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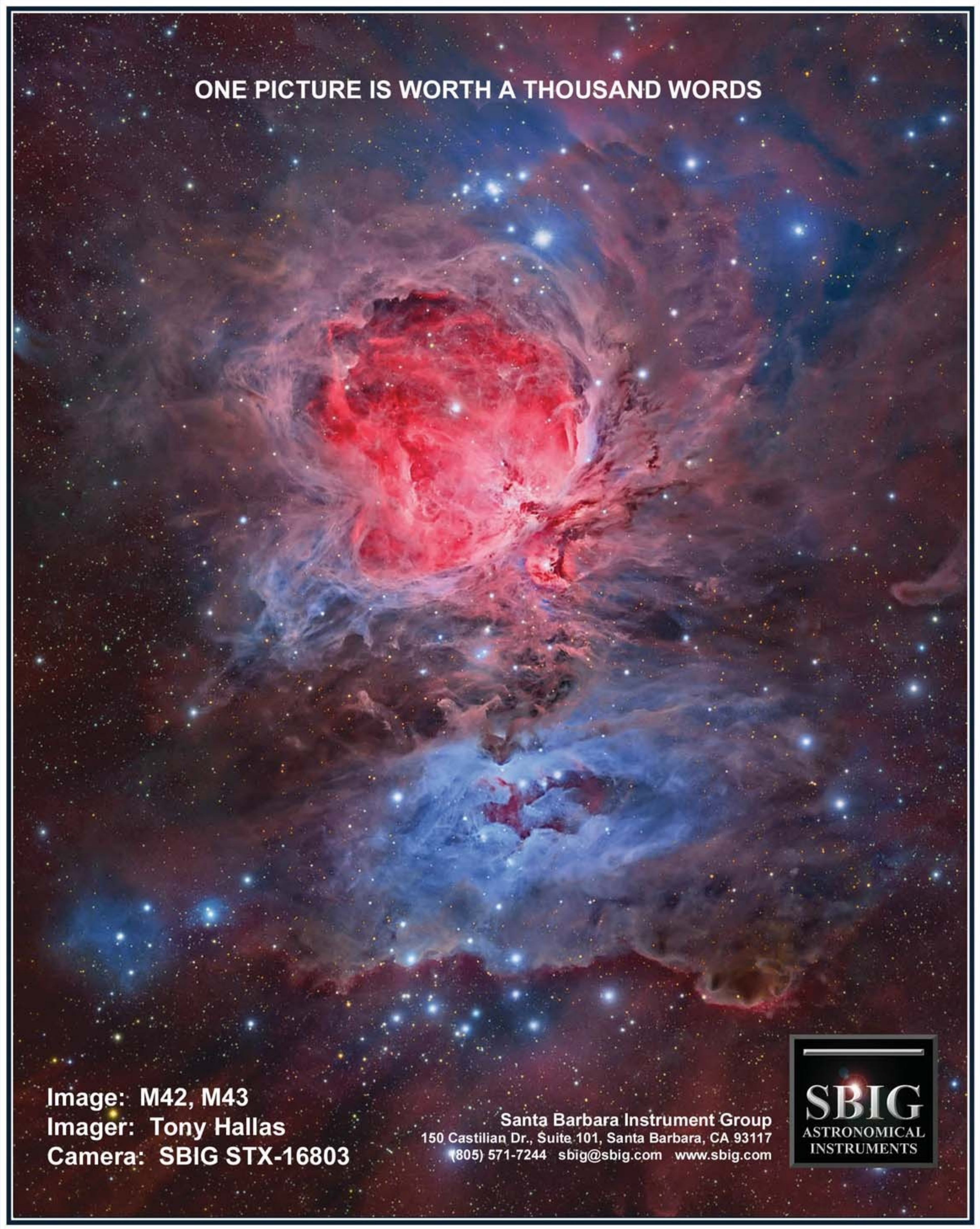

SKY & TELESCOPE

October 2014 VOL. 128, NO. 4

On the cover: M31 is slightly larger than the Milky Way, but it doesn't best our galaxy in every way.

M31 PHOTO: ROBERT GENDLER

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OBSERVING OCTOBER

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Passing the Torch

WHEN I ASSUMED the mantle of *S&T* editor in chief in June 2008, in the back of my mind I figured my run would last about 5 to 7 years before I'd burn out and turn to other things. I had it just about right. As I write these words in late July, a little more than 6 years after my start, I have informed my colleagues of my intention to move on, and our parent company, F+W, is now looking for a new person to grab the torch and carry it forward. I'll stay on until a replacement is on board, and I look forward to contributing in various ways after my departure.

I'll be leaving *S&T* with a heavy heart, but with my head held high. I've enjoyed many wonderful moments during this 6-year tenure: meeting countless *S&T* readers at star parties and trade shows, putting out a magazine and website that people love, and working with a dedicated bunch of people. I can't thank my fellow editors and art colleagues enough for their tremendous effort and support. As senior editor Alan MacRobert likes to say, "I have one of the few good jobs left in America. I get to work in a no-jerk* zone." (*Not Alan's original word.) I can't thank all of our contributors enough. I thank Stephen Kent and Joel Toner of New Track Media for giving me this opportunity. And most of all, I thank all of you loyal readers for your long-standing support!

Sometimes people will ask me at astronomy events how *S&T* is doing, with an expression of concern given the knowledge that print publishing is suffering economic hard times. I take comfort knowing that I leave with *S&T* standing on *terra firma*. And based on reader surveys and conversations with subscribers, I sleep soundly feeling that my colleagues and I have maintained *S&T*'s hard-earned reputation for accuracy, quality, and integrity despite challenging circumstances.

Still, a lot of pressures and stresses have built up over the years, and I sense a deep need to take some time off and try my hand at freelancing. Also, the media world is rapidly evolving, yet I'll probably always remain a traditional print journalist at heart. I just don't think the complexity and beauty of astronomy can be adequately conveyed in a 140-character tweet, and I worry that the future belongs to media outlets who shout loudest, not to those who take the time and effort to get the story right.

Before closing, I wanted to congratulate a contributing editor who *always* gets the story right: Dutch science journalist Govert Schilling. Govert has won the prestigious 2014 David N. Schramm Award for High-Energy Astrophysics Science Journalism from the American Astronomical Society for his article "The Frozen Neutrino Catcher" in the January 2014 *S&T*.

Robert Naeye
Editor in Chief

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A Sky Full of Friends

Paul Greenewich's essay "Soothing Stars" (*S&T*: May 2014, p. 86) resonates with me. While I probably didn't reach the level of an "official" diagnosis for anything, as a child I also often felt insecure and lonely. Like Greenewich, I found the sky to be "a haven of peace, simplicity, and order." Now at 57 years old, I've outgrown my childhood anxieties and am even told that I am good with people. Yet, I still find the sky to be a way to recharge.

Every night I go out at least once to look at the sky. If conditions are good and my schedule allows, I get out my telescope or binoculars. Even when it's cloudy I go out and try to catch a glimpse of one of my "old friends" through a gap. A few weeks ago I stepped out later than usual and said out loud, "Oh, hello Mars." It was my first sighting this apparition, and it really felt like I was greeting an old friend that I hadn't seen in over a year.

I have carried this into the daytime as well, with an equatorial sundial in my wife's flower garden. Besides tracking the daily progression of the Sun's shadow, the sundial also easily shows the progression of the seasons as the Sun's declination changes. I take time to study it each day. These simple observations of the clockwork of the sky always bring a simple, childlike joy to me.

Craig MacDougal
Tampa, Florida

S&T: LEAH TISCIONE

Before I retired from Case Western Reserve University in 1997, I spent many wonderful nighttime hours observing stars and galaxies at observatories in Arizona, California, Ohio, Texas, and Chile. Those were the days when astronomers were on the observing platform, not in a room watching computers run the telescope, so we actually saw the sky and stars. I enjoyed these long hours, usually alone, at the scope. Thus I can relate with Greenewich's description of the ordered, peaceful night sky.

However, he also wrote that the "long list of high achievers who have (or are speculated to have had) Asperger syndrome includes Albert Einstein, Isaac Asimov, and Carl Sagan." I'm afraid I must refute the last example. Carl and I were classmates at the University of Chicago, where we both earned our undergraduate and graduate degrees, and I was the best man at his marriage to Lynn neé Alexander. Carl was warm, ambitious, charismatic, and enthusiastic about many things. He was influential in my choosing astronomy as a career, and I treasure the time we spent together. From what I know of the manifestations of Asperger syndrome through reading and contact with persons diagnosed to have it, Carl showed not a trace.

Peter Pesch
Beachwood, Ohio

Out, Darn Spot

I enjoyed Thomas Dobbins's column about the illusionary nature of the Terby White Spot (*S&T*: May 2014, p. 54). Despite the explanation that the illusion can manifest itself both visually and pictorially, the Terby White Spot still appears quite prominent in the Saturn image in Dobbins's article. For those of us who can't reconcile our eye with Dobbins's explanation, here's an easy way to demonstrate the false nature of the Terby White Spot on this image.

Obtain a white 3×5 index card (or a sheet of white paper) and align the left edge of the white paper with the right edge of the spot. Once aligned, the Terby White Spot will disappear as if by magic. This is because the white color of the paper removes the contrast between the edge of the illuminated portion of the ring and the shadowed portion of the ring.

Now, slowly slide the index card to the right. As soon as you uncover a sufficient amount of black between the ring and the paper, the Terby White Spot will magically reappear. It is truly an illusion.

Frank Ridolfo
Bloomfield, Connecticut

Quasars with a Backyard Radio Scope

The March 2014 issue included an article on an amateur program of observing quasars with optical telescopes ("New Jersey Quasar Quest," p. 34). Although I have seen the brightest quasar 3C 273 in my 8-inch SCT, my own quasar observation program consists of detecting radio-loud quasars with an amateur radio telescope.

My backyard radio telescope consists of two 10-foot TVRO dishes operating as a phase-switched interferometer in a 4-MHz frequency band near 1420 MHz. The output of my radio telescope is an interferogram record stored in a personal computer. So far, I have detected 11 quasars, including the loudest one, 3C 273, with a flux density of 46 janskys, and 3C 298, with a flux density of 6 janskys. (The jansky is a unit of flux density equal to 10^{-26} watts per square meter per hertz). For the fainter quasars, I have to average multiple interferograms together in order to achieve a signal-to-noise ratio adequate for detection.

The quasar 3C 273 lies at a redshift of 0.16 (light travel time of 2 billion years), whereas 3C 298 has a redshift of 1.44 (light travel time of 9.3 billion years). It is mind-boggling to me to realize that the energy from these quasars has been traveling through space at the speed of light for billions of years before arriving at my backyard.

Jim Abshier
Via e-mail

Invitation to Seagrave Centennial

Skyscrapers, Inc., the amateur astronomical society of Rhode Island, is proud to announce the celebration of the 100th anniversary of Seagrave Memorial Observatory in North Scituate during our annual AstroAssembly 2014 convention (September 26–27).

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

Published letters may be edited for clarity and brevity. Due to the volume of mail, not all letters can receive personal responses.

The observatory originally belonged to Frank Evans Seagrave (1860–1934), a famous Providence astronomer. The society has served as the observatory's steward since 1936. It includes four telescopes, among them the refurbished 8-inch Alvan Clark refractor for which Seagrave built the observatory. Interested readers can explore the rich history and find out more about the event at the society's website **www.theskyscrapers.org**.

David A. Huestis
North Scituate, Rhode Island

75, 50 & 25 Years Ago

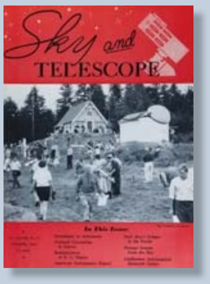
Roger W. Sinnott

September-October 1939

Sad Centennial "On August 19, 1839, the Pulkov[o] Observatory was officially dedicated in the presence of the Czar of all the Russias. The importance of this event . . . still looms large[:] The double-star work and star-position catalogues of the Struves, Belopolsky's spectroscopic contributions, and many others are preserved in the literature. . . .

"Other countries of the world became jealous of Russia's scientific fame and sought to emulate and surpass it. In France [astronomer François] Arago pointed out that the accomplishments in the land of the free were being surpassed by those in the 'land of the serfs.' John Quincy Adams impassionately echoed the phrase in this country, urging the establishment of a national observatory."

Rumors of dire events at Pulkovo under Soviet rule might have inspired this editorial tribute. Decades would pass before full details emerged of the ghastly fates of astronomers during the Great Purges under Joseph Stalin, which lasted from 1936 to 1938 (see the 1989 quotation).

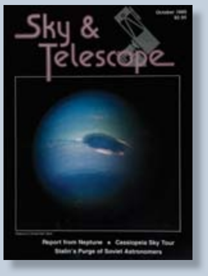


October 1964

Sounds from Meteors "There has been consistently, throughout historical times, a minority of fireball observers who claim to have heard sounds simultaneously with seeing a meteor's light. These have been described in many different languages as hissing, swishing, whizzing, whirring, buzzing, and crackling. Since the distance between the observer and the fireball is too large . . . for ordinary sound transmission, these noises have been called 'anomalous' because they appear to be transmitted at the speed of light. . . .

"One of the few recent meteors that engendered anomalous sound reports was the 'Mad Ann' fireball of September 1, 1962, seen in West Virginia, Virginia, and Ohio. [An] observer near Covington stated in an interview that a hissing noise made him look up and see the fireball."

Mary Romig and Donald Lamar (RAND Corporation) noted that "electrophonic hearing" might be involved, in which a sensitive observer picks up radio-frequency radiation (perhaps because the electromagnetic waves cause nearby objects to vibrate). In 2002 a team led by Goran Zgrablić (University of Zagreb, Croatia) reported the instrumental detection of short, low-frequency sounds from two Leonid fireballs they had observed from Mongolia.



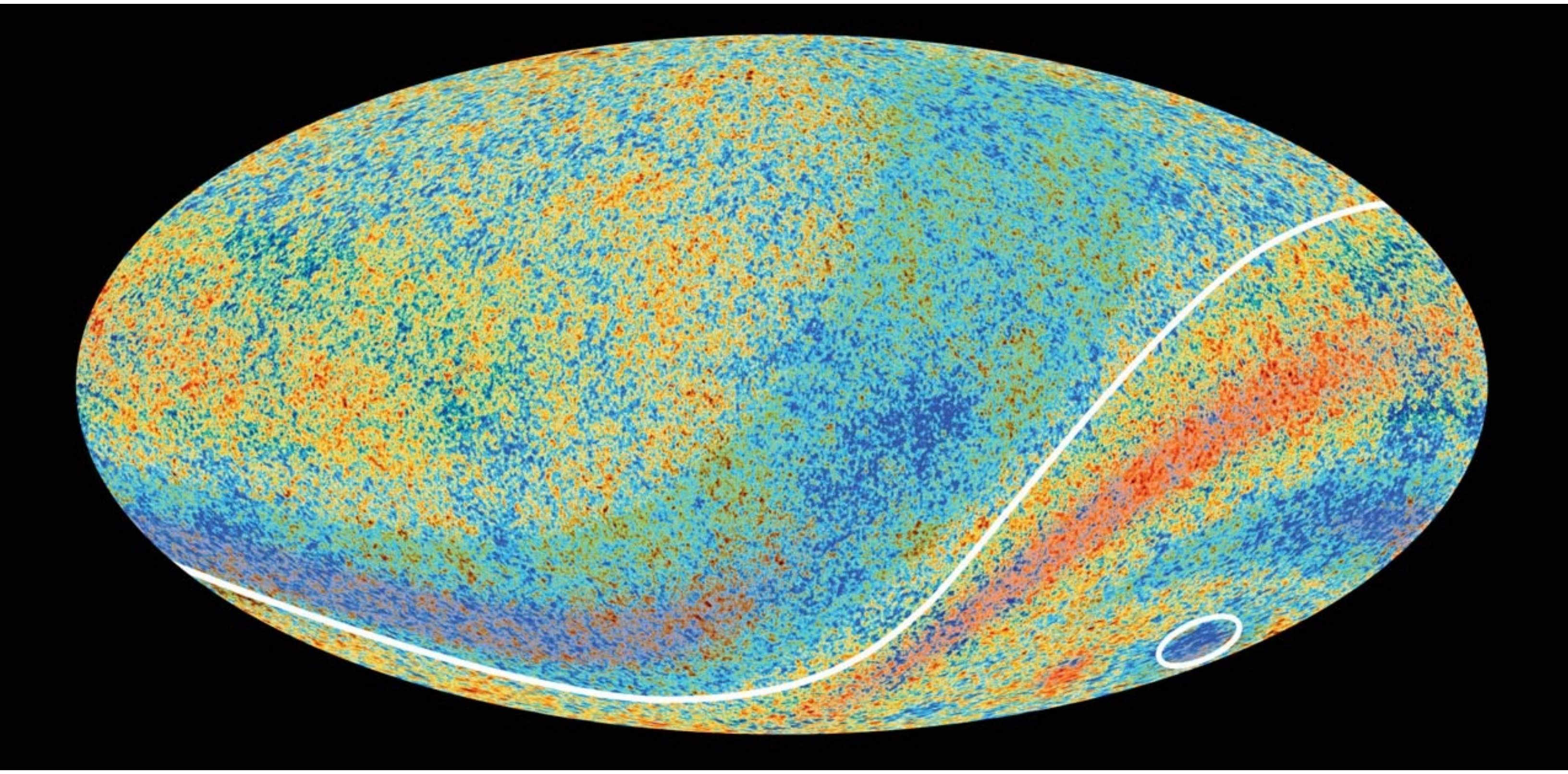
October 1989

Pulkovo Purge "According to [Iosif S.] Shklovskii, 'Pulkovo Observatory had long been a sore spot in the eyes of the Leningrad authorities.' The astronomers there were perceived as too proud and independent. Their frequent travels to foreign observatories and conferences resulted in many 'suspicious' contacts in the United States and Europe. . . .

"Overall some 25 to 30 astronomers — 10 to 15 percent of the Soviet Union's total and nearly 50 percent of those in Leningrad — were arrested between March, 1936, and July, 1937. Almost all of them came from the Pulkovo or Tashkent observatories or from the Astronomical Institute. . . . [M]ost astronomers taken into custody in 1936 and 1937 never returned."

Robert A. McCutcheon's landmark feature detailed for the first time the horrors that had befallen many astronomers and their families.

COSMOLOGY | Shadow of a Supervoid



ESA / PLANCK COLLABORATION

The Cold Spot (circled) in the cosmic microwave background appears in observations from both the WMAP and Planck spacecraft. It is one of several anomalies (also shown in the Planck data above is the "hemispheric asymmetry").

Cosmologists might have discovered the source of a mysterious cold spot in the cosmic microwave background (CMB): an enormous supervoid in the universe's web of galaxies.

Generally, the temperature variations in the CMB grew from primordial density variations that inflation stretched to gigantic scales. But during its nine-year stint mapping the CMB, NASA's Wilkinson Microwave Anisotropy Probe (WMAP) revealed several anomalies that inflation is unlikely to have created. One of the most infamous is the so-called Cold Spot, a large region spanning 10° in Eridanus that is about four times cooler than the average CMB fluctuation.

It's statistically unlikely that the Cold Spot originates from primordial density variations. And if density variations *are* to blame, then the Cold Spot's existence could pose a challenge to the favored model of inflation.

So cosmologists have sought alternate explanations. One of these is a supervoid, a large, comparatively empty region between galaxy clusters in the universe's large-scale cosmic web. As light travels through the gravitational hills and valleys created in the fabric of spacetime by cosmic structures, the photons lose or gain energy — lose if they climb the hill of a void, gain if they descend into a cluster's valley. But the expansion of space flattens this gravitational landscape. Photons will climb down a hill or out of a valley that's smaller than it was at the outset, ending up with a net loss or gain of energy in what's called the Integrated Sachs-Wolfe effect.

Cosmologists had therefore suggested that a supervoid spanning hundreds of millions of light-years could cause the Cold Spot: the energy lost would effectively create a cool fingerprint on the CMB. But previous void searches had come up empty — in part because they had searched the distant, early universe.

Now István Szapudi (University of Hawaii) and colleagues have analyzed galaxies in the WISE-2MASS catalog to discover a vast supervoid that might be responsible for the Cold Spot.

Szapudi's team combined data from the WISE-2MASS catalog and Pan-STARRS1, a robotic telescope that images the full sky once per week. They mapped relatively nearby galaxies lying within the Cold Spot's boundaries on the sky and found that the density of galaxies existing 11.1 billion years after the Big Bang decreased near the center of the Cold Spot.

The supervoid appears to be roughly

continued on page 14

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continued from page 12

spherical, though its internal structure might be more complex, containing smaller voids and filaments, the team reported earlier this year at the Moriond Cosmology Conference in Italy. The researchers estimate that the supervoid, possibly the largest yet discovered, spans about 900 million light-years. According to Mark Neyrinck (Johns Hopkins University), this is "the clearest evidence yet that there is a supervoid that substantially affects the cosmic microwave background."

But there are still a few unanswered questions. One is the strength of a supervoid's impact on the CMB: the initial calculation for the newly spotted supervoid does not fully account for the CMB temperature drop of the Cold Spot.

Another question is how prevalent supervoids are. If a larger sky survey reveals that they are fairly common, then a single supervoid would be a less likely explanation for the anomaly. "With a larger sample, it would be clearer that this supervoid is the only thing on the sky capable of making a big imprint like the Cold Spot," explains Neyrinck. "This would make the issue basically indisputable."

■ **MARIA TEMMING**

EXOPLANETS | Debated World Doesn't Exist

A new analysis of stellar activity for the *M* dwarf star Gliese 581 confirms that its planet d is likely a ghost in the data.

GJ 581 has been a poster child for multiplanet systems for several years. In 2005 a Geneva-led team using the ESO's HARPS spectrograph discovered the first planet, b; in 2007 they reported c and d, and in 2009 e. All these planets have orbits smaller than Mercury's, but around a star 30% the size of the Sun and 60% as hot.

A second team used a combination of observations from HARPS and Keck's HIRES spectrograph to suggest the presence of two more planets, f and g, but these were quickly questioned and have basically fallen away.

Some astronomers have also questioned whether d actually exists, notably Roman Baluev (Pulkovo Observatory, Russia), who in 2012 did a careful analysis of noise in the observations and raised a red flag. But analyses of stellar activity turned up no big starspots that could masquerade as a planet, and d stayed in the catalogs — and on the list of potentially habitable planets, because much of its predicted orbit fell in GJ 581's habitable zone.

The new work by Paul Robertson (Penn State) and colleagues makes clear that d needs the boot, too. The team took another look at the HARPS spectra, focusing on hints of stellar activity from hydrogen-alpha emission. This emission comes from hydrogen atoms being hit by particles accelerated along magnetic field lines in the star's atmosphere. Stronger magnetic fields mean more acceleration, which means more emission.

But stronger magnetic fields also mean more stellar activity, which can create shifts in starlight that look much like the radial-velocity wobbles induced by an orbiting planet.

Robertson's team found that during times of higher magnetic activity, the strength of d's signal went up. When the star was less active, the signal weakened.

They also found that the star's rotational period is twice as long as planet d's orbital period of 66 Earth days. That suggests d's signal is from the star itself, the team reported online July 3rd in *Science*.

Taken together, the observations support only one likely conclusion. "I think the evidence shown by Robertson et al. is strong enough to remove GJ 581d from the list of exoplanets," says Xavier Bonfils (Grenoble Observatory, France), who coauthored the original discovery paper.

Although Bonfils and his colleagues searched for starspots, GJ 581 appeared to be starspot-free during their observations. But Robertson's team found that, although no big, dark blemishes showed up on the star's surface, the H-alpha emission clearly indicates that the star had magnetically active regions at the time. It's these regions that mucked up the spectra.

Stellar activity is a known problem with searches for exoplanets, particularly around *M* dwarfs. Given the signal strengths involved, Bonfils thinks that only a few reported exoplanets at most might prove to be from active regions like those Robertson's team found. Accounting for these shifts in starlight will prove especially important for low-mass planets in moderate to long orbital periods, he adds.

■ **CAMILLE M. CARLISLE**

BLACK HOLES | Gas Streamer Eclipses AGN

Observations of the Seyfert galaxy NGC 5548 show a new gas streamer flowing from near its supermassive black hole, astronomers report in the July 4th *Science*. Many active galactic nuclei (AGN) spew gaseous outflows, but NGC 5548 is the first whose streamer has moved into our line of sight.

Previous high-resolution X-ray and ultraviolet observations showed a persistent outflow of gas from this AGN, which is expected for these objects. But while monitoring NGC 5548 last June, Jelle Kaastra (Netherlands Institute for Space Research) and colleagues detected a new, clumpy stream of ionized gas that was blocking 90% of the AGN's X-ray emission. This gas streamer probably originates near the accretion disk, mere light-days from the central black hole, and flows outward at 1,000 kilometers per second (2 million mph). Kaastra's team estimates that the outflow has lasted between 2½ and 6 years.

As matter spirals into a black hole, it emits ultraviolet radiation that can excite surrounding gas and induce powerful outward-bound winds. But if the gas is too saturated by X-ray radiation, then it gets "cooked" and loses its ability to absorb the ultraviolet radiation that launches it away. The new streamer in NGC 5548 shields surrounding gas from the AGN's X-ray radiation, allowing the powerful winds seen to come from the AGN.

Although the winds billowing from NGC 5548 are not strong enough to significantly affect the galaxy's evolution, this study improves our understanding of how shielding mechanisms could influence galaxies with more powerful AGNs.

■ **MARIA TEMMING**

NGC 6514 (M20) The Trifid Nebula courtesy of Jay GaBany: RCOS 20- inch, Apogee Alta U16M, Astrodon E-Series filters; 360 minutes Luminance, 120 minutes Red, 120 minutes Green, 120 minutes Blue (All 1X1)

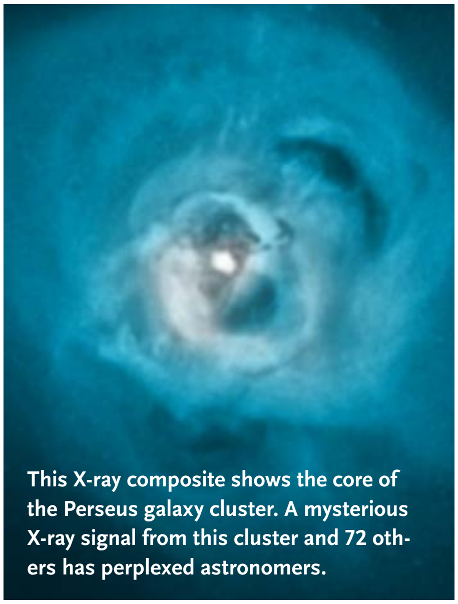
GALAXIES | Mysterious X-rays Hint at Dark Matter

Two teams of astronomers have discovered an inexplicable spike in X-ray emission from galaxy clusters. Using independent methods and observations, Esra Bulbul (Harvard-Smithsonian Center for Astrophysics and NASA Goddard) and Alexey Boyarsky (Leiden University, The Netherlands) and their teams have found a previously undiscovered spectral line in long-exposure observations of more than 70 clusters.

Galaxy clusters are vast repositories of hot, ionized gas. Exploding stars, which forge heavy elements, eject the gas from the galaxies. Over billions of years, this heavy-element-contaminated plasma collects between galaxies and glows brightly in X-rays.

Bulbul's team collected and combined archival XMM-Newton observations of 73 galaxy clusters, ranging from the brightest — the nearby Perseus Cluster — to fainter and faraway clusters. Their careful analysis, which smeared out instrumental noise, revealed a statistically significant, if somewhat ratty-looking, bump with an energy of roughly 3,550 electron volts (3.55 keV). The bump remains even when they divide the stacked spectrum from the 73 clusters into sub-samples and redo their measurements.

The team checked archival observations from Chandra, confirming the same detection with a different instrument. And Boyarsky's team sees the same bump at the same energy in a separate, not-yet-published study of the Andromeda Galaxy and the Perseus Cluster.



This X-ray composite shows the core of the Perseus galaxy cluster. A mysterious X-ray signal from this cluster and 72 others has perplexed astronomers.

CHANDRA: NASA / CXC / SAO / ESRA BULBUL ET AL.; XMM: ESA

Yet there shouldn't be a bump at that energy, according to known plasma physics. The most likely "normal" explanation, a super-strong line from the element argon, is "physically impossible," Bulbul says. To produce the 3.55 keV bump, argon would also have to produce a line at 3.12 keV that is 30 times stronger than observed.

Even before the *Astrophysical Journal* published Bulbul's results in its June 10th issue, dozens of papers flooded the arXiv online preprint repository, serving up various theories to explain the mysterious X-ray spectral line. Nearly all of them turned to dark matter.

Why? Galaxy clusters are the largest gravitationally bound structures in the universe. That means they're one of the best places to search for dark matter, which reveals itself by its gravitational interactions with ordinary matter.

The proposed dark matter explanations range from annihilating sterile neutrinos to what's called eXciting Dark Matter (XDM). In the XDM model, dark matter has its own forces that act only on it and not on ordinary matter. The interaction of XDM particles expected in hot, high-density environments might explain why the still-forming Virgo Cluster doesn't show evidence of the 3.55-keV bump: dark matter hasn't had time to settle to its center.

"We know that the dark matter explanation is a long shot, but the payoff would be huge if we're right," Bulbul says. "So we're going to keep testing this interpretation and see where it takes us."

■ **MONICA YOUNG**

IN BRIEF

Black Hole Triplet Found. On July 3rd in *Nature*, astronomers reported that the double AGN SDSS J1502+1115 is actually a highly compact triple active galactic nucleus (AGN). Such systems have been predicted to form in galactic mergers, but only a few have been observed, so astronomers assumed multi-AGN cores were rare. Using very long baseline interferometry, Roger Deane (University of Cape Town, South Africa) and colleagues found their black hole trio after searching only six galaxies, indicating that these systems might be more common than previously thought. The inner two black holes are about 450 light-years apart and lie 24,000 light-years from the third. Twists found in one black hole's jet confirm that looking for warped jets might reveal binaries that astronomers can't otherwise resolve.

■ **MARIA TEMMING**

NASA Amasses Asteroid Targets. As of late June, NASA had found six "valid candidates" that meet rendezvous criteria for its mission to find, retrieve, and explore an asteroid (*S&T*: July 2013, p. 12). For Option A, which aims to bag a small asteroid and bring it back to lunar retrograde orbit, mission planners have three candidates: 2009 BD, 2013 EC_{20}, and 2011 MD. Each candidate is less than about 10 meters across and spins less than once every 2 minutes. The other three candidates are for Option B, which involves retrieving a boulder from a larger asteroid. These are 25143 Itokawa, 2008 EV_5, and 101955 Bennu, the target of the upcoming OSIRIS-Rex mission. Ongoing searches might find an additional two to three candidates per year until 2018, when the agency will have to decide both which option they're going with and which asteroid they'll target for a projected 2019 launch.

■ **MONICA YOUNG**

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OBIT | Bill Bradfield, Comet Hunter Extraordinaire (1927–2014)

William A. Bradfield, the mild-mannered comet hunter of South Australia, died on June 9, 2014, at age 86. His remarkable tally of 18 comets, each discovered visually and credited to him alone, puts him among the most prolific and elite comet discoverers of all time.

Yet Bradfield didn't even take up comet hunting until his mid-40s. He was only an off-and-on amateur astronomer until 1970, when Comet Bennett vaulted into the predawn sky. It got him thinking that he could find a comet, too.

By 1976 Bradfield was already a celebrity, having made six comet finds in as many years. A detailed account of the visit *S&T*'s Dennis di Cicco and I paid him that October appears in the April 1977 issue. His comet-hunting telescope had been cobbled together by a fellow amateur and was equipped with a giant, 6-inch Dallmeyer camera lens, made a century earlier for portrait photography. A war-surplus Erfle eyepiece provided 26×. With a 2-foot lever arm the instrument could be raised or lowered to let the observer stand comfortably at the eyepiece.

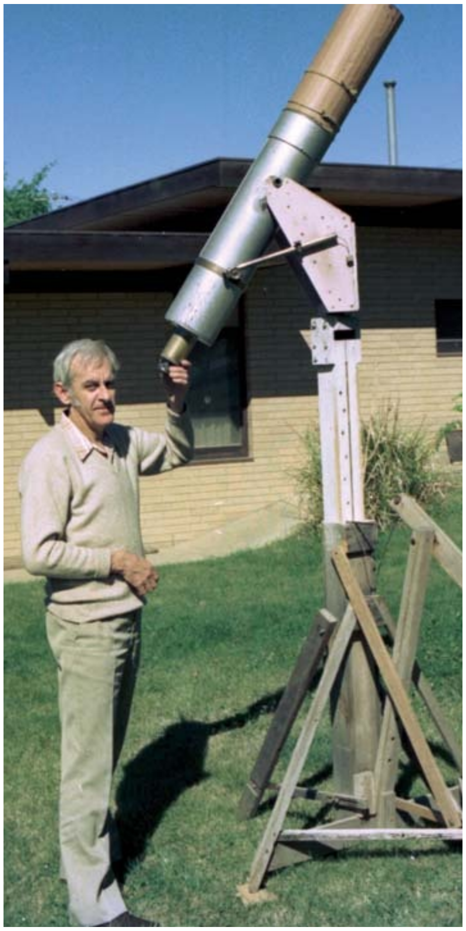
Although none of his comets gave us the jaw-dropping spectacle of a Comet Bennett, several did reach naked-eye visibility and were of scientific interest, too. Spectra of C/1974 C1, for example, were among the first to show bands of ionized water in a comet.

Bradfield found his last comet in 2004, and it was his best. After it rounded the Sun, C/2004 F4 entered the morning sky. As comet expert John Bortle recalls, "For a week or so it remained an extraordinary sight, with a bright 3rd-magnitude starlike head and a very long, narrow, and wispy tail that could be traced for 12° or more."

None of Bradfield's 18 comets will return to the Sun's vicinity anytime soon. We are not likely, either, to see another visual comet hunter as persistent, clever, and successful as Bill Bradfield.

■ **ROGER W. SINNOTT**

To read the full obituary, please visit skypub.com/bradfieldobit.



S&T: DENNIS DI CICCO

Bill Bradfield, seen with his unusual comet-seeking telescope in Australia in 1976.

IN BRIEF

Titan Sheds Light on Exoplanets. Cassini observations of Saturn's largest moon suggest that astronomers have oversimplified how a thick layer of haze might affect an exoplanet's appearance, Tyler Robinson (NASA Ames Research Center) and colleagues report in the June 24th *Proceedings of the National Academy of Sciences*. Astronomers study the atmospheres of distant worlds by observing the chemical fingerprints that the exoplanet's atmosphere imprints on starlight that passes through it. But a few well-studied exoplanets show a lack of spectral features. Just as clouds on Earth appear white because they absorb and scatter light equally across a wide wavelength range, these enigmatic exoplanets likely have a high-altitude layer of clouds or haze. To better study clouds' effects, the team used Cassini to observe Titan as the hazy moon passed between the Sun and the spacecraft. Surprisingly, the team did not see the featureless spectrum they expected. Instead, Titan's haze extinguished bluer light much more effectively than redder light, creating a complex spectrum that carries more information at longer wavelengths. So it appears future telescopes might have better luck peering through planets' clouds at redder colors.

■ **SHANNON HALL**

Sea Changes on Saturnian Moon. Fleeting radar features in a sea in Titan's northern hemisphere are tantalizing evidence of seasonal changes. Thus far the Cassini spacecraft has seen only smooth lakes, but planetary scientists suspected that, as summer approaches, wind speeds might rise and blow ripples across the ethane-dominated seas. Writing in *Nature Geoscience*, Jason Hofgartner (Cornell University) and colleagues report the detection of a small assemblage of *something* that appeared and disappeared off the coast of a peninsula in the northern sea Ligeia Mare in 2013. To the eye, the transient features look kind of like an extension of the peninsula, but they don't match what would be expected for image artifacts or terrain momentarily revealed by tides. Instead, the most likely explanations are transitory phenomena such as waves, bubbles (perhaps of gas released from the sea floor thanks to changing temperatures), or the Titan version of silt suspended or floating in the sea. ✦

■ **CAMILLE M. CARLISLE**

Battle of the Titans:

The Milky Way vs. Andromeda

The Milky Way and Andromeda galaxies vie for Local Group supremacy.

MICHAEL RICH

Astronomers have long known that the Milky Way and Andromeda galaxies are approaching each other at 300 kilometers per second. Thanks to the Hubble Space Telescope's exacting measurements of the relative motion of the two galaxies, it's a virtual certainty they will engage in a massive prizefight 3 to 5 billion years hence, with the result being a merger that will ultimately create a giant red elliptical galaxy. Similar bouts can be seen in progress right now: interacting spirals such as the Mice and the Antennae that will someday merge into ellipticals.

There will be no knockout in our contest, but it's interesting to consider how the two champions match up. Indeed, it's a surprisingly even competition, even though our contestants look quite different at first glance.

Our galactic neighborhood, the Local Group, is a relatively small cluster of galaxies about 6 million light-years across. It's dominated by the Milky Way and Andromeda (M31), whose centers lie 2.5 million light-years apart. Our cluster hosts about 100 far less massive galaxies, including M33 and the Magellanic Clouds. Think of the Milky Way and Andromeda as two major cities, flanked by numerous small suburbs — the dwarf galaxy members of the Local Group.

Sizing Up the Contestants

In our corner stands the Milky Way Galaxy. With its two major star-forming spiral arms and ancient central bar weighing in at 20 billion Suns, the Milky Way rules a retinue of nearly 160 globular clusters and 26 known dwarf galaxies. These include the prominent Magellanic Clouds, whose mass including their dark matter may be as high as 10% that of the Milky Way — respectable galaxies in their own right, with their own systems of globulars (*S&T:* Oct. 2012, p. 28). Both the Large and Small Magellanic Clouds are very likely newcomers to the Milky Way's environs, and both are wreathed in a stream of hydrogen gas (the Magellanic Stream) that winds around our galaxy.

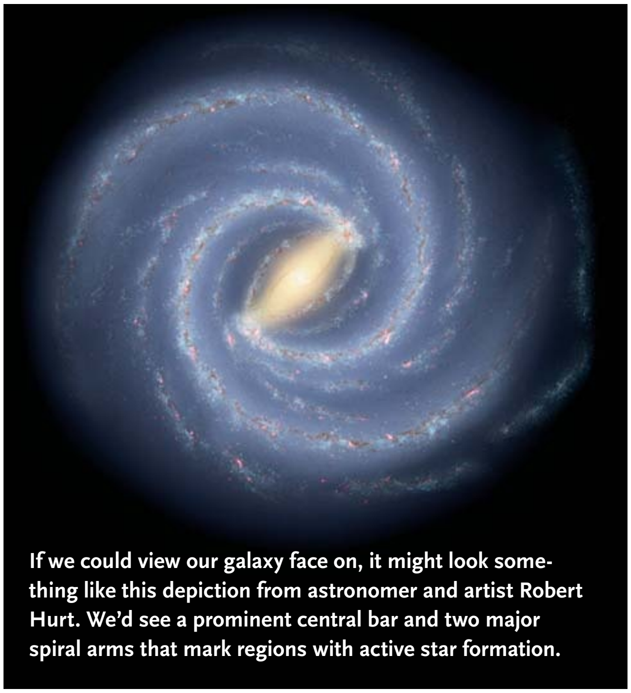
The Sagittarius Dwarf Spheroidal Galaxy has mistakenly challenged the Milky Way: no bantamweight beats a heavyweight. Sagittarius has wrapped itself around our galaxy, with its core some 60,000 light-years from our galaxy's center. Sagittarius's stars will ultimately dissolve into the Milky Way's halo in a process that has probably repeated itself many times over the past 10 billion years. In dominating the Sagittarius dwarf, the Milky Way doesn't even have to lift a glove: gravity is delivering the blows in the form of tides (see "Tides," page 22). Numerous other dwarfs have suffered the same fate, and their remaining tidal streams litter the Milky Way's environs.

M31 features a whopping 500 globular clusters. It has three noteworthy galaxy companions, each roughly as massive as the Magellanic Clouds: the dwarf compact elliptical M32, the dwarf elliptical M110 (also known as NGC 205), and the spiral M33. In addition, M31 has nearly 40 identified dwarf satellite galaxies, with potentially many more to be discovered.

It appears that M32 has punched through the disk of M31 at least once. Although not scoring a knockout, this blow very likely cost M31 its grand-design spiral structure, leaving instead two rings of star formation, including the prominent Ring of Fire that surrounds the galaxy's nucleus at a distance of 30,000 light-years. First suggested as a possibility in 2006, recent simulations strongly suggest that the Ring of Fire is a consequence of M32 plowing through M31's disk 210 million years ago and triggering density waves in the gas that led to a burst of star formation.

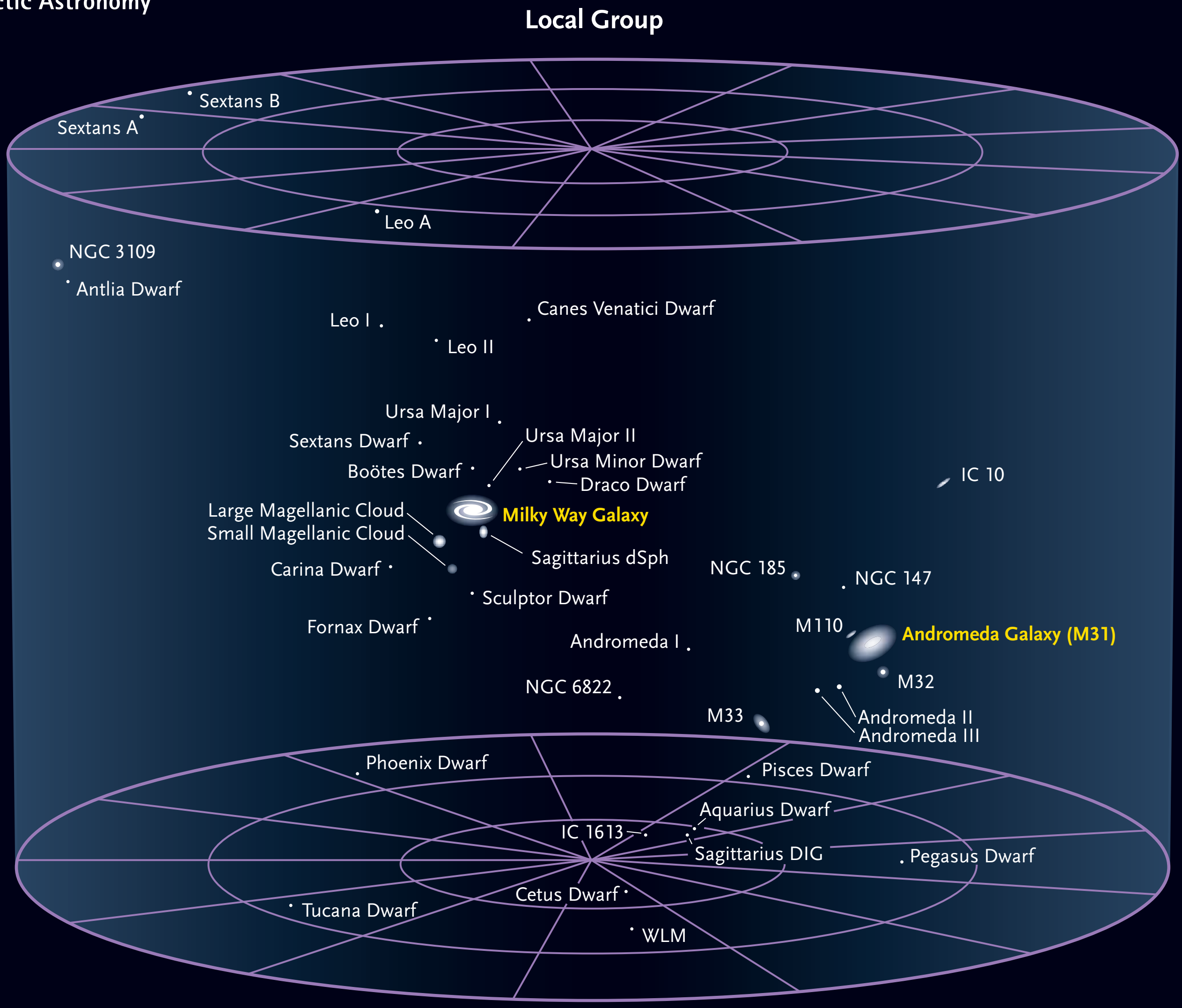
Astronomers have weighed both contestants by applying Kepler's law to the motions of each galaxy's most distant satellites. In terms of *total* mass — 90% or more in the form of dark matter — both galaxies appear similar to the level of accuracy that we can measure: slightly greater than 10^{12} solar masses. Our perspective within the Milky Way makes these measurements somewhat more difficult, and determining the total mass (including the dark matter) of either galaxy requires painstaking measurements of the motions and velocities of a relatively small number of distant satellite galaxies as well as mod-

The Milky Way and Andromeda galaxies are moving inexorably closer, and will collide in 3 to 5 billion years. This photo illustration depicts M31 and the Milky Way's galactic plane looming large in the night sky when the two galaxies have come close. By this time, the expanding Sun will have roasted Earth to a cinder. NASA / ESA / Z. LEVAY / R. VAN DER MAREL (STSCI) / T. HALLAS / A. MELLINGER



If we could view our galaxy face on, it might look something like this depiction from astronomer and artist Robert Hurt. We'd see a prominent central bar and two major spiral arms that mark regions with active star formation.

NASA / JPL-CALTECH / R. HURT (SSC-CALTECH)



S&T: LEAH TISCIONE

The Milky Way and M31 dominate the Local Group, depicted in this illustration of its brightest members. This small cluster has roughly 100 galaxies stretching across 6 million light-years. The two big boys contain the large majority of the total stellar mass.

Tides

Earth is affected by tides that raise the seas twice a day. But as manifestations of gravity, tides affect galaxies too. Gravity is a "central force" — the force is a vector, having a magnitude and a direction that always points toward the center of mass. In our daily experience of gravity, we feel the same gravitational force throughout our bodies. But for very large objects in a gravitational field, such as a satellite galaxy orbiting our Milky Way, or eventually, when M31 and the Milky Way come closer, one side feels a much stronger amount of force than the other, giving rise to a stretch-and-squeeze effect. On galactic scales, the difference in gravitational force can cause stars to wander away from the parental herd. It's this tidal force that's tearing apart the Sagittarius Dwarf Spheroidal Galaxy, and that ultimately plays a major role in disassembling great galaxies as they collide.

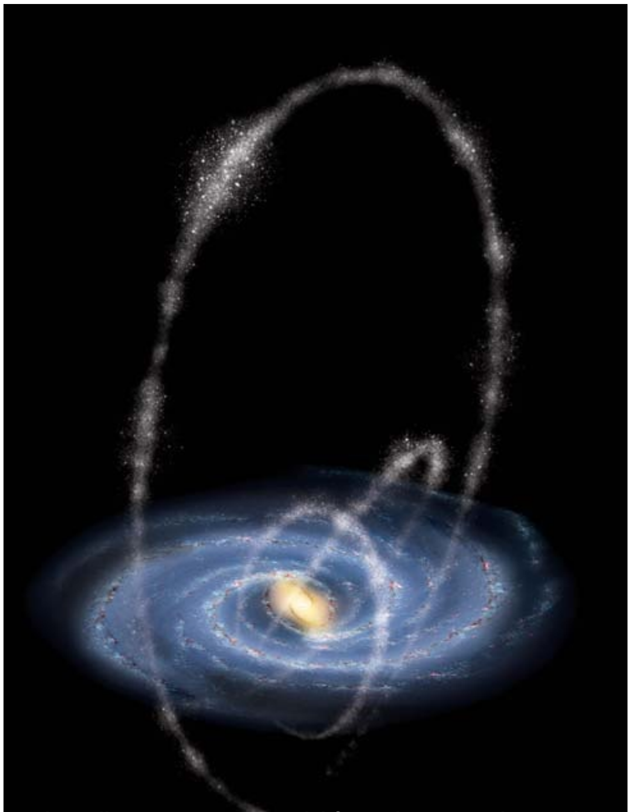
eling the motions of galaxies in an expanding universe. Astronomers are still debating the numbers; depending on the Sagittarius dwarf galaxy's orbit, the Milky Way's mass might be a factor of two lower than the canonical 10^{12} Suns.

In terms of sheer size and brightness, M31 has the edge. It's challenging to estimate the Milky Way's total brightness from a vantage point within it, but it has an absolute visual magnitude of about –20.5. Best current estimates find M31 to have about twice the brightness in stars, making it roughly one magnitude brighter. The easily visible part of M31's disk of stars and gas is a whopping 150,000 light-years across compared to the Milky Way's still impressive 90,000-light-year-diameter disk. Both galaxies have halos of stars and dark matter that extend far beyond the visible disk of stars. The stellar mass of M31's

M31: ROBERT GENDLER; INSET: NASA / MICHAEL RICH (COLUMBIA UNIV.), ET AL.

M31 has about twice as many stars as our Milky Way and a larger visible disk, but it lacks spiral arms. The satellite galaxies M32 and M110 are to M31's upper center and lower left.

Left: The author used Hubble to capture the Andromeda globular cluster G1, the largest globular in the Local Group. G1 has a black hole of about 20,000 solar masses, and is the only globular with strong evidence for a massive black hole.



The Milky Way's immense tidal forces have ripped apart the Sagittarius Spheroidal Dwarf Galaxy and stretched it into a long stream of stars that wraps around our galaxy. This process has played itself out tens of times with other dwarfs, adding about 50 million stars to the Milky Way's halo.

S&T: GREGG DINDERMAN

If we could view the Milky Way and M31 edge on from a large distance, we'd see galaxies that resemble NGC 4710 (*below*) and M104 (*below, facing page*), respectively. Like the Milky Way, NGC 4710 has a central bar, which resembles a peanut from the side. Note the faint X-shape flare. M31 has a more spherical bulge, like M104 (the Sombrero Galaxy), although M104's bulge is much larger and more extreme. Both images were taken by Hubble.

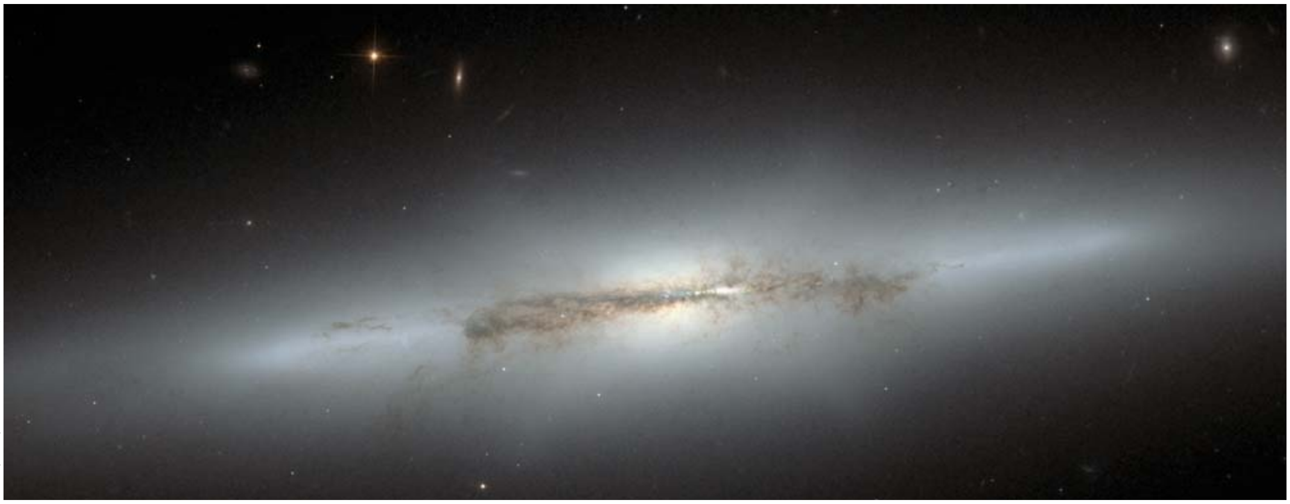
disk and bulge totals around 100 billion solar masses; the Milky Way's total is around 50 billion solar masses. M31 has 400 to 600 billion stars, roughly twice as many as the Milky Way.

Central Regions Compared

One of the most striking differences is the appearance of their central bulges. If we could see our Milky Way face on from "above," we'd see a bar that hosts an ancient stellar system whose members surprisingly contain, on average, roughly the same heavy-element abundance as our Sun. Considering both the bar's shape and stellar motions, theoretical modeling suggests that it buckled under its own gravity from a pre-existing massive protodisk that formed early in the Milky Way's history. As the stars orbited and interacted through mutual gravitation, the disk's central region evolved into a flattened, football-shaped structure, ultimately forming a central bar.

One mystery is how our Milky Way was able to evolve as a pure disk galaxy. The widely favored cold dark matter theory of galaxy formation posits that galaxies have grown in size through merging clumps of dark matter. In the early universe, these clumps also contained gas and stars that contributed to the fueling of the star-formation bursts that built galaxies, especially their bulges. But in the case of our Milky Way and other familiar spiral galaxies such as NGC 4565, the bulge appears to have formed from the disk. From the side, these bulges have a peanut shape, and viewed face on, they appear as bars. It's now known that our galaxy also has X-shaped lobes, a feature common in galaxies with prominent bars.

In contrast, M31's bulge looks more like an elliptical galaxy and has a feeble star-formation rate. Central galactic bulges appear to come in two flavors: bars such as the Milky Way's, and mini-elliptical galaxies such as M31's. The Sombrero (M104) has an extreme case of a classical "round" bulge, and that's the kind M31 appears to host. M31's bulge is about twice as massive as the Milky Way's.



NASA / ESA / PAUL GOUDFROOIJ (STSCI)

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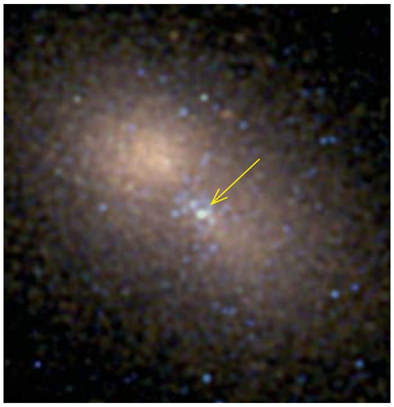


TOD LAUER (NOAO) / NASA / ESA

***Far left*: This remarkable image taken with one of the 10-meter Keck telescopes shows the Milky Way's central region in infrared light. Astronomers are using adaptive optics to study the orbits of dozens of stars caught in the grip of Sagittarius A* (arrowed), a strong radio source that marks the location of a 4.2-million-solar-mass black hole. Most of the bright stars in this image are orbiting the black hole at close range, whereas most of the fainter stars are in the foreground or background.**

***Near left:* This Hubble image resolves M31's central region. Strangely, the brightest spot in visible light is offset 5 light-years from the central black hole (arrowed), which contains a whopping 100 million solar masses.**

Using image-sharpening adaptive optics on the world's largest telescopes and (in the case of M31) the Hubble Space Telescope, astronomers have found overwhelming evidence that the Milky Way and Andromeda both host supermassive black holes at their centers. The Milky Way's central black hole weighs in at 4.2 million Suns. Independent teams led by my UCLA colleague Andrea Ghez, and Reinhold Genzel (Max Planck Institute for Extraterrestrial Physics, Germany), have measured this mass by determining the velocities of individual stars orbiting the black hole and then applying Kepler's laws.

M31's central black hole easily wins this contest, however. Best estimates of M31's black hole from Hubble observations place it at 100 million Suns, roughly 25 times more massive than our Milky Way's beast. Its high measured mass raises the possibility that M31 in its youth was among the most spectacular of cosmic heavyweights: a quasar. Although not in the billion-solar-mass class of central black holes in giant elliptical galaxies such as M87, Andromeda's monster likely blazed brightly in the first 2 billion years of its life, fueled by the ample gas from which the bulge formed.

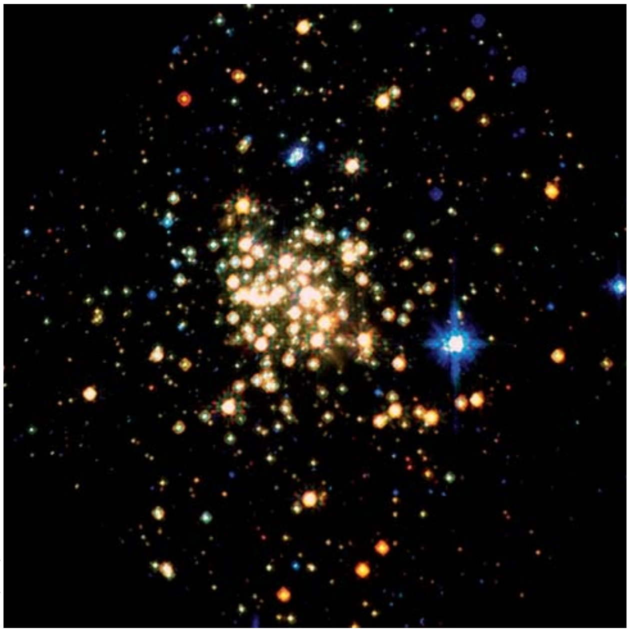
Yet despite the black hole's high mass, M31's central realms are quiet, except for a small cluster of young stars and a little gas. M31's nucleus is also quite peculiar because it appears to be double. The brightest peak in visible light is not where the black hole and a small young star cluster are located. Instead, it's 5 light-years away. Theoretical models suggest that this "false peak" resides in a disk of stars that orbit the black hole.

Unlike M31, the Milky Way's central region is abuzz with star formation, as exhibited by the recently minted Arches and Quintuplet star clusters. The Arches has some 100 stars weighing up to 100 solar masses and shining with 1 million or more solar luminosities. These behemoths are only about 2 million years old. The galactic center is also the site of twisted and complex magnetic

Andromeda's Satellite Plane

I'm a member of a team led by Rodrigo Ibata (Strasbourg Observatory, France) that has measured distances and velocities of M31 dwarf galaxies using red giants. We recently showed that 13 of the dwarfs are arrayed in a narrow plane 1.3 million light-years across. Nothing like this structure is known around the Milky Way, and theories of galaxy formation struggle to explain its existence.

NASA / HUBBLE HERITAGE TEAM (STSCI / AURA)



NASA / ESA / DON FIGER (STSCI) (2)

The Milky Way's central region features two large clusters of massive, highly luminous young stars, the Arches (*left*) and Quintuplet (*right*). How these clusters formed remains a mystery. M31 has no central star clusters of comparable size and youth.

fields, and additional massive young stars are clustered around the black hole. The origin of these stars is a deep mystery, because the extreme tidal forces near the black hole should prevent stars from forming, and we don't know an obvious way to move stars there in a short time.

The Galactic Boondocks

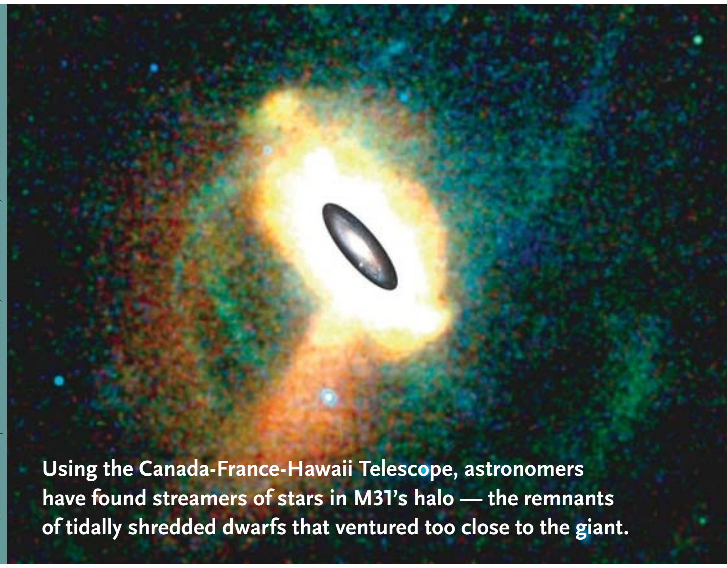
Both galaxies have diaphanous, extended halos. M31's has been traced to a radius of 500,000 light-years — about 50% larger than the Milky Way's. As mentioned earlier, M31's halo has an extraordinary endowment of 500 globular clusters, three times that of the Milky Way. Almost all of the globulars in both galaxies are ancient stellar systems. The oldest datable Milky Way stars range from 11 to 12.5 billion years.

Each halo also has streams of stars that are almost certainly the debris of unlucky cosmic contestants — systems similar to the Sagittarius Dwarf Spheroidal Galaxy. In an observational tour de force, Thomas Brown (Space Telescope Science Institute) and a team to which I belong imaged a number of different locations in M31's halo and found old stellar populations, as well as stars a few billion years younger — a population we don't see in the Milky Way's halo. Using the MegaCam imager on the 3.6-meter Canada-France-Hawaii Telescope to cover an area of sky nearly 20° × 20°, the Pan Andromeda Archaeological Sur-

The Milky Way and Andromeda Compared

	MILKY WAY	ANDROMEDA
Globular clusters	160	500
Known satellites	26	38
Absolute magnitude	–20.5	–21.5
Stars	200 to 300 billion	400 to 600 billion
Mass	~10^{12} solar masses	~10^{12} solar masses
Disk diameter	90,000 light-years	150,000 light-years
Halo radius	300,000 light-years	500,000 light-years
Central black hole	4.2 million solar masses	100 million solar masses
Star-formation rate	~2 solar masses per year	~1 solar mass per year

NICOLAS MARTIN / ALAN MCCONNACHIE / RODRIGO IBATA / PANDAS TEAM



Using the Canada-France-Hawaii Telescope, astronomers have found streamers of stars in M31's halo — the remnants of tidally shredded dwarfs that ventured too close to the giant.

vey, led by Alan McConnachie (NRC Herzberg Institute of Astrophysics, British Columbia), produced a map of M31's halo (from measurements of 10 million red giants) that shows spectacular streamers and arcs. The most prominent feature, the so-called Giant Stream, may be the debris left by the infall of a disk galaxy about the mass of M33.

Another noteworthy feature of M31's halo is its large population of stars with high heavy-element abundances. The typical star in the Milky Way's halo has around 2% the Sun's iron abundance whereas the typical star in M31's halo is 10 times more metal-rich than this. The new Hyper Suprime-Cam on the 8-meter Subaru Telescope, along with an advanced spectrograph currently being built, may help provide many more abundance and velocity measurements for M31 halo stars, helping settle the mystery of how and when this galaxy assembled. The planned Thirty Meter Telescope will also have a spectrograph capable of studying faint stars in M31's halo.

Stellar Populations Compared

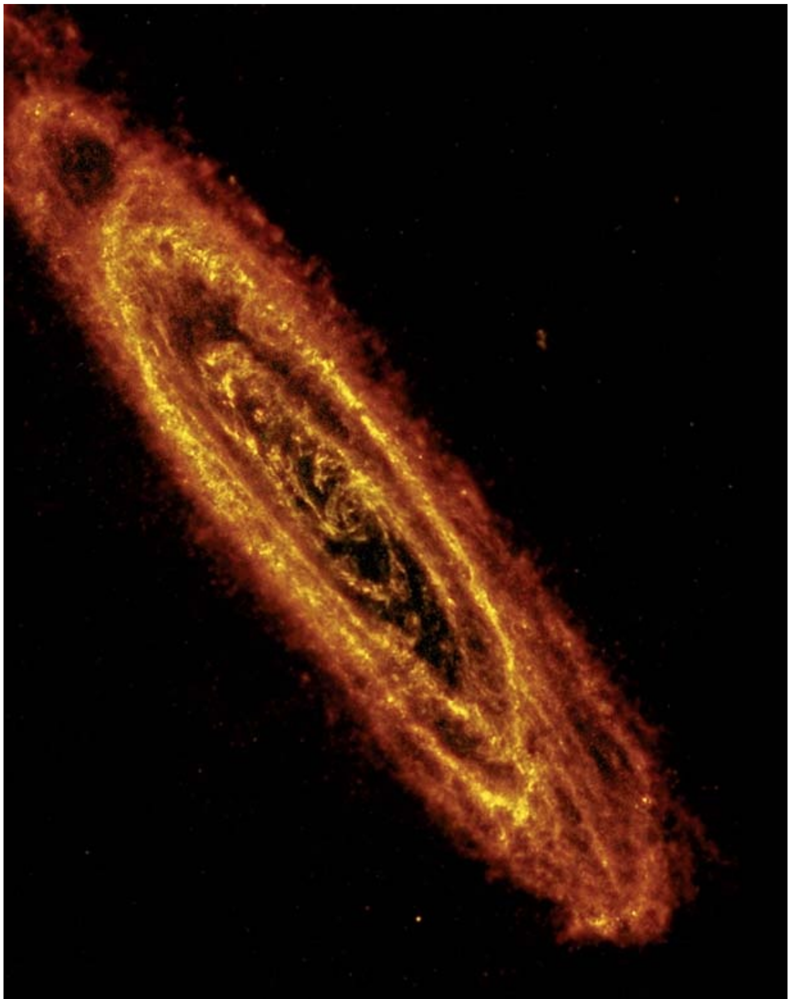
The recently decommissioned Galaxy Evolution Explorer (GALEX) satellite produced one of the greatest M31 portraits, combining far- and near-ultraviolet imaging (*S&T:* April 2012, page 20). The light of massive young stars illuminates the spiral arms, whereas the bulge is seen not by the light of young stars but by the ultraviolet light of ancient stars whose energy is produced by helium (not hydrogen) fusion.

The spectacular GALEX image belies a different reality. Although astronomers estimate that both M31 and the Milky Way are currently forming about 1 star per year, both galaxies appear to be transitioning from a lively star-forming spiral galaxy of youth to a quiescent, massive galaxy of maturity — a denizen of the so-called "red sequence" populated by ellipticals and massive spirals. Most of M31's light arises from older stars, and there appears to be relatively few stars formed in the past 100 million years.

Within M31 there is one major exception: the Ring of Fire includes the molecular hydrogen (H_2) and carbon-monoxide (CO) gas needed to form new stellar generations. Still, our galaxy appears to have about three times more molecular gas than M31. It's possible that M31 experienced more significant interactions (like the possible collision with M32) that caused it to form more stars than the Milky Way, and thus it used up its inventory of gas, or that the formation of its more massive bulge encouraged it to convert more of its gas into stars in its youth.

End Game

Precision Hubble measurements of the space motions of the Milky Way and M31 support the long-standing suspicion that these contestants are falling toward each other. However, the first blow will not take place for billions of years. In the early rounds, computer simulations suggest

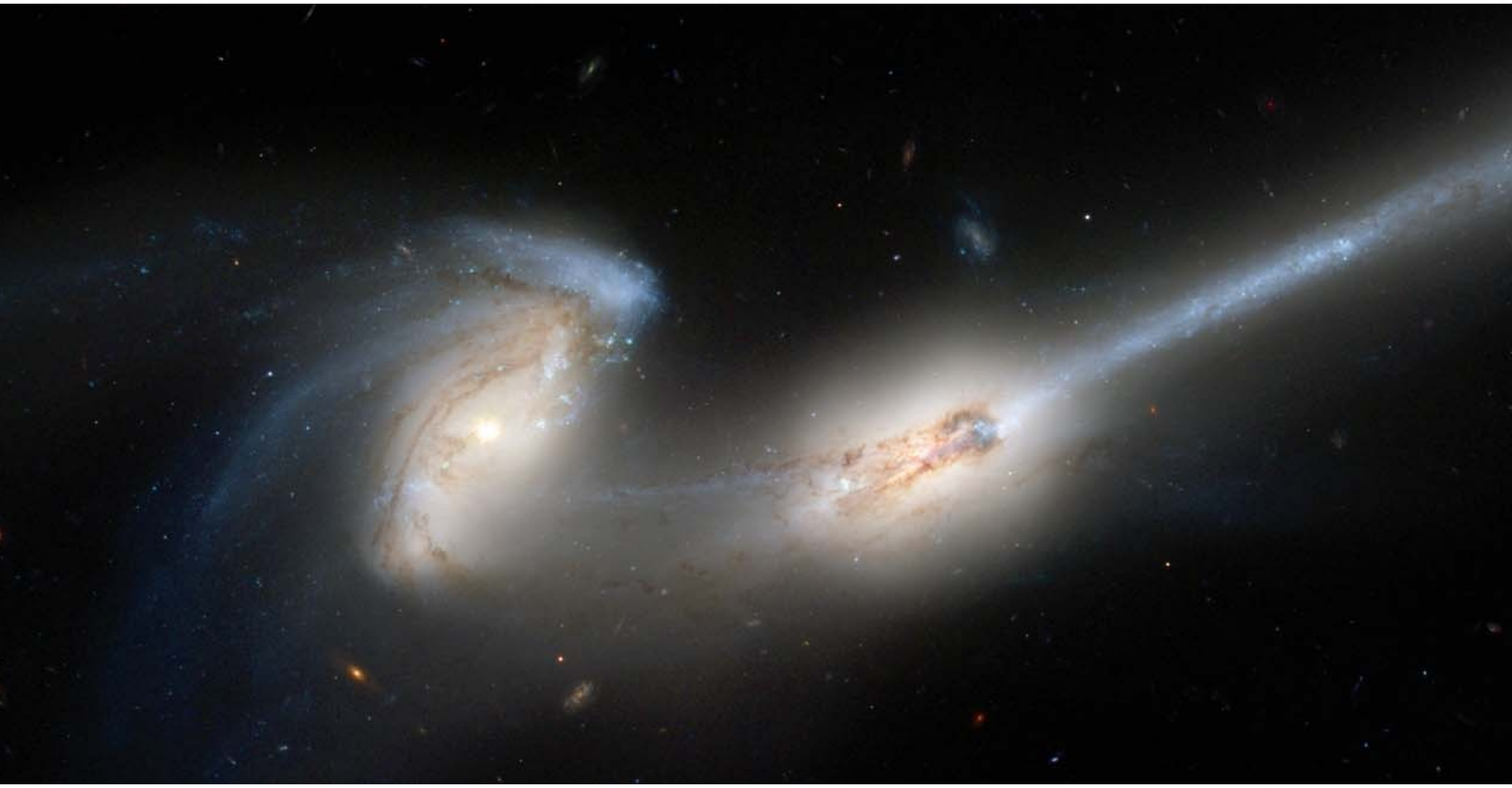


This image from ESA's Herschel Space Observatory shows M31 in far-infrared light, revealing cold dust from which stars form. The prominent Ring of Fire circles the nucleus at a distance of 30,000 light-years. This ring of active star formation might have resulted when galaxy M32 plowed through M31's disk 210 million years ago. This image also reveals a fainter outer ring.

ESA / HERSCHEL / PACS / SPIRE / J. FRITZ / U. GENT

Andromeda's Three Big Black Holes

Unlike the Milky Way and its solitary supermassive black hole, Andromeda and its satellites host at least three. Besides M31's 100-million-solar-mass monster, its companion elliptical galaxy M32 hosts a black hole of 2.5 million Suns. The nuclei of the nearby galaxies M33 and M110 have been inspected carefully with Hubble's spectrograph and the telltale signatures for supermassive black holes are lacking. Now consider M31's peculiar globular cluster G1 (the most luminous and massive globular cluster in the Local Group), whose appearance resembles a mini-M32, with a compact nucleus. Its odd appearance inspired me to search for a massive black hole in its core. From analyzing the velocities of stars in the "integrated" or unresolved light of G1's nucleus, Karl Gebhardt (University of Texas, Austin), Luis Ho (Carnegie Observatories), and I found that G1 hosts a 20,000-solar-mass black hole. G1 remains the most widely accepted case for a very massive black hole in a globular cluster.



NASA / HOLLAND FORD (JHU), ET AL. / ACS SCIENCE TEAM / ESA

This Hubble image of the Mice (NGC 4676) gives us a sneak preview of the Milky Way–Andromeda collision that will take place 3 to 5 billion years from now. Tidal forces create the tails that give the Mice its nickname. Regions of vigorous star formation appear blue.

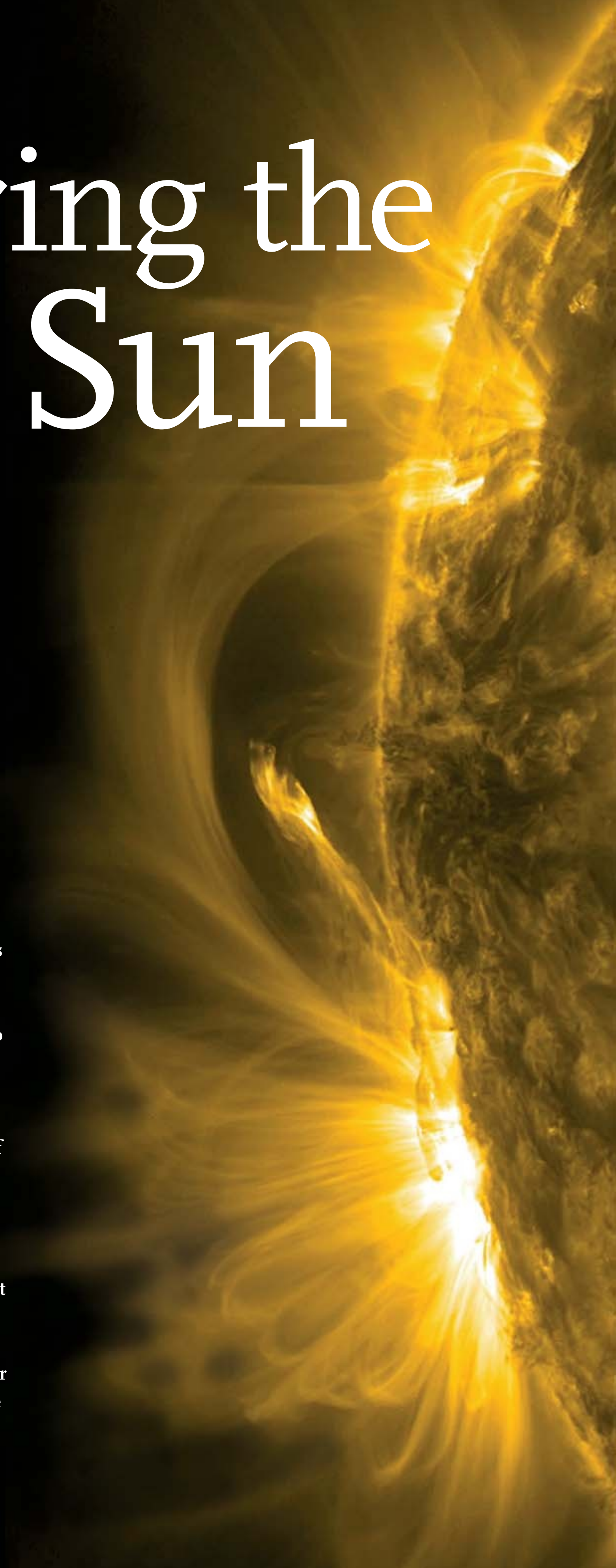
that spectacular tidal streamers will be expelled, making the Milky Way/Andromeda pair potentially resemble the Antennae Galaxies (NGC 4038/4039), the Mice (NGC 4676), or perhaps after some time, the Atoms for Peace Galaxy (NGC 7252), with the Milky Way appearing to arc crazily over the entire sky as seen from the perspective of our solar system (*S&T:* Oct. 2006, p. 30). The interaction will set alight all the remaining gas in the two galaxies, and the end result will be the consumption of virtually all of the gas in spectacular bursts of star formation.

Eventually, the Milky Way and Andromeda will collide and merge, forming a giant elliptical galaxy. Among the more interesting finales will be the orbital dance of two or even three supermassive black holes in the center of that newly minted elliptical. Theory predicts that much of the gas in both galaxies will collide and flow to the center. If this occurs, a new quasar may flare for hundreds of millions of years. If any of our descendants are around to view the bout, it's unlikely they will be living on Earth. By then, the Sun will have evolved into a red giant and our planet will cease to be a comfortable place.

The appearances of the Milky Way and M31 have likely been molded by their extensive history of absorbing cosmic blows. M31's more classical bulge may reflect a merger in its youth, and passage of M32 through its disk may have sparked additional star formation and depleted much of its gas. M31's Giant Stream and the Milky Way's Sagittarius dwarf are both remnants of small galaxies that tangled with the heavyweights. Our Milky Way's central bar more likely owes its existence to the force of gravity acting on the protodisk, and the bar channels gas to the galactic center where it forms spectacular star clusters.

A more precise comparison awaits a new generation of studies of Andromeda, and future work on the Milky Way that may reveal more details about its geometry and clarify the structure of its spiral arms. Although the Milky Way and Andromeda galaxies have prominent disks and similar masses, they have strikingly different appearances, and their origins and histories remain to be fully understood. The galactic contestants are now inexorably moving quietly from their corners of the celestial ring toward their date with destiny. ✦

***Michael Rich** is an astronomer at the University of California, Los Angeles, who has studied M31 using the Galaxy Evolution Explorer (GALEX), W. M. Keck Observatory, and the Hubble Space Telescope. He helped advance Neil deGrasse Tyson's career in astronomy by serving as his Ph.D. thesis advisor at Columbia University. Rich also authored the feature article about GALEX in the April 2012 issue.*



Discovering the Radio Sun

The wartime discovery of radio emissions from the Sun gave birth to the field of solar radio astronomy.


J. Kelly Smith & David L. Smith

In 1890

the famous American inventor Thomas A. Edison, spurred on by Heinrich Hertz's discovery of radio waves three years earlier, set out to prove that the active Sun was capable of emitting radio waves. But despite his (correct) conviction that these emissions should exist, the discovery of the radio Sun would not come for another 52 years.

The search for these invisible electromagnetic waves included some of the most notable figures of the world's scientific community. Some failed in their quest because of primitive equipment, others because their efforts did not coincide with periods of vigorous solar activity. Still others failed because they did not recognize the significance of periodic radio static. Ultimately our star gave up its secrets serendipitously, testing the wits of the young radio physicist who finally identified emissions from the Sun using radar receivers during World War II.

This discovery of the radio Sun expanded the view of our star by more than seven orders of magnitude, initiating the birth and explosive growth of solar radio astronomy.

Valiant Efforts

Edison's interest in detecting radio emissions from the Sun shines through in a letter sent at his behest by his associate, Professor Arthur E. Kennelly, to Professor Edward S. Holden, director of the Lick Observatory in California. In the letter Kennelly explains:

> *Along with the electromagnetic disturbances we receive from the Sun which, of course, you know we recognize as light and heat, . . . it is not unreasonable to suppose that there will be disturbances of much longer wavelength. If so, we might translate them into sound.*

Kennelly went on to ask Holden to provide details of solar activity for comparison with Edison's own results.

At the time, Edison was in his "Iron Period" — a span of 10 years during which he perfected his method of extracting iron from low-grade ore. His radio telescope was to consist of millions of tons of locally mined magnetite, surrounded by a suspended loop of well-insulated telephone wires that terminated in a suitable detector, possibly a telephone. The telescope was to detect kilometer-long radio waves by their inductive effects on the cable loop and the magnetite.

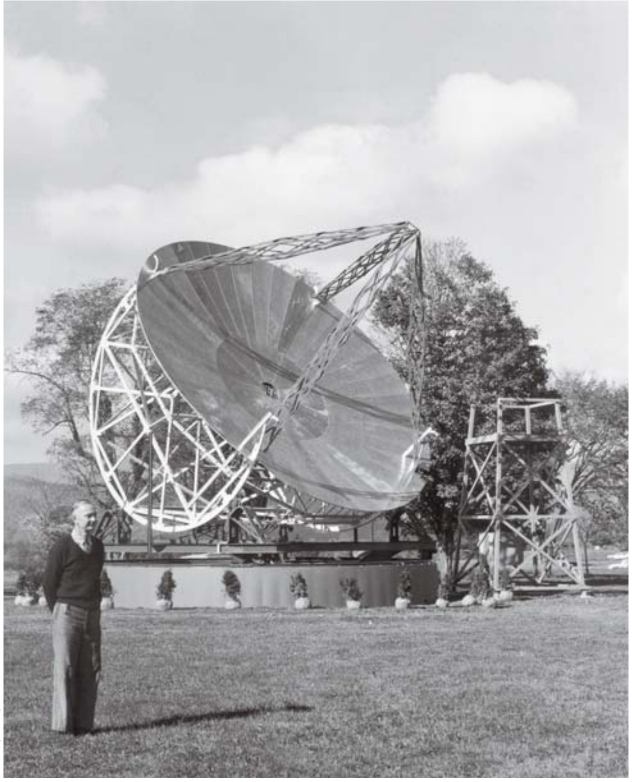
Unfortunately, there is no record describing the performance or results of the experiment, but, if performed, it almost certainly failed. First, the massive receiver would have been too insensitive to detect solar radio emissions; second, kilometric radiation is blocked by the Earth's ionosphere, a fact unknown at the time. (Ironically, Kennelly actually codiscovered the ionosphere in 1902.)

Although Edison was the first, he was not the only famous scientist to attempt this feat. Sir Oliver Lodge was a professor of physics at University College in Liverpool, England, with a lifelong interest in electricity and magnetism. In 1894 he gave a lecture before the Royal Institution in London on Hertz's work that included a demonstration of radio-wave transmission. During the lecture he proposed "to try for long-wave radiation from the sun, filtering out the ordinary well-known waves by a blackboard, or other sufficiently opaque substance."

MAGNETIC ARCS *Left:* Plasma outlines magnetic field lines arching between two active regions on the Sun. The discovery of radio emission from such regions in 1942 marked the birth of solar radio astronomy.

EDISON'S ORE Thomas Edison sits at his ore mill in Ogdensburg, New Jersey. For a decade he worked to develop a method for extracting iron from low-grade ore. The radio telescope he planned to build from that iron seems never to have materialized, nor did his extraction method prove profitable.

SUN: NASA / SDO / AIA / EVE / HMI; THOMAS EDISON: U.S. DEPT. OF THE INTERIOR / NATIONAL PARK SERVICE / THOMAS EDISON NATIONAL HISTORIC PARK



NRAO / AUI / NSF

GALACTIC MAPPER Grote Reber stands here in 1960 with his restored 9.5-meter radio telescope at the National Radio Astronomy Observatory site in Green Bank, West Virginia. When first constructed in Reber's backyard in 1937, the parabolic dish attracted the attention of pilots, who would circle over Reber's home to get a better look. It also collected gallons of rain water, prompting speculation by some of his neighbors that he had invented a rain-making machine. Reber produced the first radio map of the sky, although he didn't detect emission from the quiescent Sun during that survey. His telescope remains the prototype for many of today's radio telescopes.

True to his promise, he constructed a receiver that, coincidentally, was capable of receiving radio waves short enough to penetrate the ionosphere. Unfortunately, the receiver proved too insensitive to pick up solar radiation, but it functioned well enough to detect loud bursts of interference from electrical machinery in industrial Liverpool, the site of his experiment. In frustration, Lodge abandoned his search.

A third, but again unsuccessful, attempt was made in September 1901 by Charles Nordmann, a young French scientist in pursuit of his doctorate. To rise above the absorbing effects of the atmosphere, Nordmann placed his equipment on Mont Blanc in the French Alps, 3,100 meters (10,200 feet) above sea level. Unfortunately, his measurements occurred during solar minimum, and he abandoned his search after a few days. Nonetheless, in defending his thesis, he considered it extremely probable that the Sun did emit radio waves. Had he waited for solar maximum, he might well have proved it.

The last known unsuccessful attempt was made by Grote Reber, a young radio engineer from Wheaton, Illinois. In 1937, inspired by Karl Jansky's discovery of galactic radiation, Reber quit his job as a radio designer and in four months' time constructed a 9.5-meter parabolic dish antenna in his backyard using his own labor and money. His initial efforts to measure the radio sky, using receivers tuned to 9- and 33-centimeter wavelengths, failed. Undaunted by nearly two years of these negative results, he built a third receiver that worked at a wavelength just short of 2 meters. To his great relief, he detected signals coming from the plane of the Milky Way.

He then launched into an intense observing schedule, carrying out measurements from midnight to 6 a.m., when radio interference was at a minimum, and then driving 50 kilometers to his new job with a Chicago radio company. After the evening meal he would sleep to midnight and then resume his observations. By 1939 he had completed the world's first radio map of the sky, which he published in 1940. Unfortunately for Reber, the Sun was in a period of quiescence and he didn't detect solar radio emissions until 1944.

The Radio Fizzlies

For years prior to the discovery of the radio Sun, radio operators had reported periods when shortwave radio reception was disrupted by bursts of a static-like noise that could not be traced to terrestrial sources. In a paper published in 1936, H. W. Newton called this noise the "radio fizzlies" and noted that this high-level noise often preceded periods of radio fadeouts known to accompany strong solar flares. In 1938 a British ham operator, D. W. Heightman, came near to the correct explanation for the noise when he wrote:

> *At such times [when fadeouts occur] the writer has often observed the reception of a peculiar radiation, mostly on frequencies over 10 Mc/s [or about 30 meters in wavelength], which on the receiver takes the form of a smooth but loud hissing sound. This is presumably caused by the arrival of charged particles from the Sun on the aerial.*

In 1939 two Japanese researchers, Minoru Nakagami and Kenichi Miya, measured the direction of arrival of the noise at wavelengths of 17 and 23 meters. Although the source corresponded with the Sun, they concluded incorrectly that the radiation originated in or near the E layer of Earth's ionosphere.

Serendipity

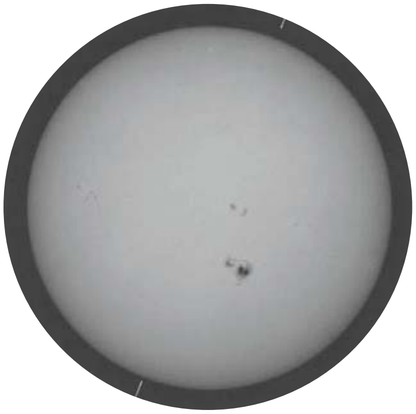
On the night of February 11, 1942, during World War II, two of Germany's capital battleships, the *Scharnhorst* and *Gneisenau*, slipped out of their births in Brest, France, and made their way up the English Channel undetected until they passed the Cliffs of Dover. They were accompanied by the heavy cruiser *Prinz Eugen*, 6 destroyers, 14 torpedo boats, 26 *schnellboots* (similar to British and American motor torpedo boats), and an escort of approximately 280 fighter planes. For the first time since the Spanish Armada, a hostile fleet had sailed through the English Channel. But, unlike the Armada, this one got through.

The Channel Dash succeeded due to a mixture of audacity, luck, and human error. The Germans had waited for a favorable tide and launched the fleet in darkness. They also increased their jamming of British radar by small increments over a number of days so that operators would fail to recognize how intense it had become. One day before the Channel Dash, a frustrated Colonel Wallace of the British Radio Interception Unit told a member of British Intelligence, "Will you chaps take me seriously? No one else will. For days our radar sets down on the coast have been jammed, and the jamming is getting worse every day. I am sure the Germans are up to something!" And indeed they were.

In response to this catastrophic failure, the British War Office ordered their Army Operational Research Group to monitor all reports of radar jamming and, whenever possible, to implement countermeasures. This responsibility

U.S. NAVAL HISTORICAL CENTER PHOTOGRAPH

THE CHANNEL DASH Photographed from the cruiser *Prinz Eugen*, the Nazi battleships *Gneisenau* (closer) and *Scharnhorst* make their way up the English Channel in February 1942. The radar jamming that enabled the daring passage impelled the British to improve their radar surveillance. This careful monitoring enabled James Stanley Hey to identify radio emission from the Sun.



HEY: CAMBRIDGE UNIVERSITY PRESS
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DISCOVERER OF THE RADIO SUN *Left:* Physicist and British radio operator James Stanley Hey discovered radio emission from the Sun while working with the Army Operational Research Group. After the war he helped confirm that intense radio bursts were often associated with solar flares. He also was the first to use radar to study meteors and discovered the variable radio source Cygnus A. *Right:* This picture of the Sun was taken on February 27, 1942, at the Royal Observatory, Cape of Good Hope, South Africa. Radio emission from the sunspots near the central meridian jammed British radar that day, revealing that the Sun does emit radio waves.

was given to James Stanley Hey, a young physicist who had just received six weeks of intensive training at the Army Radio School at Petersham, Surrey. Hey had earned his master's degree in X-ray crystallography from Manchester University in 1931 and taught physics in a grammar school prior to his military assignment.

In cooperation with army officials, Hey devised instructions for radar operators that included a mandate to report all instances of jamming to his office. In addition, he set up a mobile laboratory on the cliffs at Dover that was manned by a member of his team, which served to monitor the Germans' radar-jamming activities.

On February 27th and 28th, 1942, he was deluged with reports of widespread daytime jamming of anti-aircraft radar working at wavelengths between 4 and 8 meters. The interference was of such intensity as to render radar operation impossible. Recognizing that the directions of maximum interference followed the Sun, he telephoned the Royal Greenwich Observatory and learned that an exceptionally active sunspot was in transit across the solar disk at that time. He later wrote:

> *It was clear to me that the Sun must be radiating electromagnetic waves directly — for how else could the coincidence in direction be explained — and that the active sunspot region was the likely source. I knew that magnetron valves generated centimetric radio waves from the motion of electrons in kilogauss magnetic fields, and I thought why should it not be possible for a sunspot region, with its vast reservoir*

of energy and known emission of corpuscular streams of ions and electrons in magnetic fields of the order of 100 gauss, to generate metre wave radiation.

Despite skepticism on the part of his colleagues, and much to the relief of the British War Office, he correctly surmised that the radar jamming was not manmade but rather emanated from the Sun.

Later that year, George C. Southworth also detected solar radiation, using a microwave receiver that he had designed while working at Bell Telephone Laboratories in the United States.

For security reasons, Hey and Southworth could not distribute their 1942 discovery papers until after the war. But the radio Sun had finally revealed itself and was soon to become the center of attention.

Postwar Boom

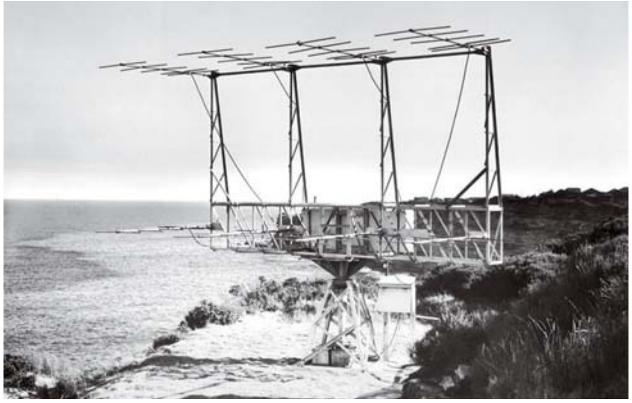
The discoveries of Jansky, Reber, Hey, and Southworth triggered an exponential growth in radio astronomy in the immediate postwar period, first in Australia and Britain, then in Canada and the United States.

Engineers and scientists involved in electronics research during the war were now free to investigate peacetime uses of radio. And they had access to state-of-the-art aerials, transmitters, recorders, and receivers no longer being used by the military. Many of the investigators were young, and their wartime training in radar had imbued them with a sense of confidence. Collectively, these factors provided fertile ground for the growth of the new science of radio astronomy.

Because two of the natural frequencies of the solar atmosphere (both related to electrons' movements in the magnetic-field-infused hot plasma) are in the radio band, Hey's discovery proved vital to our understanding of the electromagnetic and thermal properties of the Sun. In 1945 Australian observers measured the corona's temperature at an astounding 1 million kelvin, a finding that remains the subject of intense study (*S&T*: Oct. 2012, p. 16).

CSIRO

AUSTRALIAN RADIO PIONEERS Members of CSIRO's Division of Radiophysics in New South Wales, Australia, worked at the forefront of the growing field of radio astronomy after WWII. Shown from left to right are John Bolton, Gordon Stanley, and Joe Pawsey.



CSIRO

SEA INTERFEROMETER This eight-element Yagi sea interferometer was erected in 1951 near Sydney, Australia. The antenna picks up a source's radio signal along two paths, one straight from the source and the other reflected from the sea. The two signals superimpose to form an interference pattern and much-improved angular resolution. In 1946 Joe Pawsey, Ruby Payne-Scott, and Lindsay McCready used this technique to show that the Sun's most powerful emissions originate in the area of sunspots.

One year later came proof that loud, sporadic radio noises previously described by shortwave radio operators and by Hey were emitted over sunspots or flares, whose energies had accelerated electrons to relativistic speeds. Researchers found that the wavelength of radio emissions increased with increasing height above the photosphere, thereby providing a basis for tracking the origin and trajectory of solar flares, classifying radio bursts, determining the properties of different layers of the Sun's atmosphere, and observing the corona at distances far beyond what one can see in visible wavelengths. (Amateurs can do their own solar radio investigations, too; see our article on page 66 of the February 2011 issue.)

And the desire for better and better angular resolution of the Sun motivated both the Australian radio physicist Joe Pawsey and the British radio astronomer Sir Martin Ryle and their colleagues to design radio interferometers, which later proved to be crucial to the discovery of radio galaxies, quasars, and pulsars. In uncloaking the radio Sun, these pioneers opened the door to a wider universe.

In 1946 there were less than a dozen publications describing radio emissions from the Sun. Today there are thousands. In less than a century, we have gone from detecting radio static from the center of our galaxy and the Sun to visualizing the enormous radio energies of quasars, pulsars, black holes, and exploding stars — some of which are located millions of light-years away.

Thomas Edison would be pleased. ✦

J. Kelly Smith is an emeritus professor of medicine at the James H. Quillen College of Medicine at East Tennessee State University and a long-time amateur radio astronomer. His son David L. Smith is an inventor with a special interest in solar radio astronomy.

Chris Dalla Piazza

Stars & Planets *in*

Yes **you really can see stars** and planets during the daytime. Venus is surprisingly easy to spot if you know where to look, and Jupiter is also visible without optical aid. A telescope expands the possibilities greatly, showing all of the classical planets as well as stars down to 4th magnitude. That's beyond the naked-eye nighttime limit in some brightly lit cities!

Even if you can do this, why would you bother? Partly, it's the challenge. The Sun is easy, but spotting your *second* star in daylight is a memorable experience. Who would guess that you can pick a star out of the featureless blue ocean overhead? Yet the brightest stars stand out surprising well through a telescope, and their appearance is striking when surrounded by blue sky. Sharing this experience can be effective public outreach. You're more visible during the day, when people are out and about, and you can pique their interest with the unexpected.

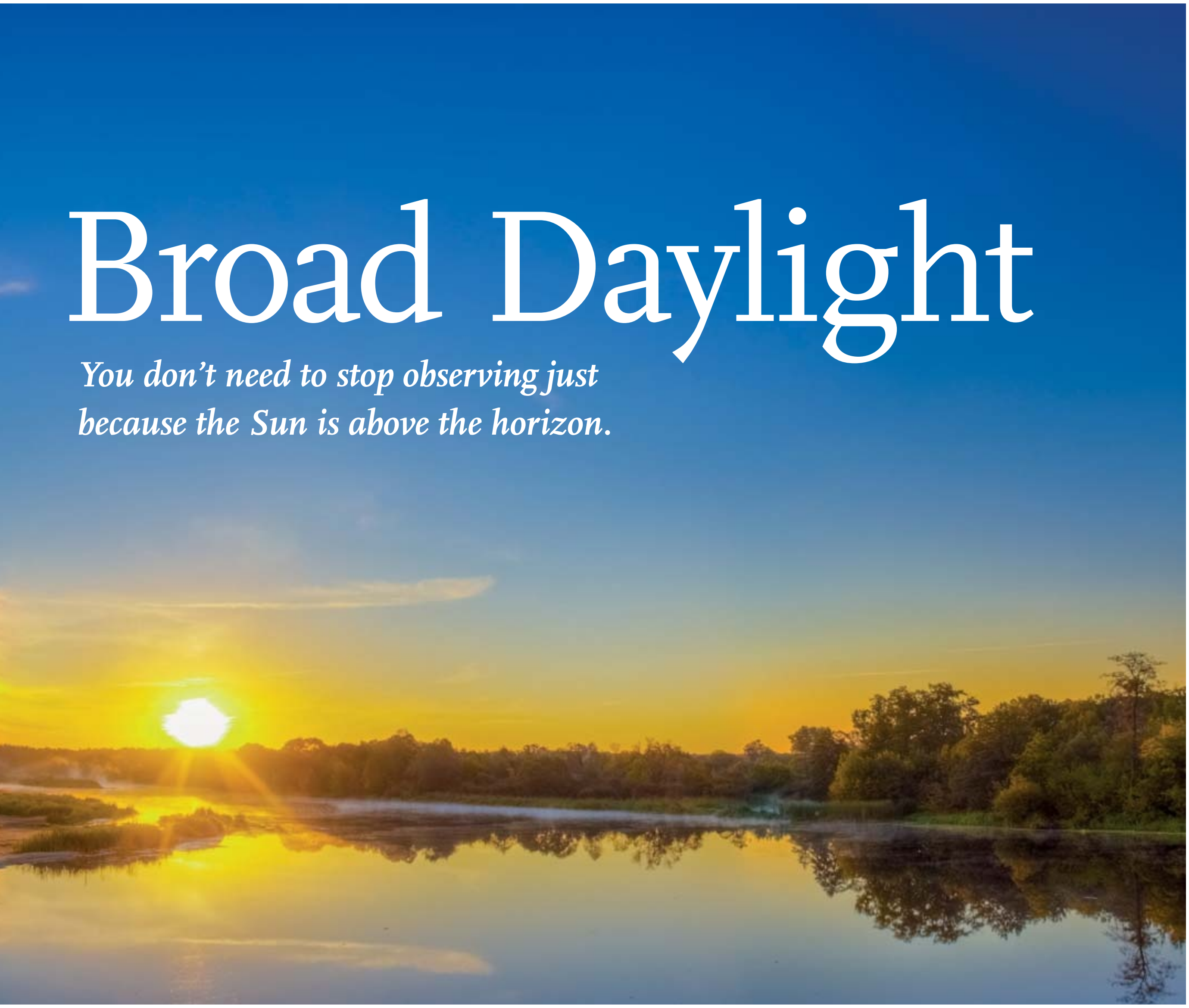
The innermost planets actually show more detail during the day than at night. Mercury never strays far from the Sun, so it's low in the sky whenever the Sun is below the horizon. That means that the image is blurred by passing nearly horizontally through the atmosphere. Your best chance for a clear view of Mercury's surface features is to catch it between sunrise and sunset.

Unlike Mercury, Venus is occasionally high at nighttime. But Venus is blindingly bright when viewed against a dark background. The daytime sky tames Venus's otherwise overwhelming brilliance, and may even allow you to glimpse subtle features in its uppermost cloud deck.

Some things can *only* be seen during the day. Venus is most spectacular near inferior conjunction, when it's almost directly between Earth and the Sun. It's so close to Earth then that its razor-thin crescent is much longer from tip to tip than Jupiter is wide. Likewise, many com-

Broad Daylight

You don't need to stop observing just because the Sun is above the horizon.



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ets are at their brightest when they're closest to the Sun, visible only in the daytime sky.

Lunar occultations, when the Moon passes in front of a planet or bright star, are rare and spectacular. Occultations are equally common at day and night, so being versed in daylight observing techniques doubles your chances of catching these events.

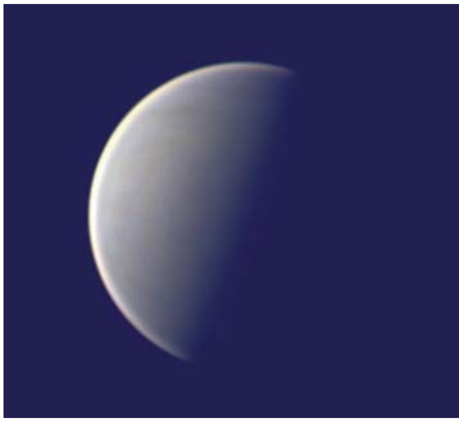
Equipment

The hardest part of daylight observing is locating your target. That traditionally required equatorial mounts equipped with setting circles, and some people use Dobsonian telescopes with homemade alt-azimuth setting circles. But modern Go To and Push To mounts make this feat much easier. A finderscope can be a big help in locating Venus, Jupiter, and the brightest stars, especially if your pointing system has limited accuracy.

A safe solar filter will enable you to align your telescope accurately by centering the Sun in the eyepiece. It will also allow you to view this most spectacular of all daytime objects. Of course, you must **never look at the Sun through a telescope, finderscope, or binoculars without using a safe solar filter**.

Detecting objects in daylight is a different challenge from detecting faint objects at night. I find that the sweet spot for detecting stars during the day is around 6 inches of aperture. Larger scopes may show additional details on the planets, but poor daytime seeing tends to turn stars into fuzzy, quivering masses. To minimize this effect, keep your telescope in the shade and try to observe over grass rather than hot asphalt.

It's a good idea to pick out one eyepiece and stick with it if possible. The simple act of switching eyepieces can cost a lot of time due to the difficulty of recovering focus.



S&T imaging editor Sean Walker prefers to study Mercury (*far left*) and Venus during the day. These photos accurately capture what he saw through the eyepiece of his 12-inch Newtonian.

Instinct would lead you to select a low-power eyepiece because it will be easier to get an object into the field of view, but I find that mid-power eyepieces are easier to focus. Relatively high magnifications also yield a darker sky background, which is particularly useful for detecting stars. A 1° field of view that shows the Moon with plenty of room to spare is ideal.

It's also helpful to optimize your scope and eye. Proper baffling will boost a scope's contrast. Owners of Newtonians can leave the bottom tube cover on to block stray light. SCT and refractor owners can use a dew shield. Fine-tuning the collimation makes star images as tight as possible. Those of us with astigmatism may want to leave corrective lenses on.

German astrophotographer Stefan Seip used a polarizing filter to darken the sky while photographing Comet McNaught (C/2006 P1) just after perihelion, on the afternoon of January 13, 2007.

Practicing in the Dark

Most of the hard work of locating objects during the day will already be done if you have a permanently mounted scope that routinely locates objects near the center of the eyepiece and doesn't need training during startup. But if you need to assemble and initialize your equipment each time you use it, then it pays to practice in the dark.

During the day you can align your scope on the Sun, but that's obviously not available at night. The Moon makes a great substitute, and it's also a fine secondary alignment point during the day, assuming that it's above the horizon. However, the Moon's position varies considerably due to parallax; people viewing the Moon simultaneously from different locations may see its position among the stars vary by a degree or more. Most Go To and Push To mounts take your location into account, but some do not. It's wise to find out at night!

Once you've aligned on the Moon, you can practice the skills needed to find Venus. Venus is typically about 2 hours of right ascension (30° in the sky) from the Sun, so use your system to locate an object that's about that distance from the Moon. You're allowed to use your finderscope during this exercise, because Venus is readily visible in a finderscope during the day.

For all systems, locate a few of the bright stars in the Winter Hexagon or Summer Triangle, depending on the season. For German equatorial mounts, try to incorporate a "pier flip" to see how well the pointing accuracy survives as you cross the meridian. If the mount loses accuracy after the flip, note the discrepancy so that you can compensate for it during your daytime session. Use short hops to the brightest stars to work your way across the sky. Resynchronizing the scope as you go minimizes the demands on the pointing accuracy.

Spiral search functions can help land an object in the eyepiece. And faint points of light may catch your eye better when the scope is moving than when it's stationary.

If you can align your scope during the night and leave it "parked" until the next day, by all means do so. And even with the simplest equipment, you can locate your target before dawn and keep tracking it as the Sun rises.

When and Where to Look

Picking the right time to observe is the first key to success. Choose a dry day with a beautifully deep blue sky. The second day after a cold front comes through is often best; the first day tends to have clear but unsteady air, preventing pinpoint star images.

The daytime sky's brightness varies greatly. It's relatively dark just after sunrise or before sunset; the sky becomes much brighter when the Sun is high. At any given moment the sky is brightest near and below the Sun, and it's darkest high above the horizon and at least 90° from the Sun. The Winter Hexagon and Summer Triangle are well placed around the equinoxes, when the air is often clearest.

Venus is the easiest object to locate during the day besides the Sun and Moon. It's obvious in any instrument, and it's spectacular through a telescope, especially during its crescent phase. Jupiter is a runner-up for detectability, but it appears washed out, making its belts hard to see. Mars and Mercury vie for third and fourth place; both planets vary greatly in brightness and detectability. Saturn is dimly lit because it's so far from the Sun, so it appears barely brighter than the background sky. But keen eyes may detect its rings as an apparent defect or elongation of the disk.

The brightest stars pierce the daylight sky surprisingly well; they're even visible through finderscopes and binoculars when they're reasonably far from the Sun and the air is clear. Star colors are visible through a telescope, although not as obvious as they are at night. Red stars such as Betelgeuse make a nice contrast in color against the blue sky. When the seeing is good, 2nd-magnitude stars look like perfect little dots — a neat effect.

Your First Daylight Observing Session

The most important thing to bear in mind is that daytime observing can be dangerous. Even a momentary glimpse of the Sun can blind you, and the Sun can set objects near the eyepiece on fire if it drifts through the field of view while the scope is unattended. So make sure that you keep both the main scope and the finderscope capped when you're moving the scope, or anytime you're not actually viewing your target object.

It's much safer to set up a telescope in the shade. This will also prevent tube currents from harming the image. If you need to align on the Sun, try to set up in the afternoon just outside the shadow of a building, and then start observing once the shadow has covered the scope. Alternatively, use a beach umbrella to shade the scope after doing the alignment.

Determine your targets in advance using a planetarium program, a sky app on a handheld device, or the free skychart at **skypub.com/skychart**. If you're using traditional setting circles, find the precise offsets of your targets from the Sun and/or Moon.

Princeton University professor Robert Vanderbei used this equatorially mounted 3.5-inch Questar to capture the Jupiter image shown on the following page. Note that the scope is set up in the shade to minimize tube currents and eliminate the possibility of pointing the scope unintentionally at the Sun.

PRESERVING ALIGNMENT

Polar-align your scope at night. If you can't leave it set up until your daytime session, mark the locations of the tripod feet so that you can set it up with the same orientation. A bubble or torpedo level can be a great help with alt-azimuth mounts as well as equatorial mounts. These steps will maximize your pointing accuracy if you must calibrate your system using only one object.

S&T editorial intern Maria Temming demonstrates an iOptron Go To mount that makes locating planets and stars during daylight much easier.

S&T: DENNIS DI CICCO

S&T: DENNIS DI CICCO

Sky & Telescope **editors gathered around midday on November 9, 2004 to watch the thin crescent Moon occult Jupiter.**

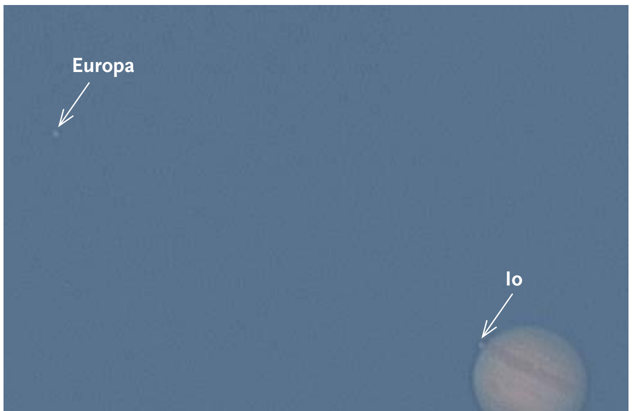
Good focus is critical for detecting stars during the daytime. You can focus on the Moon, the edge of a cloud, or a tree or building at least 1,000 yards (or meters) distant.

If you were able to align your system the previous night and leave it running, see if it's still accurate enough to locate your targets. Otherwise, you will need to fall back on the techniques that you practiced in the dark. Align your scope on the Moon if it's visible. You can get a crude fix on the Sun by minimizing the shadow that your telescope casts on the ground. If you have a safe solar filter, you can make this much more accurate by centering the Sun in your telescope's eyepiece.

If Venus is visible, it makes an excellent second or third alignment point. It's a short hop from the Sun, and often from the Moon, so pointing accuracy isn't crucial. It's also bright enough that you will see it easily in your finderscope. Once you have Venus in the center of the eyepiece, sync on it to improve pointing accuracy. I use Venus as a trusty anchor to come back to if I lose my way. Jupiter also works well, but it's not as obvious in a finderscope.

From Venus you can move on to any of the bright stars in the Summer Triangle or Winter Hexagon, just as you did at night. When going for a star, bear in mind that

S&T **editor Gary Seronik photographed Jupiter disappearing behind the Moon through his 3.5-inch Questar.**



Vanderbei's daylight Jupiter image, also taken with a Questar as shown on the previous page, captured amazing detail on the planet's disk.

even if focus is perfect, the star may be at the edge of the field and distorted. Once you capture the star, try moving it around the field to see how the visibility changes. If you wear eyeglasses, view with and without them to see which you prefer. As you get used to picking stars out of the daylight sky, you can move on to more challenging fare.

Pushing the Envelope

Now that you can locate the brightest stars, try looking for 2nd-magnitude stars. Start with a constellation in the darkest part of the sky. The Sun never comes near the Big Dipper or Cassiopeia, and at least one of those patterns is always fairly high for northern observers.

Double stars can make a good test for your limiting magnitude. Second-magnitude Mizar has a 4th-magnitude companion just 14″ away. Alcor is as bright as Mizar's companion, but it's tough to locate because it's 50 times farther from the anchor star. In any case, 4th-magnitude stars are tricky to spot. But once you've captured those little flecks in the eyepiece, they're much easier to hold.

The ultimate daytime observing prize is a naked-eye sighting. Spotting a planet when the Sun is up can give you a unique feeling for our place in the solar system — especially when the Moon is in the scene too.

Venus is visible without optical aid on any clear day as long as it's reasonably far from the Sun and also higher than the Sun in the sky. Jupiter is surprisingly easy to hold in view immediately after sunrise, but it's very hard to locate later in the day. Any object is easiest to find when it's near the Moon, and the Moon also gives you a target to focus on — a feat that's difficult to accomplish when looking high in a featureless blue sky.

Familiarize yourself with the method of approximating angles with your fist held at arm's length, which measures out about 10°. Use an almanac or computer to determine the angular separation between the Sun and Venus. Try to visualize how the ecliptic arcs upward from the Sun in the sky, and measure out that angle. Then locate Venus in binoculars.

John Kielkopf took this all-sky panorama of the University of Lousiville's Moore Observatory late on the afternoon of February 27, 2007. The darkest part of the sky lies opposite the Sun and well above the horizon. The pinkish artifact toward the right is lens flare.

Robert Vanderbei was able to image Messier 42, the Great Orion Nebula, through a 10-inch scope 15 minutes after sunrise on September 9, 2007. The key to this exposure was shooting through a hydrogen-alpha filter, which like any red filter greatly reduces the brightness of the blue daytime sky.

A parking lot with a flagpole is useful for the next trick. Walk around until you place the flagpole directly below Venus, then put down the binoculars and look for Venus with your unaided eyes. A tree can work well, too. But if the tree or flagpole is nearby, you may have trouble focusing beyond it to spot Venus.

The same technique works for Jupiter, though you probably need to be within 2 hours of sunrise or sunset. March 2015 presents ideal geometry for observers at mid-northern latitudes, with Jupiter high in the east in the late afternoon as the Sun descends in the west. An even bigger prize may be available for those in the Southern Hemisphere, where the geometry is favorable for spotting Sirius before sunset in March.

As you locate more stars and planets during the day, consider this: In addition to your amateur-astronomy brethren, there's another group that can boast of seeing stars when the Sun is in the sky — astronauts! ✦

Chris Dalla Piazza *has been an amateur astronomer and astrophotographer since 1992. He would like to thank the members of the Astronomical Society of Harrisburg for nurturing a lifelong love of astronomy, and Robert Job in particular for his first daytime view of Venus.*

▼ **EYEPIECE PROJECTION** CNC Parts Supply unveils VariMax ($129), the largest variable eyepiece projection adapter for DSLR cameras available today. This CNC-machined adapter allows you to use any 1¼-inch eyepiece on the market with your digital camera to capture closeups of the Sun, Moon, and planets. Its wide housing can accommodate the largest 1¼-inch-format eyepieces with an upper housing diameter of up to 2½ inches and 3½ inches in height. VariMax attaches to any T-ring adapter and is extendable up to 1.26 inches, and its laser-engraved scale enables you to repeatedly set the perfect distance for photography with your favorite eyepieces. VariMax attaches to your telescope with a 1¼-inch barrel or optional 2-inch adapter.

CNC Parts Supply, www.telescopeadapters.com

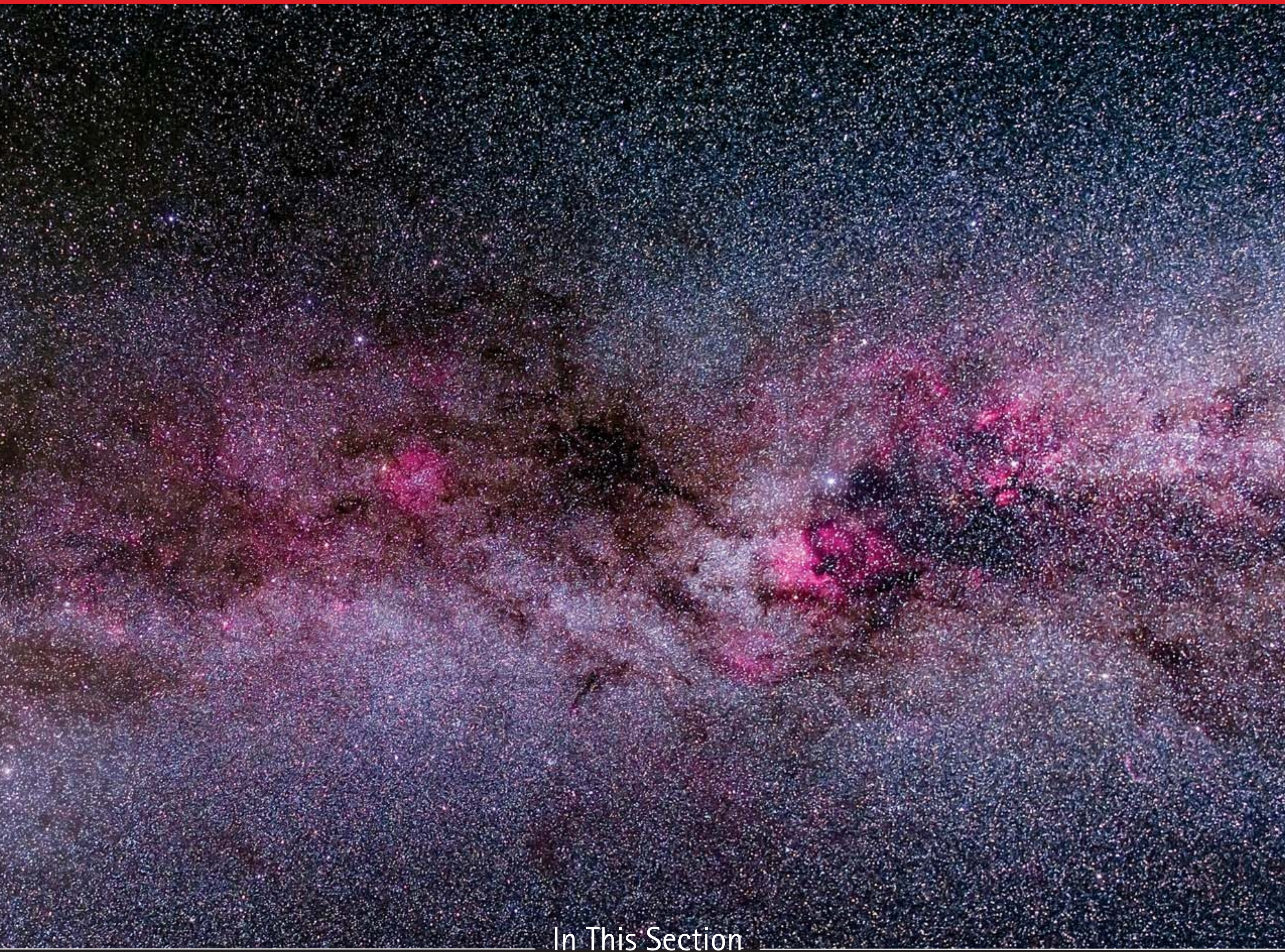
▲ **PORTABLE PRECISION** iOptron announces the iEQ45 Pro ($1,848), a portable German equatorial Go To mount. Weighing 25 pounds (11 kg), the mount offers many improvements over its predecessor, the iEQ45. Featuring precision stepper motors, 256- and 228-teeth aluminum right ascension and declination gears, respectively, the iEQ45 Pro boasts zero backlash to produce error-free tracking during long-exposure astrophotography. The unit's electronics are controlled via the Go2Nova 8407 hand controller that includes a database of more than 350,000 objects, and can slew at speeds of up to 1,400× sidereal rate. Its 6-inch dovetail saddle plate accepts both Vixen and Losmandy-style dovetail bars. The mount includes a heavy-duty stainless-steel tripod, an illuminated AccuAlign G2 polar scope, and DC power supply. See the manufacturer's website for additional details.

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

DOB CONTROL Add stability and slow-motion controls to your Dobsonian telescope with ZLOMOTION ($349). The ZLOMOTION accessory kit attaches to your 8-, 10-, or 12-inch Zhumell, Apertura, and Sky-Watcher Dobsonian telescopes with stainless-steel and brass hardware requiring only minor modifications. The kit includes an innovative dual-rod altitude device that combines a stainless-steel threaded rod with a custom micro-adjustment wheel, while a belt-driven pulley system provides smooth azimuth motions. The ZLOMOTION kit enables observers to track objects at relatively high magnification at any point in the sky. Rapid motions in altitude are performed using an extendable rod and locking knob visible at the lower end of the altitude attachment. Specify your telescope make and model when placing your order.

Chattanooga Millworks, 3107 East 44th St., Chattanooga, TN 37407
423-867-9911; www.chattmill.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.



In This Section

PHOTOGRAPH: ALAN DYER

Dark, spiderlike Le Gentil 3 blots out the Milky Way to the upper left of the bright North America Nebula; see pages 45 and 58.

Additional Observing Article:

Sky at a Glance

OCTOBER 2014

Sept 21 – Oct 6 **DAWN:** The zodiacal light is visible 120 to 80 minutes before sunrise from dark locations at mid-northern latitudes. Look east for a huge, tall pyramid of light stretching up through Jupiter.

Oct 8 **A TOTAL LUNAR ECLIPSE** is visible in the predawn or dawn over North America, and at other times of night in the Pacific and eastern Asia. See page 50.

17, 18 **DAWN:** The Moon shines upper right of Jupiter on the 17th and lower right of Jupiter on the 18th.

19 **NIGHTFALL:** Comet C/2013 A1 Siding Spring passes very close to Mars; see page 53.

20–22 **PREDAWN:** The modest Orionid meteor shower is active shortly before dawn's first light.

Oct 20 – Nov 4 **DAWN:** The zodiacal light is again visible before sunrise, as described above.

22 **DAWN:** Binoculars may show Mercury below the thin crescent Moon very low in the east a half hour before sunrise.

23 **A PARTIAL SOLAR ECLIPSE** is visible over most of North America; see page 52.

25 **DUSK:** Saturn floats a few degrees to the lower right of the thin crescent Moon low in the west-southwest a half hour after sunset. The Moon occults Saturn during daylight in easternmost Canada and during dusk in parts of Europe.

27, 28 **DUSK:** The waxing crescent Moon shines to the right of Mars on the 27th (as seen from North America) and above Mars on the 28th.

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

	◄SUNSET	MIDNIGHT	SUNRISE►
Mercury		Visible Oct 24 to Nov 19	E
Venus		Visible through Oct 4	E
Mars	SW		
Jupiter		E	SE
Saturn	SW	Visible through Oct 26	

Moon Phases

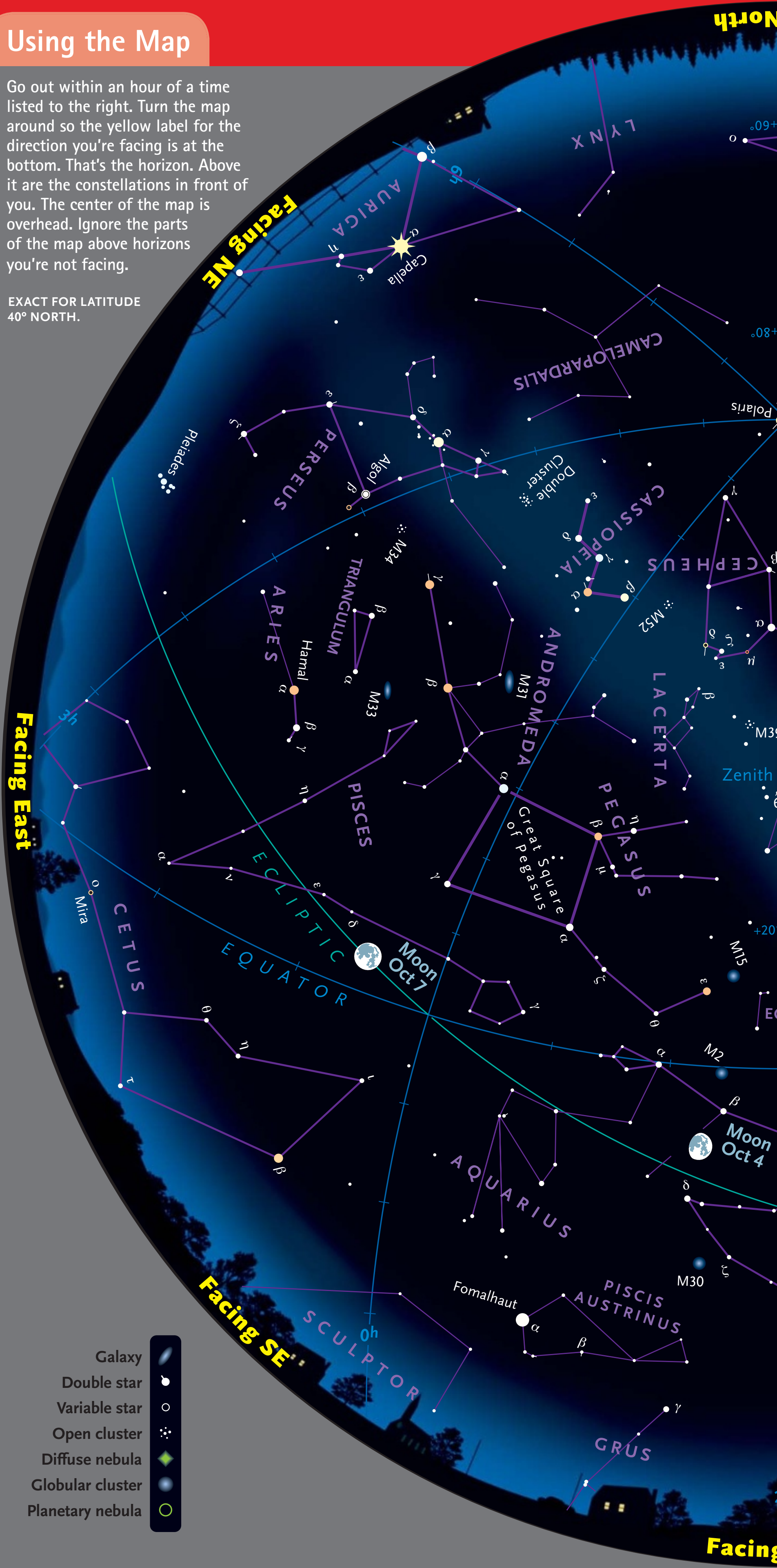
First Qtr Oct. 1 3:33 p.m. EDT
Full Oct. 8 6:51 a.m. EDT
Last Qtr Oct. 15 3:12 p.m. EDT
New Oct. 23 5:57 p.m. EDT
First Qtr Oct. 30 10:48 p.m. EDT

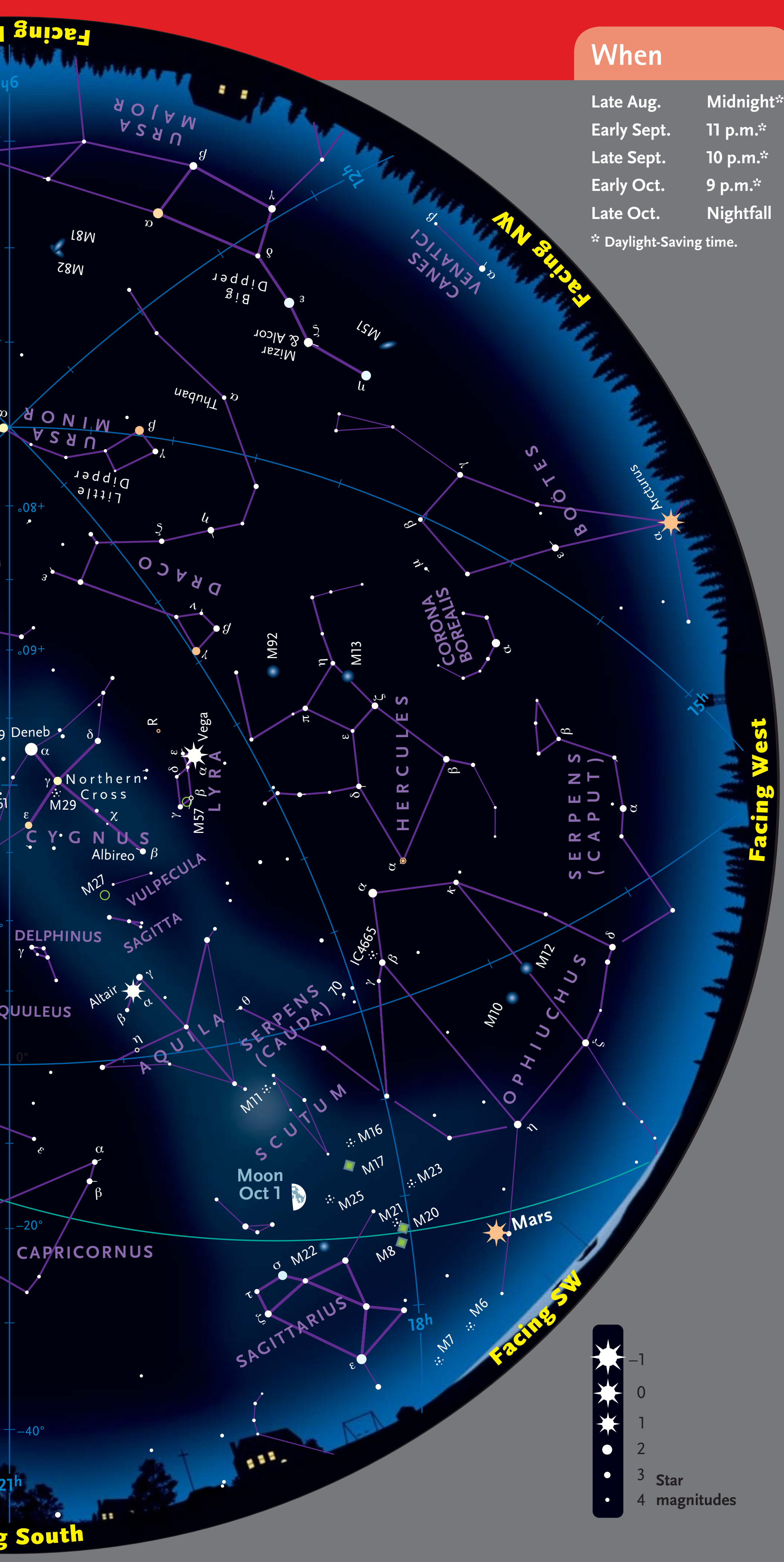
SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

Late Aug.	Midnight*
Early Sept.	11 p.m.*
Late Sept.	10 p.m.*
Early Oct.	9 p.m.*
Late Oct.	Nightfall

* Daylight-Saving time.

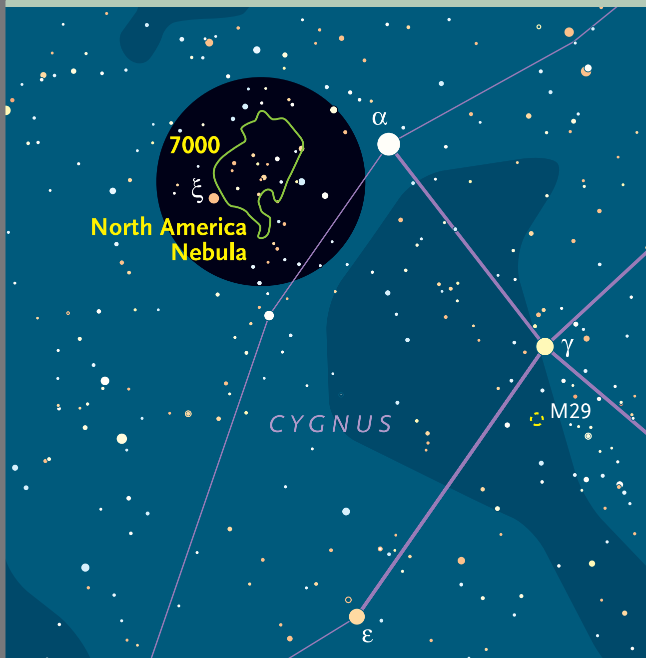
Gary Seronik
Binocular Highlight

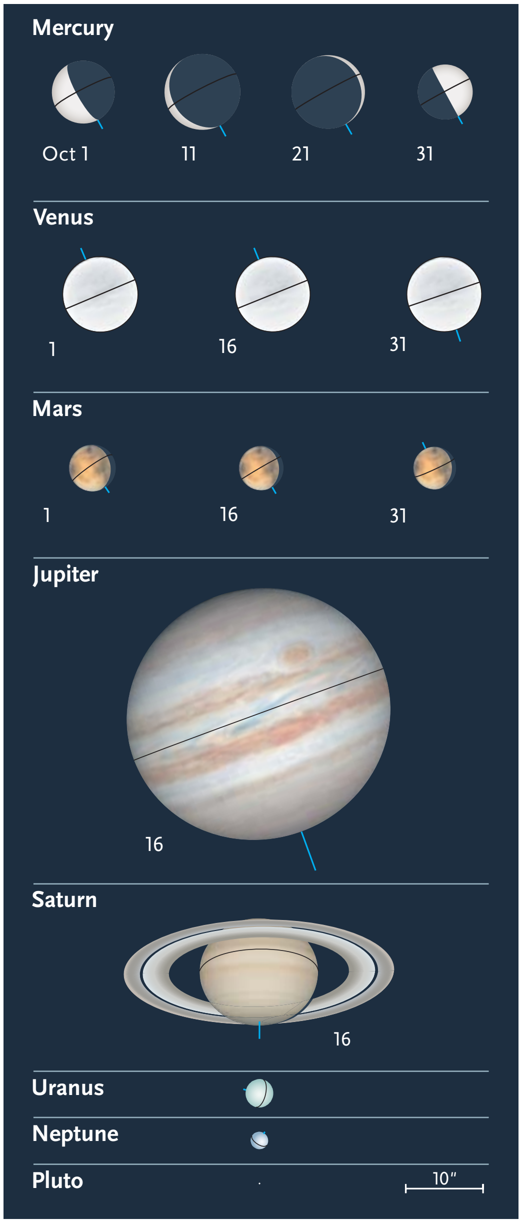
The North America Nebula

For observers at mid-northern latitudes, Cygnus is one of the most familiar constellations. Not only is it visible for much of the year (it shows up on 9 of our 12 monthly all-sky charts), it's at its best in autumn, when skies are usually clearest. Arguably its most famous (and photographed) deep-sky treasure is the notoriously difficult North America Nebula.

Cataloged as NGC 7000 and Caldwell 20, the emission nebula's name arises from its resemblance to the continent of North America. But discerning its form — or for that matter, seeing it at all — can be challenging. Although some sources list the nebula as bright as magnitude 4, it's very big, meaning that its surface brightness is low. And given that it was discovered by the great astronomer William Herschel in 1786 with his workhorse 18¾-inch reflector, you might be surprised to learn it can be seen in binoculars at all. Yet it can.

Dark skies are a must, but at least the North America Nebula's position is easy to pin down, just a couple of degrees east of Deneb. I can see the object readily in my 10×30 image-stabilized binoculars, and it fills the 4½-degree field of view of my 15×45s. Much of the nebula's expanse is tricky to distinguish from the rich starry background — it's almost easier to see where it isn't, rather than where it is. The most prominent area is the one bordered by the dark Gulf of Mexico. Central America and the Eastern Seaboard are the brightest and easiest sections to make out, whereas the northern region fades into the Milky Way's glow. A prominent orange star, 3.7-magnitude Xi (ξ) Cygni, shines like a beacon from a dark void off the Pacific coast, adding a little extra sparkle to the scene. ✦



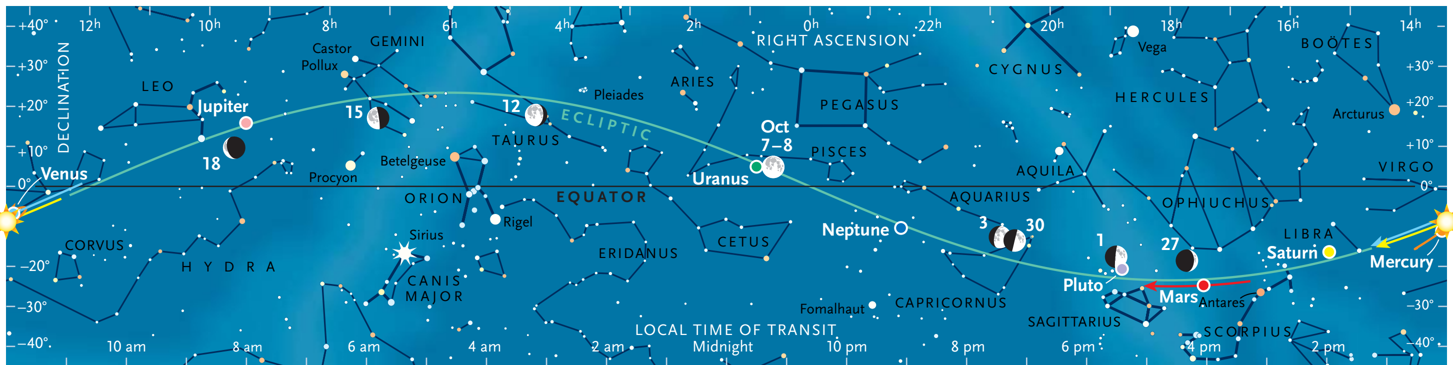


Sun and Planets, October 2014

	October	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$12^h\ 27.7^m$	–3° 00′	—	–26.8	31′ 57″	—	1.001
	31	$14^h\ 19.7^m$	–13° 56′	—	–26.8	32′ 13″	—	0.993
Mercury	1	$13^h\ 51.8^m$	–15° 15′	24° Ev	+0.3	8.1″	39%	0.825
	11	$13^h\ 45.6^m$	–14° 09′	13° Ev	+2.4	9.8″	10%	0.684
	21	$13^h\ 08.9^m$	–7° 24′	9° Mo	+3.0	9.5″	6%	0.707
	31	$13^h\ 12.7^m$	–5° 30′	19° Mo	–0.5	7.1″	50%	0.944
Venus	1	$12^h\ 06.7^m$	+0° 50′	6° Mo	–3.9	9.8″	99%	1.706
	11	$12^h\ 52.5^m$	–4° 11′	4° Mo	–4.0	9.7″	100%	1.713
	21	$13^h\ 38.8^m$	–9° 04′	2° Mo	—	9.7″	100%	1.717
	31	$14^h\ 26.5^m$	–13° 37′	2° Ev	–4.0	9.7″	100%	1.715
Mars	1	$16^h\ 38.9^m$	–23° 39′	64° Ev	+0.8	6.1″	89%	1.535
	16	$17^h\ 25.5^m$	–24° 43′	60° Ev	+0.9	5.8″	89%	1.610
	31	$18^h\ 14.0^m$	–24° 54′	56° Ev	+0.9	5.6″	90%	1.682
Jupiter	1	$9^h\ 13.4^m$	+16° 38′	52° Mo	–1.9	33.7″	99%	5.850
	31	$9^h\ 30.8^m$	+15° 22′	77° Mo	–2.1	36.3″	99%	5.431
Saturn	1	$15^h\ 13.7^m$	–15° 54′	43° Ev	+0.6	15.6″	100%	10.649
	31	$15^h\ 26.7^m$	–16° 47′	16° Ev	+0.5	15.3″	100%	10.892
Uranus	16	$0^h\ 52.5^m$	+4° 52′	172° Ev	+5.7	3.7″	100%	19.026
Neptune	16	$22^h\ 27.9^m$	–10° 26′	133° Ev	+7.8	2.3″	100%	29.288
Pluto	16	$18^h\ 46.7^m$	–20° 39′	79° Ev	+14.2	0.1″	100%	32.926

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-October; 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

Doubling Up in Cygnus

The celestial Swan boasts some of the sky's best double stars.

The trees are in their autumn beauty,
The woodland paths are dry,
Under the October twilight the water
Mirrors a still sky;
Upon the brimming water among the stones
Are nine-and-fifty swans.
. . .
But now they drift on the still water,
Mysterious, beautiful;
Among what rushes will they build,
By what lake's edge or pool
Delight men's eyes when I awake some day
To find they have flown away?
— William Butler Yeats, *The Wild Swans at Coole*

Back in the autumn of 1992, I was treated to a pair of wild swans staying week after week at the small pond near where I live. I was hoping they'd stay long enough to be on the water at moonrise just before the total lunar eclipse of December 9, 1992. My wish came true, and I was able to photograph the two as they drifted across the full Moon's glitter path on the water. But after that night, I never saw them again.

As Yeats said, the swans had flown away. Fortunately, at October nightfall one great swan still hangs very high in the western sky for all of us in northern lands. Its name is Cygnus, and this month we continue the exploration of its diversities and motions. We will double up on doubles, exploring two matched pairs of double stars.

Albireo and Omicron Cygni. Cygnus is home to the most famous of all strongly colored double stars — Beta Cygni, better known as Albireo. Magnifications as low as 10× can show that this star, which marks the beak of the Swan, is really a 3.1-magnitude gold star with a 5.1-magnitude blue star 34″ from it. Amazingly, Albireo is moving almost straight toward us — in a few million years its proximity will make it one of the brightest stars in the night sky.

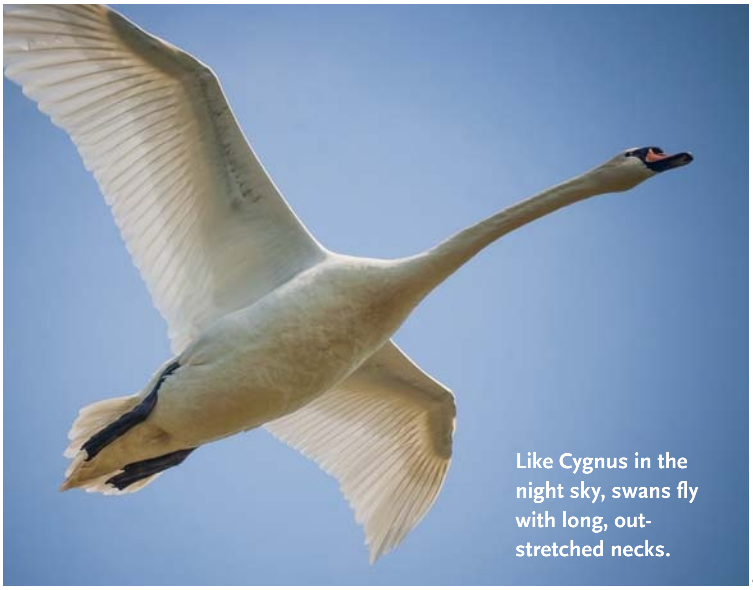
Albireo has competition on the opposite end of Cygnus. Just a few degrees northwest of Deneb is a pair of stars separated by about a degree: Omicron^1 and Omicron^2 (o^1 and o^2) Cygni. I first discovered their marvelous secrets in the 1970s.

The two stars are a 3.8- and 4.0-magnitude pair to the naked eye. But binoculars and telescopes (and keen naked eyes, as described on page 66 of last month's issue) show the 4.8-magnitude star 30 Cygni 338″ northwest of Omicron^1. I have seen 30 Cygni as delicately green, a handsome contrast to nearby golden Omicron^1 and more distant, vividly orange, Omicron^2.

But that's not all. A 7.0-magnitude star shines 107″ south of Omicron^1. Some observers say it is blue, but I have observed it as distinctly purple. See what you think!

Pairing 61 Cygni with 16 Cygni. A double star in Cygnus perhaps as famous as Albireo is 61 Cygni, Piazzi's Flying Star, which is discussed at length on page 50 of the August issue. It's just 11.4 light-years from the Sun — the fourth closest naked-eye star, after Alpha Centauri, Sirius, and Epsilon Eridani. (Procyon is probably slightly more distant, though the error bars in the measurements leave room for doubt.) Telescopes show that 61 Cygni is a beautiful pair of orange stars, magnitude 5.2 and 6.0, which are currently 31″ apart.

If you reverse the numerals of 61 Cygni, you get 16 Cygni, which turns out to be a slightly fainter, similarly wide and well-matched pair. It lies near the Swan's west wing, whereas 61 Cygni is near the east wing. The yellow components of 16 Cygni shine at magnitude 6.0 and 6.2, and lie 39″ apart. NGC 6826, the "Blinking Planetary," shines less than ½° east of this double. ✦



Like Cygnus in the night sky, swans fly with long, outstretched necks.

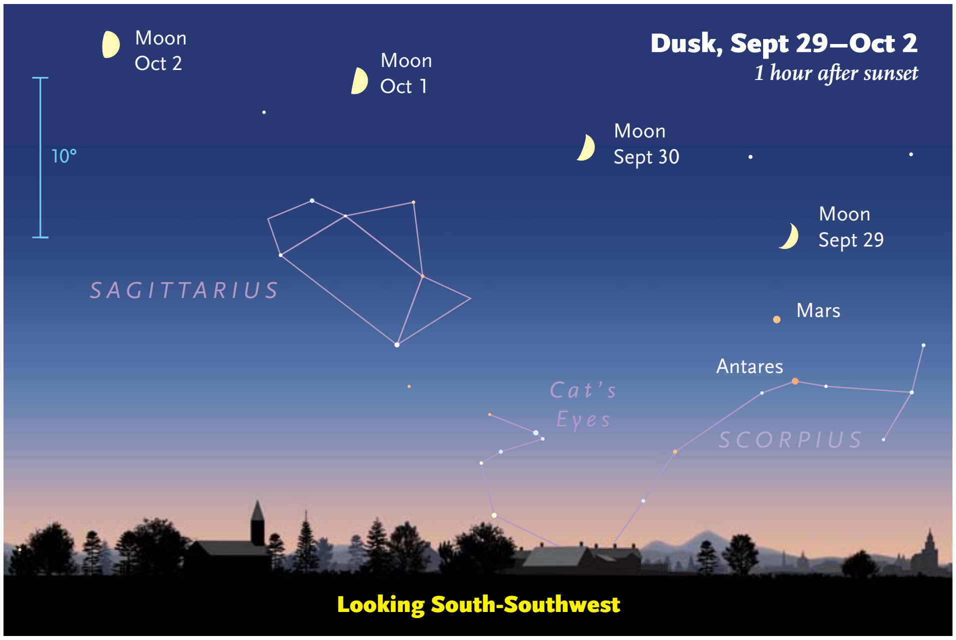
A Busy October for the Moon

The Moon experiences one eclipse, causes another, and hides Saturn.

The second eclipse season of 2014 brings most of North America exciting views of a total lunar eclipse and, two weeks later, a partial solar eclipse. Only the easternmost U.S. and Canada miss out on these events. See page 50 for the lunar eclipse early on the morning of October 8th and page 52 for the October 23rd eclipse of the Sun.

Dusk this month features Saturn sinking very low in the west-southwest and Mars maintaining its modest height in the southwest. Mars has a startlingly close encounter with Comet Siding Spring (C/2013 A1), both in space and on the sky, in mid-October; see page 53.

Bright Jupiter rises after midnight and is fairly high by dawn. Venus may be visible shortly before sunrise at the beginning of October, but it soon disappears into the Sun's glow. And late in the month Mercury approaches the peak of its best dawn apparition of 2014 for Northern Hemisphere observers.



DUSK & SOON AFTER

Saturn begins October only about 10° high in the west-southwest an hour after sunset for mid-northern observers. By month's end the ringed world is probably too low in bright twilight to spot without optical aid.

A challenging occultation of Saturn by the 3.5%-lit Moon may be visible through a telescope around midday on October 25th from easternmost Canada; see the article on page 36 about daylight observing. The occultation should be somewhat easier for Spain and the British Isles, where it takes place in the late afternoon, and much easier from France and Italy to southern Scandinavia, where it happens in twilight.

Mars sets about three hours after the Sun all month and is about 15° high an hour after sunset for observers around 40° north latitude. The Red Planet begins October at magnitude +0.8, slightly brighter than Antares, its rival in color, and only about 4° from the star. But Mars glides rapidly east through the stars during the month, ending October just 2½° to the right of 3rd-magnitude Lambda (λ) Sagittarii, the top of the Sagittarius Teapot.

Along the way, around 18^h UT on October 19th, faint **Comet Siding Spring** passes less than 100,000 miles from Mars in space and about 2′ from Mars on the sky, as described on page 53. Mars's globe has dwindled to less than 6″ wide.

Pluto, in northeastern Sagittarius, is highest in a dark sky at the end of evening twilight, but that's still painfully low for mid-northern viewers. See the June issue, page 50, for a finder chart.

ALL NIGHT LONG

Uranus reaches opposition in Pisces on October 7th and is therefore visible all night this month. By amazing coincidence, Uranus has a close conjunction with the Moon near the peak of October 8th's total lunar eclipse — a conjunction that will be an occultation in some Arctic regions. At magnitude 5.7, Uranus is usually too faint to spot through a telescope when near the full Moon, but it should be easy when the Moon is drastically dimmed in Earth's shadow. The 3.7″-wide blue or blue-green disk of Uranus should look especially beautiful in a telescope near the vast reddish eclipsed Moon.

Neptune, in Aquarius, transits the meridian in the evening about 2½ hours before Uranus does. It shines 2.1 magnitudes dimmer than Uranus and appears about ⅔ as wide through a telescope. See page 50 of the September issue for a finder chart for both planets.

LATE NIGHT TO DAWN

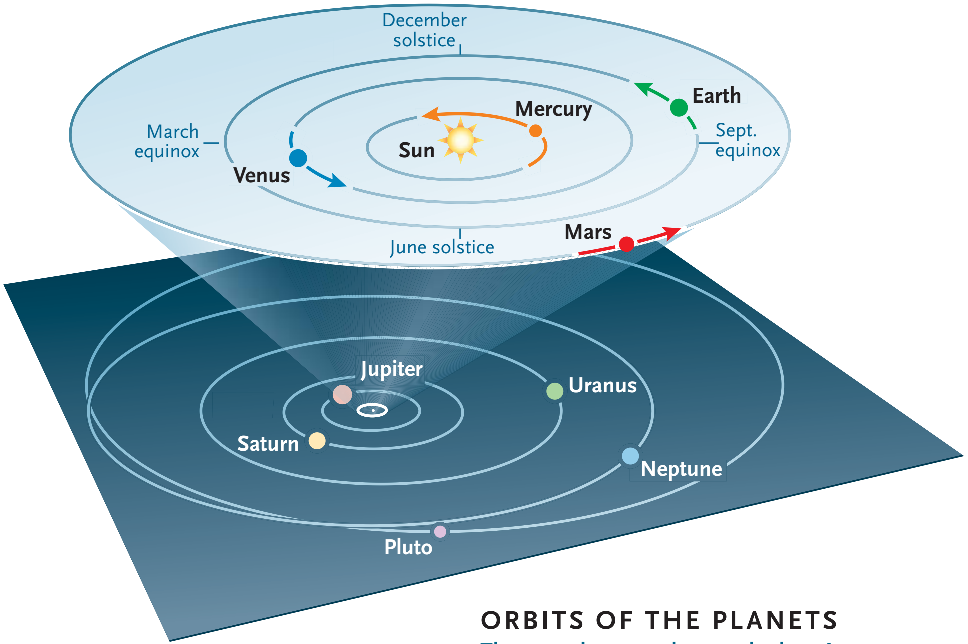
Jupiter rises around 2:30 a.m. (daylight-saving time) at the start of October, and around 1 a.m. by the end of the month. The kingly planet brightens to magnitude –2.1, Fred Schaaf

but its globe is still only a little larger than its minimum apparent diameter. Even so, Jupiter climbs high in the southeast by morning twilight, and telescopes will show interesting details on its cloudy face. Jupiter crosses from Cancer into Leo around mid-month. Regulus is roughly a fist-width at arm's length to its east.

DAWN

Mercury goes through inferior conjunction on October 16th and then rapidly ascends into dawn view, appearing higher in the east-southeast each morning on its way to greatest elongation on November 1st. It should become visible to the unaided eye around October 24th, shining at magnitude +1.1. In a telescope that morning it's a 8.7″-tall, 19%-lit crescent. By October 31st it has brightened fourfold, to magnitude –0.5, and it's more than 50% illuminated. Mercury then shines about 9° high 45 minutes before sunrise, with Spica about 7° to its lower right.

Venus starts the month rising only ½ hour before the Sun, and it rises later each morning. The planet soon becomes lost from view in the solar glare, passing through superior conjunction about 1° north of the Sun on October 25th.



ORBITS OF THE PLANETS

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

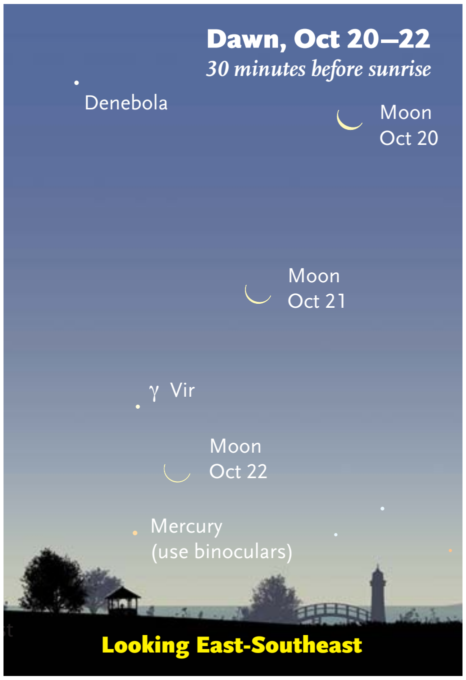
SUN AND MOON

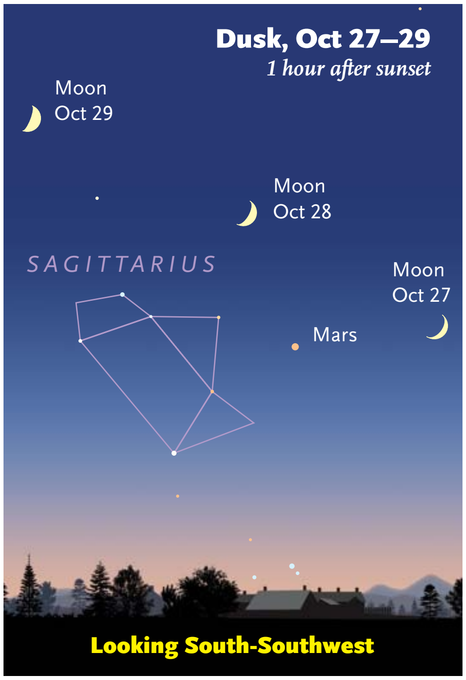
The **Sun** experiences a partial eclipse on October 23rd; see page 52.

The **Moon** undergoes a total eclipse while passing near or in front of Uranus on October 8th (see page 50).

The waning crescent Moon is to the right of Jupiter at dawn on October 17th and below Jupiter, forming a triangle with Regulus, on the 18th.

Back in the evening sky after the solar eclipse, the thin waxing lunar crescent is just upper left of Saturn shortly after sunset on October 25th in the Americas, and it occults Saturn in parts of Canada and Europe as described above. A thicker crescent passes to the right Mars on October 27th and above Mars on the 28th. ✦





Eclipse of a Large Moon

The full Moon will be near perigee when it slides through Earth's shadow on the morning of October 8th.

A totally eclipsed Moon can be anything from bright, coppery orange to deep red-black. And even within a given eclipse there's a lot of variation across the Moon's face, as seen here.

DENNIS DI CICCO

We're approaching the second of four total lunar eclipses that come at half-year intervals this year and next: a lunar-eclipse *tetrad*. All four can be seen from at least parts of North America. The one coming on the morning of Wednesday, October 8th, will be visible from nearly all of the Americas. Moreover the Moon, two days after perigee, will be 5.3% larger in diameter than it was during the first eclipse of the tetrad last April 15th.

The map, diagram, and timetable on the facing page tell what to expect at your location and when. If you're in the central or western parts of the U.S. and Canada, you'll see the total eclipse high in a dark sky well before sunrise. Easterners will find dawn brightening and the Moon sinking low in the west while the eclipse is in progress — offering particularly interesting photo opportunities.

Stages of the Eclipse

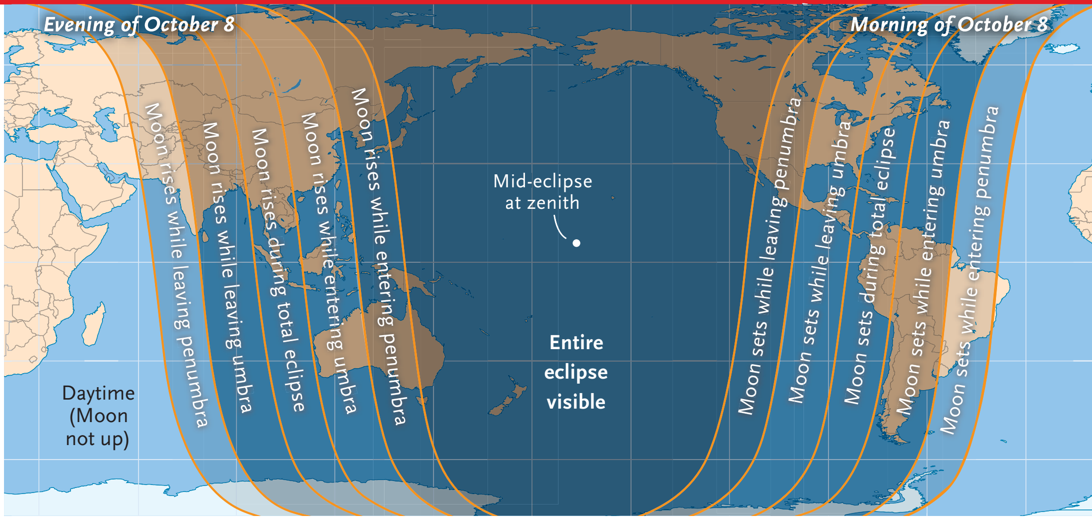
A total lunar eclipse has five stages, with different things to watch at each.

The first *penumbral* stage begins when the Moon's leading edge enters the pale outer fringe of Earth's shadow, the penumbra. But the shading is so weak that you won't notice anything until the Moon has intruded about halfway across the penumbra. Watch for a slight darkening to become apparent on the Moon's celestial eastern side. The penumbral shading becomes stronger as the minutes tick off and the Moon moves deeper in.

The second stage is *partial eclipse*. This begins much more dramatically when the Moon's leading (eastern) edge enters the umbra, Earth's inner shadow, where no direct sunlight reaches. With a telescope, you can watch the edge of the umbra slowly engulfing one lunar feature after another, as the entire sky grows darker and darker.

An hour or so into partial eclipse, only a final bright sliver of Moon remains outside the umbra. And the rest is already showing an eerie reddish glow.

The third stage is *total eclipse,* beginning when the last rim of Moon slips into the umbra. Although the Sun here is completely hidden, the Moon is sure to glow some shade of orange or red. This red light on the Moon is sunlight skimming and bending through Earth's atmosphere: it's the light of all the sunrises and sunsets that



S&T ILLUSTRATIONS (2)

For your location, see if the Moon will set or rise during any stage of the eclipse. Because an eclipsed Moon is always full, the Sun rises or sets at almost the same time on the opposite horizon. This means a lunar-eclipse moonset or moonrise always happens in a bright sky.

ring our world at any given moment. An astronaut standing on the Moon would see the Sun hidden and the dark Earth ringed with sunset- and sunrise-colored brilliance.

On rare occasions the eclipsed Moon does go almost black. Other times it appears as bright as a fresh penny. Sometimes it turns brown like milk chocolate.

Two factors affect an eclipse's color and brightness. The first is simply how deeply the Moon goes into the umbra; the umbra's center is much darker than its edges.

The other factor is the state of Earth's atmosphere along the sunrise-sunset line. If the air is very clear, the eclipse is bright. But if a major volcanic eruption has recently polluted the stratosphere with thin global haze, the eclipse will be dark red, ashen gray, or almost black.

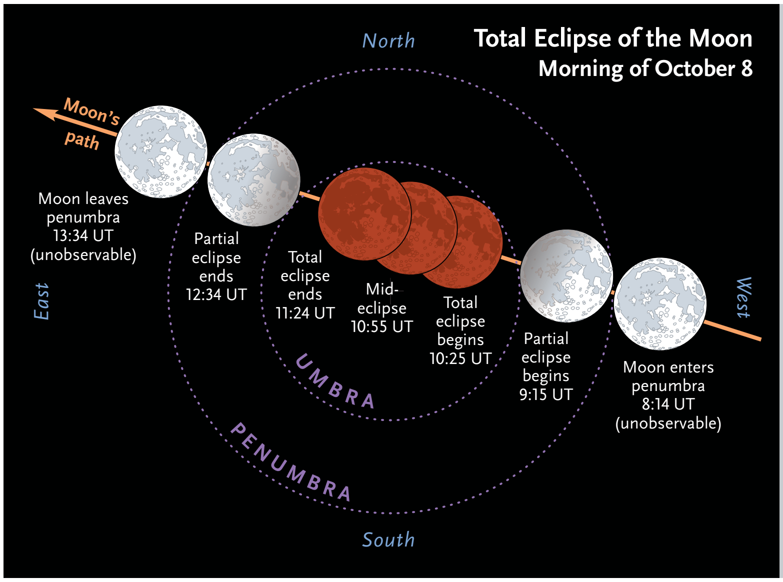
In addition, blue light refracted by Earth's clear, ozone-rich upper atmosphere can also add to the scene, especially near the umbra's edge, creating a subtle mix of changing colors. Time-lapse videos may show large "flying shadows" in the umbra, caused by changing cloud-shadowing effects around the sunrise-sunset line as Earth turns.

Totality this time lasts 59 minutes. And then, as the Moon continues eastward along its orbit, events replay in reverse order. The Moon's leading edge re-emerges into sunlight, ending totality and beginning stage four: partial eclipse again.

When all of the Moon escapes the umbra, only the last, penumbral shading is left for stage five. This final duskiness slowly fades away, leaving the Moon as bright as ever.

Uranus Too!

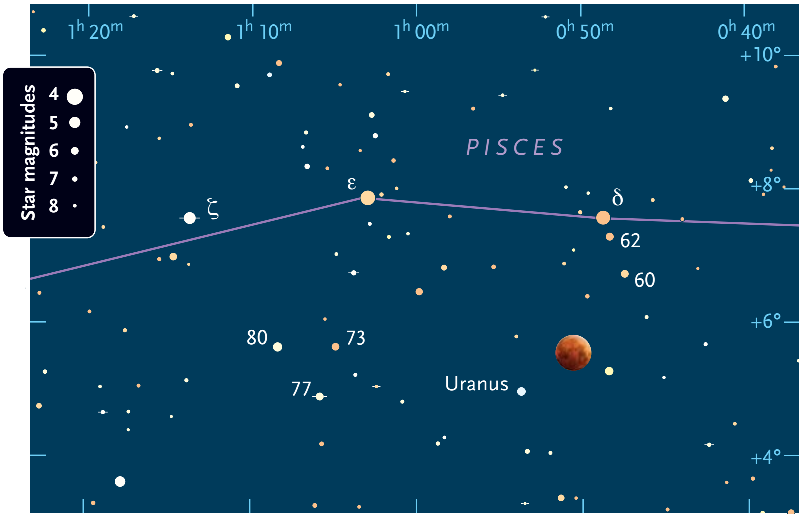
By quite a coincidence the planet Uranus, magnitude 5.7, will appear only about 1° from the Moon during totality. Spot it with your telescope or binoculars using the chart



Total Eclipse of the Moon
October 8, 2014

Eclipse event	EDT	CDT	MDT	PDT
Penumbra first visible?	4:45 a.m.	3:45 a.m.	2:45 a.m.	1:45 a.m.
Partial eclipse begins	5:15 a.m.	4:15 a.m.	3:15 a.m.	2:15 a.m.
Total eclipse begins	6:25 a.m.	5:25 a.m.	4:25 a.m.	3:25 a.m.
Mid-eclipse	6:55 a.m.	5:55 a.m.	4:55 a.m.	3:55 a.m.
Total eclipse ends	7:24 a.m.	6:24 a.m.	5:24 a.m.	4:24 a.m.
Partial eclipse ends	—	7:34 a.m.	6:34 a.m.	5:34 a.m.
Penumbra last visible?	—	—	7:05 a.m.	6:05 a.m.

below. The actual position of the eclipsed Moon on the starry background in Pisces will depend slightly on where you are and the stage of the eclipse. On the chart, the Moon is positioned for the middle of North America at the start of totality, but elsewhere the difference won't be more than a couple of Moon diameters at most. You should have no trouble finding 4½-magnitude Epsilon (ε) and Delta (δ) Piscium north of the Moon. Identify Uranus by the shape of the triangle it makes with those two stars.



Spot 5.7-magnitude Uranus near the Moon using this chart of Uranus's position among the stars. The Moon's position may vary a bit; it's plotted here for an observer in the middle of North America at the start of totality.

Can you see anything of Uranus's aquamarine blue-green tint? Contrast with the vivid orange-red Moon may make this color a little more apparent. In a telescope Uranus is a tiny disk 3.7 arcseconds wide. It's 2.6 light-hours from Earth, compared to the Moon's 1.2 light-seconds.

And a Selenelion?

If you're in central or eastern North America, the Moon will still be at least partially eclipsed when it sets in the west and the Sun rises in the east. For most of the East Coast, this happens during totality. Meteorologist Joe Rao points out that this eclipse presents an unusual chance to try seeing a *selenelion:* when the Sun and eclipsed Moon are

October's Partial Solar Eclipse

On the afternoon of October 23rd, two weeks after the Moon passes through Earth's shadow, the Moon will cast some of its own shadow onto Earth.

Nowhere will this eclipse of the Sun be total. But as the map at right shows, the Sun will become partially eclipsed for North America and Mexico.

You'll need a safe solar filter designed for Sun viewing if you want to look at the Sun directly, either with or without other optical aid. Staring at the bright Sun without a safely designed filter can permanently damage your vision. Another option is to project a sharp image of the Sun onto a piece of paper with binoculars or a small telescope; you watch the paper. Or you can try pinhole projection, though this gives an image of the Sun that's very small and dim. For more about viewing and photographing the partially eclipsed Sun safely, see **skypub.com/observing/celestial-objects-to-watch/eclipses**.

For this event, the farther west and north you are the better, as shown on the map. In the American and Canadian West, the entire eclipse happens while the Sun is still fairly high in the afternoon sky. In most of the eastern half of the continent, the eclipse will still be in progress at sunset — offering dramatic photo opportunities if you can find a low western horizon. Along a line running from the Florida Panhandle through Michigan and the Hudson Bay, the Sun sets right when the eclipse reaches its maximum depth.

East of that line, the Sun will set after the partial eclipse begins but before it reaches maximum. Maine and the Maritime provinces miss out altogether.

The farther north you are, the *deeper* the partial eclipse will become. In San Diego, for instance, the Moon's silhouette will reach 43% of the way across the Sun's disk at mid-eclipse (3:32 p.m. Pacific Daylight Time). In Vancouver the silhouette will extend 66% of the way across (at 2:57 p.m. PDT). For precise local times for many cities and towns, and more about the eclipse, see **eclipse.gsfc.nasa.gov/OH/OH2014.html**.

Things to Look For

• Can you see any sunspots? Watch the Moon's edge creep up to them! By comparing them to the Moon's blackness, can you see that sunspots are not actually black, just darker than their surroundings?

• Look for irregularities on the edge of the Moon's silhouette. These are mountains seen in profile on the Moon's limb.

• As the eclipse progresses, look around at the landscape and the blue sky. Has the blue become deeper and purer? You may be surprised by how much sunlight has to be lost before anything looks different, due to how well our eyes adapt to changing lighting conditions.

• Look for dim dapples of sunlight on the ground under leafy trees. During a partial eclipse, random pinhole projectors form among leaves and branches, and each dapple-image of the Sun's disk will have an identical dent. Or make little holes between the fingers of your two hands laid across each other at right angles, and both above the horizon at once.

For most eastern cities, sunrise will occur a good 5 minutes before moonset. This is possible for three reasons: it's the *center* of the umbra that's exactly opposite the Sun, and the Moon is not quite there. Moonset and sunrise refer to the top edges of the Moon and Sun, not their centers. And atmospheric refraction at the horizon lifts the apparent position of all celestial objects there by 0.6°.

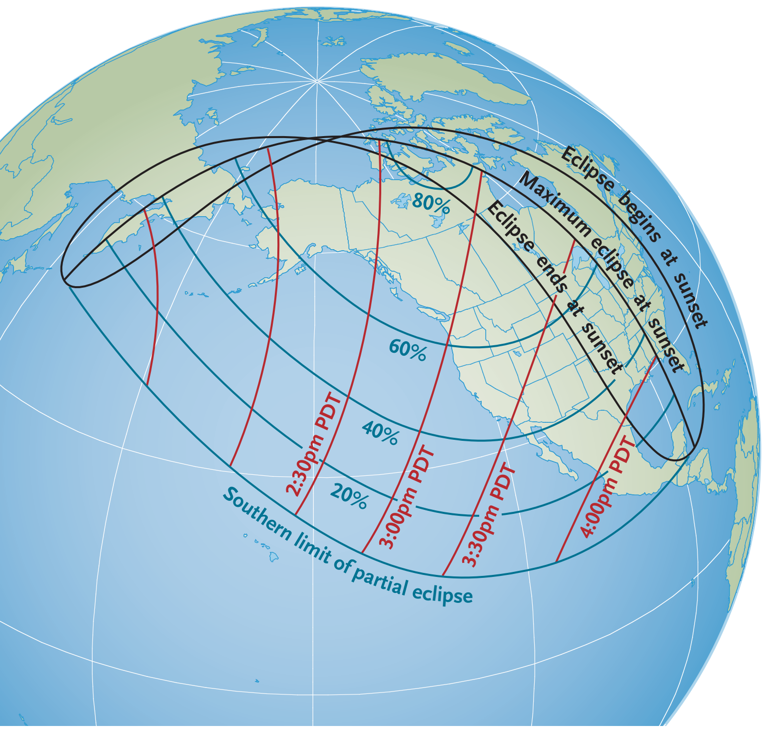
Of course you'll need true, flat horizons both to your east and west. An even trickier problem will be the bright sky. Bradley Schaefer, who made a study of the low Moon's visibility, reported in the August 1989 *Sky & Telescope* that even an uneclipsed full Moon is only visible when it is at least 2° above the horizon and the Sun is at least 2° below the horizon. So bring good optical aid, and settle for a partial-eclipse selenelion if that's what you get. When is the last moment you can detect the Moon? For more, see Rao's article at **skypub.com/selenelion**.

Minima of Algol

Sept.	UT	Oct.	UT
1	1:14	2	14:10
3	22:03	5	10:59
6	18:52	8	7:47
9	15:40	11	4:36
12	12:29	14	1:25
15	9:18	16	22:14
18	6:06	19	19:02
21	2:55	22	15:51
23	23:44	25	12:40
26	20:32	28	9:29
29	17:21	31	6:18

look at the shadow cast by your hands.

This partial eclipse is just a warm-up. America's next *total* eclipse of the Sun is only three years away, on August 21, 2017, when the dark center of the Moon's shadow will pass from Oregon to South Carolina. See **skypub.com/observing/celestial-objects-to-watch/eclipses**.



Westerners can see all stages of the October 23rd partial solar eclipse. In most of North America's eastern half, the Sun will set while the eclipse is still in progress. Find what time the eclipse will be deepest at your site by interpolating between the red lines. All times are given in Pacific Daylight Time; add 1 hour to get MDT, 2 hours to get CDT, 3 hours for EDT. The blue lines show what percent of the Sun's diameter the Moon will cover at that time.

S&T: LEAH TISCIONE

Faint Comet Buzzes Mars

Comet Siding Spring was still only 14th magnitude when crossing Fornax last February 2nd.

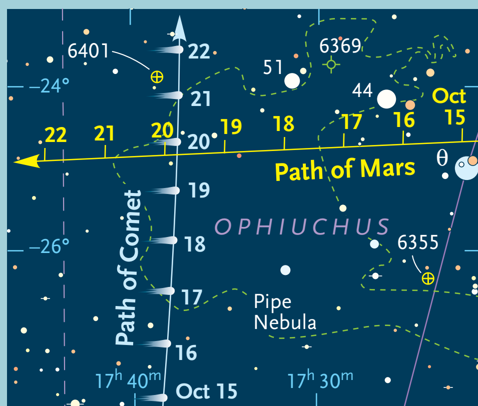
DAMIAN PEACH

Sometimes other planets get all the good stuff! On October 19th, Comet C/2013 A1 (Siding Spring) will pass 16 times closer to Mars than any known comet has ever come by Earth. It will miss Mars by just 82,000 miles (132,000 km). The record-holder for Earth is Lexell's Comet of 1770, which missed us by a relatively wide 1.4 million miles.

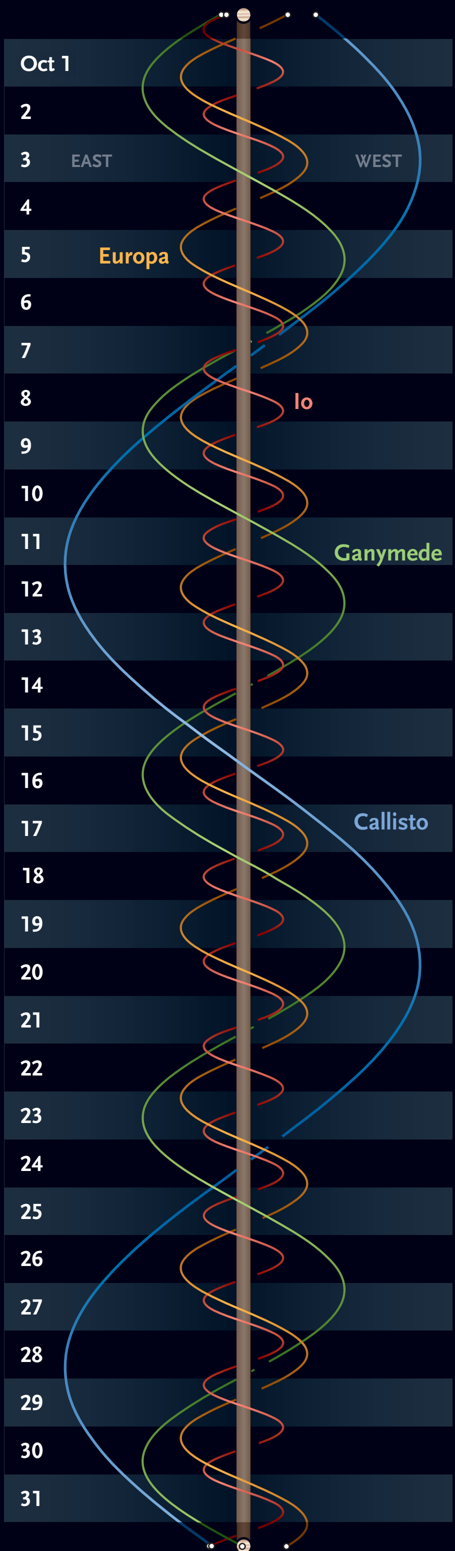
Seen from Earth, Comet Siding Spring should be about 9th magnitude in mid-October. It will be low in the southwest at the end of twilight, but at least Mars will be an easy marker for finding the right area.

The chart shows where to narrow in with your scope. The daily ticks are at 0:00 UT. Put dots on the positions of Mars and the comet for when you'll observe, and work in from Mars using the stars (plotted to 9th magnitude).

Expect this event to make news when the time comes. The various spacecraft on and around Mars will attempt close-up observations, though their cameras and instruments were never designed for quite this purpose!



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.

Phenomena of Jupiter's Moons, October 2014

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

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

Action at Jupiter

Jupiter shines very high before the late-arriving dawns of October, but it's still only 34 to 36 arcseconds wide.

Any telescope shows Jupiter's four big moons. Identify them using the diagram at left. Interactions between Jupiter and its satellites are listed above.

And here are the Universal dates and times when the Great Red Spot should cross Jupiter's central meridian:

October 1, 0:31, 10:27, 20:22; **2**, 6:18, 16:14; **3**, 2:10, 12:05, 22:01; **4**, 7:57, 17:53; **5**, 3:48, 13:44, 23:40; **6**, 9:36, 19:31; **7**, 5:27, 15:23; **8**, 1:19, 11:14, 21:10; **9**, 7:06, 17:01; **10**, 2:57, 12:53, 22:49; **11**, 8:44, 18:40; **12**, 4:36, 14:32; **13**, 0:27, 10:23, 20:19; **14**, 6:15, 16:10; **15**, 2:06, 12:02, 21:58; **16**, 7:53, 17:49; **17**, 3:45, 13:40, 23:36; **18**, 9:32, 19:28; **19**, 5:23, 15:19; **20**, 1:15, 11:10, 21:06; **21**, 7:02, 16:58; **22**, 2:53, 12:49, 22:45; **23**, 8:40, 18:36; **24**, 4:32, 14:28; **25**, 0:23, 10:19, 20:15; **26**, 6:10, 16:06; **27**, 2:02, 11:58, 21:53; **28**, 7:49, 17:45; **29**, 3:40, 13:36, 23:32; **30**, 9:28, 19:23; **31**, 5:19, 15:15. ✦

Rocking and Rolling

Set your sights on the ever-changing lunar limb.

Anyone who looks at the Moon regularly notices that features appear to change their positions with respect to the limb. Sometimes the eastern shores of **Mare Crisium** nearly touch the limb (as it appears to on October 1st), while most nights it's sufficiently far away for the highland terrain beyond to be easily visible. The Moon's rocking motion is known as *libration* and it changes our view of features along the limb, alternately revealing farside features and hiding some nearside ones.

Librations are *not* caused by the Moon itself physically tilting and bobbing. Instead, the Moon's movement through its orbit controls which parts of the limb we can see. The Moon rotates at a constant velocity around its polar axis (its day is of constant length), but because of its elliptical orbit around Earth, its orbital movement slows down when it is farthest from Earth and speeds up when closest in accordance with Kepler's Second Law of planetary motion. These changes in velocity result in terrestrial observers being able to peek around the lunar east and west limbs by as much as 7.7°. Thus we can periodically see some farside equatorial features not normally visible.

A second aspect of the Moon's motion gives us improved views of its polar regions. Because the Moon's polar axis is slightly inclined to its orbital plane, it is tilted so that periodically we see as far as 6.7° beyond its poles.

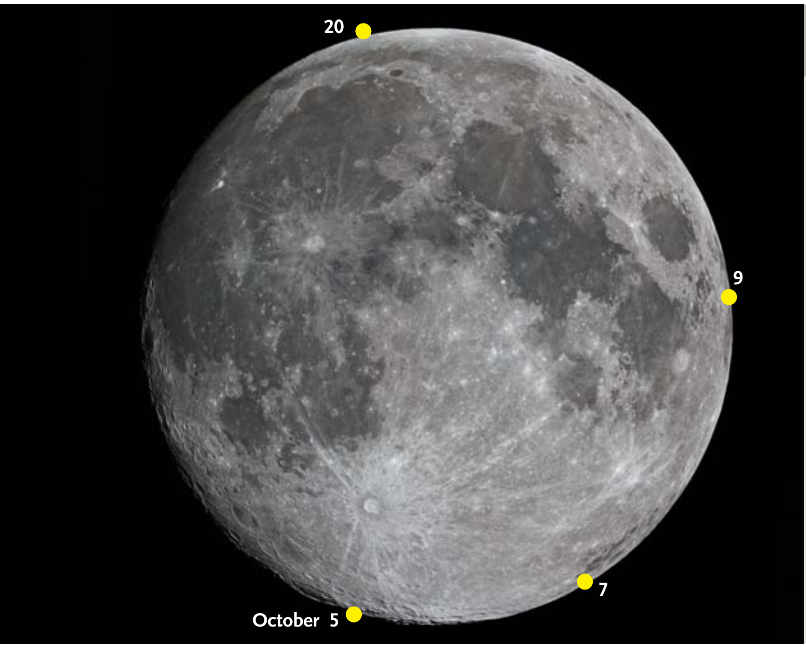
A third factor is the Moon's distance from Earth. When

S&T: SEAN WALKER (2)

Due to lunar libration, every night we see the Moon from a slightly different angle that doesn't repeat for more than 18 years. Note the extreme difference of perspective between these two images of the flooded crater Endymion (center in the far left image). At far left, the crater is well seen far from the lunar limb during a rare extreme libration, whereas at the near left, we see its outer rim projecting prominently above the lunar surface during a "negative" libration.

Contributing editor ***Charles A. Wood*** *never consults a libration chart, preferring to be surprised at what chance bestows on him.*

Charles A. Wood



S&T: DENNIS DI CICCO

The Moon • October 2014

Phases

FIRST QUARTER
October 1, 19:33 UT

FULL MOON
October 8, 10:51 UT

LAST QUARTER
October 15, 19:12 UT

NEW MOON
October 23, 21:57 UT

FIRST QUARTER
October 31, 2:48 UT

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

Distances

Perigee	October 6, 10^h UT
225,233 miles	diam. 32′ 58″
Apogee	October 18, 6^h UT
251,590 miles	diam. 29′ 31″

Librations

Wilson (crater)	October 5
Lyot (crater)	October 7
Neper (crater)	October 9
Desargues (crater)	October 20

the Moon is at apogee — its farthest point from Earth — we can see slightly farther around its entire limb than when it is closest at perigee. You can demonstrate this for yourself: hold an orange about 6 inches in front of your nose and then at arm's length. You'll see farther around the circumference when it's at arm's length.

Because the total libration of the Moon depends on a combination of all of these physical factors (and others), calculating the libration zone was quite difficult before the advent of electronic computers. Today, a variety of software programs can do it, and each issue of *Sky & Telescope* includes a map that pinpoints the best libration areas throughout the month and notes interesting features to observe (see above).

This month there are no extreme librations visible on the illuminated limb. The strongest libration starts on October 5th along the south-southwest limb near the crater **Wilson**. The best libration then migrates eastward to the southeast limb near **Lyot** two nights later, and continues to **Neper** on October 9th. By October 20th the part of the Moon with maximum tilt toward Earth is near the crater **Desargues**, just west of the lunar North Pole.

Unfortunately, the areas best tilted into view are not always visible. On the 5th the librated limb lies in shadow and thus is not observable. Similarly, on the 20th, although the region of Desargues is illuminated, it's near the sunset terminator and you can see very little at the tip of the thin lunar crescent. This month's examples of libration are pretty typical, and the frustrations that librations can provide remind me of the title of one of Robert A. Heinlein's best novels: *The Moon Is a Harsh Mistress*.

If you follow librations for a few lunations you'll notice that the librated limb migrates all the way around the edge of the Moon each month. That cycle continues, with greater or lesser degrees of tilt, every night afterwards, forever. Because of the interplay of all the different components of libration, it takes one saros cycle of 18 years, 11 days, and 8 hours before the exact libration and lighting repeats. This means that every time you observe the Moon, you see essentially a slightly different view.

When observing the Moon, *S&T* imaging editor Sean Walker suggests that librations provide *two* areas to observe. Although the positive liberated areas reveal Earthward tilted views of those limbs, the opposite limb is worth looking at too. Craters on that limb appear more in profile than how we usually see them. On the evening of October 5th, while the libration zone is in the south-southwest limb near Wilson, the opposite limb around the north polar area is tilted away from Earth, giving a profile view of craters such as **Scoresby** and **Anaxagoras**.

Looking at craters under "negative" libration reveals that crater rims are relatively low, compared with the great depths of their floors. You can experience this effect closer to home if you ever have a chance to visit Meteor Crater in northern Arizona. As you approach the site from a distance, the crater rim appears to be a low plateau, with no hint that it's really the mountainous edge of an amazing hole.

Librations, both positive and negative, reveal lunar features in a new light and help you understand limb craters in 3-dimensional space. Such changing perspectives make observing the Moon endlessly fascinating and new. ✦

Darkness and Light

Cygnus is replete with wonders, both bright and dark.

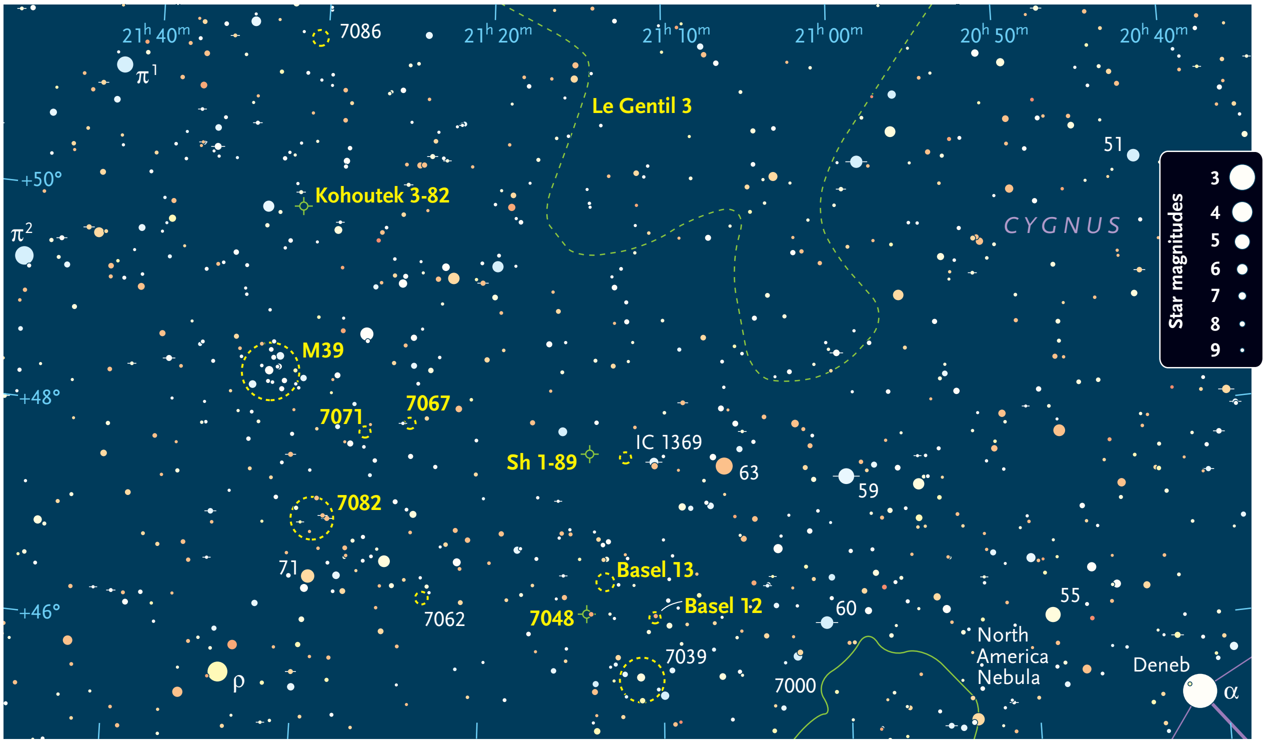
In 1749, the French astronomer Guillaume Le Gentil described a remarkable object behind the tail of Cygnus: "It seems of a different nature from all nebulae observed before and from the Milky Way, which it crosses at nearly a right angle. It's a large cloud, wider at one end than the other, the narrower end toward the southeast. This cloud is only about six degrees from the tail of Cygnus. It is almost opaque and very dark. A telescope reveals a few stars in this part of the sky, but none appear to the unaided eye. The cloud is visible without a telescope."

Have you ever noticed this dark nebula? **Le Gentil 3** is a striking feature when the sky is dark enough to lay the splendor of the Milky Way before your eyes. Training 10×30 binoculars on it, a wonderfully intricate study in shadow and light unfurls. The nebula tapers and shreds as it crosses the Milky Way, like black-lace curtains tattered by age in some long-forgotten mansion of the night.

Le Gentil 3 is simply a cold, dark cloud of interstellar gas and dust. Without the dense star fields that it obscures, we wouldn't be treated to this amazing interplay of light and dark.

Binoculars also reveal the open cluster **Messier 39**, just east of where Le Gentil 3 dissolves into streamers, encompassing 16 stars within its hallmark triangular shape. Through a telescope, M39 shows best at a magnification that frames it with a generous amount of surrounding sky. Through my 130-mm refractor at 37×, M39 appears a little more than ½° across with somewhat irregular borders. I count 50 stars. The brightest stars in this fairly young cluster glitter an icy white or blue-white, while many of the fainter ones are Milky Way backdrop.

M39 is an astonishingly triangular group of bright stars through my 10-inch reflector at 43×. I see a few touches of color among its stars. There's a yellow star in the group's western edge, an orange one south-southeast of M39's brightest star, and a golden one east of the triangle's northern point. A 9th-magnitude star along the eastern side of the triangle is the primary of the John Herschel double star h1657 (HJ 1657), whose 12th-magnitude companion sits 23″ to the north-northeast. A few stars south of the triangle make a short trunk for a very wide Christmas tree.



I count 25 bright stars in M39 through the 10-inch, ranging from magnitude 6½ to 10, and about three times as many stars from the opulent Milky Way background.

Folks with large telescopes might like to acquire the nice little planetary nebula **Kohoutek 3-82**, perched 1.6° north of M39. Once spotted, I can hold it steadily in view with averted vision through my 15-inch reflector at 133×. Kohoutek 3-82 is easier to see at 216×, and I give it a very rough size estimate of 25″. I can hold the planetary with direct vision with the help of a narrowband nebula filter, and an O III filter works even better. The nebula is subtly annular, and my notes say that it looks slightly oval, tipped east of north. Although the nebula isn't quite round, images show a 16th-magnitude star off its north-northeastern rim. Could this unseen star have contributed to my perception? With his 27-inch reflector, German amateur Uwe Glahn has been able to see this star and a similarly feeble one that's superimposed on the annulus of Kohoutek 3-82, west-southwest of the planetary's center. See the next page for Glahn's sketch of the nebula.

Star clusters abound in Cygnus. **NGC 7071** and **NGC 7067** rest 1.2° west-southwest of M39 and emerge as two small fuzzy patches through my 130-mm scope at 37×. NGC 7071 hovers 7′ northeast of a distinctive 2.7′-tall Z outlined by several faint stars. The 9th-magnitude star northwest of the cluster shines orange. NGC 7067 sports two faint stars near its center and one that's a little brighter on its southern edge. At 164× NGC 7071 is a 3.8′-long band of nine stars, but one of the stars in the curve at the southeastern end is hard to see. NGC 7067 shows a fourth star making an arc with the two near the center. The haze is oblong, about 2½′ long and half as wide. Zooming in at 234× in the 130-mm scope, NGC 7067 shows a total of nine stars.

Through my 10-inch scope at 187×, NGC 7071 marshals 14 stars in a thin, wavy ribbon that's 4.2′ long, while NGC 7067 reluctantly gives up a smattering of extremely faint stars and spans 3′.

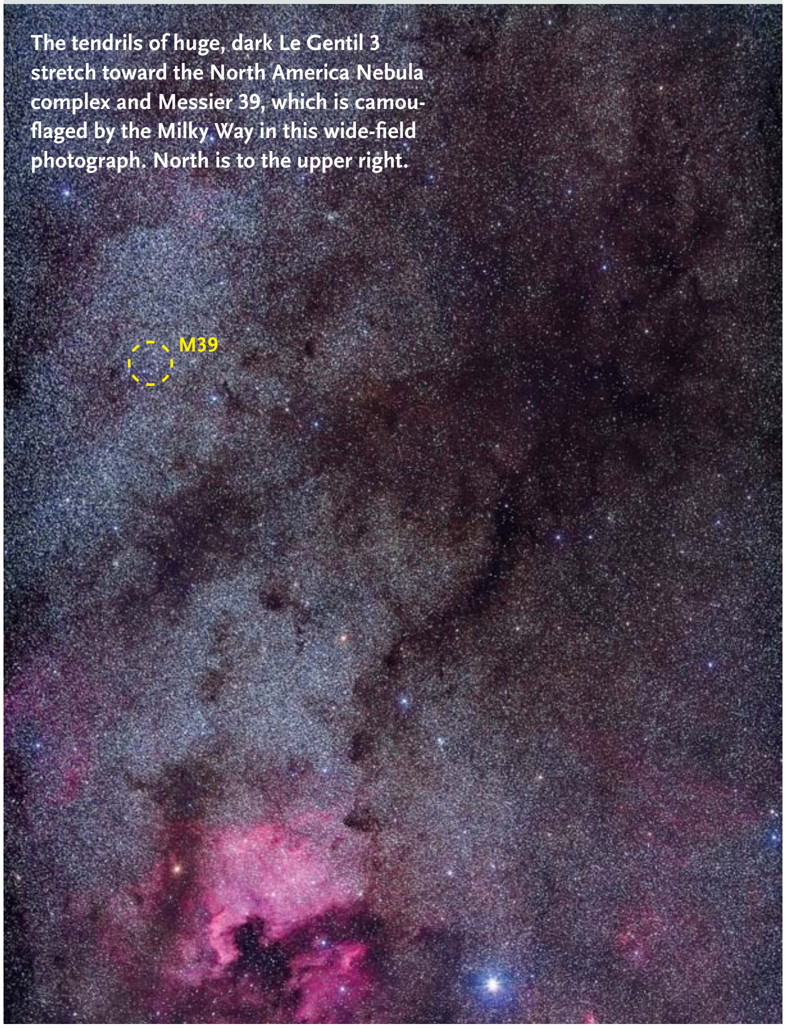
Nearby, **NGC 7082** is a pretty cluster residing 32′ north of golden 71 Cygni. My 130-mm refractor at 48× shows about 50 moderately bright to faint stars in a 25′ group with borders that are easy to lose track of amid the Milky Way. Five of the brightest stars make a squarish figure that nearly spans the cluster. The northern and two western stars shine gold, the eastern star pale yellow, and the southern star orange.

Basel 12 and **Basel 13** are two of the open clusters discovered at Switzerland's Astronomical Institute of the University of Basel, which was founded in 1874 and closed down in 2007. A lasting tribute to the Institute, this interesting cluster pair is located 1.5° southeast of yellow-orange 63 Cygni.

Bright Objects and One Great Dark Cloud in Northeastern Cygnus

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Le Gentil 3	Dark nebula	—	7° × 5°	$21^h\ 08^m$	+51° 40′
Messier 39	Open cluster	4.6	31′	$21^h\ 31.9^m$	+48° 26′
Kohoutek 3-82	Planetary nebula	14.9	22″ × 20″	$21^h\ 30.9^m$	+50° 00′
NGC 7071	Open cluster	10.0	4′	$21^h\ 26.7^m$	+47° 55′
NGC 7067	Open cluster	9.7	3′	$21^h\ 24.2^m$	+48° 01′
NGC 7082	Open cluster	7.2	24′	$21^h\ 29.4^m$	+47° 05′
Basel 12	Open cluster	—	4′	$21^h\ 10.5^m$	+46° 14′
Basel 13	Open cluster	—	10′	$21^h\ 13.2^m$	+46° 34′
NGC 7048	Planetary nebula	12.1	62″ × 60″	$21^h\ 14.3^m$	+46° 17′
Sharpless 1-89	Planetary nebula	14.8	64″ × 28″	$21^h\ 14.1^m$	+47° 46′

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



The tendrils of huge, dark Le Gentil 3 stretch toward the North America Nebula complex and Messier 39, which is camouflaged by the Milky Way in this wide-field photograph. North is to the upper right.

ALAN DYER

RICHARD ROBINSON AND BEVERLY ERDMAN / ADAM BLOCK / NOAO / AURA / NSF

Above: **Handsome NGC 7048 is by far the brightest planetary nebula discussed in this article.**

Left: **German stargazer Uwe Glahn sketched the planetary nebula Kohoutek 3-82 as seen with a nebula filter at 419× through his 27-inch reflector.**

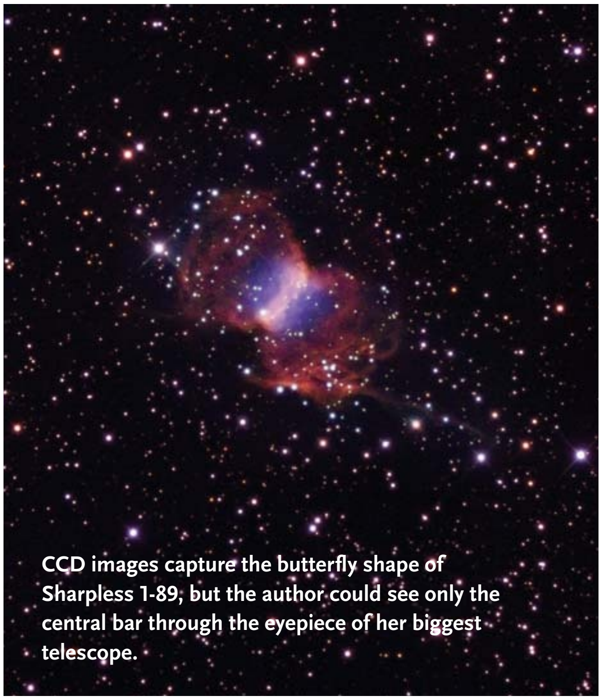
Through my 130-mm scope at 37×, Basel 12 wears an 8.5-magnitude reddish orange gem surrounded by little sparkles spanning 4½′. The grouping I see has 11th-magnitude stars on its east-northeast edge, just off the west-northwest edge, and a few arcminutes off the south-southwest edge. Basel 13 shares the same field of view and looks much like a patch of Milky Way set off by the dark nebulae that thread their way through much of this area and create many islands of stars. It has an irregular shape and covers about 10′ × 6′, running approximately north-northwest to south-southeast. Seen at 102×, Basel 12 also has an irregular border. It appears semi-detached from the field stars, about 6′ across, and shows 20 stars.

At 1,100 light-years, Messier 39 is the nearest star cluster in our tour. It resides, along with our Sun, in the spiral-arm shard of our galaxy known as the Orion Spur. The most distant cluster in the tour is NGC 7067, about 12,000 light-years away from us in the next spiral arm outward, the Perseus Arm. The others are strung between them, with Basel 13 at 4,000 light-years, galactic neighbors NGC 7082 and Basel 12 at about 4,700 light-years, and NGC 7071 at 5,500 light-years.

I noticed the planetary nebula **NGC 7048** in the field with Basel 13 at 63×, but the view is better at 117×. A 10th-magnitude star hugs the nebula's south-southeastern edge, and an 8th-magnitude star dwells 3.3′ west-southwest. The planetary stands out well with a narrowband filter and is round with a diameter of about 1′. It's also nice with an O III filter, but an H-beta filter banishes it from the sky.

Our final stop is the planetary nebula **Sharpless 1-89**, located 19′ southwest of the 6th-magnitude star HD 202654. With my 130-mm refractor at 91×, Sh 1-89 becomes detectable at 117×, a definite nebula at 164×, and best at 234×. It appears elongated southeast to northwest, with possible brighter spots at the ends. Checking this with my 10-inch reflector at 213×, I can see a star superimposed on the southeastern end. The nebula appears about 1′ long and one-third as wide. The ends may be weakly brighter than the rest of the nebula, but I'm not certain. My 15-inch scope offered no further elucidation.

On deep images, there's much more to Sh 1-89 than the bar-like structure that I was able to see. Big lobes balloon out from each side, metamorphosing the caterpillar-like planetary into a beautiful cosmic butterfly with a wingspan of more than 3′ northeast-southwest. Can anyone see these magnificent wings through the eyepiece of a telescope? ✦



CCD images capture the butterfly shape of Sharpless 1-89, but the author could see only the central bar through the eyepiece of her biggest telescope.

MAKIS PALAIOLOGOU / STEFAN BINNEWIES / JOSEF PÖPSEL

Alan Dyer

ESPRIT 100ED:
A Fast, Affordable Astrograph

Sky-Watcher touts its Esprit line as high-end astrograph refractors at a fraction of the usual cost. Does the new 100ED match the hype?

Sky-Watcher Esprit 100ED

U.S. price: $2,499
Available from www.skywatcherusa.com and through dealers worldwide

ALL PHOTOS COURTESY OF THE AUTHOR

IF YOU HAD TO LIVE with just one telescope, what would it be? For me, I'd pick a 4-inch apochromatic refractor. If designed right, an "apo" can serve for both visual observing and deep-sky imaging, yet it's highly portable. We have no shortage of such telescopes on the market.

The latest entry is a new model in the Esprit line of refractors from Sky-Watcher. The Esprit 100ED is advertised as offering image quality equal to refractors selling for twice the price. Indeed, it retails for $2,499, whereas most competitors with similar specs run $4,000 to $6,000. Too good to be true? *S&T* tested a unit on loan from Sky-Watcher Canada to find out.

Looking Through the Esprit

Like other refractors in the series, the Sky-Watcher Esprit 100ED employs a triplet objective with one element made from premium FPL53 extra-low dispersion glass for the pinnacle of color correction. The challenge is the 100ED's fast f/5.5 focal

The Sky-Watcher Esprit 100ED is a fast apochromatic refractor designed for imaging as well as visual use. It promises first-class performance for an affordable price. The tube collapses to a compact 46.5 centimeters (18.3 inches) but has a generous dewcap that extends to yield a total tube length of 64.3 cm.

The included 9×50 finderscope is an erect-image, right-angle design. You can focus it by loosening the retaining ring at the front end and then turning the objective.

ratio. Compared to slower f/7 and f/8 models, fast apos are tougher to make free of false color and other aberrations.

But my testing shows that Sky-Watcher succeeded. Although the Esprit line, and the 100ED in particular, are sold as *astrographs* — telescopes optimized for photography — the beauty of refractors is that making them great for imaging rarely compromises them for just visual use. By comparison, optimizing reflectors for imaging usually requires oversizing the secondary mirror, which degrades visual contrast and resolution.

The 100ED proved to be a superb visual instrument. Viewed at high power, stars looked "textbook perfect," with little evidence of spherical aberration disturbing their Airy disk patterns, and there was no hint of astigmatism distorting them into ellipses or other odd shapes from malformed or pinched optics.

Using Vega, racking to inside of focus revealed a trace of blue tint on the perimeter of the diffraction pattern, while outside of focus the pattern showed the palest rim of magenta. But when in focus, Vega was colorless with no halo of blue or violet. This is color correction on a par with other premium fast apos I have tested over the years.

Using a 41-mm Tele Vue Panoptic eyepiece to achieve the widest possible field with this telescope, stars looked sharp across the field, distorting only slightly at the very edges. Switching to a high-power 3-mm Radian eyepiece, I tried a popular test for resolution, the "Double Double" star Epsilon Lyrae. Each of its two tight pairs was cleanly split, with tiny Airy disks surrounded by a single diffraction ring and clear dark sky between the component stars. Visual observers will find little to criticize about the Esprit 100ED.

Photographing Through the Esprit

As it is sold in North America, the Esprit 100ED is supplied with a two-element field flattener. This device is not a focal reducer and does not change the f/ratio. The flattener replaces the visual back and has a step-down ring with a standard male T-thread for attaching CCD cameras. Also included is a T-ring adapter for Canon EOS cameras that threads onto this step-down ring. Owners of other camera brands will need to supply their own T-rings. Details on the adapter ring system are found in the telescope's manual, downloadable as a PDF from the Canadian Sky-Watcher site at **tiny.cc/ngdvhx**.

A word of caution: attaching a camera to the focuser involves three adapter rings plus the field flattener. Lose any one ring and you're out of business!

Images taken with the field flattener and a full-frame Canon 5D Mark II showed round stars across the field, with only very slight distortions in the extreme corners. This performance is as good as with any other telescope/flattener combination I've used.

The outer area of the frame was darkened slightly by vignetting, but no more so than with any fast apo in my

The f/5.5 objective elements are flawlessly multicoated, and the tube has one knife-edge baffle halfway down the tube to eliminate off-axis glare. The focal length as tested was 550 mm (21.7 inches) — just as advertised.

The included tube rings are each drilled with five ¼-20 bolt holes on both their tops and bottoms, making it easy to attach additional plates, rings, or other accessories.

experience. The vignetting was uniform and would be easy to correct with flat-field calibration frames or, as I prefer with raw DSLR files, using *Adobe Camera Raw*'s lens-correction settings.

Handling the Esprit

The tube weighs 7.6 kg (16.8 pounds) with its field flattener, tube rings, and dovetail plate — pretty hefty for a 4-inch telescope. Depending on what weight of camera and guidescope gear you would want to add, I'd suggest at least a medium-duty mount for any astrophotography performed with the Esprit 100ED. In the Sky-Watcher line, the EQ6 or AZ-EQ6 mounts would do the job.

The generously long dewcap is secured with two locking screws, so it won't slide back down the tube with a bang when aimed straight up. The supplied 9×50 finderscope offers decent optical quality, though stars were distorted in the outer half of the field. Its eyepiece provides generous eye relief, which enabled me to view its entire field of view while wearing glasses.

The solid 3-inch focuser combines a helical-cut rack-and-pinion gear on the bottom and a Crayford slider on the top. The top surface (not shown) features a graduated scale for pre-setting the focuser. The little silver lever is the lock.

The finderscope has sturdy rings and six nylon-tipped collimation bolts, which provide solid alignment. The finder's bracket attaches with a standard dovetail shoe secured to the main tube with a single setscrew. I was concerned this might lead to some wobble, but it proved solid and secure. This is important because some imagers will replace the 9×50 finder with a small guidescope in the same rings — and any looseness will be a problem.

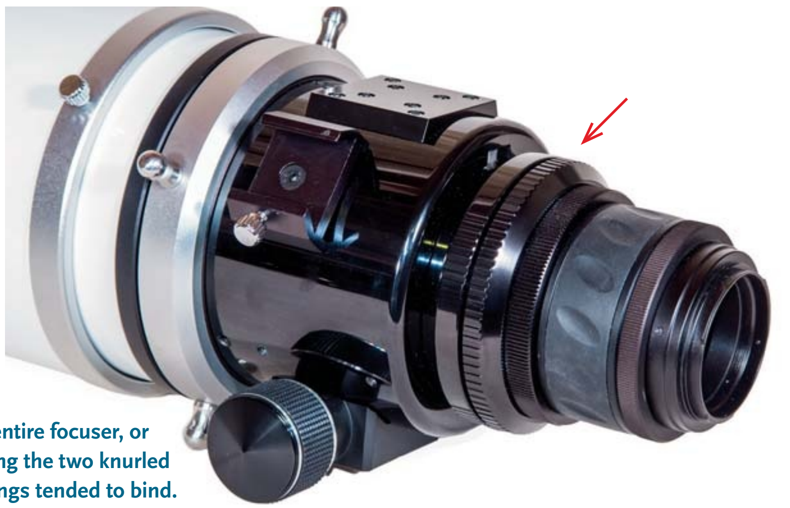
Focusing the Esprit

Besides the objective, the telescope's focuser is the most important element in any astrograph. The Esprit line uses what Sky-Watcher calls a "linear power" focuser, a hybrid rack-and-pinion and Crayford design. I found no wobble or image shift with heavy 2-inch eyepieces or a DSLR camera, though I did not weigh it down with massive CCD imagers, filter wheels, and robotic focusers. My impression is that the Esprit line is designed with the DSLR shooter in mind.

The distance from the back of the focuser to the focal plane is 185 mm. But for the flattest field, the critical

The focuser accepts either a 2-inch visual back for the included star diagonal, or a field flattener with its 48-mm step-down ring and T-ring for a Canon DSLR.

WHAT WE LIKE:
Superb optical quality for visual use
Flat field for photography use
Excellent focuser and fittings
Sturdy carrying case
WHAT WE DON'T LIKE:
Awkward camera rotation
Uses multiple adapter rings



You can loosen the spoked silver ring to rotate the entire focuser, or rotate just the camera and field flattener by loosening the two knurled rings (arrowed). Neither method was easy, as the rings tended to bind.

distance to maintain is the 63-mm spacing from the back surface of the field flattener to the focal plane — optimal for the back focus required by DSLRs and their T-rings. CCD cameras might require a custom-made spacer ring.

The 90 mm of focus travel provided more than enough range to accommodate all of the dozen or so 1¼- and 2-inch eyepieces I tried. But my William Optics binoviewer would not reach focus even with its Barlow lens installed and when used with a 1¼-inch diagonal.

The focuser has an 11:1 dual-speed mechanism, which proved very smooth and precise. There was enough tension so that even the heaviest eyepiece did not cause the focuser to slip when it was unlocked and aimed straight up. Yet it was easy to make fine adjustments. The lock lever did just that — it prevented further movement without introducing any image or focus shift.

My only issue with the Esprit 100ED's design is how it handles camera rotation. You want to easily rotate a camera up to 180° to frame the field, switch from landscape to portrait orientation, or put the camera right-side up after doing a meridian flip with a German equatorial mount. Rotation should be quick and easy, yet it should also lock back down again with no image or focus shift.

This setup offers two rotation points: a large "ship wheel" ring can be loosened, enabling the entire focuser to turn; or the camera and field flattener can turn by loosening two counter-rotating lock rings at the camera end of the focuser. With the former, it was just as easy to unscrew the entire focuser from the tube. But with the latter method, I often found it difficult to loosen the knurled rings.

Both methods risk shifting the focus — not to mention bumping the telescope off target as you wrestle with the locked-up rings. Far preferable is a rotation mechanism using large, glove-friendly setscrews, the method used on Sky-Watcher's larger Esprit 120. The 100-mm model should use the same design.

As best I could determine, this shortfall was the only significant price to pay for getting an astrograph that can indeed compete with the best, but at a substantially lower price. The Esprit 100ED's fast f/5.5 focal ratio is about two-thirds of an f/stop faster than the many f/7-class 4-inch apos on the market, and this gives you shorter exposures.

Overall, I recommend the Esprit 100ED as a superb telescope for all-purpose observing and wide-field imaging. It's a refractor I could happily live with if I had to survive with just one telescope. ✦

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*Contributing editor **Alan Dyer** recently retired from 40 years of producing planetarium shows. Follow his continuing astronomical exploits and photo blog at **www.amazingsky.net.***

Above: **This uncropped image of the North America Nebula (left) and Pelican Nebula (right) shows a nearly perfectly flat corner-to-corner field, thanks to the included flattener lens.** ***Inset:*** **Stars show only very slight elongation at the extreme corners, and there's no variation from one side of the frame to the other.**

Check Out This

S&T: J. KELLY BEATTY

An innovative program allows newcomers of all ages to borrow compact, high-quality reflectors from public libraries

JOHN JARDINE GOSS

The library-telescope program is a fun way to help more youngsters become involved in amateur astronomy. Here, patrons at Adams Library in Chelmsford, Massachusetts get ready to borrow a user-friendly telescope for a full week.

AMATEUR ASTRONOMY has seen many significant changes over the past 30 years. One worrisome, often-discussed trend has been the declining numbers of young people taking up the hobby. Although the reasons for the dearth of young skygazers are complex, one factor is clear: If you haven't been exposed to a star-filled night sky, you're far less likely to pursue amateur astronomy.

As he pondered this dilemma six years ago, Marc Stowbridge of the New Hampshire Astronomical Society (NHAS) had a "eureka moment." He realized that many people — particularly youngsters — could be introduced to our hobby through a venue familiar to nearly everybody: the local public library.

Stowbridge's idea was both simple and game-changing. In December 2008, he modified a small telescope to increase its durability and then donated it to his hometown library. Patrons could then check it out just as they would a book. Anyone with a fledgling interest in astronomy would have the chance to use a

Telescope!

S&T: J. KELLY BEATTY

Thanks to an outreach program started by the New Hampshire Astronomical Society, nearly 200 specially modified Orion StarBlast 4.5 telescopes are now available to library patrons across the U.S.

compact, high-quality, easy-to-use telescope in the comfort of their home.

He convinced his club to donate more scopes to libraries throughout New Hampshire. Another 10 found homes at other libraries the following year, and interest in the program soared. Recently, the count of NHAS-facilitated telescopes reached 100.

Loaning telescopes certainly is not a new practice. Many clubs let their members borrow modest Dobsonian reflectors or various other types, and some groups also make these available to the public. But the NHAS concept sidesteps the complications of lending equipment by partnering with local libraries — institutions that, by design, loan things to the public.

The Perfect Library Loaner Telescope

What instrument best fulfills the requirements of being highly portable, simple to use, and relatively inexpensive — while providing steady, clear views of the objects that novices want to observe? Stowbridge and other NHAS members, resisting the temptation of aperture creep, decided on Orion's 4.5-inch StarBlast reflector. It provides plenty of aperture in a compact, portable, easy-to-use package.

Then the library-telescope team opted to replace the two modest eyepieces supplied with each StarBlast in favor of a single 8-to-24-mm zoom eyepiece. It provides good eye relief and a relatively wide true field, making it easier for the uninitiated observer to locate bright sky objects.

This combination provides a 2½°-wide view at low power (19×). That's enough to fit all of the Pleiades stars, the Double Cluster, and the Orion Nebula in one wide field, each giving impressive scenes for excited eyes. At 56×, the eyepiece's other extreme, users can pick out lunar craters and mountains, see hints of Jupiter's cloud features, resolve Saturn's rings, and glimpse Venus's crescent.

Making the Scope Library-Ready

Any off-the-shelf telescope, even the rugged little StarBlast, needs a few modifications to withstand the rigors of unsupervised home visits — and to make it as trouble-free and easy to use as possible.

Over time the NHAS library-telescope team has developed tried-and-true upgrades that have worked well. Every few months the club holds a "scope-modification party," at which an assembly line of up to a dozen volunteers (now led by Pete Smith) turns new StarBlasts into library-ready units. Here's a recap of the most important changes they make:

• ***Eyepiece focuser:*** The zoom eyepiece can easily be dropped, lost, or mishandled. So it's secured in the focuser tube with button-headed setscrews that can't be easily removed.

• ***Collimation knobs:*** A novice user might be tempted to fiddle with the six shiny mirror-collimation knobs at the rear of the optical tube. So club members remove the knobs and replace them with three locknuts on short, spring-loaded screws.

• ***Dust caps:*** The plastic dust caps that cover the main optical tube and the eyepiece can, and likely will, be lost in no time. So "Can't Lose Strings" are added to attach these caps to the scope.

• ***Red-dot finder:*** The StarBlast sports a 1× red-dot finder. When aligned with the main tube, it's quite sufficient for putting target objects in the eyepiece view. But the factory-supplied button battery dies in a few days if the unit is left on. A much more durable solution is to replace it with an external plastic case

S&T: J. KELLY BEATTY

To make the beginner-friendly Orion StarBlast 4.5 tabletop reflector even easier to use and more rugged, volunteers make several modifications, among them: (1) adding "Can't Lose Strings" to loose parts; (2) cutting a 2-inch hole in the end cap to reduce the Moon's brightness; (3) installing an AA-battery pack for the red-dot finder; (4) adding setscrews in the focusing tube; (5) providing an 8-to-24-mm zoom eyepiece; and (6) adding a Sun warning and other stickers to the main tube.

S&T: J. KELLY BEATTY

The standard StarBlast (left) comes with two sets of collimation screws, a temptation for inexperienced hands. They're removed for the library version (right), replaced by short screws and hard-to-turn locknuts.

JOHN JARDINE GOSS

TED BLANK

JOHN JARDINE GOSS

***Above left*: Another way to keep hands away from the Orion StarBlast's collimation screws is to install a plastic cap over the mirror cell. *Top right*: Marc Stowbridge initiated the NHAS's library-telescope program in 2008. *Bottom right*: A young boy gazes through the eyepiece of a StarBlast, a scene that is repeating itself all over the country thanks to the library-telescope program.**

holding two AA batteries. Another solution is to replace the red-dot pointer with a notched alignment sight.

• ***Aperture reduction:*** The Moon is a popular nighttime target, but the intensity of its light during gibbous and full phases needs to be reduced for comfortable viewing. Many observers screw a neutral-density "Moon filter" into the eyepiece barrel, but that could be easily lost. A solution that avoids the filter altogether is cutting a 2-inch-wide hole in the optical tube's end cap to block most of the moonlight entering the telescope. The hole is covered with a small plastic cap, again anchored with a string.

After making these changes, volunteers apply laminated, self-adhesive labels to the main tube and mount. These labels provide a handy Moon map, magnification and field-of-view charts, and a safety warning to discourage pointing the telescope toward the Sun. Club members complete the "kit" by attaching a small pack containing a laminated 4-by-6-inch instruction manual, National Audubon's pocket guide to the constellations, and a strap-on headlamp equipped with red LEDs.

New Hampshire's Successful Model

"If I build it, will they come?" Well, that depends a lot on how your library and club publicize the program. After speaking with librarians who've been involved in the program for at least a year, Stowbridge reports, "The typical age range of adults checking out the instrument is 30 to 40 years old, and they bring it home for their kids and their kids' friends to use." He estimates that, on average, six people use a telescope each time it's checked out — and long waiting lists of patrons are common.

Like books that are heavily used by the public, these telescopes have limited life spans — they won't last forever. So the NHAS team pairs each library loaner with a local "foster astronomer" who checks the telescope periodically for damage, adjusts collimation, and cleans the optics if needed. Stowbridge reports that none of the NHAS telescopes has been damaged due to mistreatment and that no problems have been reported — except for complaints about the weather!

A Great Community Project

Clearly, the NHAS is onto something, and other clubs across the U.S. (and in other countries) have initiated library-telescope programs of their own. To make the startup process easier, the website **nhastro.com/ltp.php** has all the details you'll need — including parts lists, detailed modification instructions, and downloadable labels.

The StarBlast 4.5 telescope normally retails for $200, but the zoom eyepiece and other accessories bring the total cost to about $325. Aside from an outright donation by your club, you can raise funds by asking library patrons, partnering with "Friends of the Library" groups, and seeking sponsorships from local businesses.

The library-telescope program was brought to the attention of the Astronomical League in 2011 by members of the Astronomy Enthusiasts of Lancaster County in Pennsylvania. They had learned about it from the January 2011 Focal Point in *S&T* written by NHAS members.

Since then, the League has been promoting the LTP to its member clubs. The March and June 2013 issues of its publication, *The Reflector,* were largely devoted to youth in astronomy, and one article featured the NHAS program.

The Southern Maine Astronomers have placed 30 telescopes in area libraries. "It's been a great outreach program for the SMA," says club officer Ron Thompson. "We have a number of members who volunteer their time as mentors to the libraries." Both SMA and NHAS work with Maine's Cornerstones of Science, a nonprofit group that procures the telescopes at discounted prices.

Michigan has at least two astronomy groups actively involved. The University Lowbrow Astronomers has placed 30 telescopes with the Ann Arbor Public Library, and the Kalamazoo Astronomical Society has donated four. Mike Cook, who heads the Kalamazoo effort, explains, "This program will give us the avenue to reach many who have never had the opportunity to look through a good telescope."

Naturally, clubs want to avoid any mishaps with their first foray into the program. "Before we presented the first telescope to the library, we field-tested both the telescope and the concept of loaning it by allowing a local scout troop to use it, with guidance from us. Several scouts earned their Astronomy Merit Badges as a result," explains Dave Koren of the Kiski Astronomers in Pennsylvania.

The library-telescope program is a work continually in progress, and the LTP has undergone many improvements since its introduction six years ago. The New Hampshire Astronomical Society wants to hear from other clubs taking up the cause and to learn about different modifications that have been made to the telescopes. Contact Pete Smith or the club at **nhastro.com/contact.php**. Club officers interested in obtaining StarBlast telescopes for their own program should send an e-mail to cynthia.randall@cornerstonesofscience.com.

Will all this effort increase interest in amateur astronomy? Will it cause more young people to become stargazers and join astronomy clubs? No one knows, because it might take years before any lasting effects are evident. Nevertheless, the library-telescope program is having a positive impact on communities across the country right now. It's the perfect outreach project. ✦


JENNIFER STOWBRIDGE

Nia Shea Ashby, Zeth Ashby, and their mother Karson Ashby learn how to use a NHAS loaner telescope.

A lunar observer and member of the Roanoke Valley Astronomical Society, ***John Goss*** *was recently elected to serve a two-year term as president of the Astronomical League.*


NHAS

A year ago, this team of NHAS volunteers modified and readied 10 StarBlasts for delivery to libraries throughout New Hampshire. The club has now distributed 100 telescopes statewide.

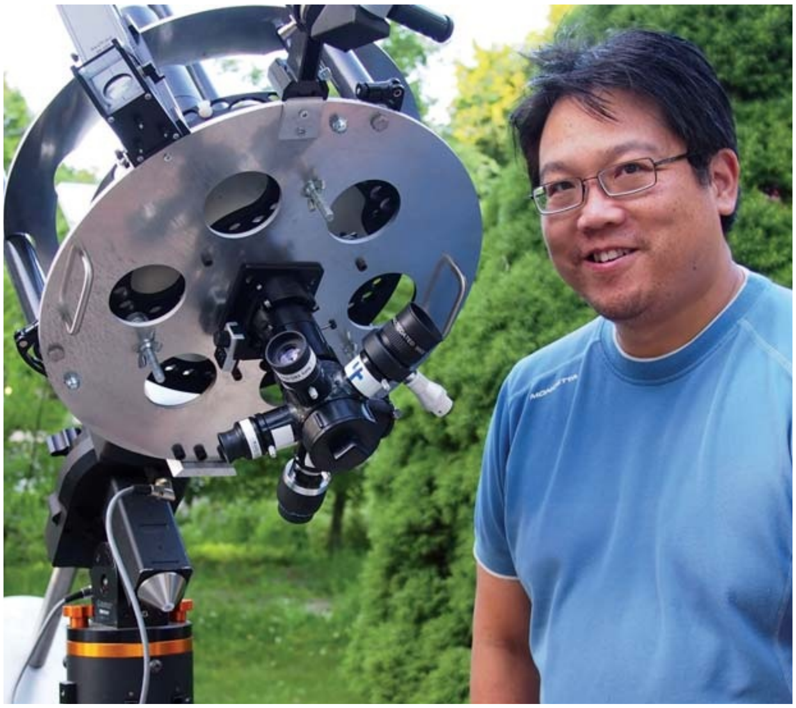
A Turret Eyepiece Holder

Avoid fumbling in the dark when you change your telescope's magnification.

Have you ever dropped an eyepiece while swapping it out of your scope's focuser? Many of us are sadly familiar with the heart-stopping sound of an expensive piece of gear hitting the ground in the dark. Fortunately, you can build a device that will make this potential disaster less likely: an eyepiece turret.

But preventing heart attacks isn't the only reason to build one. Not having to use a flashlight when you change eyepieces will appeal to deep-sky observers eager to preserve dark adaptation. One can also quickly compare views of an object at different magnifications. This device also makes it much easier to evaluate different eyepieces.

Toronto, Ontario, ATM Jim Chung has built a nifty turret that holds up to five eyepieces — any one of which can be switched into the optical train in seconds. Best of all, they're easy and inexpensive to make, costing "no more than a cheap lunch," according to Chung.



ALL PHOTOS COURTESY OF JIM CHUNG

Jim Chung made the inexpensive eyepiece turret shown here mounted in the focuser of his 12-inch Cassegrain telescope. This handy device enables him to quickly and easily change the scope's magnification.

The turret is made from several inexpensive and readily available ABS plumbing fittings.

His eyepiece turret uses inexpensive and commonly available ABS plumbing parts, and consists of two main components: a rotating ring with eyepiece holders, and a stationary body that attaches to the telescope's focuser. Housed inside the stationary section is a diagonal mirror, which feeds light through a hole to one of the eyepieces.

To make the rotating ring, Jim utilized a 2-inch coupling fitting. Around its outer circumference, he affixed a piece of masking tape marked with the locations of the five eyepiece holders. He cut the holes with a hole saw in a drill press. He then glued 1¼-inch inside-diameter PVC electrical-conduit couplers into each hole. The holders had earlier been drilled and tapped to accept the three nylon set screws used to secure the eyepieces.

The inner, stationary sleeve is an assemblage consisting of four ABS plumbing parts. The rear piece is a 2-inch cleanout adaptor with plug. Next is a pair of 2-by-1½-inch reducer bushings (flush style) that serve as spacers. These three pieces are glued together to form a single cylinder, into which a hole is drilled to allow light from the diagonal mirror to feed the eyepiece. Jim salvaged the mirror from an old star diagonal, and it can be affixed to an aluminum bracket bent to 45° and mounted inside the inner sleeve. But for his turret, Jim cast a diagonal holder with two-part resin, to precisely match the interior curve of the inner sleeve assembly. Last is an outer ring trimmed from the same coupling used to make the rotating piece. When the turret is assembled, this ring prevents the rotating eyepiece holder from sliding off the front of the assembly.

Once the two parts are complete and all the rough edges have been sanded smooth, it's time for final assembly. First, the outer, rotating piece slips onto the inner sleeve, then the retaining ring is glued in position against the front of the rotating piece. Jim made sure there was just the right amount of friction to ensure that the eyepiece wouldn't rotate out of position on its own, but not so much that switching eyepieces would change the telescope's position. Lastly, Jim glued a 2-inch, T-thread nosepiece (purchased from a telescope dealer) to the front of the assembly so that the turret slips into his scope's 2-inch focuser.

In use, Jim notes that the best procedure is to set the telescope focuser to accommodate the eyepiece that requires the most in-travel. Next, he focuses the other eyepieces individually by sliding them slightly out of their holders, then locks them into position with the set screws. This ensures that all the eyepieces in the turret are parfocal. "I load the turret with eyepieces in ascending order of focal length and it becomes effortless and convenient to change magnification without losing the target," Jim says. "Now, each clear night, I look forward to taking out the scope and giving the turret a spin!"

To learn more, e-mail Jim at jim_chung@sunshine.net. ✦

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*Contributing editor **Gary Seronik** is an experienced telescope maker and observer. He can be contacted at **www.garyseronik.com**.*

A set of PVC electrical conduit couplers are glued to the outer, rotating ring. The couplers serve as eyepiece holders.

Eliminating Band

Here's a technique that removes common artifacts from DSLR and CCD images.

THERE'S LITTLE DOUBT that digital SLR cameras have opened the hobby of astro-imaging to the masses. Never before has it been so easy (and relatively inexpensive) to take great shots of twilight conjunctions, Milky Way nightscapes, and even deep-sky vistas. But most DSLRs and even some CCD cameras aren't perfect detectors. Although they take exquisite daylight images, many produce "banding" and line noise that show up in low-light conditions.

Fortunately, banding and line artifacts are easy to correct using modern astronomical image-processing programs. Follow these steps to transform your noisy images into clean, smooth data.

Band and line noise, sometimes referred to as *horizontal and vertical banding noise* (HVBN), are common artifacts in images of the night sky taken with DSLR and some CCD cameras. The problem has multiple sources, some as a result of your camera's sensor readout, others due to its analog-to-digital conversion and signal amplification using high ISO settings (gain settings on video cameras work in a similar way). Banding can also come from electrical interference from adjacent equipment on the same power circuit. In all cases, these issues can detract from an otherwise fine image.

CHUCK VAUGHN (2)

Although virtually all astrophotos from recent years were taken with digital cameras, the images often suffer from banding and line noise, which can compromise an otherwise excellent image. Author and software engineer Michael Unsold describes his innovative technique for correcting this problem using his program *ImagesPlus*. He used this software to remove the broadbanding artifacts from the left image of NGC 7000, which was taken with a modified Canon EOS 40D. Unsold's processing led to the smooth result at right. Unless otherwise noted, all images are courtesy of the author.

& Line Noise

Michael Unsold

AJAY TALWAR (2)

Left: The small-scale line noise seen in this close-up image of the Horsehead Nebula often appears in DSLR images taken at high ISO settings. *Right:* Although the lines are easily corrected using a simple algorithm, bright objects such as stars have added additional artifacts in the image.

Band and line noise exist in most images taken with a DSLR, even daylight photos, though they aren't often visible. This is because HVBN resides in the low-signal area of your images, such as the shadows. In daylight imagery, light levels are easily sufficient to overwhelm that signal. Unfortunately for astrophotographers, light from deep-sky objects is extremely faint compared to subjects illuminated by our Sun, so astro-imagers need to "stretch" the low-end signal to reveal most targets, such as the Milky Way over a landscape or the faint ion tail of a comet. This stretching unfortunately also amplifies band and line noise.

Line noise appears as a periodic pattern of narrow vertical or sometimes horizontal lines that become more pronounced as you enhance an image. Banding is similar, though with much wider "stripes" than what appears with line noise. These stripes often have a color bias in color images, with some bands in blue, green, or red.

Popular methods for correcting these artifacts attempt to mask or blur their effects but do not actually remove them from your data. These techniques can also soften image detail, which reduces the final quality and sharpness of your image. Using my program *ImagesPlus,* which I wrote specifically for processing astronomical images taken with color and monochrome cameras, I've devised a technique that removes line and band noise from an image without loss of small-scale detail.

Simple Correction Theory

The key to removing band and line noise is to first recognize that these signals are periodic and repeat at specific frequencies. As such, they are best corrected using the Fourier transform function, a mathematical tool that allows you to target specific frequencies and remove them from digital images.

The problem is that many desirable features in our astrophotos, particularly the ever-present stars, also occupy some of the same frequencies as the lines and bands. So if you globally apply line or band suppression using a Fourier transform to an image with stars, then you'll not only remove the lines and bands, you'll also introduce undesirable artifacts around the stars — particularly new dark bands that emanate from any bright stars or galaxy nuclei in the photo.

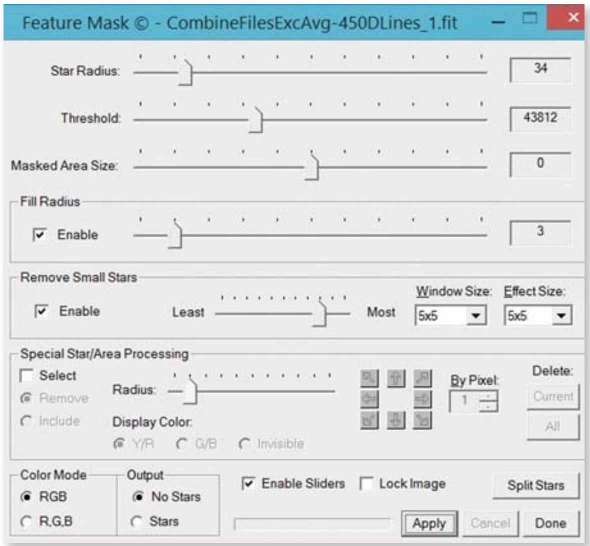
Targeted Processing: Line Noise

The best approach to correcting band and line noise is to split the image into two separate files in *ImagesPlus* as Blair MacDonald describes in detail in the June issue (page 72); abridged star-splitting directions appear below. By splitting the image onto two images, one with only the stars and the other with the lines, bands, and other subject matter (we'll call this the "subject image"), we can target just the artifacts while avoiding the introduction of additional ones. The split is done in a lossless state so that you get the same image as you started with when you merge the split star and object images. You then create the final photo by merging the corrected image with the star image. You can correct band and line noise in *ImagesPlus* using either "raw," unprocessed data or a final image.

To split the stars and subjects into two images, begin with your calibrated and combined image in *ImagesPlus*, and select Special Functions / Mask Tools / Feature Mask © from the pull-down menu. A new window opens, where you can adjust the star radius size, threshold, and Mask Area Size until you're satisfied that you've selected all the stars and other bright features in the image. Make sure that your selection includes the bright nuclei of galaxies, bright planetary nebulae, or comet heads, since each can add artifacts to your result if not properly selected.

Once you're satisfied with your selection, click the Split Stars button at the bottom right of the window. In a few moments, you'll have two images: one with only the star

Identify and separate the stars and other bright objects from the fainter signals in your image using the Feature Mask © tool (*far right*). Move the Star Radius slider to the right to increase the amount of stars in your selection, and expand the area of your mask by moving the Masked Area Size slider to the right, producing the black masks in the image at near right.



data, and the other with your nebulae, galaxies, and other subject matter in addition to the bands and lines you want to correct.

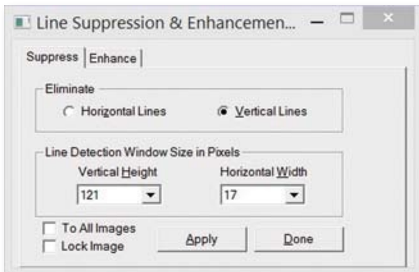
ImagesPlus uses two separate tools to correct lines and bands, and since both artifacts don't always appear in every image, let's begin by correcting an image with line noise. Click on the subject image and open the Smooth Sharpen / Line Enhancement and Suppression Tool to remove the fine vertical-line pattern. A dialog window opens, with a few important options. If your photo suffers from vertical or horizontal line noise, select which type you want to address in the Eliminate section. Next you'll change the Vertical Height to the maximum setting of 121 in the Line Detection Window Size in Pixels section. Now you want to adjust the Horizontal Width parameter and click the "Apply" button. I suggest starting with the lowest setting first.

In a minute or so, the process completes and displays your result. If lines are still visible in your image, increase the Horizontal Width parameter and repeat the process until they are no longer visible in your image.

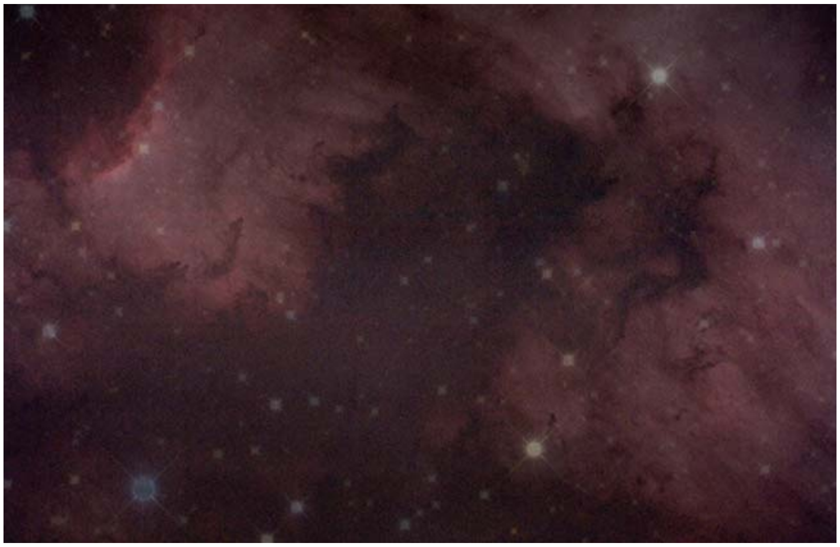
Removing Bands

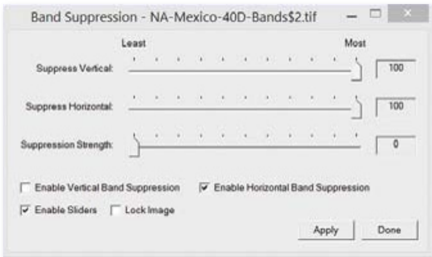
If your image suffers from wide colored banding, split the image into stars and subject images as described earlier. Next, select Smooth Sharpen / Band Suppression from the pull-down menu. A small dialog window opens, where you can select the Enable Vertical Band Suppression or the horizontal option. Depending on which you choose, the top Suppress slider controls vertical banding, while the second slider adjusts for horizontal bands. Both begin at the "Most" setting at right, so reduce the number slightly and wait a minute for the program to process your image. I suggest lowering the setting in increments of 5 to narrow down what works best for your particular photo.

When you're happy with the result, click the "Done" button, and you can proceed to recombine the star image with your nebulae, galaxy, or nightscape photo.



Once you've split the stars and other bright objects into a separate image, click on the image with your target object and open the Line Suppression & Enhancement tool. Simply select the Horizontal Lines, Vertical Lines, or both from the Eliminate section of the tool, and adjust the height and width options until the lines disappear from your photo.



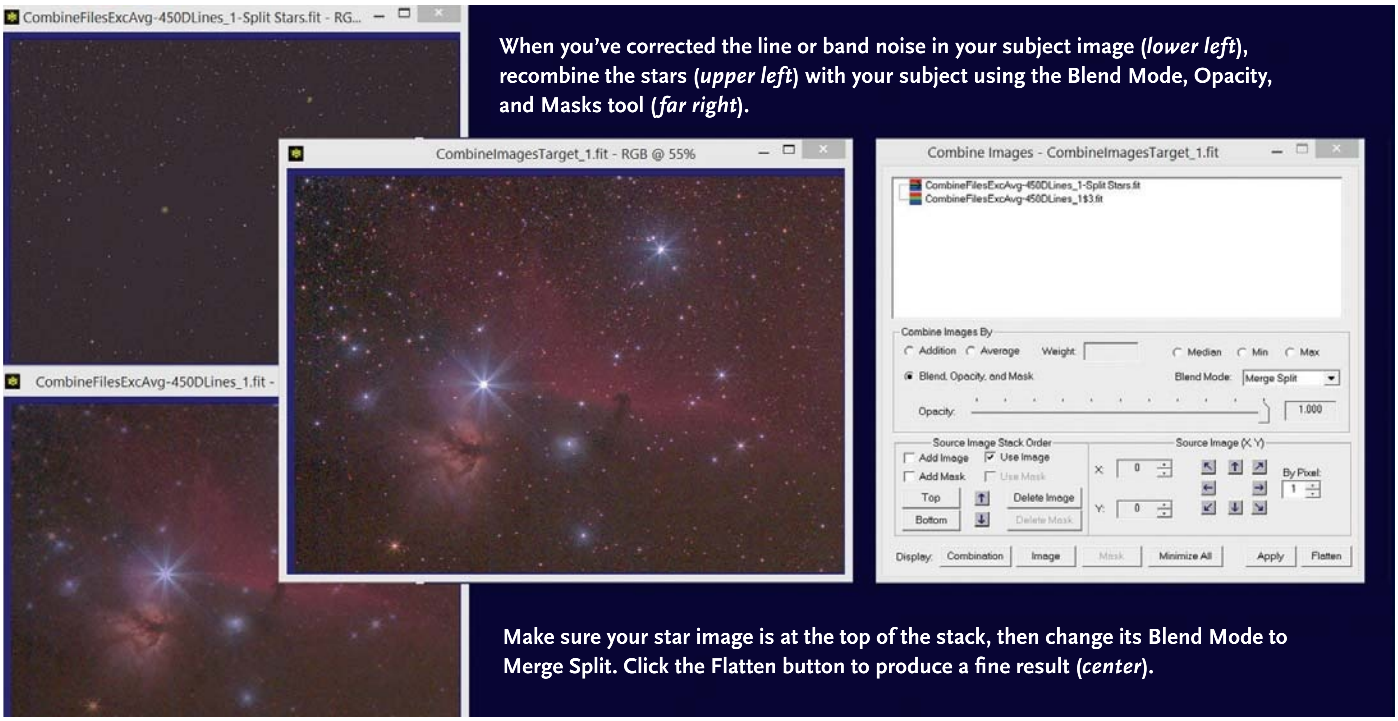


Wide banding can be addressed using the Band Suppression tool in *ImagesPlus*. Click on your subject image then open the tool and select the Enable Vertical Band Suppression (or horizontal if necessary). Pull the Suppress Vertical (or Horizontal) sliders left to reduce the effect on your image until you match the width of the bands.

Select the Special Functions / Combine Images Using / Blend Mode, Opacity, and Mask. This time two widows open — the Combine Images Setup window, where you first can title the combined result, and the Combine Images window. The Combine Images Setup window allows you to title your merged result, then click OK. In a moment, a new image appears, and the Combine Images window displays a list with the working titles of your image and stars-only photos. Make sure your corrected image is at the bottom of the image stack by clicking the up or down arrows. Next, change the Blend Mode of the star image from Normal to Merge Split. In a moment both images will appear as a combined result. Click the Flatten button, and then save your final result.

You can apply band and line correction to any color or monochrome image, and the correction can help with most astronomical images to rid them of repeating noise. Many high-speed video cameras used for planetary imaging often suffer from line noise, too, and you can quickly address it with this technique. Tools such as these are often the final key to raising your images to the next level of proficiency. ✦

***Michael Unsold** has grown* ImagesPlus *to a mature astronomical imaging program for DSLR and CCD imagers alike. Explore its other features at **www.mlunsold.com**.*



When you've corrected the line or band noise in your subject image (*lower left*), recombine the stars (*upper left*) with your subject using the Blend Mode, Opacity, and Masks tool (*far right*).

Make sure your star image is at the top of the stack, then change its Blend Mode to Merge Split. Click the Flatten button to produce a fine result (*center*).

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

◄ **REFLECTIONS OF MONOCEROS**

Gerald Rhemann

This colorful region in Monoceros boasts a cornucopia of nebulosity, including long streamers of dark dust, reddish emission, and bluish reflection nebulosity.

Details: *ASA12N-OK3 f/3.6 astrograph with FLI MicroLine ML8300 CCD camera. Total exposure was 11⅓ hours through color filters.*

▼ **A CELESTIAL SPARE**

Damian Peach

Located in the southern constellation Grus, planetary nebula IC 5148, the "Spare Tyre Nebula," displays thin arcs of material in large amateur instruments.

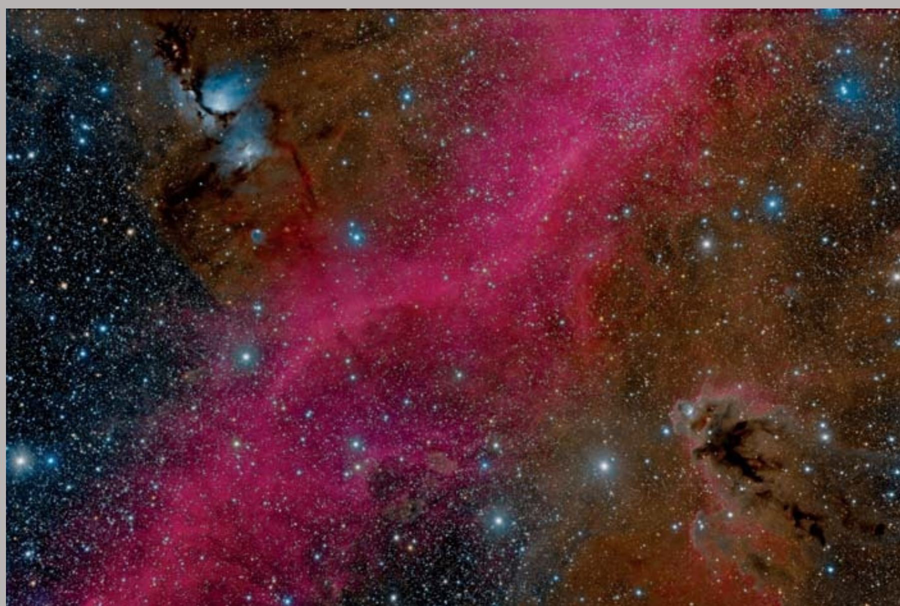
Details: *PlaneWave Instruments CDK700 corrected Dall-Kirkham telescope with FLI ProLine PL16803 CCD camera. Total exposure was 1½ hours through Astrodon color filters.*

▼ **BETWEEN TARGETS**

Eric Africa

The glowing, pinkish gas of Barnard's Loop bisects this region of Orion between the dusty batch of LBN 1622 at top left and the reflection nebula M78 at bottom right.

Details: *Takahashi FSQ-106N astrograph with SBIG STL-11000M CCD camera. Total exposure was 21 hours through Astrodon color filters.*



▲ **CRESCENT EMBRACE**
Terry Hancock
Long filaments of hydrogen gas from the expansive nebula IC 1318 (left) curve around brighter NGC 6888, the Crescent Nebula, at the lower right.
Details: *Takahashi Epsilon-180ED astrograph with QHY11 CCD camera. Total exposure was 4.4 hours through color and Hα filters.*

► **ASHEN MOONRISE**
Steve Thornton
The waning Moon rises through smoke and ash clouds from wildfires as seen from Murrieta in southern California on the evening of May 18th.
Details: *Nikon D300 DSLR with 70-to-200-mm lens. Total exposure was 4 seconds at f/5.6, ISO 400.* ✦

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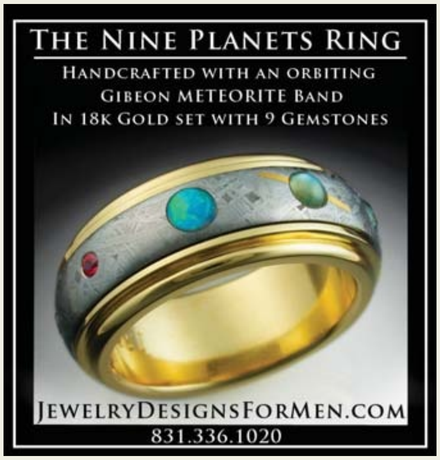

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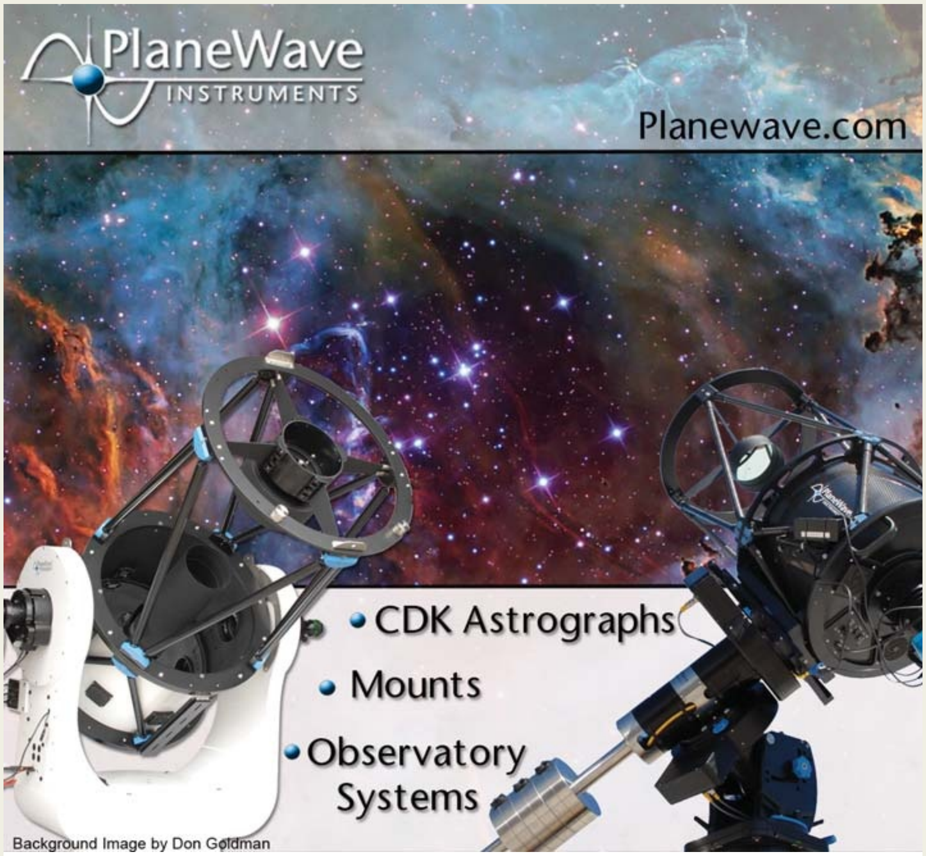

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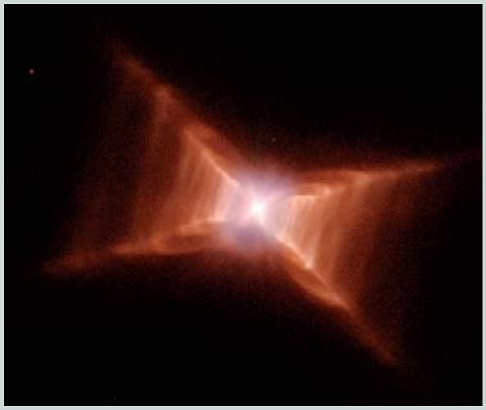

Sculpting Planetary Nebulae

Astronomers still struggle to understand how stars create the delightful and bizarre shapes of planetary nebulae.

Galaxy Pairs and Trios

What's better than a galaxy? Two or three in the same field of view.

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Winning Converts to the Cause

It takes effort to turn interested people into full-blown amateur astronomers.

We like to believe we are converting the world to amateur astronomy when we hear the "Wow!" at our star parties. Truth be told, most of those "wows" are forgotten by the next morning or as soon as the person discovers the effort required to progress from an appreciative spectator to an active participant. The effort involves self-motivated reading and study to bring order to the apparent random chaos of the night sky and to learn about the instruments we use.

The weather we must contend with to view Orion under a cold winter sky may also be a negative factor. As for our instruments, we often overemphasize them to the point that our audiences may feel they must own a telescope or binoculars as an initiation fee to our hobby. Remember, naked-eye observing can be very rewarding and should be encouraged. This is particularly true in our age of Iridium flares and the International Space Station.

For many people I encounter at star parties, the spirit is willing but the flesh is weak. Yes, we see lots of telescopes at star parties and know many friends with operating telescopes, but the number of scopes in basements and attics gathering dust far exceeds the number gathering starlight. How many times have you heard, "Yeah, I have a telescope, but after looking at the Moon, Saturn, Venus, and Jupiter, what else is there to see?"

To overcome these obstacles one must have an inherent curiosity about the night sky and be intrigued by questions such as: What's up there? How far can I see? Why does it change from season to season? Where are the boundaries of the universe, if there are boundaries? Where do shooting stars come from? Why do we see only one side of the Moon? Are we alone?

TRACI DABERKO

One must also have an attraction to seemingly insoluble mysteries, such as: How many stars are there? How can glaciers be miles thick? Can it really be true that no two snowflakes are alike?

There are many amateur astronomers born with the inherent attributes of curiosity and wonderment, but they have not awakened to their full potential to enjoy a lifetime of satisfaction from our hobby. This is where outreachers come in. We need to help people discover their full potential. With dedicated effort, example, and patience, you can kindle that inherent spark into a flaming amateur astronomer. This may not happen often, but when it does it is oh so gratifying. And sometimes you may never receive feedback; such is the plight of a missionary. And we must accept the fact that no matter how many beautiful views are up there, many folks are simply not intrigued with the night sky.

Example and patience are vital when handling fragile neophytes. Remember at star parties and lectures, you are there to help guide your audience, not to impress them with your knowledge. Just do a quick flashback to your own early days when you thought the precession of the equinox was a parade of some political group.

Take heart; there are born amateur astronomers out there waiting for you to ignite the flame. Go do it! ✦

*Retired NASA engineer **Bert Probst** has been an amateur astronomer for more than 40 years. He presents astronomy classes at the Ellicottville, New York Memorial Library and conducts astronomy events at Acadia National Park in Maine.*

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TO THE NEXT GENERATION
OF DISCOVERY
Sirius, the brightest star in the heavens.... My grandfather would say we're part of something incredibly wonderful - more marvelous than we imagine. He would say we ought to go out and look at it once in a while so we don't lose our place in it.
Robert
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