch nosepiece adapter, and CD with camera drivers and control software.

Atik Cameras
Unit 8 Lodge Farm Barns,
New Rd., Norwich, UK; NR9 3LZ
+44(0)1603-740397; atik-cameras.com



New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information contact the manufacturer or distributor. Announcements should be sent to nps@SkyandTelescope.com. Not all announcements can be listed.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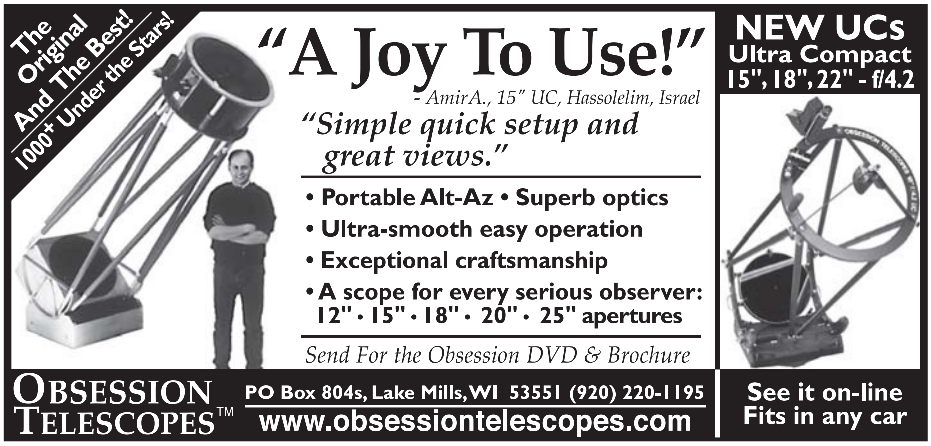
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Look-Back Time

Reflecting on 200+ telescope-making articles.

ON SEPTEMBER 10, 1998, I walked into the Bay State Road offices of *Sky & Telescope* for my first day of work as an associate editor. Almost immediately, Roger Sinnott handed me two big U.S. Mail totes full of unused telescope-making submissions. “Welcome to the deep end of the pool,” laughed then Editor in Chief Leif Robinson. It was sink-or-swim time. And now, 208 issues later, it’s time to let someone else tread the ATM waters at *S&T*.

I’ve had the pleasure of showcasing the efforts of many clever equipment makers in this space over the years. And while I don’t remember every single article, there are a few favorites worth revisiting in this final Telescope Workshop column. I encourage you to give these a second look (or first look, if you’re a new reader).

Of all the ideas I helped present, I think the most innovative was Alan Adler’s flex-mirror design (“Flexing Spheres into High-Quality Telescope Mirrors,” Nov. 2000, p. 131). The concept was so intriguing that I flew to Arizona to meet with Alan and fellow ATM Bill Kelly, who had previously written an article describing a more rudimentary flex-mirror design. I ended up building two scopes to test the concept before running Alan’s article. I can’t speak for him, but I was a bit disappointed that the idea didn’t catch on in a big way. Perhaps it was an idea just ahead of its time.

ALAN DYER

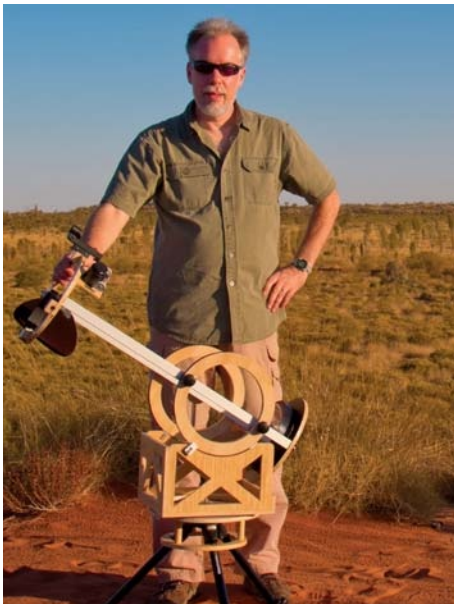
Described in the December 2001 issue, page 120, this 8-inch travelscope was one of several telescopes built by Gary Seronik and featured in the pages of *Sky & Telescope*.

One concept that did gain quite a bit of traction, though, is telescope thermals. A warm primary mirror is arguably the single biggest reason reflectors lag behind refractors when it comes to first-rate performance. If there were a Nobel Prize for telescope making, I’d nominate Bryan Greer for putting this issue front and center. His first article on the subject, “Understanding Thermal Behavior in Newtonian Reflectors” (Sept. 2000, p. 125), was both carefully researched and compelling. I remember his submission package well — it included a video shot using Schlieren imaging to show a telescope mirror slowly cooling. After seeing that, the problem and its solution (inexpensive computer fans) were obvious. As a result of Bryan’s efforts many more telescopes today — both home-built and commercially produced — utilize fans and deliver better views.

Other innovations were less revolutionary, but no less helpful. Have you ever wondered where the notion of collimating with a Barlowed laser came from? You have Nils Olof-Carlin to thank with his January 2003 article “Collimation with a Barlowed Laser” (p. 121) to thank. I think it’s genius — and so do quite a few readers. The technique is simple, effective, and can be used to align a reflector’s optics in the dark. A couple of manufacturers have even gotten into the act by making commercial Barlowed-laser collimators. Thanks Nils!

One dominant trend that coincided with my tenure as the magazine’s ATM editor was the push for high-performance portable scopes. Although the concept doesn’t originate with any one telescope maker, it nicely illustrates the power of iterative design. Albert Highe and Mel Bartels are two ATMs who have contributed tremendously to the cause of bigger/lighter scopes. All their *S&T* articles are illuminating.

The ingenuity of telescope makers never fails to impress me. I remember one article in particular put that trait to the test. In the March 2009 issue (p. 72), I



GEORGE BRANDIE

Built for a trip to Australia, Gary's Outback Travelscope was described in his March 2013 Telescope Workshop column.

put forth a friendly challenge to readers to see who could come up with the most compact 8-inch travelscope. I received a gratifying number of submissions, and in the August issue (p. 62) I presented seven finalists. Their designs revealed two characteristics emblematic of telescope makers in general. First, all seven ATMs built remarkably elegant, portable scopes. And yet, no two were alike — proving that there are usually several solutions to any one problem. Second, the finalists were scattered far and wide and included contributors from Canada, Germany, France, and Holland. Clearly, the enjoyment derived from making and using telescopes knows no borders.

Sadly, there isn't enough space to mention every noteworthy contribution I've had the good fortune to work on in my time here. I'd need another 200 issues to do all of them justice! But to everyone who has added to our shared pool of ATM knowledge via this department, thank you for the inspiration, generosity, and imagination you've provided in such great abundance. I can't wait to see what you'll come up with next! ✦

Gary Seronik is an accomplished telescope maker and observer. He can be contacted via his website, **garyseronik.com**.

Targeting Luna

High-resolution close-ups of the Moon can be a satisfying challenge for modest apertures.

Robert Reeves

Lunar photography has always been a relatively simple procedure: aim your telescope, focus, and snap a bunch of pictures. Indeed, the same basic technique used in 1840 by John Draper when he shot the first lunar daguerreotype remains essentially unchanged for everyday full-disk images (see page 52). But taking detailed close-ups of crater fields is a different nut to crack. Recording sharp lunar images used to require an enormous amount of effort and luck.

Fortunately, with the advent of electronic imaging and frame stacking, that has all changed. These days we use the established technique of "lucky imaging" — recording a series of images in rapid sequence, and then combining the sharpest frames into a final, high-resolution result. This permits amateurs with modest equipment to produce lunar images that easily surpass the quality of those from professional observatories from the age of glass plates and film. Here are some of the methods that can help you get the most out of your equipment and take your own sharp lunar close-ups.

ALL PHOTOS COURTESY OF THE AUTHOR

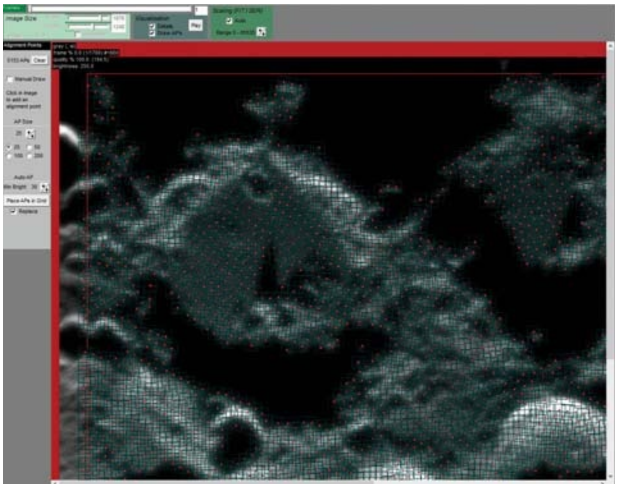
When attempting to shoot high-resolution crater images, you'll get more nights of success with a mid-size telescope compared to a large one. A 6- to 8-inch aperture will often resolve small lunar features better than larger instruments — in spite of the fact that resolution increases with aperture. This is due to "seeing cells" in the air above you that are relatively small. A larger telescope will look through multiple cells of turbulent air while a smaller scope might look through just one.

Your choice of camera will also influence how you can achieve a high-resolution image. About a decade ago, most video cameras popular with lunar and planetary imagers had small CCD detectors with 6-micron pixels, typically in a 640 by 480 array. These relative large pixels often required additional magnification with a Barlow lens to achieve high-resolution images resolving details of 1 arcsecond or smaller, not to mention having to mosaic many images to cover a substantial area of the lunar surface. Today's planetary cameras use fairly large CCD and CMOS arrays with tiny pixels, often smaller than 3 microns. These little pixels more than double the resolution over those old webcams, sometimes eliminating the need for additional magnification boosts when using telescopes with long focal ratios of f/10 or more. Additionally, these big detectors allow imaging of much wider swaths of lunar real estate in one shot.

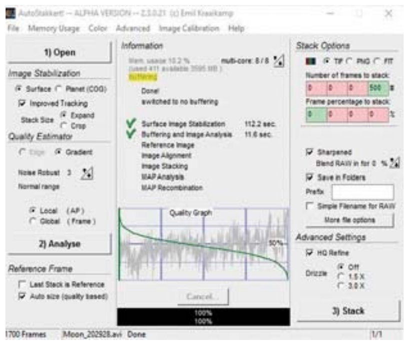
You can calculate the magnification using this formula: Arcseconds per pixel = $(P/FL) \times 206.3$, where P is the pixel size in your camera measured in microns, and FL is the focal length of your telescope in millimeters.

When choosing a camera for high-resolution lunar imaging, keep in mind that the Moon is predominantly a monochrome object, so a color camera is not necessary. Monochrome cameras are also more sensitive, enabling you to record at faster frame rates than most color cameras achieve, particularly at high focal ratios.

ZOOMING IN ***Facing page:*** **High-resolution shots of crater fields, maria, and rays are within most any amateur's grasp. Author Robert Reeves shares his techniques to capture sharp images like this one showing Rupes Recta (the Straight Wall).** ***Above:*** **The Moon is loaded with interesting areas great for any size telescope, such as the oddly elongated crater Schiller found near the southwest limb.**



MULTI-POINT STACKING A relatively new program for stacking lunar and planetary images is *AutoStakkert! 2*, which includes batch-processing of multiple videos and a powerful multi-point alignment routine.



The CMOS and CCD detectors in planetary cameras are sensitive to ultraviolet and infrared wavelengths. These come to focus at slightly different points than visible light when passed through refractive optics, reducing fine detail in your images. So consider installing an UV/IR filter to block these wavelengths.

Most planetary cameras include an operating program and drivers. These generally work well, as long as they include a few key functions. One of the most important features is the histogram, which allows you to monitor the brightness levels in the video output. Without a histogram or levels gauge, it's difficult to accurately judge the exposure to avoid overexposing bright areas in the camera's field.

I prefer to control my camera using the free program *FireCapture* (**firecapture.de**). Written by planetary imager Torsten Edelmann, this program supports nearly all planetary cameras and includes many features important for lunar, solar, and planet imaging.

Besides your telescope and camera, one additional and essential accessory for high-resolution lunar photography is a dual-speed focuser. The stock focusers on most telescopes are adequate for prime-focus imaging, but once you add a Barlow into the mix, you can easily over-shoot optimum focus with just slight turns. Grabbing the focus knob at high magnifications also introduces furious shaking of the field of view, making it nearly impossible to focus the camera precisely. I use a dual-speed Crayford focuser with a 10-to-1 reduction, and I clip a clothespin to the fine-focus knob. This lets me tweak focus by nudging the clothespin with my fingertip, eliminating the vibration induced by grasping the knob. Adding a motorized or electronic focuser is also a good alternative.

Beating the Seeing

No matter what telescope or camera you use to shoot lunar close-ups, you'll be at the mercy of something you have no control over: Earth's turbulent atmosphere. Astronomers refer to the churning effect of our atmosphere as "seeing." You can use online weather services to get a good idea of what the sky might be like before you set up. Watch for the location of the jet stream, a narrow, fast-flowing current in the upper atmosphere. If the jet stream is passing overhead in your area, the seeing will be poor.

While you can't control the atmosphere, you *can* control some of the factors that affect local seeing conditions. The first occurs within the telescope itself: allow your optics to cool to the ambient temperature before beginning to shoot. That way you won't be looking through the heat rising off of your primary mirror or objective lens.

The area surrounding your scope is an important consideration too. Avoid setting up on concrete or asphalt, which slowly radiate heat for much of the night. Avoid shooting over buildings and large structures that emit rising currents of heat at night.

LUNAR SCOPE You don't need a big telescope to take great close-ups of lunar crater fields. Scopes with apertures of 6 to 8 inches will often perform better than larger scopes in average seeing conditions. The author records most of his lunar images using this Sky-Watcher 180mm Maksutov-Cassegrain telescope.

The altitude of the Moon also greatly affects your images. The lower the Moon is in the sky, the more atmosphere lies between it and your telescope. So try to shoot when the Moon is high up. Another consequence of increased air mass at low elevation is atmospheric dispersion. The stack of air near the horizon acts like a weak prism, splitting visual light into its separate color wavelengths. The higher the Moon's altitude, the less dispersion you'll record and the sharper your results will be.

One way to improve your images in unsteady seeing is using filters that transmit only the redder wavelengths of the spectrum. Shorter, bluer wavelengths are blurred much more than the longer red and near-infrared wavelengths, so a red filter will give you the sharpest results in adverse conditions.

Capturing Videos

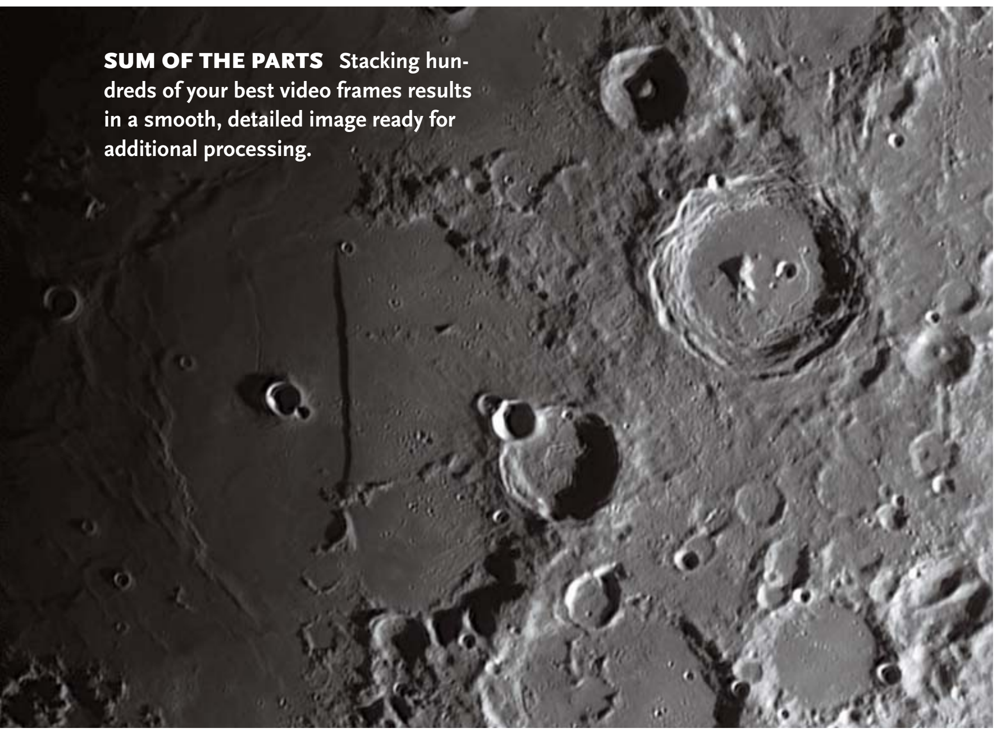
Before you start recording lunar close-ups, make sure your optics are properly aligned — collimation is critical to getting the best results. If you use a Schmidt-Cassegrain or Newtonian reflector, be sure to check its collimation before imaging. While my Maksutov-Cassegrain is permanently collimated, my C11 occasionally requires slight adjustments despite being permanently mounted.

Before hitting "Record," spend a few minutes determining what magnification best suits the conditions for the evening. If the seeing is poor, shoot at prime focus without any additional magnification. The shorter focal length lets you use faster shutter speeds and capture more frames per second, which ensures some sharper frames are recorded. If the seeing is good, adding a 1.5× Barlow will resolve more detail. If the seeing is great, even stronger amplification can be used. In my experience, shooting at about f/25 is optimal during the best seeing.

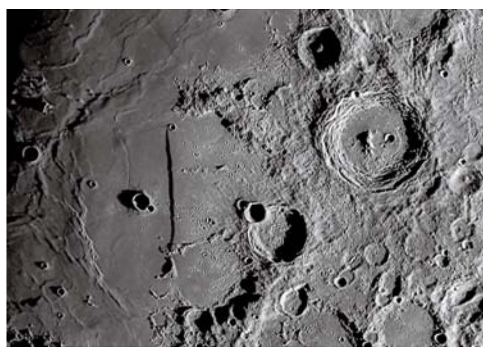
Now it's time to record some high-resolution videos. While monitoring the histogram, set the camera's gain at its midpoint and increase the shutter speed until the right end of the histogram (indicating the brightest levels in the video) is just short of the right edge of the graph. Avoid allowing the histogram levels to hit the right end of the graph, or else you'll end up with overexposed regions in your stacked images that can't be recovered during processing.

I typically capture many 3,000-frame videos in AVI format, which span roughly 30 to 50 seconds, depending on the focal length I've chosen. This produces 7-gigabyte video with the Celestron Skyris 236M camera I use. Be sure to have plenty of hard-drive space, because you'll record upward of 100 GB of videos each night!

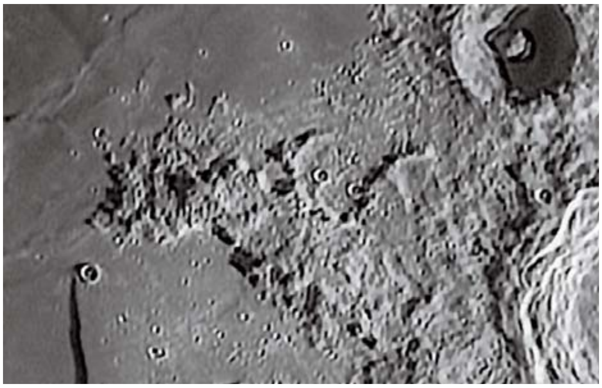
The Moon moves across the sky at a different rate than the background stars do, so unless your tracking mount includes a "lunar rate" setting, you'll see some image drift while recording. I keep my videos roughly on target by placing the cursor on a small crater in the field and then nudging the drive corrector to keep the crater centered under the cursor.



SUM OF THE PARTS Stacking hundreds of your best video frames results in a smooth, detailed image ready for additional processing.



SHARPENING RINGS ***Right, top:*** **Sharpening can often result in some processing artifacts that need to be corrected. Note the "rings" seen within crater shadows in this brightened image of Rupes Recta (the Straight Wall).** ***Right bottom*****: Shadows in lunar craters should appear black in your images. If not, you can selectively darken them using the Burn Tool in** ***Adobe Photoshop CC*****.**



REAL OR ARTIFACT? Another artifact to watch out for in lunar close-ups is false central peaks in small craters. These often appear in images taken in poor seeing conditions.

Stacking and Sharpening

Now that you have some quality videos, it's time to sort and stack the best frames into single images. This can be performed using a host of programs, but I prefer using *AutoStakkert! 2* (**autostakkert.com**) to stack my videos, and *RegiStax* (**www.astronomie.be/registax**) or *Adobe Photoshop CC* (**adobe.com**) to sharpen and clean up the results.

AutoStakkert! 2 is an easy-to-use program that lets you process many videos in a single batch. To use the program, begin by clicking 1) Open and select your first video. Next, under the Image Stabilization tab, select Surface, and check the Improved Tracking box. Now click the 2) Analyse button, and the program will evaluate your video. Once it's complete, switch to the screen showing your video, and on the left-hand column, select an alignment point (AP) size — I usually choose 25 pixels — and press the Place AP grid button. This results in thousands of alignment points. If any points fall in shadowed regions, increase the Min Bright setting and click the Place AP grid button again.

Switch back to the control window, and in the Stack Option column on the right, select the format you'd like your stacked result to have and the number of frames to stack. I usually stack the best 500 out of 3,000 video frames. Although the program has a rudimentary sharpening feature, uncheck the Sharpened box if you prefer to sharpen the results using other software. Finally, initiate stacking with the 3) Stack button. Once your file has been stacked into a single image, the result will appear in a new folder within the original location of your video files.

At this stage, you can move your image into another image-processing program to sharpen the details. If you use *RegiStax*'s wavelet sharpening, experiment with the slider settings; no two optical systems are the same, and what works for one scope-and-camera combination might be too much for another. The key to great high-resolution lunar images is to avoid over-sharpening.

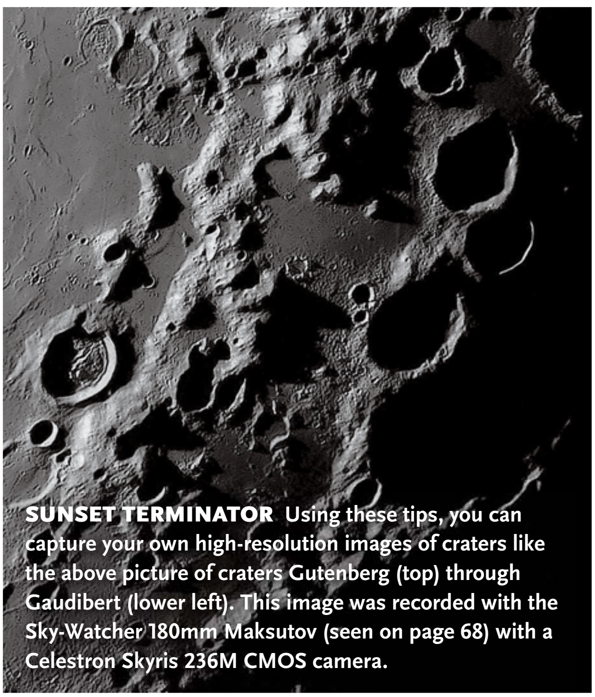
My favorite sharpening tool in *AdobePhotoshop CC* is the new Shake Reduction filter, located at Filter > Sharpen > Shake Reduction. The filter includes artifact suppression and noise reduction, which produce results similar to shooting through better seeing or using a higher-resolution instrument.

As with most astrophotos, some additional processing is helpful beyond sharpening. I prefer to do any final processing in *Photoshop CC*.

Stacking several hundred frames effectively increases the bit depth of the final result, so *AutoStakkert! 2* generates 16-bit TIF, PNG, or FIT images with a very high signal-to-noise ratio. This makes it easy to brighten dark areas without increasing objectionable noise in shadowed regions close to the terminator. I often do this using the Camera Raw filter (Filter > Camera Raw).

Finally, I perform any cosmetic cleanup. An unintentional side effect of the stacking and sharpening processes is they can generate artifacts that mimic real detail. Recognizing and removing them greatly improves your final result. Using the Burn Tool from the tool palette set to about 5% is the easiest way to darken shadow areas, as well as reduce any ring artifacts along the edge of craters. Use the Eraser or Clone Stamp tools to remove false central peaks in smaller craters, being careful not to eliminate real detail or duplicate an existing feature.

By following these tips, exquisitely detailed images of crater fields on the Moon will be within your grasp. Relive the most exciting times in space exploration with your own telescope and rediscover the joys of lunar photography by exploring our neighboring world. ✦



SUNSET TERMINATOR Using these tips, you can capture your own high-resolution images of craters like the above picture of craters Gutenberg (top) through Gaudibert (lower left). This image was recorded with the Sky-Watcher 180mm Maksutov (seen on page 68) with a Celestron Skyris 236M CMOS camera.

***Robert Reeves** shoots the Moon at every opportunity from his backyard observatory in San Antonio, Texas.*

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

PLANET PARADE
Gradient Lok
As seen before dawn on January 29, 2016, from Kuala Lumpur, Malaysia, the widely viewed arc of all five naked-eye planets — plus the Moon — passed almost directly overhead. **Details:** *Canon EOS 6D DSLR camera used at ISO 800 and an 8-to-15-mm zoom lens used at 14 mm. Exposure: 5 seconds.*

SUN-AND-MOON DÉJÀ VU

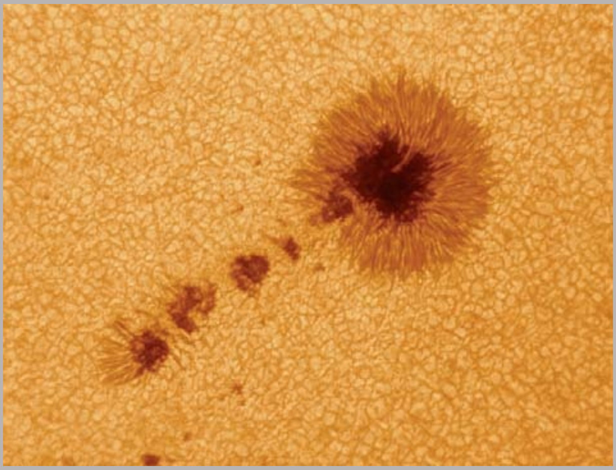
Marcella Giulia Pace & Marco Meniero

The coincidence of a lunar eclipse at an equinox permitted this dramatic pairing of moonrise on September 27, 2016, and sunrise the previous morning with the same tree-lined horizon.
Details: *Canon PowerShot SX50 HS camera; Moon: 1⁄125-second exposure at ISO 100; Sun: 1⁄25-second exposure (filtered) at ISO 80.*

SWAYING THROUGH CEPHEUS
David Mittelman
The Elephant's Trunk (vdB 142) winds for some 20 light-years through the star-forming complex IC 1396. Its rim glows due to light from the very bright, massive star HD 206267 (not seen).
Details: *PlaneWave CDK20 astrograph and FLI MicroLine ML16803 CCD camera with Astrodon filters. Total exposure: 27½ hours.*

▲ **PAIRED POLLYWOGS**
John Vermette
The emission nebula IC410, located about 12,000 light-years away in Auriga, provides the backdrop for a pair of isolated, backlit clouds called the Tadpoles.
Details: *Hyperion 12.5-inch astrograph and SBIG STL-11000M CCD camera with Hα and RGB filters. Total exposure: 9 hours.*

► **SUNFLOWER**
Leo Aerts
As active region 12132 crossed the Sun's face on August 5, 2014, its main sunspot group took on the appearance of a Van Gogh-like sunflower roughly 1 arcminute across.
Details: *Celestron C14 Schmidt-Cassegrain telescope, Baader solar filter, and Imaging Source DMK31AU03.AS CCD video camera. Stack of 800 1⁄60-second exposures.* ✦



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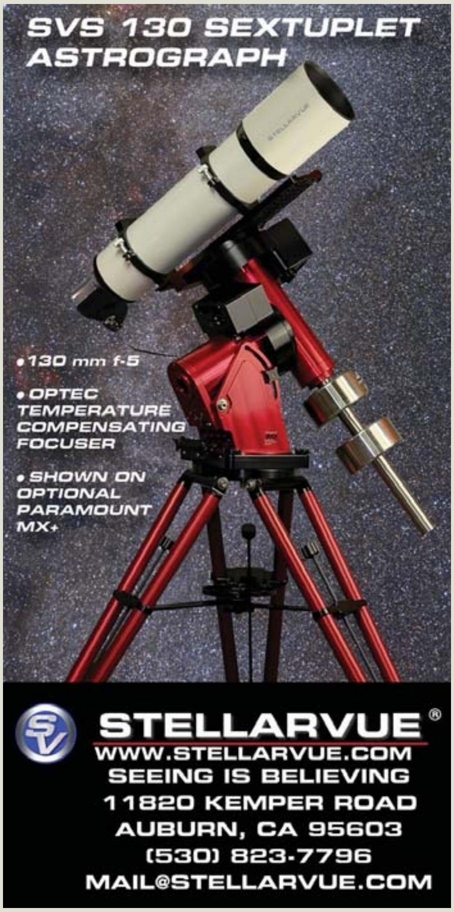

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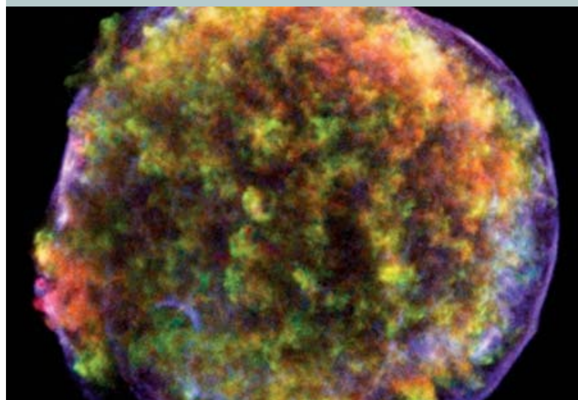

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Learn how to observe one of the most challenging deep-sky targets, the on-the-move remnants of Tycho's Supernova (above).

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A trek away from home can be just the thing to experience sights you've never seen and maybe refresh and invigorate your hobby. Some of my own most memorable moments in astronomy have come about as a result of traveling.

In 1985, when I was 15, my family drove me to a dark-sky observatory for my first look at Comet Halley (*S&T:* Feb. 1999, p. 84). Scanning the western sky with my 6-inch f/5 Vixen reflector, I came across a white, triangular nebulosity. A cry from another amateur nearby that he'd located Halley drew me momentarily from my telescope to his. That's when I realized I'd already swept up the comet myself.

In March 1986, we made an eight-hour round trip to see Halley rising in the predawn sky from a friend's farm. My final view of Halley with the unaided eye involved leaving town again, on April 24, 1986. Normally, one wouldn't undertake a three-hour drive to observe under a full Moon. But this was something extraordinary — a total lunar eclipse was taking place — and my family gazed one last time upon the famous comet high overhead, together with the eclipsed moon.

Comets have been a reason for heading far afield at other times as well. During an early-morning jaunt to the mountains, I witnessed an unforgettable sight: Hyakutake, the Great Comet of 1996, with its tail like an exclamation mark dividing the sky. The following year I drove Bill Bradfield, the 20th century's greatest visual comet hunter, to a star party where we viewed Comet Hale-Bopp shining brightly.

JOHN S. DYKES

Occasional strokes of fortune have favored me when I've hit the road for astronomy. My wife, an astrophysicist, is a regular observer with the 3.9-meter Anglo-Australian Telescope at Siding Spring Observatory. In 2011, I was there with her and our two sons, then aged 10 and 8. We were staying in the Director's Cottage, and I'd just come in from stargazing for a coffee. The phone rang. It was Robert McNaught calling: "Greg, I think I've found a comet." My sons and I walked to the 0.5-m Uppsala Southern Schmidt Telescope where Robert was working, and we became the second, third, and fourth people in the world to see what would subsequently be called Comet C/2011 N2 (McNaught).

Getting far from home has also enabled me to see Supernova 1987A under dark skies, delight in a spectacular Leonid meteor shower in 2001, and stand in awe of a perfect solar eclipse at Cairns in 2012.

All this notwithstanding, on the afternoon of July 22, 2028, I expect to be sitting right in my own backyard. Why? A total solar eclipse will cross Australia that day, and my home city of Sydney lies right in its path. Mind you, if the weather forecast that day is looking better elsewhere.... ✦

Contributing Editor ***Greg Bryant*** *served as editor in chief of* Australian Sky & Telescope *from 2006 to 2014.*

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