Sky & Telescope Digital Extra

WEB EXTRAS

FEB. 2013 ISSUE

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- Sinking a Submarine
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- Guide to Jupiter

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Image by Tim Jensen

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February 2013

SKY & TELESCOPE

VOL. 125, NO. 2

On the cover: Scientists have come a long way in understanding the sweeping curtains of light called the aurora.

COVER IMAGE: OLE C. SALOMONSEN

FEATURES

OBSERVING FEBRUARY

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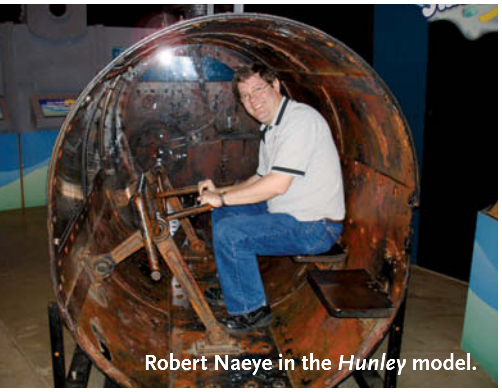
Visiting the Hunley

ONE OF THE MANY qualities that I have always admired about amateur astronomers is the fact that every single one that I have ever met has a wide range of interests. Sure, we're all passionate about the night sky and learning about how the universe operates, but we're also fascinated with topics that have little or nothing to do with astronomy.

Like a high percentage of our readers, I have always been a history buff. So when Bill Stevenson submitted his article about how the Moon and tides influenced the final (and fatal) mission of the Confederate submarine *H. L. Hunley* (page 26), it got my juices flowing because this kind of story combines two of my biggest passions.

I recently had an opportunity to visit the *Hunley* in Charleston, South Carolina. My friend John Cox, whom I had met on eclipse trips to Libya and China, invited me to give a talk about amateur exoplanet research at Clemson University in November 2011. After spending a couple of days in western South Carolina, I rented a car and crossed the state to Charleston, where I visited Jim Phillips — a long-time *S&T* subscriber and expert astrophotographer (and coauthor of the new book *Lunar Domes*). After lunch he drove me to the Warren Lasch Conservation Center to see the *Hunley* on display.



Robert Naeye in the *Hunley* model.

JIM PHILLIPS

Jim and I both have a long-standing interest in the American Civil War, so we were thrilled to see the submarine in person. The *Hunley* was raised from the sea floor in 2000 and currently resides in a giant water tank to minimize deterioration. Jim and I were pleasantly surprised by the quality of preservation, and we found the sub to be longer than expected. We took turns sitting inside a model and marveled that people could summon the courage and commitment to serve on what seemed to be an obvious death trap.

The next day, Jim and I visited the *USS Yorktown* in Charleston Harbor. Moored next to this aircraft carrier is the *USS Clamagore*, a sub built in 1945 that served in the waning days of World War II and the Cold War. It was breathtaking to see how far submarine technology had advanced in less than a century. And I'm sure the *Clamagore* pales in comparison to modern nuclear-powered, nuclear-armed subs.

Walking through the *Clamagore* reminded me of how the pace of technological change has accelerated since the Industrial Revolution. The human way of life has been radically transformed over the past 200+ years. On the down side, our weapons have become so deadly that they threaten our existence. But the technological advances have also made it possible to unlock many of the universe's deepest secrets. ✦

Robert Naeye
Editor in Chief

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The Essential Guide to Astronomy

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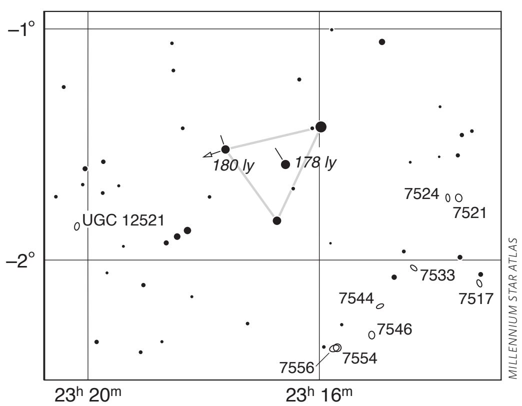
Asterism in Pisces

I recently happened upon a very attractive asterism in Pisces, which I don't find mentioned in any of the asterism lists that I have consulted. It's composed of three stars forming an almost equilateral triangle with sides about 25′ long, with a close double star (Σ2995) near its center. There's a short line of three stars just to the southeast that points to the triangle. It's located at right ascension $23^h\ 16.6^m$, declination –1° 35′.

I have contacted my local club (Austin Astronomical Society) and the *Sky & Telescope* staff to gather more information about this asterism. Thus far, it seems that it is undocumented and unnamed. I would be pleased to have anyone with more information about it contact me at **posey@nctv.com**.

Dan Posey
Granite Shoals, Texas

Editor's Note: *Indeed, this asterism is a new one for us. The triangle is about 4° southwest of the circlet of Pisces and about ½° on a side. It shows up clearly in the* Millennium Star Atlas *chart shown below (triangle lines added for clarity), since it's mostly made of 7th- and 8th-magnitude stars. The triangle is much harder to spot in* SkyAtlas 2000.0, *though, where it's the same size as a No. 2 pencil eraser.*



NEW ASTERISM? An equilateral triangle sits in Pisces at right ascension $23^h\ 16.6^m$ and declination –1° 35′. Gray lines have been added to designate the stellar trio.

Three Cheers for Curiosity

Upon reading your excellent article "Touchdown on the Red Planet" (November issue, page 20), I could not help but go back to my copy of Kim Stanley Robinson's novel *Blue Mars*, the last in his sci-fi Mars trilogy. In Part 12 of that volume Robinson describes Gale Crater in the year 2181, when it has become a lake along The Grand Canal built between Hellas Sea and Isidis Bay on the well-colonized and watery planet. Although Curiosity explores a Mars nothing like Robinson's terraformed world, I still enjoyed the fact that NASA's latest rover has landed somewhere my imagination has visited.

Tom Gewecke
Scottsdale, Arizona

I enjoyed the well-written and informative article about Curiosity on Mars, but I must take exception to one phrase in the introduction: "The Rube-Goldbergian chain of events required to bring Curiosity to a soft landing. . . ." "Rube-Goldbergian" implies the mission's complexity was unnecessarily fantastic or impractical, but there was nothing impractical about the landing procedure or the hardware it took to accomplish it. The landing was ingeniously designed and executed with the utmost precision. Let us not belittle the efforts of the people who accomplished the near-impossible.

Having said that, I think *Sky & Telescope* is great!

Bill Boyd
Salem, South Carolina

I would like to commend you on your November issue. The brilliant article by Emily Lakdawalla about Curiosity's accomplishments in Gale Crater has given me a new appreciation for NASA's initiatives in this age of tight budgets. Lakdawalla is an outstanding spokesperson for the Planetary Society who can engage public understanding and enthusiasm on technical matters. This connection is critical for stimulating public support of the space effort in these days of financial constraints.

I also very much enjoyed the Focal Point commentary by Karl Matz, affording us insight into the perspective of Native Americans on the heavens. Thanks for a marvelous and memorable issue!

Martin Lee Collin
Ramat Aviv, Israel

Back to Basics

Congratulations to Gary Seronik on his coverage of David Groski's new innovations on the seemingly age-old amateur pipe mount (November issue, page 67). Groski's use of such common items as PVC reducing bushing, a track ball from an old computer mouse, and simple wing nuts is both clever and refreshing. His ingenuity harkens back to the early days of our hobby when we procured accessories on the work bench and not online. It is heartening to see *Sky & Telescope* include articles that go back to backyard astronomy, where we amateurs all began. Keep up the good work of informing your readers about our innovative brethren.

Bert Probst
Ellicottville, New York

Double Stars Revisited

As Chris Lord correctly noted in his letter (December issue, page 8), I failed to point out in my article (September issue, page 68) that he based his predictions of aperture on actual observations. In addition to the link provided in his letter, you can find an explanation of his nomogram — you use it like an old-fashioned slide ruler — on page 118 of *Sky and Telescope*'s January 2002 issue. I highly recommend it for double-star observers.

His project and mine are two different studies that complement rather than compete. Chris gives a formula for predicting the minimum aperture for any pair. On the other hand, the study I'm directing is simply an observational one. It is only designed to find the smallest aperture *observed* to resolve specific double-star pairs. These test pairs are charted in orderly increments of separation and magnitude inequality. (For example, one increment is for a pair 1.0" apart and unequal by 2.0 magnitudes. The next is for 1.0" but 2.5 magnitudes unequal. And so on.) With this information in hand, observers can know what is possible for a particular aperture, and if they cannot resolve the pair with that aperture, they can know it's for other reasons, such as sky conditions or eyesight.

To this end, I am seeking dozens of observations for each increment, obtained from many different observers. I can still use all the help I can get, especially from Southern Hemisphere observers.

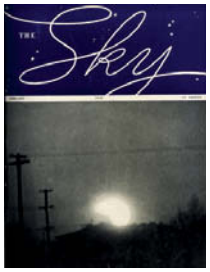
Sissy Haas
Greensburg, Pennsylvania
has103@comcast.net

For the Record

On page 44 of the December issue, the observing note for the 25th should say the "nearly full Moon" instead of "just-past-full Moon." For the full list of corrections for 2012, see **www.skypub.com/errata**.

75, 50 & 25 Years Ago

Roger W. Sinnott



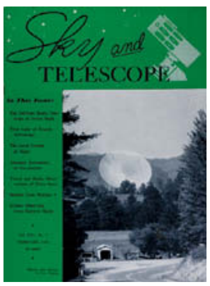
February 1938

Huge Ghost Star "The largest star in the universe so far to be reported . . . is not the well-known visible star Epsilon Aurigae, which can be seen with the naked eye, but the invisible 'ghost' companion [in this eclipsing binary system]. . . .

"The super-giant of space belongs to the recently discovered new category of stars known as the infra-red, or black, stars. . . . The dimensions of the 'ghost-star,' according to the data of the Yerkes astronomers, are 3,000 times the diameter of the sun. . . .

"'The spectroscopic and photometric observations during the eclipse . . . show that the infra-red star (I-star) is semi-transparent. . . .' Only a shell of absorbing material surrounding the eclipsing star will be able to produce the observed type of minimum light during the eclipse."

Otto Struve's discovery was a little off: astronomers now think the eclipsing companion is an orbiting disk of dust with a star hidden inside (S&T: March 2012, page 18).

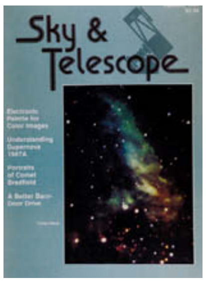


February 1963

Need for Optical Telescopes "'Modernization requires more than replacing the oil-lamp illumination of setting circles by electric lights.' These words of Lawrence H. Aller, University of California at Los Angeles, keynote a strong appeal for increased support of optical astronomy everywhere in the world. . . .

"Many astronomers are struggling . . . with instrumentation almost a hundred years old in some instances, whereas in radio astronomy and space studies large sums of money are being lavished on new equipment. . . . This anomaly is most deplorable in the Southern Hemisphere."

Aller's wish came true. Back then the two largest Southern Hemisphere telescopes were 74-inch reflectors in South Africa and Australia. Today's southern giants include the four 8.2-meter reflectors of the Very Large Telescope in Chile. Chile in particular is the current and future home of several huge scopes.



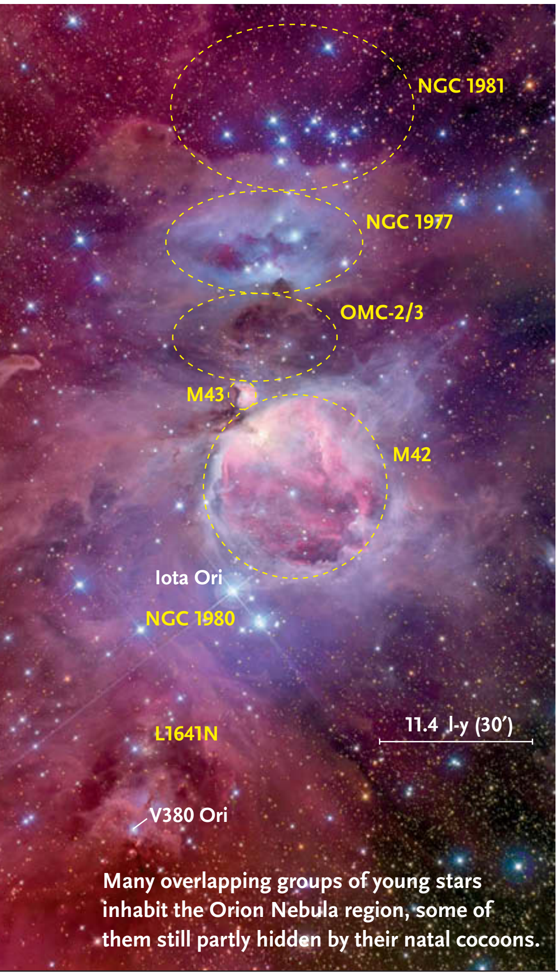
February 1988

Hyades Distance "The Hyades are the nearest and best-studied star cluster, yet we don't know just how far away they are. . . . They are the cornerstone of the entire galactic distance scale beyond the nearest stars. And the galactic distance scale is the foundation of the much larger cosmic distance scale, so that every time someone revises the value for the Hyades, the entire universe shrinks or expands by the same percentage. . . .

"For now, it's probably safe to say that the Hyades are 147 light-years away plus or minus 10 light-years. But more surprises may be in store."

Since Paul Hodge's lament, the distance to the Taurus cluster has been refined a bit. A 2007 study by Hipparcos team member Floor van Leeuwen gives 152 ± 1 light-years.

ORION | Nebula Cluster “Shrinks” . . .



Many overlapping groups of young stars inhabit the Orion Nebula region, some of them still partly hidden by their natal cocoons.

JON CHRISTENSEN

The Great Orion Nebula (M42) is not only one of the sky’s most accessible and rewarding sights, it’s one of the most studied. M42 is the closest region of intense star formation, including several young star clusters burning away at the thick veils of gas and dust. The central Orion Nebula Cluster (ONC) is the most familiar group and includes the Trapezium of young, hot *O* and *B* stars. The cluster set the benchmark for our understanding of how stars form in rich, massive nebulae.

But it turns out that the ONC’s membership has been overestimated. Ground- and space-based observations analyzed by João Alves (University of Vienna, Austria) and Hervé Bouy (Center for Astrobiology, Spain) add to a growing body of evidence that Orion’s gold-standard star cluster is contaminated by an unrelated foreground group. Some 10–20% of its assumed members might actually belong to the closer NGC 1980 cluster, which is centered around Iota Orionis ½° to the south, the researchers estimated in the November *Astronomy & Astrophysics*.

Contamination by foreground stars has long been a concern, says Charles Lada (Harvard-Smithsonian Center for Astrophysics), and astronomers knew that there must be some overlap. The problem was finding where the overlap lies. The nebula has been churning out thousands of stars for the last 10 million years, in bursts lasting a couple million years apiece. As a result, many groups punctuate the region, and uncertainties in their distances make their 3-D positions unclear.

Alves and Bouy overcame this difficulty using dust. Dust blocks light in a biased way, scattering blue light while letting red through. The astronomers used data from seven telescopes, including NASA’s Spitzer Space Telescope, to sort stars near the Orion Nebula by how much they’re dust-reddened. In doing so they also sorted by distance, because more distant stars tend to lie behind more dust.

Using dust reddening as a proxy for distance, Alves and Bouy found a distinct population of stars in front of the ONC. Their properties suggest that they’re actually part of the older NGC 1980.

Once the ONC catalog is “cleaned” of false members, adjustments might have to be made to the supposedly universal star-formation theories that have come from it.

■ **MONICA YOUNG**

. . . And Grows a Black Hole?

The Orion Nebula Cluster could be home to an unexpected black hole with more than 100 times the mass of the Sun, according to a recent computer simulation. At 1,300 light-years away, that would make it the closest known black hole to Earth.

This idea comes from watching gravitational interactions between thousands of stars as they move in a simulated cluster over time. Ladislav Šubr (Charles University, Czech Republic) and his colleagues found that, in the cluster’s early years, stars might have been packed so tightly that collisions and mergers were unavoidable. If so, multiple mergers could have led to a runaway ingathering that created a massive black hole. Today the black hole would dominate the Orion cluster’s core, the team reported in the September 20th *Astrophysical Journal*.

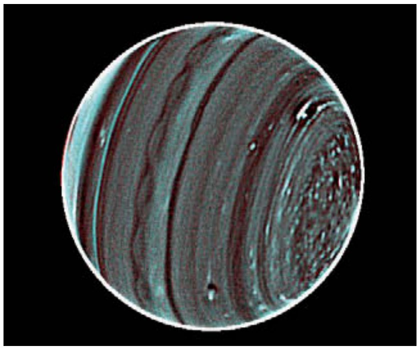
The idea of runaway black-hole growth in stellar clusters isn’t new, but previous studies have focused on even higher-mass star clusters, ideal breeding grounds for “intermediate-mass” black holes with thousands of times the mass of the Sun. The new simulation is the first to show that even low-mass star clusters could grow their own black holes, says Jan Pflamm-Altenburg (Bonn Astronomy Institute, Germany), who was not involved in the study.

If it exists, the Orion black hole probably isn’t growing much today. After only a few hundred thousand years, intense radiation from the Orion cluster’s hottest, most massive stars drove out the gas filling the young group. With less mass to hold it together, the cluster swelled and possibly lost some weakly bound stars. Not only would gas have stopped feeding the hole, but stars also collided less frequently in the expanded cluster, slowing down the black hole’s runaway growth.

Many of the simulation’s heaviest stars either merged or escaped, which might explain why the Orion cluster only has 10 *OB* stars instead of the expected 40.

■ **MONICA YOUNG**

SOLAR SYSTEM
Best-Ever Pix of Uranus


NASA, ESA, L. SROMOVSKY, P. FRY, H. HAMMEL, I. DE PATER, K. RAGES

When Voyager 2 flew by Uranus in 1986, the planet offered little to see: just a deep, clear atmosphere of greenish blue "air." Last July astronomers using the Keck II telescope on Mauna Kea obtained more than 200 near-infrared images of Uranus, 117 of which are combined to create this composite. The team's composites are the most detail-rich Uranus images ever taken from Earth. They were released October 17th at the American Astronomical Society's Division for Planetary Sciences (DPS) meeting in Reno, Nevada.

Uranus's hydrogen-and-helium atmosphere contains substantial methane, which can freeze out and form white clouds. Some of the resulting weather systems stay at fixed latitudes and undergo large variations in activity, says team leader Larry Sromovsky (University of Wisconsin–Madison). Others drift toward the planet's equator even as they undergo great changes in size and shape. This meteorological complexity is puzzling because the strength of sunlight at Uranus is only 1/900 that at Earth, and (unlike Neptune) the planet has no detectable energy coming from its interior.

In this image, white features are high-altitude, opaque clouds (like Earth's cumulus clouds), and bright blue-green features are semitransparent clouds (akin to cirrus clouds). The planet's north pole is on the right, and the narrow aqua arc on the left is Uranus's Epsilon ring. Just south of the equator is a scalloped wave pattern, which has never been seen on Uranus before and is similar to instabilities that develop in regions of horizontal wind shear.

■ **ALAN MACROBERT**

EXOPLANETS | New Goldilocks Planet

Astronomers may have found six super-Earths orbiting an orange dwarf star, and one of them lies in the system's habitable zone, an international team reports in an upcoming *Astronomy & Astrophysics*. The system lies only 42 light-years from Earth.

In 2009 observers using the exoplanet-hunting HARPS spectrograph in Chile discovered three super-Earths hugging the type-*K*2.5 star HD 40307 in Pictor. All three circle the star well within a Mercury-like orbit, leaving them too hot to sustain liquid water.

Mikko Tuomi (University of Hertfordshire, England, and the University of Turku, Finland) and his colleagues re-analyzed several years of HARPS radial-velocity measurements using a new technique. This technique, paired with the researcher's focus on only the reddest parts of the star's spectrum (to reduce false signals induced by stellar activity), allowed them to tease out signs of three additional planets.

The most distant planet, HD 40307g, is garnering the most interest. With a mass between 4 and 10 Earths, the planet might be rocky. (Or it might not: Uranus has 14.5 times Earth's mass, and HD 40307g's range is only a lower limit.) The exoplanet's orbital period is 198 days, meaning HD 40307g receives about 62% of the heat Earth receives from the Sun. That would still put it within the habitable zone.

Most habitable-zone planets discovered so far have important caveats attached, such as tidally locked rotation. The most promising candidate to date has been Kepler-22b, a world 2.4 times the diameter of Earth (*S&T:* March 2012, page 14), but its discoverers could only put an upper limit on its mass of 124 Earths (0.4 Jupiter).

■ **JOHN BOCHANSKI**

IN BRIEF

AAS Division for Planetary Sciences Meeting, Reno, Nevada

Julia Fang and Jean-Luc Margot (University of California, Los Angeles) reported October 15th that most exoplanet systems are "flatter than pancakes." The duo created computer mockups of a diverse range of exoplanet systems in which the planets took less than 200 days to orbit their suns. Then they determined what these systems would look like to the Kepler spacecraft and compared the results to actual Kepler detections. In 85% of all cases, the planets' orbital inclinations were less than 3° from one another, meaning that if you looked at the systems from the side, their thicknesses would be something between a crepe and a pancake (as determined by Margot's cooking trials). This flatness is similar to that of our own solar system's nearly coplanar planets. It suggests that most planetary systems evolve undisturbed by major chaotic shakeups, contrary to what exoplanet specialists thought they'd find.
■ **CAMILLE M. CARLISLE**

Franck Marchis (SETI Institute) and his colleagues have captured 40 images of volcanic eruptions on Jupiter's moon Io over the last decade using Earth-based telescopes. Equipped with adaptive optics, 8- to 10-meter telescopes such as Keck II can resolve details as small as 100 km (60 miles) apart and detect many distinct Ionian volcanos, Marchis reported October 17th. The team has watched several fire fountains erupt over the years, but oddly enough, not one young eruption has flared since 2010. Astronomers hope that long-term monitoring will help them better understand the moon's volcanic activity.
■ **MONICA YOUNG**

New simulations by Matija Ćuk and Sarah Stewart (Harvard University) may resolve dilemmas in theories of our Moon's birth. Planetary scientists generally agree that the Moon formed when a Mars-size object sideswiped the young Earth and plowed off a chunk of mantle. This "big splat" satisfies an array of physical and geochemical constraints, but a glancing blow leaves the Moon with too much impactor and too little proto-Earth. The new study finds that if a smaller impactor directly hit an Earth spinning once every 2 or 3 hours — whirling so rapidly that it was close to flying apart — it would make a system with the right composition and high angular momentum.
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IN BRIEF

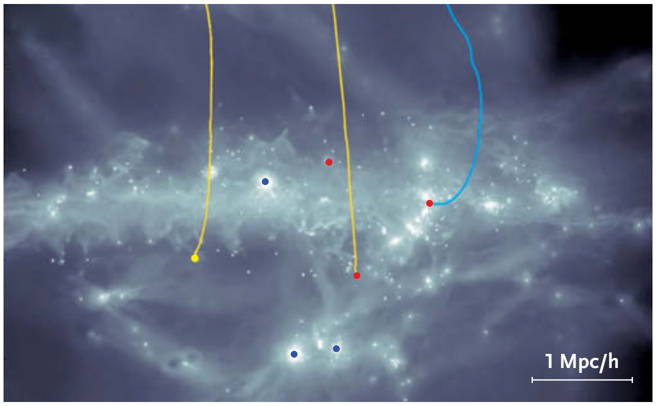
Decades after Supernova 1987A detonated in the Large Magellanic Cloud, astronomers are still reaping observational rewards, Sergei Grebenev (Space Research Institute, Russia) and his colleagues reported in October 18th's *Nature*. The team used more than two months' worth of X-ray images taken by the ESA's International Gamma-Ray Astrophysics Laboratory (INTEGRAL) to capture emission from — and weigh the mass of — titanium-44, a key radioactive product that should reveal secrets of how stars explode. Before exploding, stars produce Ti-44 in a region just outside a dividing line called the "mass cut." Inside this line, the core of the star implodes to become a black hole or neutron star. Outside the line, the rest of the star is thrown off to become the visible supernova remnant. Simulations can predict the mass of Ti-44 made during the explosion, but the exact amount depends on the supernova's symmetry, or lack thereof. The observations show more Ti-44 emission than simulations predict, suggesting that 1987A's blast was asymmetric.

■ **MONICA YOUNG**

Astronomers using NASA's Fermi Gamma-ray Space Telescope have used the disappearance of high-energy photons to narrow in on the origin of some of the radiation suffusing the cosmos. This "extragalactic background light" (EBL) spans the ultraviolet to far-infrared, and from the point of view of a very-high-energy gamma-ray photon, it acts as a cosmic fog, blocking or scattering gamma rays beyond a certain energy. Published online November 1st in *Science*, the new study used this fog-like attenuation to put an upper limit on how thick the ultraviolet part of the EBL could have been about 4 billion years after the Big Bang. The result turns out to be very close to the lower limit given by Hubble Space Telescope observations of light from remote galaxies, implying that nearly all of the ultraviolet EBL at this epoch came from galaxies. This leaves little room for other sources, such as the universe's first stars, which the team did not detect. That null result supports current thinking that the peak in first-star formation happened at a very high redshift: less than 500 million years after the Big Bang.

■ **CAMILLE M. CARLISLE**

GALAXIES | Cosmic Web Weeds Dwarfs



ALEJANDRO BENÍTEZ-LLAMBAY ET AL.

This frame from the researchers' simulation shows a gigantic pancake of intergalactic material, through which forming galaxies (colored dots) are passing. As they pass through, some dwarf galaxies (paths traced with yellow lines) can't withstand the pancake's ram pressure and are stripped of their star-forming gas.

Astronomers have discovered an unexpected explanation for why they can only find a small fraction of the dwarf galaxies that are supposed to swarm around the Milky Way: cosmic friction.

Cosmological simulations predict that thousands of dwarf galaxies should be roaming around each large galaxy. But astronomers find only tens to hundreds. Solutions to the "missing satellites problem" generally assume that the dwarf galaxies are out there, but with few or no stars, making them invisible. Such so-called dark galaxies do exist, such as Segue 1 in Leo. The question is, what stopped stars from being born?

A new simulation has zoomed in on a virtual version of the developing Milky Way's neighborhood to discover the unexpected culprit. Unlike most simulations of this kind, the new work followed both dark matter and normal gas's behavior. Gas is a minor constituent compared to dark matter and is often ignored in studies of the universe's large-scale, spiderweb-like structure. In this structure, dark matter forms gigantic filaments, and these act like riverbeds that draw streams of dark and normal matter into forming galaxies.

But these big webby structures don't just sit there. They move through the universe, sweeping through one another, growing over time. The new work followed the evolution of the filamentary "pancake" that created the Local Group, the family of galaxies that includes the Milky Way and M31. The scientists found that, as the forming dwarf galaxies swept through a thick concentration of material (the pancake), the gas in the pancake stripped most of the gas from the smallest dwarfs. Without gas, the dwarfs couldn't form stars.

"This is completely new," says study coauthor Julio Navarro (University of Victoria, Canada). He says no one — including himself — expected that the cosmic web was able to remove gas from dwarf galaxies. "I told my students, 'It must be wrong. Go and do it again.' So I sent them back to do it, and I eventually got convinced that it was right."

Although filaments look obvious in simulations, they're much less dense than even the outer halos of galaxies. Intuition suggested that such diffuse stuff could not affect dwarf galaxies, Navarro says.

What astronomers didn't anticipate was speed. The sheets move at hundreds of kilometers per second, speeds typical of the Local Group system. And a sheet moving at 300 km/s could ram gas out of dwarfs even if they were 50 times denser than the ones simulated.

But the cosmic web can't be the only culprit, says Puragra GuhaThakurta (University of California, Santa Cruz), who was not involved with the study. The web developed over billions of years as gravity pulled structures together, and it continues to evolve. It wouldn't really have a gas-stripping effect until about 3 billion years after the Big Bang. Other processes — such as the ionizing radiation of the first stars — must have also played a part.

■ **CAMILLE M. CARLISLE**

Watch the video at skypub.com/cosmicweeding.

STARS | Auroras Grace Dwarf Skies

Stunning auroras play in Earth's upper atmosphere (page 18), but these ethereal displays aren't unique to our planet. They've been well observed on Jupiter and Saturn. An international team of astronomers reported in the November 20th *Astrophysical Journal* that auroras can happen on stars, too.

Jonathan Nichols (University of Leicester, U.K.) and his colleagues found that the runts of the star-formation litter, ultra-cool dwarfs falling below spectral type *M7*, demonstrate auroral behavior similar to the solar system's gas giants.

With their deep internal convection and turbulence, dwarfs can generate magnetic fields 10,000 times stronger than Earth's. Astronomers can't observe these fields directly, but they can infer their presence by the radio emission produced where the fields interact with charged particles. Such interactions don't occur on every ultra-cool dwarf — only 12 (out of roughly 200 observed) are known to produce intense radio emissions. These all have one thing in common: rapid rotation, with periods of just a few hours. Many of the radio signals have a periodic beat, likely matching the speedy rotation.

Jupiter and Saturn generate strong magnetic fields and rotate every 10 hours or so, and some of their radio emissions have been linked to auroral activity. So Nichols and his team modified models of Jupiter's magnetic field, scaling the planet's rotation and field strength to those observed for ultra-cool dwarfs. These simulations reproduced the strength and beat of observed radio signals.

According to their model, the signals emanate from the dwarfs' high-latitude polar regions, just like the radio signals seen from auroral ovals on the gas giants and Earth.

■ **JOHN BOCHANSKI**

NEBULAE | Explaining Cosmic Butterflies

ESO's Very Large Telescope captured this image of the planetary nebula Fleming 1. Inside the glowing gas cocoon, two white dwarfs whirl around each other every 1.2 days. The binary interaction probably led to the nebula's S-shaped symmetry.

When stars roughly the mass of the Sun or a little higher near the ends of their lives, they shed their outer layers like trees in autumn. The "leaves" expand outward to form planetary nebulae, which come in a colorful variety of shapes — a bewildering result given that stars are largely spherical. Determining how these shapes form has been a matter of fierce debate, but one mainstream theory finds firm footing in a study published in the November 9th *Science*.

Using the European Southern Observatory's Very Large Telescope, Henri Boffin (ESO, Chile) and his colleagues observed the central star in Fleming 1, a butterfly-shaped planetary in Centaurus renowned for its spectacular pair of S-shaped jets. The jets shoot out in two arcs from the dying star at the nebula's center. They span 9 light-years from tip to tip.

Theorists have argued for 30 years that the presence of a second star would best explain such curled jets. In this scenario, one star in the binary puffs up in its old age and blows out a stellar wind. The companion gathers some of this gas into a whirling accretion disk. Like many such disks, it shoots jets along its rotation axis. The stars' tight orbit causes the disk to precess, or wobble like a spinning top, making the jets wobble, too. The enlarging star eventually engulfs both stars in a common envelope, flinging away much more mass and ending accretion.

Boffin's team cemented this theory by detecting a radial-velocity wobble in the light from Fleming 1's central star, confirming that not one but two stars sit in the nebula's heart, whipping around a common center of mass every 1.2 days.

"This finding puts the binary model on very strong ground, such that it should go beyond the planetary nebula community," says Noam Soker (Technion – Israel Institute of Technology), who was not involved in the study. "The shaping of planetary nebulae is at the crossroads of many astrophysical objects, from core collapse supernovae to clusters of galaxies."

In an unusual twist, both stars are white dwarfs. They may have been similar in size initially, evolving to the white dwarf stage one right after the other — a rare occurrence in planetary nebulae. The stars currently have 0.5–0.9 and 0.7–1.0 times the Sun's mass. The more massive star likely wore the accretion disk and was responsible for the jets. Symmetrical knots line both jets, suggesting episodic activity a mere 16,000 to 6,000 years ago. ✦

■ **MONICA YOUNG**

Secrets of the Northern Lights

After centuries spent marveling at auroras' spectacular and fearful displays, people have solved many of their mysteries.

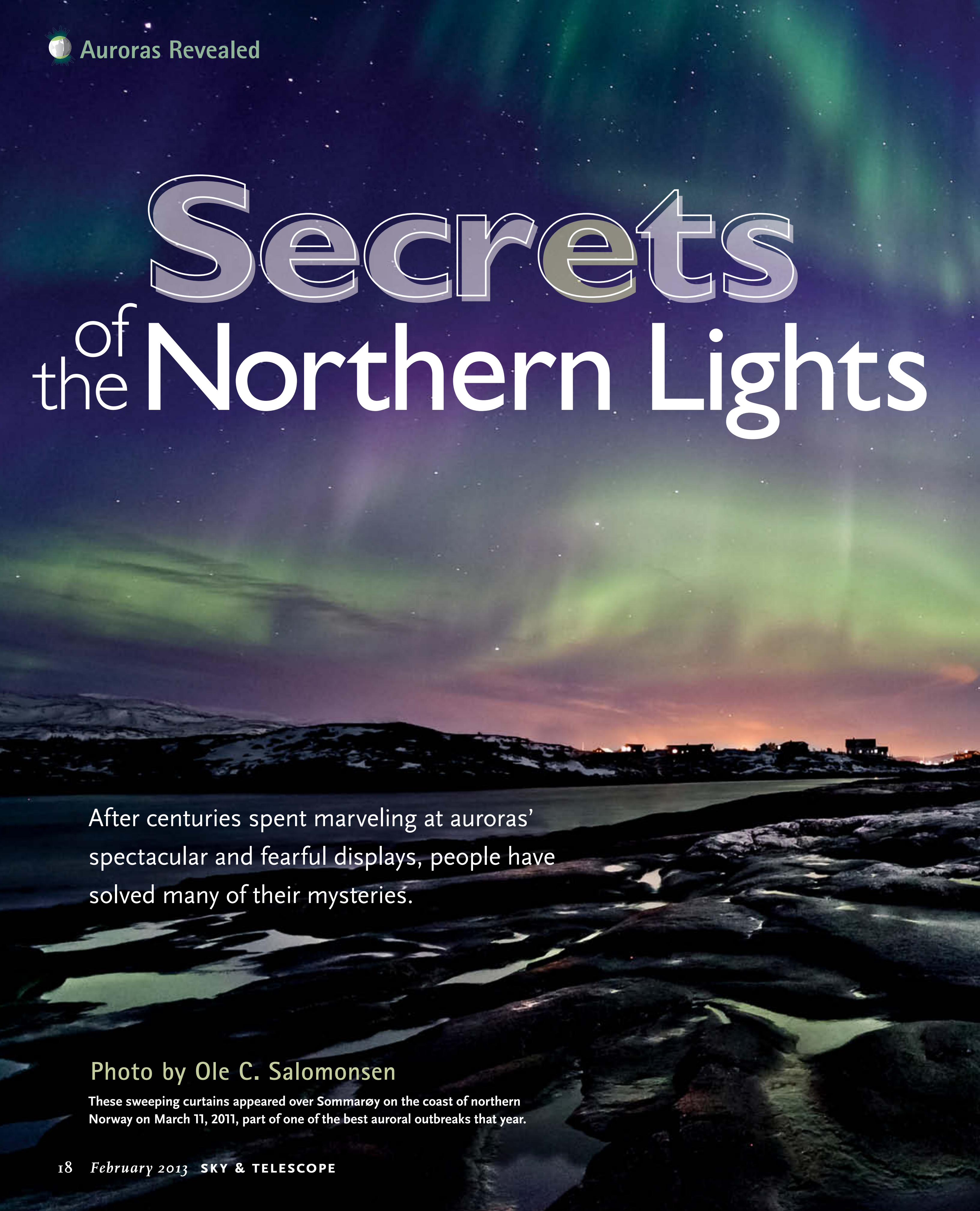


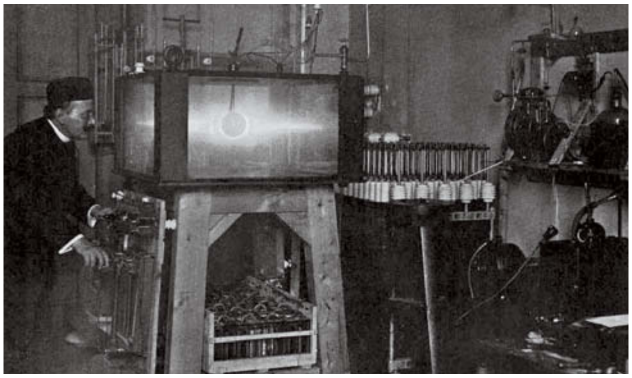
Photo by Ole C. Salomonsen

These sweeping curtains appeared over Sommarøy on the coast of northern Norway on March 11, 2011, part of one of the best auroral outbreaks that year.

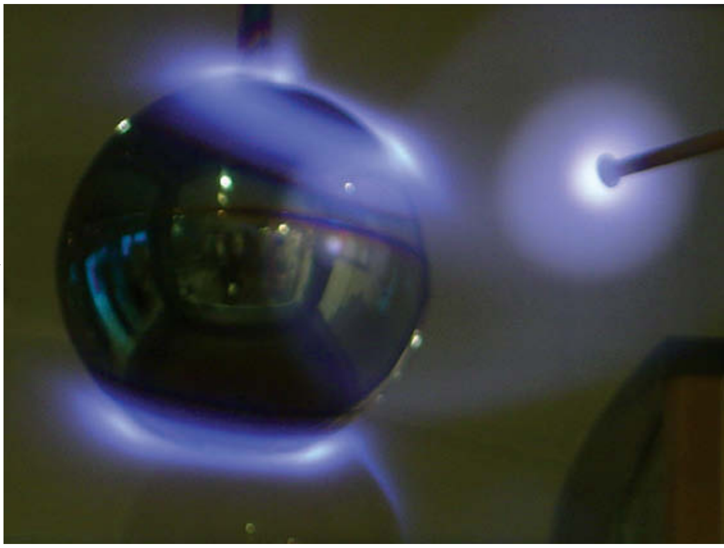
Pål Brekke

The first detailed description of the surreal sheets of light that hang in northern skies appeared in *The King's Mirror,* a Norwegian chronicle from about AD 1230 that was probably written as a prince's textbook. The author spends many lines describing the peculiar glow seen by the Vikings, but admits no one knows why the phenomenon exists. (Among the theories offered are fires at the edge of the world and gleams from the Sun, hidden beneath the horizon.)

It was only a century or so ago that people suspected a more direct connection with the Sun. Today we know that these lights, first called the *aurora borealis* or "dawn of the North" by Galileo Galilei, form when gusts of charged, energetic particles from the Sun breach Earth's protective magnetic shell and hit the planet's atmosphere. But this discovery took decades to unravel, and even today we are still grappling with the northern lights' secrets. What we have discovered about these surreal displays only heightens their beauty.



SAPERAUD / WIKIMEDIA COMMONS



DAVID MONNIAUX / WIKIMEDIA COMMONS

Left: **Kristian Birkeland studied the aurora both in nature and in his lab. He appears here with his terrella, a magnetized sphere inside a vacuum box. *Right*: Electrons shot at a terrella's magnetized metal sphere are caught by the magnetic field and channeled down to the sphere's polar regions, creating aurora-like features.**

In 1896 a breakthrough in our modern understanding of the aurora came from the Norwegian scientist Kristian Birkeland (1867–1917), who suggested that charged particles from the Sun might ignite auroras when Earth's magnetic field channels them toward the polar regions.

Birkeland was not the first to suggest a connection with solar particles, but what set his work apart was its basis in controlled experiments. To prove his theory, he built his own "world in a glass box," or a *terrella*, a vacuum chamber in which a small magnetized metal sphere (a stand-in for Earth) is bombarded by electrons injected into the box. His model planet's magnetic field captured these particles and channeled them down toward the sphere's polar regions, where they ignited aurora-like glows.

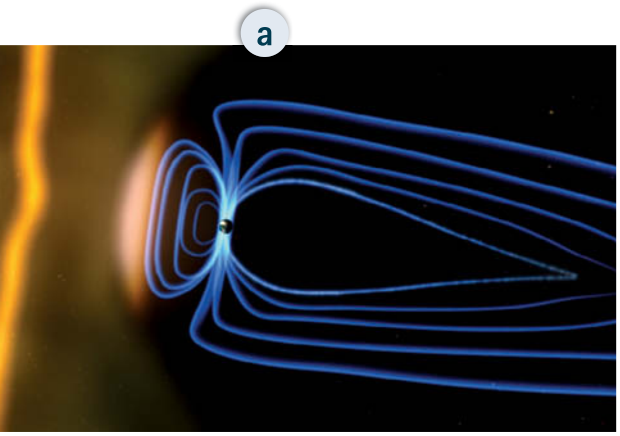
Based on this work, as well as extensive geomagnetic expeditions that showed nearly uninterrupted auroral activity around the poles, Birkeland concluded that "rays of electric corpuscles emitted by the Sun" continually bombard our planet. Today we call these charged particles the solar wind. But despite the importance of this work in retrospect, many of Birkeland's ideas were not confirmed until the Space Age. Since then, we have solved many of the aurora's secrets.

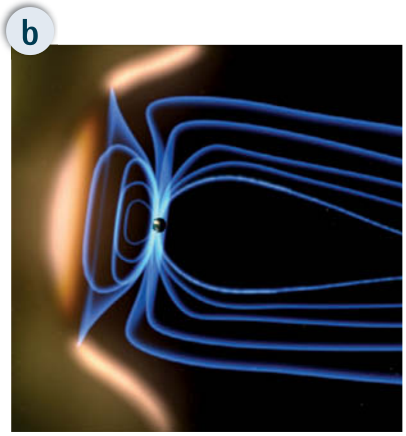
Message from the Sun

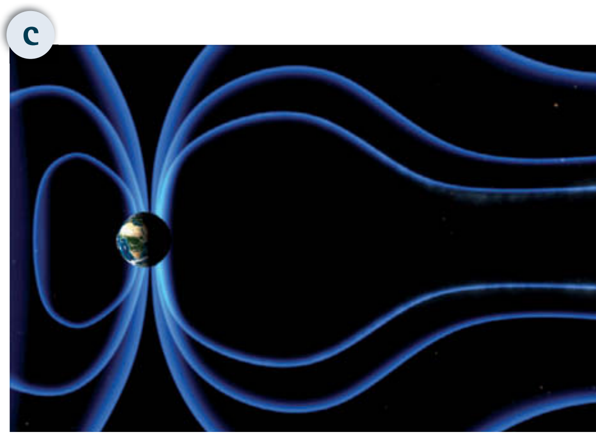
The northern lights display a variety of shapes and structures that can shift dramatically in a matter of minutes. The most common shape is the curtain-like sheet that moves and flickers like fluorescent folds of silk in the sky. These patterns are a visible manifestation of the solar wind buffeting Earth's magnetic field.

The solar wind mainly consists of electrons and protons that stream out from the Sun's outer atmosphere into space. These particles blow into the solar system at a typical speed of 1.5 million kilometers per hour (930,000 mph), nearly 40 times faster than the speed a spacecraft would need to escape Earth's gravity. Strong gusts of solar wind can zoom twice as fast as that.

A substorm occurs when Earth's magnetic tail pinches off. First, a coronal mass ejection slams into the dayside magnetosphere (a). This collision sends particles and magnetic energy around to the planet's nightside (b). The changes compress the magnetic tail (c), ultimately resulting in magnetic reconnection, which releases heat and energy (d). This reconnection sends particles shooting toward







NASA / GSFC CONCEPTUAL IMAGE LAB (6)

These gusts are sometimes joined by large solar gas eruptions called coronal mass ejections, or CMEs, that eject gigantic bubbles of ionized gas into space. These bubbles can reach velocities up to 8 million kph.

Earth's invisible, protective magnetic shell shields us against these particles. The solar wind hammers on this *magnetosphere*, compressing it toward Earth on the dayside and stretching it out in a long tail on the nightside to form a magnetic cocoon shaped like a planet-scale comet.

The weakest sites in this shield are the polar cusps, two regions above the planet's magnetic poles. Through the cusps, particles from the solar wind can access the upper layer of Earth's atmosphere directly, creating dayside auroras that are invisible to us. Some particles will also enter the tail of the magnetosphere (on the nightside) and get pushed back toward Earth, where they generate the "everyday" aurora circling the magnetic poles.

Solar wind particles also gain access through more violent means, when CMEs crash into the magnetosphere. This impact generates *geomagnetic storms*, worldwide disturbances in which the CME compresses the field, reducing its dayside size by roughly 40%. The entire magnetosphere is disturbed during one of these storms, and even a compass needle will deviate from its correct position.

But solar particles by themselves don't cause severe space weather. They need energy from magnetic processes. A geomagnetic storm's severity depends on the density of the gas and the structure of the magnetic field embedded in the CME. The Sun's magnetic field isn't confined to the immediate vicinity of our star: the solar wind carries the field with it throughout the solar system. We call the Sun's extended magnetic field the Interplanetary Magnetic Field (IMF). Because the Sun rotates (one revolution every 25 days at the equator), the IMF actually has a spiral shape — named the "Parker spiral" after Eugene Parker, the American astrophysicist who first described it. The Sun sits at the center of this spiral.

The IMF meets up with Earth's magnetic field at the *magnetopause*, and it's here that a storm's power is determined. Earth's magnetic field points north on the dayside, but the IMF's orientation often changes. If the IMF points north, there will be little interaction with Earth's magnetic field: two aligned bar magnets repel each other, so the CME basically slides around Earth's magnetosphere.

But if the IMF points south, opposite Earth's magnetic field, the two fields will link up. This linking is called *magnetic reconnection*, and it happens when magnetic lines of force snap into new arrangements, releasing heat and energy (see the time series below). The process opens Earth's field on the dayside, allowing particles and magnetic energy to enter the magnetosphere. This energy then travels to the nightside and stretches the magnetic tail, eventually causing it to pinch off and snap back toward the planet in an event called a substorm. When this substorm happens, it sends solar wind particles zooming to Earth's polar regions.

By themselves, substorms do not create the bright aurora we see. Large sheets of electric current above Earth's atmosphere accelerate the particles further; this acceleration is related to how the magnetic tail snaps back and slams into Earth's field near geosynchronous orbit (6.6 Earth radii, much closer than the substorm pinch-off, which happens at roughly 20 Earth radii). The process is similar to an old cathode-ray tube television: an electrical wire brings in electrons (the magnetic snapback phenomenon) to an electron gun (the current sheets), which shoots the electrons at the TV screen (the atmosphere).

These souped-up particles create the northern lights by colliding with atoms, primarily nitrogen and oxygen. These collisions typically occur at altitudes between 80 and 300 km — far above weather phenomena, which mostly happen within the first 20 km above the surface. The collisions transfer energy to the atoms, causing them to emit light of a certain wavelength.

Oxygen atoms cause green and bright red light, the two most prominent colors of the aurora. Red oxygen emission occurs at high altitudes, so the highest part of

Earth, where they form a plasma sheet (e). From there, the particles interact with Earth's upper atmosphere, creating auroras (f). Watch the video at skypub.com/aurorasci.

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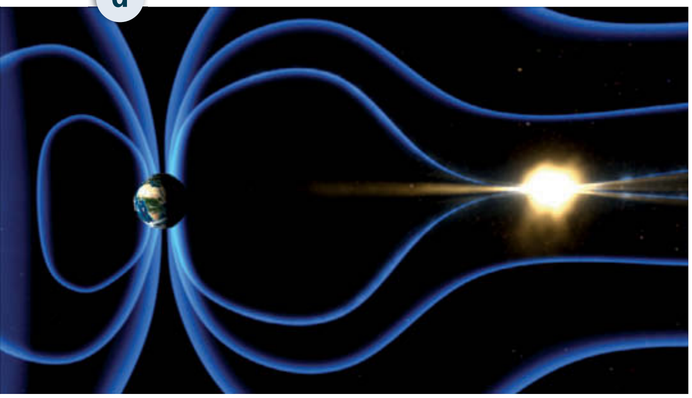

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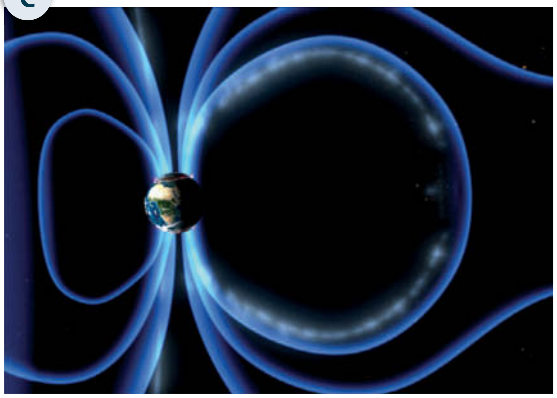

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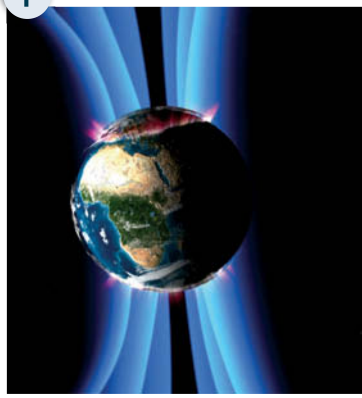


the auroral curtain is usually red. Nitrogen molecules produce bluish light and deep red.

We do not fully understand why auroras have the shapes they do. We do know that auroral curtains and beadlike structures appear after a magnetic tail pinch-off. The thick auroral curtains, which often stretch tens of kilometers across, come from the large-scale sheets of electric current that accelerate particles downward. Auroras' lengths probably relate to activity in the magnetosphere, and smaller magnetic waves might energize particles to create the narrower (1-km-wide) curtains. But other than that, these shapes are still a mystery.

Putting Auroras to the Test

Today we study the northern lights from both ground and space. A large number of all-sky cameras and instruments study the phenomenon from many northern countries. These surveys include incoherent scatter radars, such as the large European Incoherent Scatter Scientific Association's antennas on the Norwegian archipelago Svalbard. Also on Svalbard sits the new Kjell Henriksen Observatory, opened in 2008 and the largest aurora observatory of its kind, with 30 dome-topped instrument rooms. Here, scientists around the world can remotely operate their instruments from their home institutions.

What makes Svalbard special is that during the day it sits right under the northern polar cusp. Here, solar wind particles can enter directly into the atmosphere without being routed via the magnetic tail, as is the case for night-time auroras.

For decades, ground-based observations have revealed a complex and dynamic aurora. New camera technology

FRED SIGERNES / KJELL HENRIKSEN OBSERVATORY

Instruments peer out at the aurora from inside 30 domes that are nestled among mounds of snow and ice at the Kjell Henriksen Observatory on Svalbard.

has allowed researchers to obtain high-resolution time series images that reveal thin structures less than 100 meters wide, as well as patterns that can appear and disappear in a fraction of a second. There is still no consensus about the processes behind these small-scale shapes.

Rockets launched from Fairbanks in Alaska, Svalbard, and Andøya (off mainland Norway) spear the aurora and can actually measure its physical properties. And from even higher up, satellites provide a global view of the auroral oval, the ring of light circling each geomagnetic pole. In 2009 scientists at the University of Bergen in Norway presented satellite images of the aurora taken simultaneously above the Northern and Southern Hemispheres. These images reveal that the auroras in the two

A coronal mass ejection released from the Sun on January 23, 2012 created spectacular auroras the following night, when the author took this picture of the Norwegian city Tromsø.

hemispheres can be totally asymmetric, contradicting the common assumption (which Birkeland and others held) that the aurora borealis and aurora australis are mirror images of each other.

Satellite studies have also produced a lot of new knowledge about interactions between the solar wind, the magnetosphere, and the atmosphere. In 2007 NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) spacecraft fleet, together with a chain of ground-based cameras, made several new discoveries about auroral eruptions caused by energy released when the magnetosphere's tail pinches off. Scientists have studied these events for more than a century, but the new observations surprised them. The aurora brightened and moved twice as fast as was thought possible, surging westward through the atmosphere to cross an entire time zone in less than 60 seconds. The electrical power dissipated by the currents of energetic electrons was also impressive — 500 trillion joules, equivalent to the energy of a magnitude-5.5 earthquake.

THEMIS also helped unravel a long-standing mystery in the magnetosphere. We have wondered in the past how so many energetic particles sneak inside the magnetosphere, because the cusps' weakness should not allow so many in. Observations by the five THEMIS spacecraft found evidence that connections between the magnetosphere and solar wind form in short bursts. These are gigantic, twisted, ropelike bundles of magnetic field that connect Earth's upper atmosphere directly to the solar wind. When these ropes connect with the wind — on average every 8 minutes — the particles can sneak into the magnetosphere. The ropes then drag over and under Earth to the nightside, where their energy is released about 30 minutes later during a substorm. Recent observations with the ESA's Cluster satellites also suggest that the magnetosphere is more like a sieve than a shield, often allowing the solar wind to flow in.

THEMIS has also helped us understand where solar particles entering through the magnetosphere's tail receive their energy boost. In 2011 researchers found that most of the particles' acceleration happens much closer to Earth than the tail pinch-off that first shoots the particles at the planet. Instead, the particles grab energy as they cross changing magnetic fields along their path, boosting the particles' energy 10 times. But the electric currents above Earth still provide the final thrust that leads to auroras.

Modern observations have reached beyond light to auditory studies as well. Many people say that they hear crackling sounds during auroral displays, often synchronized with the phenomena's movements. Indeed, the Sami people of Norway called the northern lights *guovssahas* — the light you can hear. Since the aurora occurs at least 80 km above the surface and in a near-vacuum, it should be impossible for sound to travel from the site of emission down to the ground.

Where and When to See the Northern Lights

Auroras occur within an oval about 500 to 1,500 kilometers wide that's centered on the geomagnetic poles. They happen day and night during the entire year but are only visible from the ground during clear, dark nights because daylight outshines them. The width of the oval expands during geomagnetic storms, moving the edge farther south.

In parts of northern Norway you can see aurora almost every clear night. But the north part of Norway is at the same latitude as Barrow, Alaska, so you'll need to travel quite far north in North America to see the aurora frequently. When the Sun is active (like now), the northern lights should appear 10 to 15 times each year in the upper continental U.S., and a few times in the mid states. Very strong solar storms have sometimes pushed the aurora all the way down to Florida, such as in July 2000.

The strongest auroras often occur between 8 p.m. and 2 a.m. local time in Europe and more like midnight to 4 a.m. in North America. The best period is from September to April, when nights are dark. Strong auroras happen more often around the equinoxes, making the best time to watch September and October, March and April. Researchers don't agree on why the equinoxes are prime aurora time, but the answer could involve how the yearly wobble of Earth's spin axis toward and away from the Sun affects the interaction of the solar and terrestrial magnetic fields.

This winter should be good for aurora hunters, since solar activity is expected to peak in 2013, but the two years following solar maximum often produce the strongest auroras. That means that there should be several possibilities to experience auroras at lower latitudes in the next three years.

When planning your expedition, avoid city lights and the full Moon and find a dark place with a clear view of the northern horizon. Check predictions for solar activity before you go. Several satellites observe the Sun 24 hours a day, and by monitoring the Sun and measuring the speed of solar wind particles just outside the magnetosphere, scientists can predict the strength and location of aurora up to a couple of days in advance.

Top of page: The southernmost part of the island of Tromsøya is a popular place in Norway to view the aurora (skygazers appear as black blurs on the dock). The author captured this shot of the northern lights on January 24, 2012.

JESSE ALLEN AND ROBERT SIMMON / NASA EARTH OBSERVATORY / NOAA / CSFC / SUOMI NPP

This visible and infrared image by the Suomi National Polar-orbiting Partnership satellite reveals a scalloped auroral curtain seen above the Great Lakes region of North America on October 8, 2012, a few days after the Sun unleashed a coronal mass ejection.

Find aurora forecast resources, animations, and sounds of the northern lights at skypub.com/aurorasci.

Long-Term Ups and Downs

The northern lights vary on several timescales. The frequency of strong auroras depends on the general level of solar activity, which follows an 11-year cycle. The Sun also displays longer cycles that affect the aurora, and the last few centuries have seen an increase in solar activity. Thus, people see more northern lights today than in earlier centuries.

Whether the northern lights will be more or less frequent in the future is unknown. It depends on what the Sun does in the next century. Recent studies suggest that we have reached a grand maximum in solar activity, and that the Sun is heading toward a quieter period again — although not necessarily as severe a lull as the famous Maunder Minimum, a period from 1645 to 1715 when sunspots rarely appeared and when aurora may have disappeared entirely from many people's skies.

But even if the Sun goes quiet, there should still be good auroras. During quiet periods, holes often appear close to the solar equator in the Sun's outermost atmospheric layer, called the corona. In these holes, the Sun's magnetic field lines stretch out into space, allowing the solar wind to escape more easily and with higher velocity. If a coronal hole points toward Earth, a gust of solar wind should hit us a few days later.

No real change in auroral activity should come from Earth's magnetic field, either. The auroral oval forms a ring around Earth's *geomagnetic* pole. Unlike the magnetic pole, which is where magnetic needles become vertical, the geomagnetic pole is the intersection of Earth's surface with the imaginary bar magnet

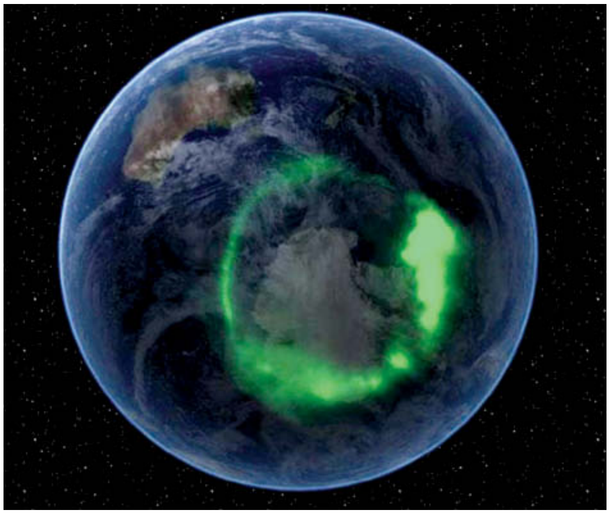
Recently, a group of Finnish scientists claimed they have found the explanation to this paradox. They used three microphones on the ground during high auroral activity to triangulate the source of the crackling. Their observations point to an origin only 70 meters above the ground, although they concluded the sounds are made by the same solar particles that generate the aurora. The team is still unsure what mechanisms are involved, since there are many types of sounds, and different mechanisms might explain each.

Still-Mysterious Lights

Despite these advances, many questions remain. Satellites and ground-based radars reveal that there is a surprising outflow of ionized oxygen atoms from the auroral zone into space. This flow points in the opposite direction from the streams of solar particles that whiz down to cause the aurora. In addition, these regions are often filled with highly energetic particles, and there has been a long-standing debate concerning how and where these particles are accelerated. New observations by NASA's Cluster mission suggest that these particles are accelerated within the cusps themselves, also by magnetic reconnection.

NASA plans to launch the Magnetospheric Multiscale (MMS) mission in 2014, a suite of four identical spacecraft variably spaced in Earth orbit, to make three-dimensional measurements of the boundaries of Earth's magnetic field and examine this reconfiguration process. Magnetic reconnection converts the energy stored in magnetic fields into both heat and the impulse energy that drives solar wind particles toward Earth, and it lies behind nearly every space weather phenomenon, including solar flares, CMEs, and geomagnetic storms. But despite how common it is, we don't fully understand it. MMS will test prevailing theories of these space-weather events to help us decipher what is going on.

These studies are not just aimed to figure out the aurora. Solar storms affect our technology-based society more and more. They can induce electric currents in power lines, causing voltage variations that trigger safety cutoffs or damage transformers and leave communities without electricity (*S&T*: February 2011, page 28). Solar storms can also damage satellites on which our civilization depends and pose a hazard for space exploration. Thus, studying the interaction between these phenomena and Earth's space environment has a practical use that goes beyond predicting the mesmerizing aurora. As we continue to advance technologically, we will need a better understanding of the Sun-Earth connection to protect ourselves. ✦



NASA's IMAGE satellite captured this ultraviolet view of the southern lights on September 11, 2005, four days after a record-setting solar flare. The auroral oval created over Antarctica appears here overlaid onto NASA's Blue Marble image.

***Pål Brekke** is a solar physicist and a senior advisor at the Norwegian Space Centre, as well as an adjunct professor at the University Centre at Svalbard. His recent books,* Our Explosive Sun *and* The Northern Lights — A Guide, *explore our stormy Sun and the aurora.*

the *geomagnetic*, not the magnetic, pole that controls the aurora. The geomagnetic pole is calculated by a mathematical analysis of Earth's overall magnetic field, assuming that the field acts as a perfect bar magnet. The north geomagnetic pole is more static and is currently located in Kane Basin, between Ellesmere Island and Greenland. (The north magnetic pole, on the other hand, is in the Arctic Ocean north of Canada.) You cannot detect the geomagnetic pole with a compass, but if you view Earth from space, the geomagnetic pole marks the center of the aurora oval.

Astronauts aboard the International Space Station caught this view of the southern lights while passing over the Indian Ocean on September 17, 2011. The ISS's solar panels poke in from the right.

IMAGE SCIENCE AND ANALYSIS LABORATORY / NASA JSC

The MOON and the Mystery

of the HUNLEY

THE MOON & TIDES PLAYED MAJOR ROLES IN THE SUCCESSFUL ATTACK & DISAPPEARANCE OF THE CONFEDERATE SUBMARINE.

WILLIAM H. STEVENSON III

On the night of February 17, 1864, sentry Robert Flemming stood on board the *USS Housatonic* peering at moonlit ripples on the water. The ship was a wooden sloop-of-war, carrying out blockade duty off Charleston, South Carolina, where the first shots of the American Civil War had been fired almost three years before. The sailors were on high alert, since the Confederates had attacked the blockading fleet with steam-powered “torpedo boats,” and there were rumors that the enemy was building an even more sinister machine that could attack underwater — silently, invisibly. From its anchorage about 4½ miles (7¼ km) offshore, there seemed to be only a small chance that such a craft could reach the *Housatonic*, but at a little over 200 feet (60 meters) in length and with a crew of about 155, the sloop presented a tempting target.

Illustration by Casey Reed

FATAL ENCOUNTER On February 17, 1864, at about 8:40 p.m., the *H. L. Hunley* attached a torpedo to the starboard side of the *USS Housatonic* — the first successful submarine attack in history. This art is based on eyewitness testimony from Union survivors, and accurately renders the positions of the two ships, the clear sky, and the phase of the Moon just before the *Hunley* emplaced its torpedo.

Based on published testimony in a U.S. Naval Court of Inquiry, we have a reasonably good idea of what happened next, and what was said. Scanning the water shoreward with a gentle breeze in his face, Flemming spotted a strange object barely visible on the surface. Was it a porpoise? A piece of driftwood? With increasing concern he saw the object move toward the ship. He ran over to the officer of the forecastle, Acting Master's Mate Lewis Cornthwait, and reported what he had seen.

"That's nothing but a log," said Cornthwait.

"It's not floating with the tide like a log," replied Flemming. "Look, it's moving across the tide." Cornthwait viewed the suspicious object again and remained unconvinced. Frustrated, Flemming called the port lookout to cross over and take a look. Cornthwait scanned the object through his field glasses.

"If no one is going to report this," exclaimed Flemming, "I'll cut the buoy adrift myself and get ready for slipping."

As Flemming rushed away, alarm bells sounded. The officer of the deck had spotted the object and raised the alarm. A sailor used a sledgehammer to smash the wooden pin securing the anchor chain, freeing the ship for movement. An engineer ordered the ship's steam-powered propeller into full reverse. Sailors rushed to the side of the ship, firing at the approaching object with rifles, shotguns, and pistols. Others worked desperately to turn the ship's pivot guns on the intruder and blast it out of the water.

DEFENDER OF CHARLESTON No known photos of the *Hunley* exist from the time of the Civil War. This painting, created by Conrad Wise Chapman in December 1863, gives us an accurate depiction of what it must have looked like two months before its final mission when the *Hunley* left its moorings from Breach Inlet on Sullivan's Island at about 6:45 p.m. It took about 2 hours to traverse the 4½ miles to the *Housatonic*. The *Hunley* had previously sunk twice during training missions, claiming the lives of 13 men, including designer Horace Lawson Hunley.

MAP: *S&T* LEAH TISCIONE; PAINTING: THE MUSEUM OF THE CONFEDERACY, RICHMOND, VIRGINIA

Impervious to the noise and activity above, the object, a gliding shadow except for two dimly glowing conning towers projecting from the water, moved on a collision course to the ship, struck the wooden hull, and then began moving backward, reversing course. Seconds later a powerful explosion tore open the side of the *Housatonic*, quickly sending her to the bottom in waters 27 feet deep. Despite the rapid sinking, only five sailors perished.

The sinking of the *Housatonic* failed to loosen the Union blockade of Charleston, but it marked the beginning of a new era in naval warfare: the first sinking of an enemy ship by a submarine — the Confederate *H. L. Hunley*. Mysteriously, the *Hunley* never returned to shore.

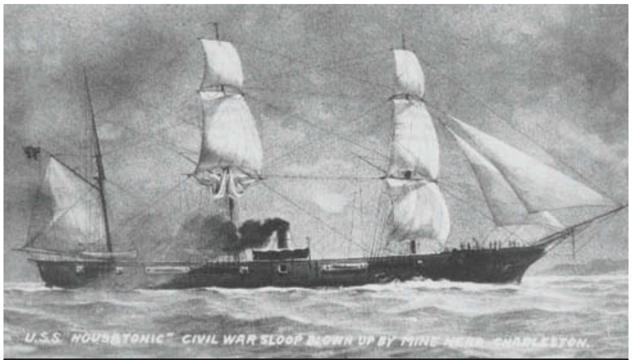
After the sub was recovered from the seabed in 2000, the mystery only deepened. The sub was found almost 1,000 feet southeast of the *Housatonic*, in the opposite direction from shore, and all eight of her crew appear to have died at their posts, with no signs of a struggle to escape. How did this happen?

Other mysteries abound. Why did Lewis Cornthwait persist in misidentifying the submarine as a log? Written accounts have generally assumed that the Moon, only a few days from being full, was bright that night, but the state of the Moon at the actual time of the attack had not been investigated in detail. In fact, an eyewitness claimed that the Moon was not very bright when the attack occurred. But if this testimony was wrong and the Moon was indeed bright, why did the *Hunley*'s commander, Lieutenant George E. Dixon, pick that night to launch his attack, when he was certain to be spotted? Was he forced to attack by tides or other circumstances? The tides are often cited as an important factor in planning the attack, but specifics are lacking. My analysis of the state of the Moon and the tides at the time of the *Hunley*'s attack answers some of these questions.

The Moon

A Naval Court of Inquiry was convened on February 26th, just nine days after the attack, to determine the cause of the sinking. The testimony allows us to reconstruct the events of the attack with a fair degree of accuracy, although there are a number of discrepancies.

Questioned concerning the conditions on the night of the attack, *Housatonic* Executive Officer F. J. Higginson testified that "the night was clear and pleasant — moonlight, not very bright." But modern calculations indicate that the Moon was bright that night. The U.S. Naval Observatory's program (available at **http://www.usno.navy.mil/USNO/astronomical-applications**) indicates that at Charleston's meridian, 79° 58′ west longitude, the waxing Moon rose at 1:59 p.m. Eastern Standard Time, or 1:39 p.m. local mean time (all subsequent times will be expressed as local mean time). The Moon reached its maximum altitude of 76.6° at 8:46 p.m., at which point it was 82% illuminated.



UNION BLOCKADER **The *Housatonic* was a 205-foot-long, 11-gun Union sloop-of-war carrying out blockade duty off Charleston Harbor. Surprisingly, only five of the ship's approximately 155-man crew perished in the *Hunley* attack. The ship's sinking only made a tiny dent in the Union blockade, which stifled almost all Confederate shipping from Charleston until the city's surrender on February 18, 1865.**

R.G. SKERRETT, SOURCE: SCOTTYBOY900Q/WIKIMEDIA COMMONS

Witnesses testified that Flemming first reported his sighting to Cornthwait at about 8:30 p.m., just 16 minutes before the Moon's maximum altitude. In its conclusions, the Court of Inquiry used "bright and moonlight" to describe the night, suggesting that either Higginson's memory was faulty or that he was covering up for Cornthwait's negligence. Considering the Moon's brightness, there seems to be little excuse for the officer of the forecastle to misidentify the *Hunley* as a log and to argue with his subordinate about it.

The lost time was crucial for the sailors who frantically tried to turn the *Housatonic*'s artillery on the sub. Captain Charles Pickering of the *Housatonic* claimed, "If I had had two [more] minutes to work in, I could probably have saved the ship and sunk the torpedo craft." Gunner Thomas Kelly concurred, stating, "If the object had been reported when it was first discovered, the number four gun . . . might have been trained on it."

Despite the testimony of several witnesses that Cornthwait's inaction lasted for several minutes, the Court of Inquiry made only a passing reference to the delay in its conclusions. Although the court was unwilling to downplay the Moon's brightness, it evidently found other reasons to gloss over what may have been a key point in the *Housatonic*'s destruction.

Since the Moon was so bright, why did Lieutenant Dixon choose this time to launch an attack? He was well aware of the *Hunley*'s vulnerability to enemy fire and the necessity for stealth. In a recollection published in the June 29, 1902 edition of the New Orleans *Picayune*, an early crewmember, W. A. Alexander, stated that a dark Moon "was essential to our success." So why did Dixon attack on the night of February 17th? He attacked because the weather was favorable and, most importantly, so were the tides.

FRIENDS OF THE HUNLEY

RAISING THE HUNLEY The wreck of the *Hunley* was discovered in 1995 and the sub was raised on August 8, 2000. The *Hunley* was about 1,000 feet from the *Housatonic* wreck and 27 feet deep.

The Weather

The *Hunley* was constructed with some impressive engineering for its era: a streamlined hull, adjustable water ballast, a depth gauge, and a spar-mounted torpedo that could be attached to a ship's hull and triggered after the sub had backed away to a safe distance. But her power plant consisted of seven men hand cranking a screw propeller. Although manpower could propel the sub up to 4 miles (6.4 km) per hour, it placed severe limits on the conditions in which she could operate. The *Hunley* could not make much headway against a strong wind and could not operate at all in stormy weather.

In his *Picayune* article, Alexander recalled that throughout the winter of 1863–64 the weather had usually been unfavorable for an attack, an opinion supported by the correspondence in official U.S. Navy records of South Atlantic Blockading Squadron commander John Dahlgren. On January 7th he reported "the weather is generally wretched, wind and rain in every variety" and on January 13th he described the previous evening as "an ugly, rainy night."

By February 1864, Charleston had been under siege for seven months. Union shells were raining down on a daily basis and Dixon was under tremendous pressure to show some results for all of the effort expended on the *Hunley*. Making matters worse, 13 crewmembers had already perished when the sub sank during two training accidents, including the designer, Horace Lawson Hunley. As late as February 16th the weather was bad, with the *Charleston Daily Courier* reporting that "a heavy blow prevailed all day . . . causing most of the fleet [of Union ironclads] to retire to the lighthouse inlet." But the weather cleared the next day. Now Dixon could attack — if the tides allowed it.

The Tides

The *Hunley* could not travel far against the tides. When Dixon was on the hunt for Union ships, the standard procedure was to leave the dock at Breach Inlet (on Sullivan's Island) after dark, venture forth to sea on a carrying ebb tide, and return to shore on the rising flood tide. On the night of February 17th the tide schedule was ideal for an attack. Calculations using the *XTide* program (written by David Flater and available on the University of South Carolina webpage **http://tbone.biol.sc.edu/tide/index.html**) indicate the following schedule for Charleston Harbor tides on February 17, 1864:

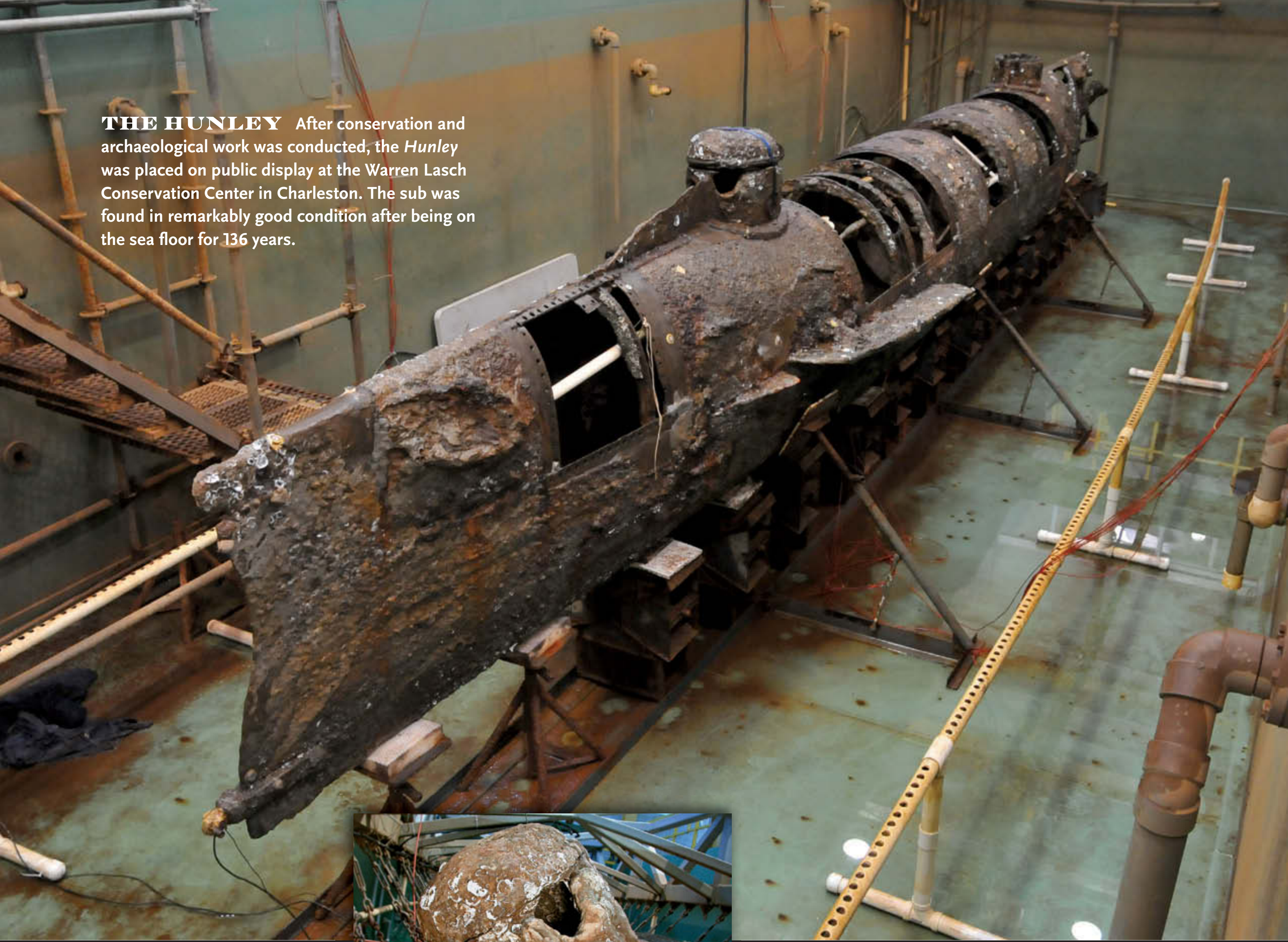
3:35 a.m.	high water
10:02 a.m.	low water
3:59 p.m.	high water
10:05 p.m.	low water

By the time twilight faded at 6:12 p.m., the ebb tide was well underway. The tide would not turn until 10:05 p.m. that night, giving Dixon plenty of time to reach the *Housatonic*, lying at anchor 4½ miles from Breach Inlet. Dixon was surely aware of the tide schedule: every week the *Charleston Daily Courier* published tables of the morning high water predicted for each day. The *Courier* states that the port calendar was "corrected weekly," so it was probably quite accurate. The high water time listed by the *Courier* for February 17th was 3:15 a.m., close to the 3:35 a.m. time calculated by *XTide*. In fact, for the week of February 14–20 the *Courier*'s predictions differ by an average of only 13 minutes from those of *XTide*.

The Naval Court of Inquiry's conclusions confirm that Dixon planned his attack well, stating that the *Housatonic* was sunk when the tide was at "half ebb." As he climbed through the hatch of the *Hunley* at dusk on the evening of February 17th, we can imagine Dixon taking a last look at the heavens and shaking his head at the Moon shining down in a clear sky, more than halfway to the zenith and still rising. But there was no turning back. This was his best chance in months, and it was a chance he had to take.

Still a Mystery

Considerations of the Moon and the tides may also help explain the *Hunley*'s ultimate fate. The flood tide did not begin until 90 minutes after the *Hunley*'s attack. One scenario is that Dixon was unwilling to buck the tide back to shore with his weary men and even more reluctant to stay afloat under a bright Moon in full view of Union rescue ships converging on the wreck of the *Housatonic*. Dixon knew that the *Hunley* could remain submerged for 2½ hours before the air became unbreathable. In order to evade the Union ships, he maneuvered the sub to the east of the *Housatonic* and lowered it to the sea floor, planning to wait a few hours for the tide to turn before making his escape. But, elated and exhausted, he lost track of the time, and something — elevated carbon monoxide levels, oxygen deprivation, fumes from a recent painting of the sub's interior — caused the crew to lose consciousness, never to awake.



THE HUNLEY After conservation and archaeological work was conducted, the *Hunley* was placed on public display at the Warren Lasch Conservation Center in Charleston. The sub was found in remarkably good condition after being on the sea floor for 136 years.

FRIENDS OF THE HUNLEY (2)

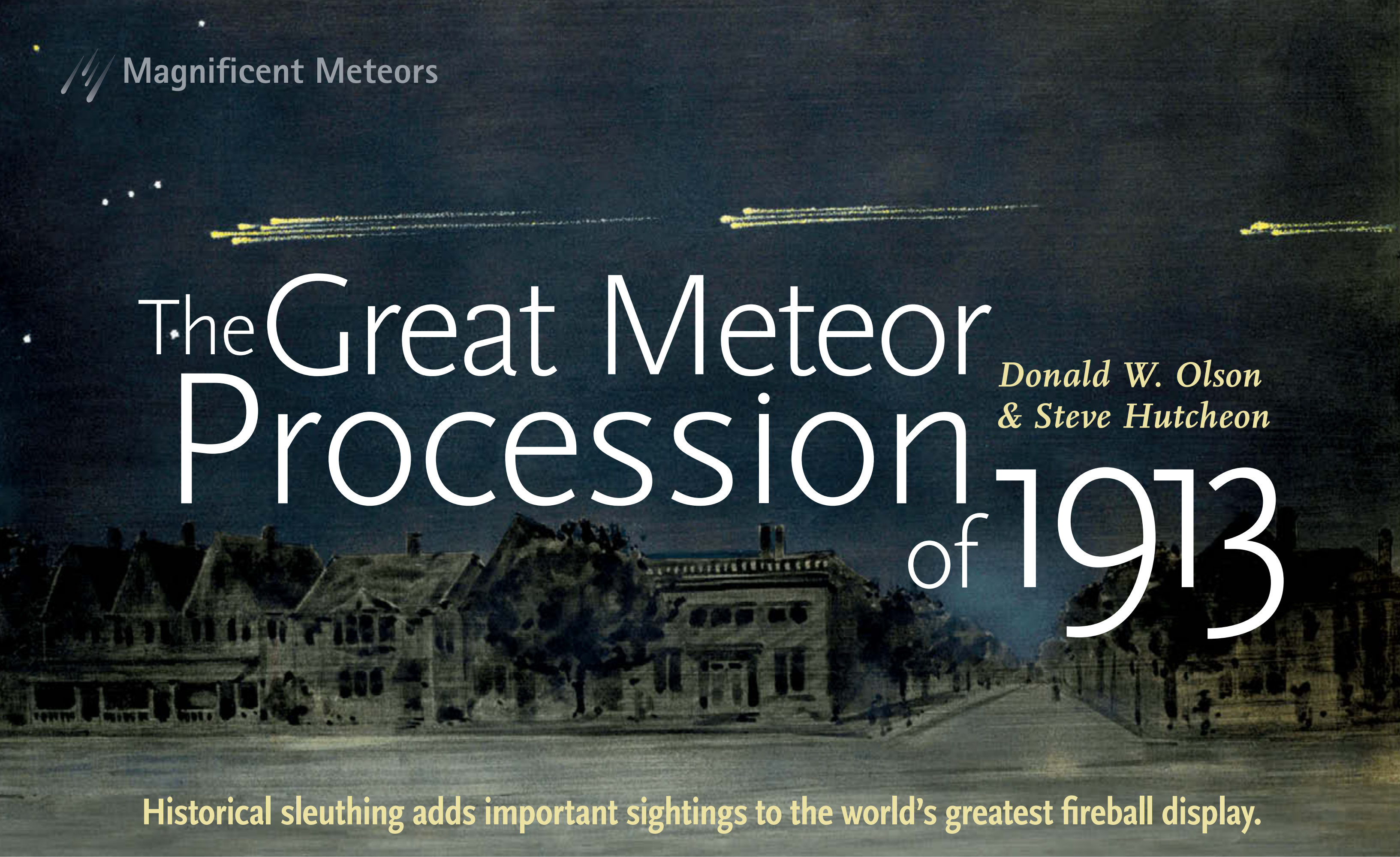
FATAL WOUND? The sinking of the *Hunley* remains a mystery, but some historians point to the grapefruit-size hole seen here on the right side of the forward conning tower. The hole might have come from a rifle bullet fired by a sailor on the *Housatonic*. If so, the two ships literally sank each other.

To listen to an audio interview with author William Stevenson, visit skypub.com/Hunley.

Maria Jacobsen, the senior archaeologist at the Warren Lasch Conservation Center directing the excavation of the *Hunley*, considers another scenario more likely. She cites a grapefruit-sized hole found on the *Hunley*'s forward conning tower that was likely caused by the impact of a rifle bullet from the *Housatonic*, and suggests this breach ultimately flooded the sub. The tides and currents off Charleston muddy the water, and the evidence suggests that the sub filled with sediment fairly soon after the damage to the conning tower. But Jacobsen cautions that the conning tower breach may have occurred after the attack, perhaps from a dragline during a Union effort to find the sub. Thus, the *Hunley*'s sinking remains a mystery.

The sinking of the *Housatonic* caused consternation throughout the blockading fleet and jubilation in Charleston. But the blockade continued, and on February 18, 1865 — just a year and a day after the *Housatonic* sank — the city surrendered to a Union army commanded by General William T. Sherman. For the *Hunley*'s crew, the attack was a triumph and a tragedy, both significantly influenced by the Moon and the tides. ✦

A South Carolina native, ***Bill Stevenson*** *(****whsteve3@gmail.com****) has been an astronomy and a history buff all his life and a freelance writer for more than 10 years. His articles have been published in* Solar Today, Baltimore, Business Alabama, *and* Toastmaster. *He is currently a chemical consultant living in Huntsville, Alabama.*



The Great Meteor Procession of 1913

Donald W. Olson & Steve Hutcheon

Historical sleuthing adds important sightings to the world's greatest fireball display.

NATALIE MCMINN / UNIVERSITY OF TORONTO ARCHIVES

Artist and amateur astronomer Gustav Hahn made this painting of the 1913 meteor procession as seen near High Park in Toronto. Hahn estimated that the fireballs passed about halfway between Rigel and Orion's Belt (upper left).

ON THE EVENING OF FEBRUARY 9, 1913 — exactly 100 years ago this month — the most remarkable procession of fireballs ever recorded passed over Canada. University of Toronto astronomer Clarence A. Chant collected eyewitness accounts, primarily from Ontario, and summarized the local observations for the *Journal of the Royal Astronomical Society of Canada:*

> At about 9:05 [Eastern Standard Time] on the evening in question there suddenly appeared in the northwestern sky a fiery red body . . . which was then seen to be followed by a long tail . . . it moved forward on a perfectly horizontal path . . . without the least apparent sinking towards the earth . . . it simply disappeared in the distance . . . Before the astonishment aroused by this first meteor had subsided, other bodies were seen coming from the north-west . . . Onward they moved, at the same deliberate pace . . . with tails streaming behind . . . To most observers the outstanding feature of the phenomenon was the slow, majestic motion of the bodies; and almost equally remarkable was the perfect formation which they retained.

Chant also obtained reports from western Canada. At Mortlach and Pense in Saskatchewan, hundreds of meteors were seen passing from west to east at about 7 p.m. Mountain Time.

Perhaps the most surprising account sent to Chant came from Bermuda. At about 10 p.m. Atlantic Time, W. R. Winter saw "two leading bodies" trailed by about 100 smaller meteors in a "procession" traveling nearly horizontally in the sky east of Bermuda. Because all the observing sites fell close to a great circle, and all the local times corresponded nearly to 2h Universal Time, Chant deduced that the same phenomenon had been witnessed along a ground track from Mortlach to Bermuda, an unprecedented distance of 2,437 miles (3,922 km).

Extending the Ground Track

British astronomer William F. Denning became interested in the event, and by 1916 he had obtained observations of the meteor procession from two ships: *SS Bellucia* and *SS Newlands*. The *SS Newlands* was just south of the equator off the coast of Brazil, and Denning remarked that the ground track of the 1913 procession thus extended for about 5,500 miles (8,850 km). In 1923 William H. Pickering at Harvard College Observatory uncovered observations from three more ships (*SS Tennyson, SS Custodian,* and *SS Manuel Calvo*) near Bermuda.

Other researchers found additional sightings. Alexander Mebane in 1956 filled in the ground track with several dozen accounts, mostly newspaper stories from Minnesota, Michigan, New York, Pennsylvania, and New Jersey. John O'Keefe in 1968 added a newspaper story from Didsbury, Alberta, which extended the known ground track farther west for a total length of about 6,040 miles (9,720 km).

As the centenary of the meteor procession approached, we wondered whether there were even more reports of the 1913 meteors. The Library of Congress historical newspaper site includes two stories based on interviews with the captain of the *SS Zafra* (located northeast of Bermuda at the time). The first is from the *New York Evening World,* February 14, 1913:

> Hardly had the skipper turned in when a white-faced seaman appeared at the door of his stateroom and pleaded with him to come on deck. "The world is coming to an end, sir, sure," he groaned . . . An unearthly flare hung over the ship, and, sailing across the sky was what looked like a flock of monstrous birds of fire. They were coming towards the Zafra, and they passed over her, shedding their unearthly radiance . . . the meteors . . . sailed on . . . The crew stayed on deck, shivering and praying, until the last faint glow of their taillights had flickered away in the distance.

The other account is from the *New York Sun,* February 15, 1913:

> The meteors were fired slowly. It took six minutes for forty of them . . . to write their glowing bluish white autographs across the sky. In this six minutes of incandescent glory the skipper read over the love letters of his youth and made his will, as he thought that the last day might be pretty close. He says the stream of meteors passed from northwest to southeast.

These reports, though colorful, did not extend the ground track. Denning's 1916 investigation remarked that as the meteor procession passed the *SS Newlands,* at latitude 3° 20′ south, the fireballs were "still going strongly . . . and may have pursued their luminous career far southwards over the South Atlantic Ocean, but navigators alone, during morning watches, can give us further information on the subject."

This call for further observations has finally been answered. With assistance from British and German archivists, we recently located seven meteorological logbook entries from ships at latitudes south of the *SS Newlands*. These entries were recorded on February 10th, since the local times were just after midnight.

A logbook at the U.K. National Meteorological Archive includes this account:

> ***SS Julia Park*** (32° 44′ W, 4° 41′ S)
>
> Witnessed a brilliant Meteoric shower immediately overhead. More

The blue dots mark locations where the meteor procession was observed. The accounts from the ships at latitudes south of the *SS Newlands* were discovered during the preparation of this article. To have traveled so far around Earth, the 1913 meteor procession apparently followed tracks similar to the gradual reentry of satellites in low-Earth orbit.

Other Historical Meteor Processions

1783 August 18: Scotland, England, English Channel, France.

1860 July 20: Wisconsin, Michigan, Ontario, New York, Pennsylvania, Atlantic Ocean.

1876 December 21: Kansas, Missouri, Illinois, Indiana, Ohio, Pennsylvania.

than a hundred being seen within a minute, and all travelling from NNW, the whole breadth of the sky, and very low down.

Six logbooks at the German Meteorological Service archives describe the meteor procession (translated from German):

Steamship ***Bahrenfeld*** (31° 55′ W, 4° 18′ S)

From 0h 5m to 0h 10m a.m. true solar time an exceptionally strong shooting star event took place. The shooting stars of intense yellow color were all moving in the west from approximately WNW magnetic to ESE. Noteworthy was their moderate speed.

Sailing ship ***Ponape*** (28° 41′ W, 8° 23′ S)

At 12½h three great meteors (emitting sparks) in succession. Impact was heard onboard.

Sailing ship ***Barthold Vinnen*** (29° 51′ W, 9° 36′ S)

At 12h 10m there was exhibited a strange spectacle of nature. In the direction NbyW suddenly appeared north of the constellation of the Lion, coming seemingly from infinity, an uncounted number of shooting stars. The track appeared like a chain of star molecules and was resplendent in a grayish light. They moved southeast at a slow speed and disappeared in the region near Alpha Crucis and Alpha and Beta Centauri . . . The duration of the display was about ten minutes.

Sailing ship ***Hans 1*** (Captain Bade, 29° 39′ W, 9° 37′ S)

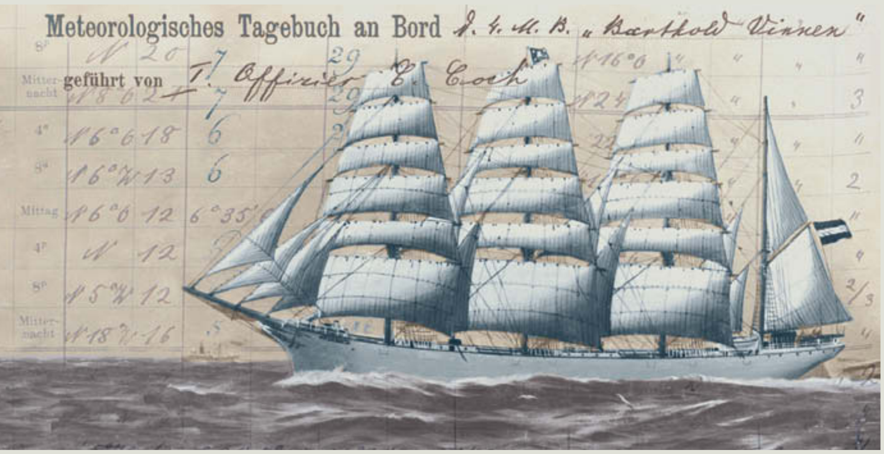
At 12h 40m suddenly about 70 shooting stars were flying across space with tremendous speed. They came up from the NNW horizon and disappeared in the SSE horizon. Many of the shooting stars had no sparkling tails behind them, but looked like stars that suddenly were flying across space.

Sailing ship ***Hans 2*** (Captain Külsen, 28° 36′ W, 10° 48′ S)

At 12h 30m an uncounted number of shooting stars passed over from NW to SE.

Sailing ship ***J. C. Vinnen*** (24° 29′ W, 14° 41′ S)

At 12h 40m local mean time we observed a strikingly bright star in the direction NWbyN, at an altitude of about 10° above the horizon. This star grew in size and brightness as we watched and eventually burst apart in a bright shower, and after this from the same direction came over 100 meteors, some of them very bright with long tails. Their path was from Orion to the Southern Cross, which they traversed in 20 seconds. The last and less bright came at 12h 50m.



The logbook from the *Barthold Vinnen*, a four-masted barque, reports "a strange spectacle of nature . . . an uncounted number of shooting stars" appeared north of Leo and passed slowly across the sky, disappearing near Crux and Centaurus.

LOGBOOK: DEUTSCHER WETTERDIENST; SHIP: STATE LIBRARY OF VICTORIA, BRODIE COLLECTION

These ship accounts, all previously unknown, extend the ground track to more than 7,000 miles (11,000 km) — more than a quarter of the way around Earth — and show how historical archives can provide new information even a century after a spectacular celestial event.

To travel so far around the curvature of Earth, the individual members of the 1913 meteor procession apparently followed tracks similar to the gradual reentry of satellites in low-Earth orbit. The lack of precise altitude and speed information from 1913 prevents us from accurately determining the orbit of the parent body before it was captured to become a temporary "mini-moon" of Earth

To explain how the individual meteors became so spread out — taking several minutes for the procession to pass each observing location — O'Keefe in 1961 suggested that the parent body fragmented in the lower atmosphere near perigee on the revolution immediately prior to the one that was observed. The individual smaller bodies would have proceeded around Earth on orbits with slightly different apogee heights and periods and would have re-entered the lower atmosphere one revolution later to form the procession that amazed observers from Canada to the South Atlantic. ✦

Don Olson *teaches at Texas State University.* ***Steve Hutcheon*** *is a researcher with the Astronomical Association of Queensland, Australia. The authors are grateful for research assistance from Mark Beswick at the U.K. National Meteorological Archive and from Wolfgang and Birgit Gloeden, and Gudrun Rosenhagen at Deutscher Wetterdienst.*

Get more from your telescope! Try these tricks, techniques, and tactics from a deep-sky veteran.

Ken Hewitt-White

KEN HEWITT-WHITE

Savvy Scoping

JOHANNES SCHEDLER

Above: **The author packs for a road trip. *Left:* The Eskimo or Clown Face Nebula, 9th-magnitude NGC 2392 in Gemini high overhead these evenings, looks very different in different skies with different apertures and powers. At 50× it's barely distinguishable from a star, perhaps with an odd color, but its high surface brightness punches through light pollution. Higher power resolves its 15″ inner disc and 10.4-magnitude central star. A 16-inch scope under a dark sky reveals the large, faint outer envelope, much more prominent in photos than to the eye. Very high power shows vague features like a face in a fuzzy hood, with the central star forming a clown nose.**

Blame it on the big chill. Like many amateur astronomers, I don't observe much on icy January and February nights. But when sky conditions are right, even this confirmed couch potato gets off his duff and out the door to explore the winter sky.

Mind you, I don't go far. I usually observe from a roadside park a half hour's drive from my suburban home. It's only semi-rural, with a starscape that's moderately light polluted but certainly useable. The last wintry night I observed there, my 10-inch Dobsonian picked up some fairly faint deep-sky objects that might surprise you.

My night was successful for several reasons. First, I was well rested with a thermos of hot coffee to keep me going. Second, I was dressed as though on an expedition to the South Pole. And third, I used some tricks of the trade I've learned over the years. Pull up a chair and I'll tell you what works for me — no matter what the season.

Heavenly Homework

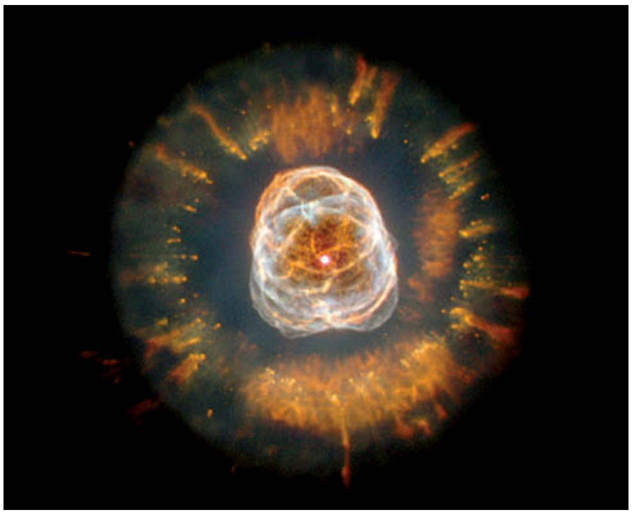
My procedure for "going deep" starts before I leave the house. I don't mean rounding up equipment and warm clothing — obviously that's important — but spreading out my celestial deskwork and making plans. Like any serious observer, I prepare for my night of sightseeing with star maps, guidebooks, and online resources. Planning is imperative, because my telescopes aren't Go To equipped and I don't take computing devices on my field trips.

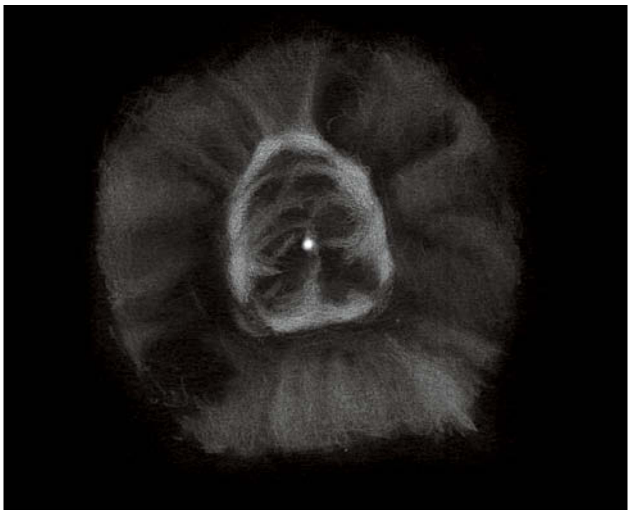
First, about star maps: For semi-rural stargazing I use the handy-dandy *Pocket Sky Atlas,* which plots deep-sky objects among stars to magnitude 7.6, and the deluxe edition of *Sky Atlas 2000.0,* with stars to magnitude 8.5. The maps in both are spiral-bound and lie flat. For pristine skies, my choice is the two-volume hardcover *Uranometria 2000.0* (magnitude 9.75) and its accompanying *Deep-Sky Field Guide,* which lists the position, size, and brightness of all 30,000 faint fuzzies plotted on the 220 *Uranometria* charts. My at-home charting software is *Starry Night,* which quickly shows me what's up and permits me to print out very deep, magnified star fields around hard-to-find objects.

At home with my computer on and charts in hand, I work up a hit list. I always include one or two difficult objects that should really push my observing skills, but also some easier fare that I've enjoyed before and want to see again. I list the targets in order of increasing right ascension and declination to ensure that I go after the most southerly, westerly stuff first, before it moves too low. I can veer away from my list any time I want, but checking it frequently usually gets me pursuing some noteworthy nebula or galaxy I might otherwise forget.

Crucial to making the list are the resources on my bookshelf. Among them are Stephen James O'Meara's three inspiring *Deep Sky Companions* tomes: *The Messier Objects* (1998), *The Caldwell Objects* (2002), and *Hidden Treasures* (2007). They include his detailed observations and sketches, made with only a short-focus 4-inch refractor, of the 219 objects in the Messier and Caldwell catalogues and another 109 selections of his own that those two catalogs miss. When I want to push deeper, I turn to the *Observing Handbook and Catalogue of Deep-Sky Objects* by Luginbuhl and Skiff (1990) for its precise descriptions of 1,500 objects as seen in scopes of various sizes up to 12 inches. I also admire the two-volume *Night Sky Observer's Guide* by Kepple and Sanner (1998), which offers data and often descriptions, photos, and eyepiece drawings for 5,500 objects, gathered from experienced observers using instruments from 2 to 18 inches aperture.

Deep-sky websites abound on the internet, but in my experience they are of uneven quality and reliability. Moreover, the authors of self-published material don't


NASA / STSCI


SERGE VIEILLARD

The view in a really big scope begins to reveal details made famous by the Hubble Space Telescope image of the Eskimo *(left)*. Serge Vieillard used a 24-inch Cassegrain telescope in the dark French Alps to make the sketch at right. (The eskimo's face is upside down.)

always reveal their sources of information. Against that trend, and well ahead of the pack, is the NGC/IC Project at **ngcicproject.org**. This site is a comprehensive modern review of the entire *New General Catalogue* of clusters, nebulae, and galaxies and its two *Index Catalogues*. It provides concise, consistent, no-nonsense descriptions (all by *S&T* contributing editor Steve Gottlieb) made with scopes of 8 to 18 inches aperture, along with fascinating historical notes and numerous corrections of old (and oft-repeated!) cataloging errors. I rarely complete my hit list without consulting The Project.

I also mine the **wikisky.org** photomaps covering the whole sky for their treasures from the Sloan and Palomar digitized sky surveys. Zooming into selected color images on Wikisky, I note faint stars (with their magnitudes revealed by running the cursor over them) conveniently close to small or dim targets. Here the deep-sky objects are photographic images, not symbols on a map, so their nature is instantly evident and my feel for their visibility improves. I make black-on-white printouts of these fields, with key stars and objects identified, and insert them in a three-ring binder together with my hit list and other notes. That binder is an integral part of my “away kit.”

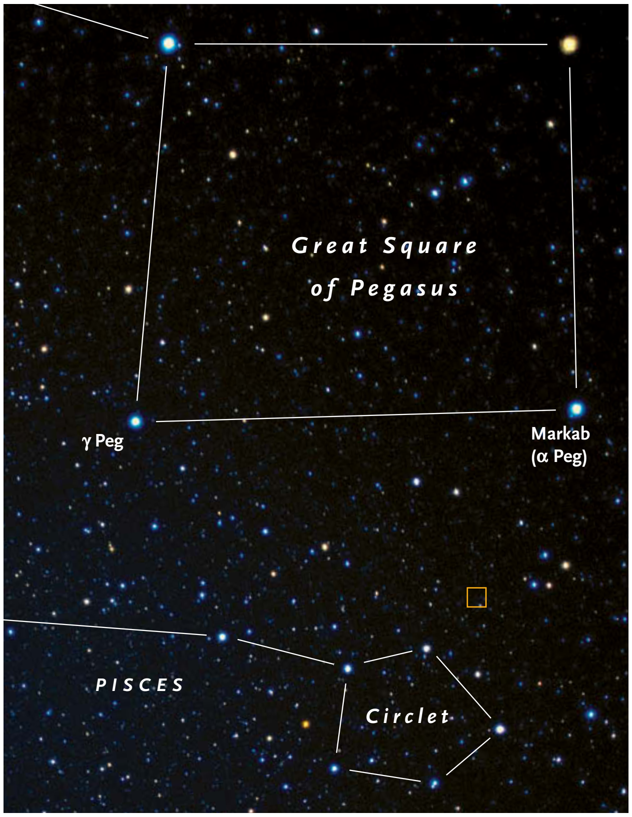
My Newtonian scope gives a correct image, not a mirror image. But if a right-angle star diagonal at your eyepiece means you’ll be observing a mirror image, charting software offers the great advantage of letting you print out mirror-image charts.

In The Field

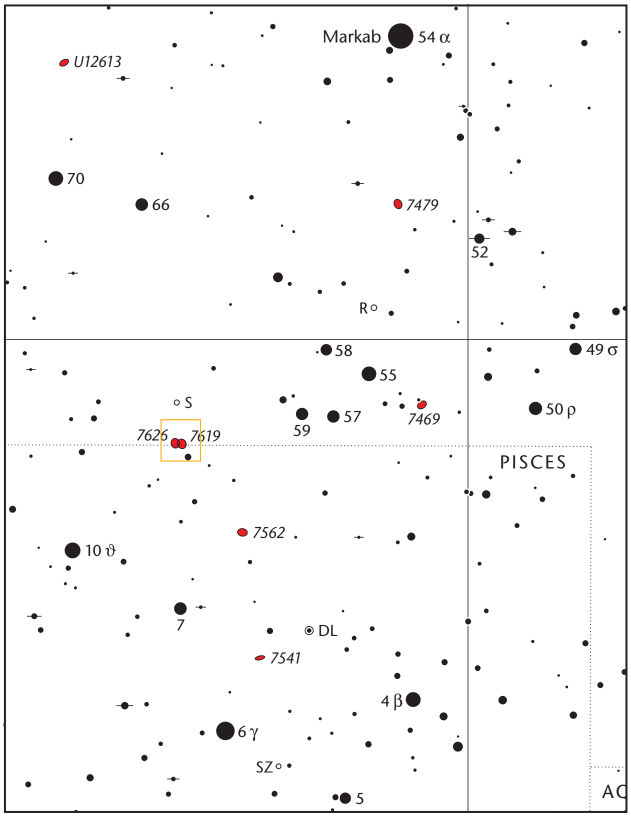
My observing site certainly isn’t perfect. But some of its perceived negatives are positives in disguise. A tall fir tree in the northwest obscures the sky in that direction, but protects me from a glaring farmyard light. A wall of evergreens to the west blocks the worst skyglow from town — and also the wind. All in all, it’s not a bad spot.

I arrive around sunset and deploy my 10-inch Newtonian right away. Allowing the scope ample time to cool off reduces the risk of a warm mirror creating image-fuzzing tube currents. I also true up the optics with the help of a collimation plug. I set up a table next to the scope and arrange my charts, eyepieces, and filters in an orderly fashion (under cover if dew is a problem) so I won’t have to fumble later in the dark. Finally, I align my 8×50 finderscope so that when a star is in the crosshairs, it shows in my highest-power eyepiece. A reflex-image finder, which superposes a red dot or red rings on the naked-eye sky, is nice in tandem with a traditional finder, but on its own it isn’t enough for a serious star-hopper like me.

I wait out the ebbing twilight by practicing star hops to difficult objects. With my atlas as a guide, I follow star patterns in my finder to the target area. Later, when the sky is fully dark, the same route goes much faster. The practice runs aren’t crucial but sure help. One time I navigated beneath the Great Square to the challenging Pegasus I Galaxy Cluster, as shown below. The galaxies weren’t yet visible in the deep twilight. But after noting



P. K. CHEN



SKY ATLAS 2000.0

some helpful "locator" stars on my Wikisky printout of Peg I, and then identifying those faint stars in a low-power eyepiece, I knew where each little smudge should be. In full darkness I switched to higher power and with great satisfaction picked up several members of the group.

A half-dozen oculars provide 50× to 400× in my 10-inch f/5.5 reflector. How high a power I select for any type of deep-sky object (other than big, bright open star clusters) is limited by the transparency of the sky and steadiness of the seeing. When I want to scrutinize a target, particularly a globular cluster, planetary nebula, or galaxy, I crank up the power not until it looks good but — wait for it — looks bad. Once the object becomes obviously too faint or blurry I know that I've gone too far, so I back off the power until the object looks best.

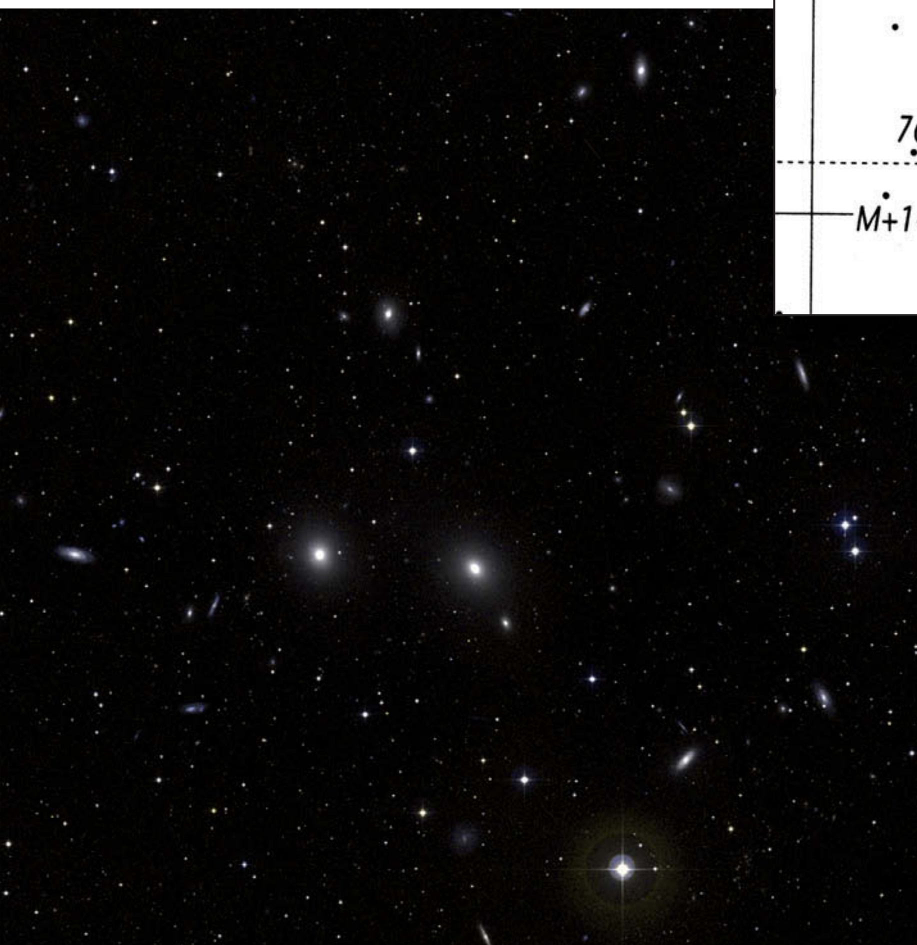
Aside from atmospherics, the best magnification depends on the object's type, size, and brightness. I consider 50× ideal for the sprawling Double Cluster (NGC 869 and 884) in Perseus, but definitely not for the smallish Eskimo Nebula (NGC 2392) in Gemini, shown on the first two pages. I need about 100× to confirm I've snared a fuzzy dot there and not just a star, while something like 200× is required to expose the features of the Eskimo's "face." On the other hand, that kind of power would spread the light of the big Triangulum Galaxy (M33) to near-invisibility. Then again, it might pick up the tenuous spiral structure of the compact Whirlpool Galaxy (M51) in Canes Venatici, or partly resolve a dense globular cluster. Experiment.

Dimmer and Dimmer

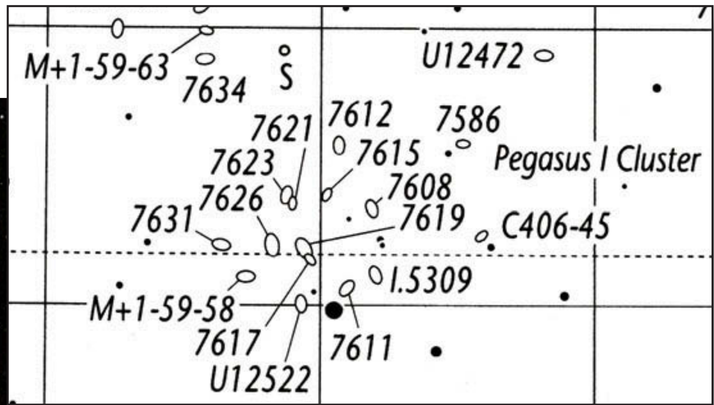
I admit I suffer from rapture of the deep. Every night out I try to make the best use of whatever sky conditions I face. I've gotten better at this in recent years. I have more experience, yes, but also better accessories. Certain eyepieces and filters allow me to push the envelope in a way not possible when I started astronomy four decades ago.

The word is out on eyepieces, and the word is "wide." Today's wide-fields sport 65° to 80° apparent fields, while the so-called ultra-wides boast a whopping 100° or even more. Depending on the scope, a low-power ultra-wide will surround even a huge cluster such as the Pleiades with the "moat" of dark framing necessary to make it stand out from the background as a coherent entity. For concentrated clusters such as M15, wide or ultra-wide eyepieces will show dark sky around the object even at high powers. And make no mistake: high power (within the limits of the sky conditions) is always desirable even for the faintest objects, because it improves resolution and reveals detail not apparent at lower values. Those extra ×s (even beyond 200× on my 10-inch) might pick up that teensy, elusive object — a remote galaxy, say — at the threshold of my vision.

A wide field of view provides another benefit. You might think that having the extra skylight and starlight in



DIGITIZED SKY SURVEY / COLOR COMPOSITING BY SEAN WALKER



URANOMETRIA 2000.0

South of the Great Square of Pegasus lies the Pegasus I galaxy cluster, still high in the west at nightfall in early winter. At a distance of 170 million light-years, it's farther than many observers often see. On the wide-field photo at far left and the *Sky Atlas 2000.0* section at next left, small orange squares mark the area covered by the Digitized Sky Survey image at near left, which is ⅔° wide. The first landmark to find in the cluster's field is the 7th-magnitude star that dominates it. Northeast of the star, locate the cluster's two brightest galaxies: the 11th-magnitude giant ellipticals NGC 7619 and 7626. They're lined up east-west 0.1° apart. The small blowup from *Uranometria 2000.0* above identifies fainter cluster members to seek. This is the sort of planning to walk through indoors as you prepare for a dark night.

an extra-wide view — instead of the blackness of an eyepiece barrel surrounding the view — would make faint things a little harder to see. But many observers find just the opposite. A black eyepiece barrel enhances the *subjective* brightness of the sky background that it encircles, due to the contrast, and this subjective sky brightening actually makes faint things harder to see in a narrow view.

Filters are another key part of my arsenal. A basic light-pollution (LP) filter offers only very modest contrast enhancement of deep-sky objects — and less so from year to year as white, broad-spectrum lights replace orange sodium-vapor lights. Much more effective for emission and planetary nebulae are narrow-band "nebula" filters. These allow only the light at specific emission-nebula wavelengths to get through. I use an Ultra-High-Contrast (UHC) narrowband filter. A UHC on the Swan (M17) in Sagittarius or the Dumbbell (M27) in Vulpecula morphs these structurally interesting objects into absolute wonders. A doubly-ionized oxygen (O III) narrowband filter isolates starlike planetaries in their rich Milky Way fields by greatly diminishing the surrounding stars. An O III also magically "lifts" ghostly planetaries, such as the Helix (NGC 7293) in Aquarius and the Owl (M97) in Ursa Major, out of a light-polluted sky. The wispy Veil Nebula in Cygnus is an unforgettable sight viewed in "Oh-3."

All this intensive ogling requires being comfortably seated at the telescope, or at least comfortably standing. Any physical stress or discomfort cuts into your visual abilities. Bring a chair or stool to avoid any straining.

I cup my hands around the eyepiece to block stray light, and I observe with my right eye while keeping my left eye closed. Try each eye. You may discover that one is slightly more sensitive in the deep dark — though if it is, it's also likely to be "noisier": producing subtle, illusory patterns and mottlings that crawl in the blackness.

For the really faint stuff I drape a dark cloth or towel over my head, or I wear a "hoodie." I try to concentrate on my target for several minutes, then rest a bit. Some observers find that breathing deeply hyper-oxygenates the eye, allowing it to register precious extra photons. I'm not sure I notice the effect, but I become more relaxed when I breathe strongly and rhythmically.

I'm always applying averted vision — looking slightly away from the object — to tease out tiny features both bright and dark: the luminous swirls of the Lagoon Nebula (M8) in Sagittarius, or the dust lanes skirting the Andromeda Galaxy (M31). Averted vision greatly expands the teensy aqua envelope of my favorite planetary, the Cat's Eye Nebula (NGC 6543) in Draco. NGC 6826 in Cygnus is another bright planetary that delights me by "blinking" on when I avert my vision. The opposite approach, gazing directly at an object, can have its place too. Staring down the nebulous disks of NGC 6543 and 6826 (and similar specimens) dims them but sharpens the eye's resolution to unveil their embedded central stars.

USING SKY CHARTS

To find your way with a deep-sky chart — whether in your finderscope or main telescope — you need to know three things: the chart's *scale* compared to your view, so you know how big a scene you're looking at; *which way is north* in your view, so you can turn the chart around to match; and whether your instrument shows you a *correct image or a mirror image.* To become a sky-navigating master, see **skypub.com/charts**.

KEN HEWITT-WHITE

The author's most basic setup: the 10-inch f/5.5 Dobsonian reflector, a stool, and a mini-table for charts and books.

Think Dark

All these techniques are wasted unless I get dark-adapted and stay that way. Strict dim-red-light protocol is essential in this business. I've seen folks at star parties brandishing observer lights that are red, yes, but way too bright. That harms their dark adaptation and mine too. Around the scope, I try not to use any light. When I study my star atlas I put on reading glasses and, with magnifier in one hand and red penlight in the other, focus on just the portion of the chart I require. Some observers wear an eyepatch for up to an hour before observing to dark-adapt one eye, and then keep that eye closed when reading charts.

My tactics pay even bigger dividends when I'm working with my 17.5-inch light bucket under a wilderness sky. But no matter where you observe, or what scope you have, remember this: patient planning, coupled with savvy scoping, is the best way to ensure a joyful exploration of the cosmos. Get out there, stay dark, and go deep! ✦

S&T *contributing editor* ***Ken Hewitt-White*** *has been exploring the deep sky for four decades from the hills of southern British Columbia. He has written many astronomy articles and scripts for planetariums, magazines, and television, but his greatest enjoyment remains working with his telescopes on clear nights.*

In This Section

The relatively nearby star cluster Messier 35 at upper left makes a celestial odd couple with distant, rich NGC 2158 (see page 47).

PHOTOGRAPH: NIGEL SHARP / NOAO / AURA / NSF

Sky at a Glance

FEBRUARY 2013

Jan. 29 – Feb. 10 **EARLY EVENING:** The zodiacal light shows very well from dark locations at mid-northern latitudes. Look west starting about 80 minutes after sunset for a left-sloping pyramid of light.

3 **PREDAWN AND DAWN:** Saturn is above or upper right of the last-quarter Moon (for North America). See page 48.

7 **DUSK:** Mars is ⅔° upper left of much brighter Mercury low in the west-southwest a half hour after sunset, a stunning binocular pair.

8 **DUSK:** Mars is just ⅓° lower left of Mercury in bright twilight, a fine pair through a telescope.

10 **DUSK:** Binoculars may show an extremely thin crescent Moon well to the lower right of Mercury and Mars shortly after sunset.

11 **DUSK:** Mercury shines lower left of the Moon.

12–20 **DUSK:** Mercury has an excellent evening apparition, at least 10° above the west-southwest horizon a half hour after sunset.

17, 18 **EVENING:** The Moon appears right of Jupiter on the 17th and left of Jupiter on the 18th. They form attractive triangles with nearby Aldebaran.

Feb. 27 – Mar. 12 **EARLY EVENING:** The zodiacal light is again on display as described at the top of this section.

28 **LATE EVENING AND NIGHT:** Spica is very close to the Moon as seen from North America. The Moon occults (hides) Spica for viewers from eastern Mexico to central South America; see www.lunar-occultations.com/iota.

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

	◄SUNSET	MIDNIGHT	SUNRISE►
Mercury	W	Visible February 2 through 24	
Venus		Visible through February 8	SE
Mars	W	Visible through February 13	
Jupiter	S	NW	
Saturn		E	S SW

Moon Phases

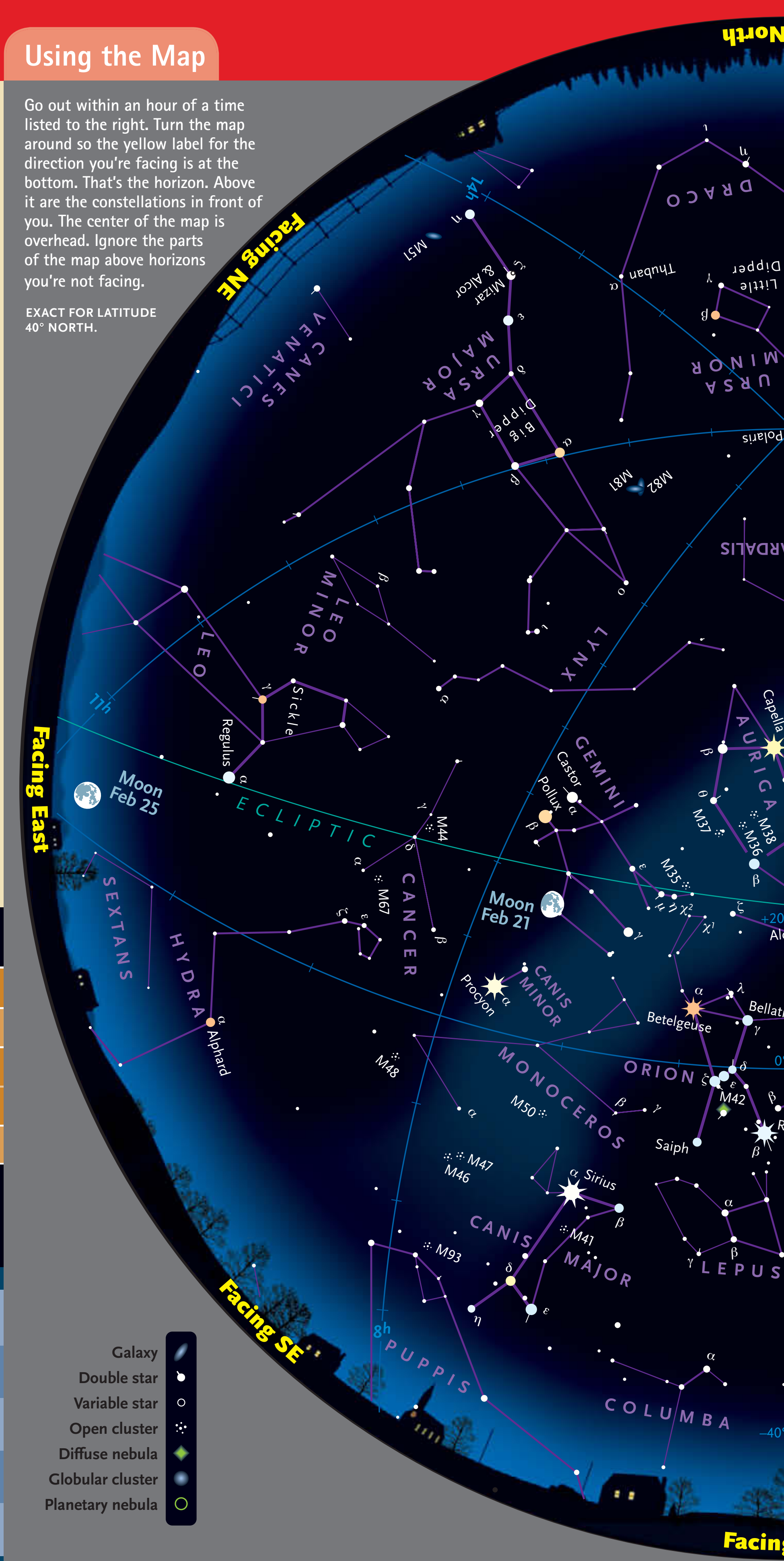
Last Qtr Feb. 3 8:56 a.m. EST
New Feb. 10 2:20 a.m. EST
First Qtr Feb. 17 3:31 p.m. EST
Full Feb. 25 3:26 p.m. EST

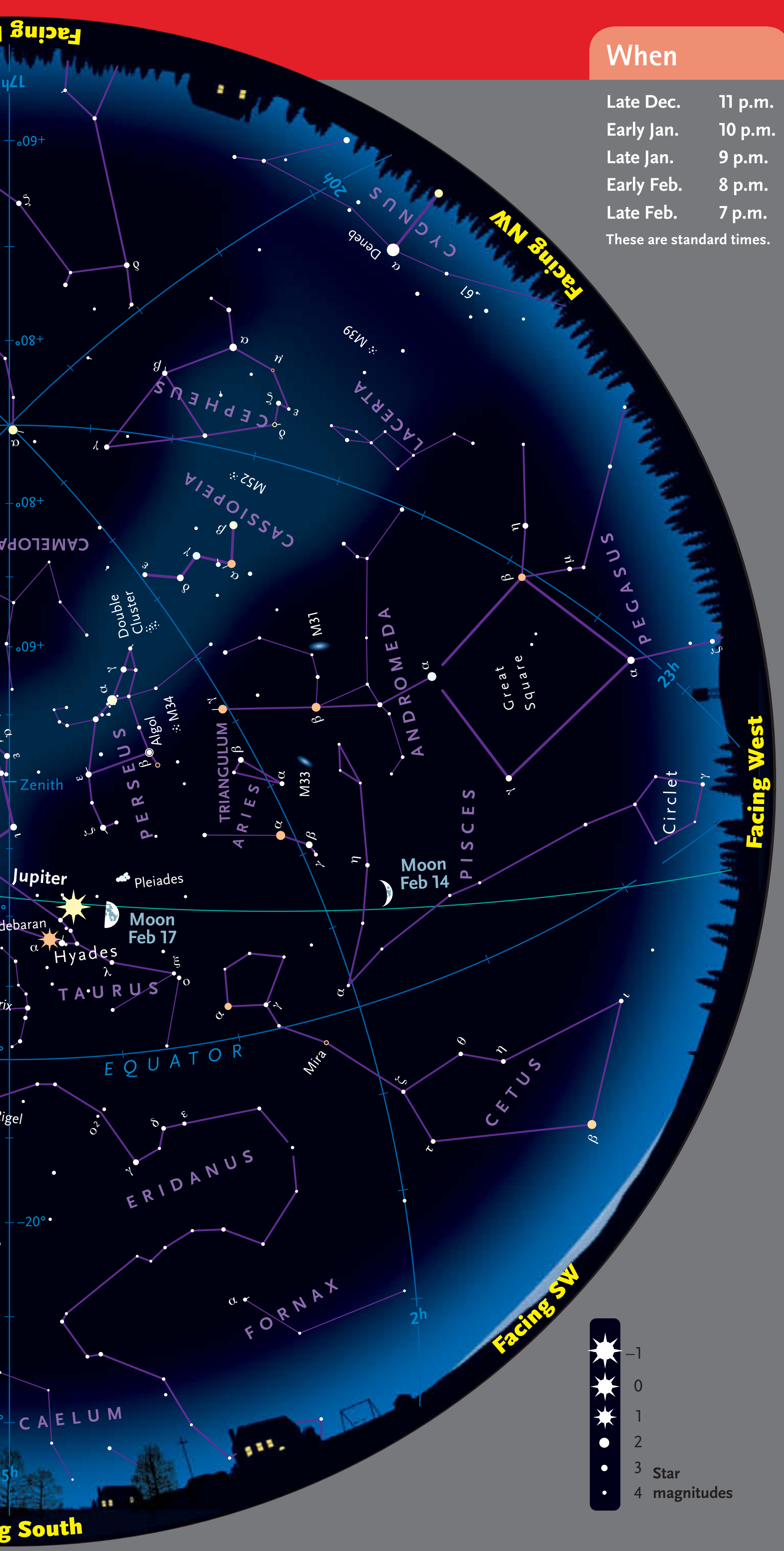
SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28		

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 Dec.	11 p.m.
Early Jan.	10 p.m.
Late Jan.	9 p.m.
Early Feb.	8 p.m.
Late Feb.	7 p.m.

These are standard times.

Gary Seronik

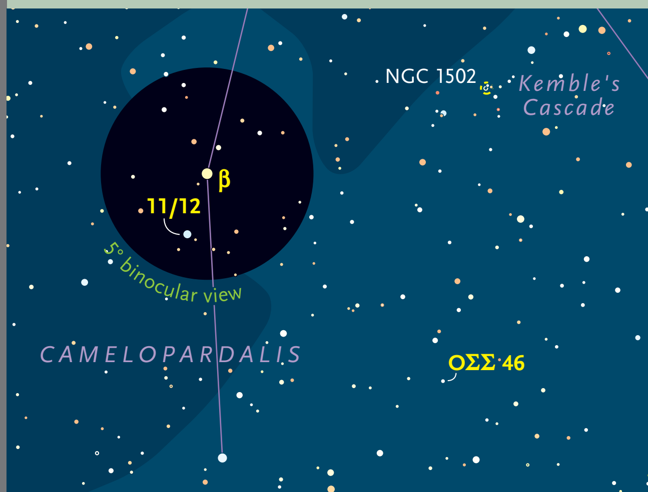
The Giraffe's Doubles

It's hard not to feel just a little bit sorry for Camelopardalis, the celestial giraffe. For binocular observers, the constellation is mostly a barren gap between the Big Dipper and the riches of Cassiopeia and Perseus. Camelopardalis has no star brighter than 4th magnitude, boasts no Messier objects, and has a ragged string of stars (Kemble's Cascade) as its most notable deep-sky target. But if you like binocular doubles, you're in luck — the Giraffe has several enjoyable pairs.

Let's begin with the constellation's brightest star, 4.0-magnitude Beta (β) Camelopardalis. Almost lost in Beta's glare is its 7.4-magnitude companion, a tiny spark 83″ away. Normally that's enough separation for an easy split even with steadily held 7× binos, but because of the 3½-magnitude difference between component suns, Beta is a challenge in 10×50s.

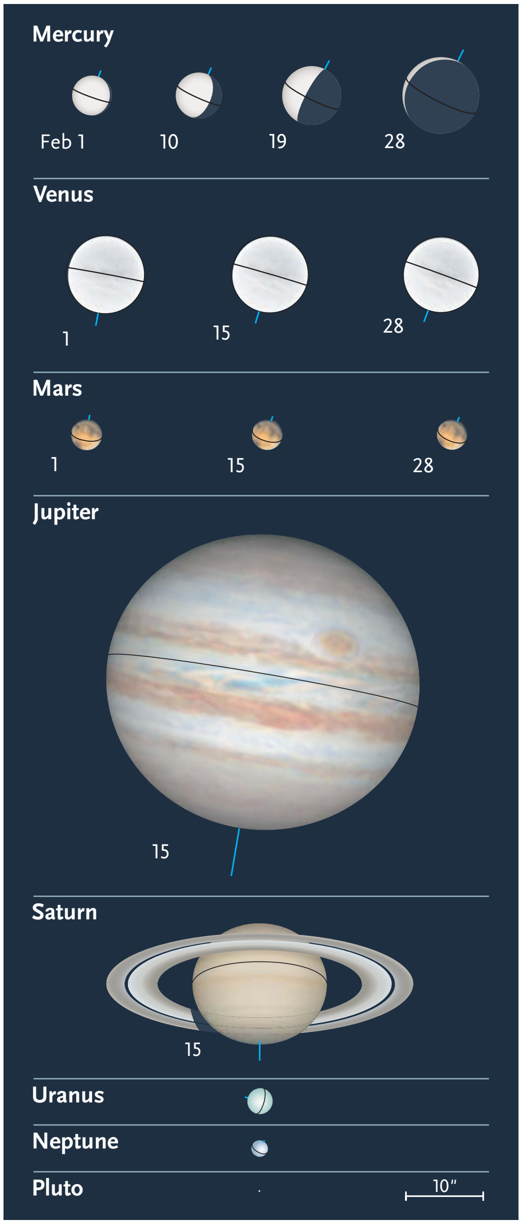
If Beta defeats your efforts, you don't have to go far for an easier double. Shift your gaze 1½° south-southeast for the pairing of 11 and 12 Camelopardalis. The stars are of similar brightness and easy to separate, thanks to a generous 179″ gap. But look closely — do you see a subtle color difference? To my eyes, the 5.2-magnitude southern star (12 Cam) is bluish-white, while its 6.2-magnitude companion is a warm-hued yellow. Is that how they appear to you?

Our final double goes by the designation ΟΣΣ 46 (also cataloged as STTA 46 AB). The component stars are very close in brightness, shining at magnitudes 7.7 and 8.0, and separated by a substantial 99.7″. In image-stabilized 10×30s, they make for an easy, if unspectacular, pairing. The extra light grasp and magnification of my 15×45 image-stabilized binos improves the view, but even with these optics ΟΣΣ 46 isn't a exactly a showpiece. Still, when the pickings are this slim, you take what you can get. ✦



Watch a SPECIAL VIDEO

To watch a video tutorial on how to use the big sky map on the left, hosted by *S&T* senior editor Alan MacRobert, visit SkyandTelescope.com/maptutorial.

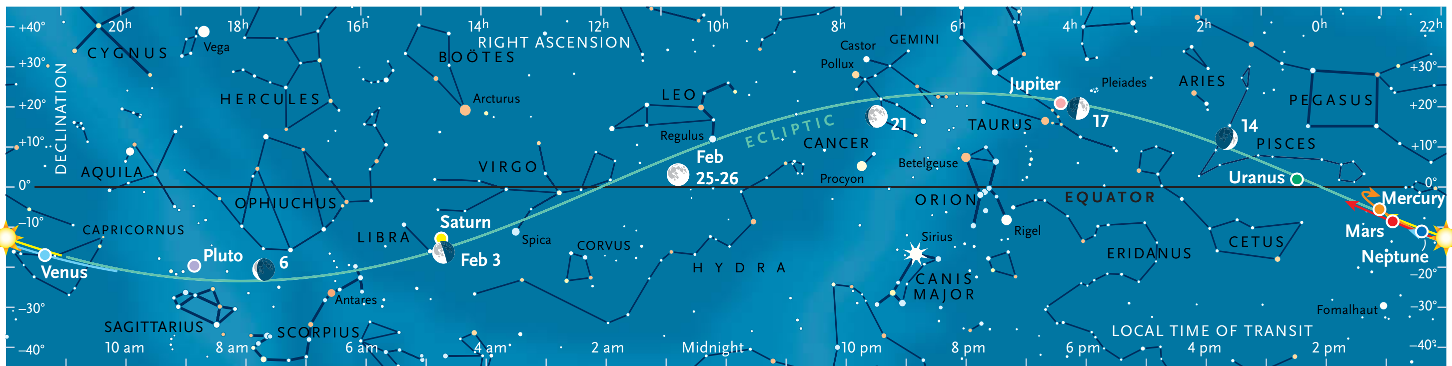


Sun and Planets, February 2013

	February	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	20^h 58.3^m	–17° 10′	—	–26.8	32′ 28″	—	0.985
	28	22^h 43.8^m	–8° 03′	—	–26.8	32′ 18″	—	0.991
Mercury	1	21^h 38.7^m	–15° 53′	10° Ev	–1.1	5.2″	95%	1.301
	10	22^h 36.0^m	–9° 22′	16° Ev	–1.0	6.0″	77%	1.126
	19	23^h 13.7^m	–3° 13′	18° Ev	–0.3	7.6″	40%	0.882
	28	23^h 10.4^m	–1° 30′	9° Ev	+3.1	9.9″	6%	0.677
Venus	1	20^h 02.6^m	–21° 03′	14° Mo	–3.9	10.1″	97%	1.646
	10	20^h 49.6^m	–18° 41′	12° Mo	–3.9	10.0″	98%	1.667
	19	21^h 34.9^m	–15° 36′	9° Mo	–3.9	9.9″	99%	1.685
	28	22^h 18.7^m	–11° 56′	7° Mo	–3.9	9.8″	99%	1.700
Mars	1	22^h 05.9^m	–12° 48′	17° Ev	+1.2	4.1″	99%	2.295
	15	22^h 47.7^m	–8° 42′	14° Ev	+1.2	4.0″	99%	2.324
	28	23^h 25.5^m	–4° 39′	11° Ev	+1.2	4.0″	100%	2.350
Jupiter	1	4^h 17.5^m	+20° 45′	114° Ev	–2.5	42.9″	99%	4.592
	28	4^h 23.1^m	+21° 04′	88° Ev	–2.3	39.3″	99%	5.018
Saturn	1	14^h 37.7^m	–12° 49′	91° Mo	+0.5	17.1″	100%	9.733
	28	14^h 38.6^m	–12° 46′	118° Mo	+0.4	17.9″	100%	9.302
Uranus	15	0^h 23.3^m	+1° 47′	40° Ev	+5.9	3.4″	100%	20.804
Neptune	15	22^h 18.4^m	–11° 11′	6° Ev	+8.0	2.2″	100%	30.971
Pluto	15	18^h 45.0^m	–19° 44′	46° Mo	+14.1	0.1″	100%	33.067

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-February; 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 *has authored 13 books on astronomy.*

Fred Schaaf

Odd Couples

The late winter sky is full of strange pairings.

More famous than any real-life human twins in history are a pair of mythological twin brothers: Castor and Pollux. These names have also been applied to two similarly bright stars that mark the heads of the brothers as they're portrayed in the constellation Gemini. And at the time of our all-sky map, those two stars lie very high in the sky, almost overhead for viewers at mid-northern latitudes.

Sometimes, however, we would rather see a duo that's the opposite of identical: two objects close to each other whose appearance or real nature is startlingly different. February evenings are an excellent time to observe a number of these celestial "odd couples."

Odd couples of Ursa Major. The most beautiful galaxy pair in the telescopic heavens is also strangely mismatched. I'm talking about Messier 81 and 82, which are already pretty high in the northeast at the time of our map. At magnitudes 6.9 and 8.4, respectively, they can be seen easily with binoculars in a dark sky. But telescopes and astrophotos show M81 as a magnificent orderly spiral of great size (26′ × 14′) and dimmer M82 as an oddly distorted phosphorescent cigar that's smaller (11′ × 5′) but much spookier than its handsome neighbor. M81 and M82 are separated by only 38′, and M82's strange shape is probably due to a close encounter with M81 millions of years ago. Few sights in the heavens will make you feel as much like you're floating out there in space with the objects that you're viewing as this pair does.

Another famous Ursa Major odd couple lies just outside the bottom of the Big Dipper's bowl. M97, the 10th-magnitude Owl Nebula, is a planetary nebula only 2.4° southeast of the Pointer star Merak. Just 48′ from the Owl in the direction of Merak is an object of similar brightness but very different appearance and physical reality: the galaxy M108, many thousand times bigger and more distant than M97.

Odd cluster couples. M35 is a famous open star cluster near the northwestern feet of Gemini, the Twins. Considering its convenient location and 5.1-magnitude brightness, you should be able to see this giant cluster with your unaided eyes if you have reasonably dark skies. M35 is best seen at rather low telescopic magnifications, but at much higher magnifications a special treasure comes into view on its fringe: the tiny (5′) 8.6-magnitude open cluster NGC 2158. NGC 2158 is about six times farther than M35, so the true sizes of the clusters are actually similar.

A different kind of cluster odd couple is M46 and M47 in Puppis, which are discussed in detail on page 56. They're about 15° east of Sirius and only 1½° apart. Both are beautiful open clusters roughly ½° across. But they're remarkably different. M47 is somewhat messy and has stars that range from magnitude 5 to 9; M46 is well-organized with more numerous but much dimmer stars (magnitude 10 to 13). M47 has a total magnitude of 4.4, M46 of 6.1. But M46 also forms a second odd couple with an object that appears just north of its center: the 11th-magnitude, 1′-wide planetary nebula NGC 2438.

A non-odd non-couple. Here's a riddle. A woman gave birth to two children in the same year, day, and hour, but they weren't twins. How was it possible? Answer: she gave birth to triplets. Many people think Beta Monocerotis is the finest triple star in the heavens. Its three components, all of spectral class *B*3e, shine at 4.7, 5.3, and 6.1. The second and third stars are 7″ and 10″ from the brightest star, respectively, and 3″ from each other. ✦

JOHANNES SCHEDLER

North is to the right in this image of Messier 81 (left) and 82. M82 appears to be exploding — due to numerous recent supernovae in its central region. This galaxy has suffered massive disruption from a close gravitational encounter with M81.

Mercury Meets Mars

The two smallest planets have a close encounter in the February twilight.

For much of February, Mercury lingers low in the west-southwest after sunset, helping guide us to much dimmer Mars. Mercury and Mars are spectacularly paired on February 7th and 8th.

Jupiter reigns high in the south at dusk, not setting until after midnight. Saturn rises before Jupiter sets and is highest in the south before dawn. Venus can be glimpsed very low at dawn in early February but soon disappears into the Sun's glare.

DUSK

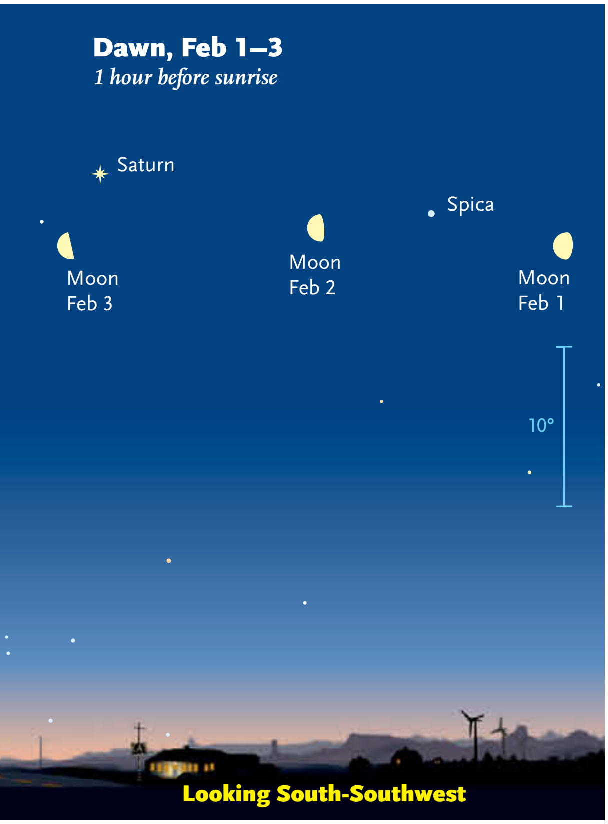
Mercury has a fine apparition low in the west-southwest for skywatchers at mid-northern latitudes. During the first part of February it comes into view higher in the fading dusk each evening, reaching its greatest elongation (18° from the Sun) on the American evening of February 16th. At that time the speedy little planet shines at magnitude –0.6, and telescopes show its tiny, 7″ disk exactly half lit — which isn't always the case at Mercury's greatest elongations. In the following week Mercury fades by a factor of four and soon sinks out of view.

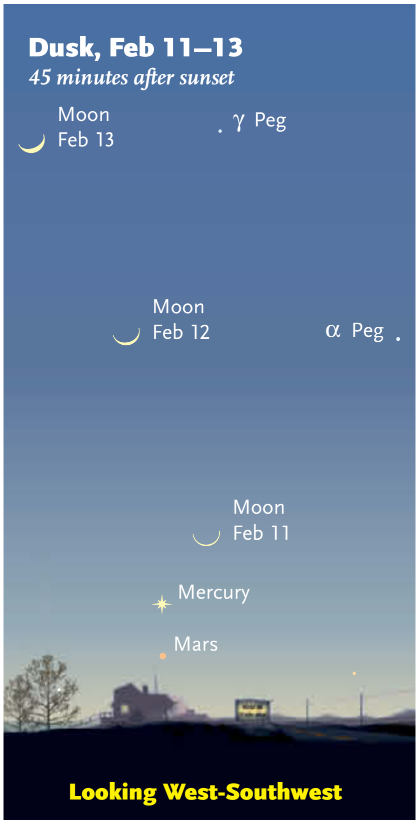
Mars is dim and very low at dusk, but during the first half of February it can be found (preferably with binoculars) using Mercury as a guide. Mercury shines around magnitude –1.0 during this period, while Mars is much fainter at +1.2.

Mars starts the month 6° upper left of Mercury but appears lower each evening and soon passes the brighter planet. Mars is ⅔° upper left of Mercury on February 7th and just ⅓° lower left of Mercury on the 8th — close enough that both easily fit in a 100× telescopic field of view. If the atmosphere allows a steady enough view with the planets so low, it will be interesting to compare Mars's 4″ round disk with Mercury's 6″-tall gibbous shape.

Dim **Uranus**, magnitude 5.9, can still be viewed through a telescope as the sky grows dark, but it's very low in the west by the end of February.

Neptune is even lower. It glows feebly at magnitude 8.0 just ½° northwest of Mercury on February 6th, but Neptune will probably be too low to spot through a telescope in the bright twilight. Neptune is certainly invisible after that, reaching conjunction with the Sun on February 21st.





EVENING AND NIGHT

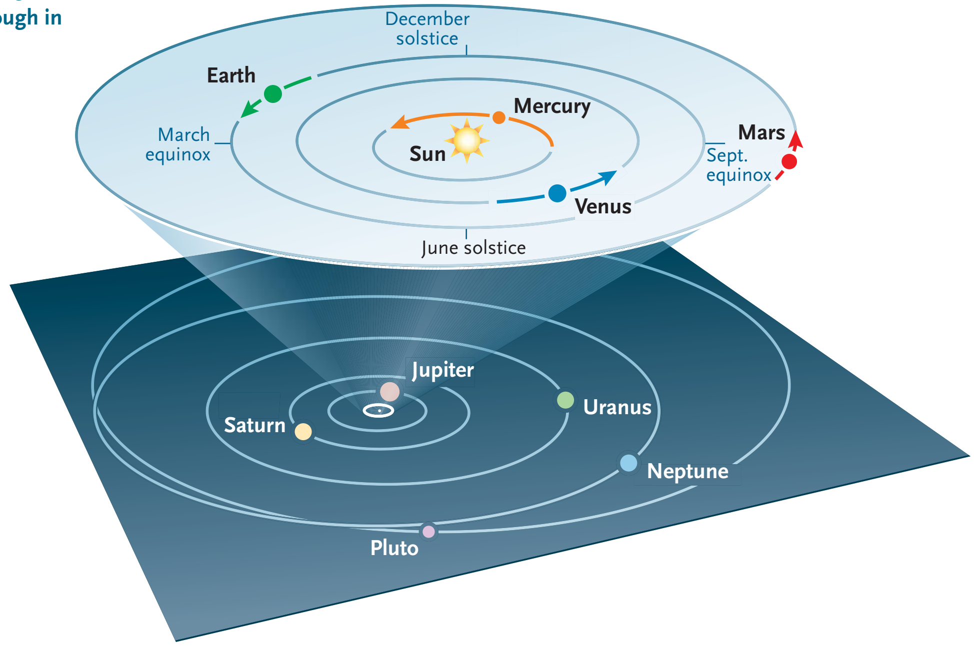
Jupiter shines very high in the south during evening twilight for observers at mid-northern latitudes. Jupiter resumed direct (eastward) motion through the stars on January 30th and moves slowly away from the Pleiades and toward Aldebaran and Epsilon Tauri throughout February. It forms a straight line with these two stars on February 27th.

Jupiter fades slightly during February, from magnitude –2.5 to –2.3, and its disk dwindles from 43″ to 39″ wide. It reaches quadrature (90° east of the Sun) on February 25th, so this is a month when the

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

ORBITS OF THE PLANETS

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



sideward-thrown shadows of Jupiter and its moons make the eclipses and shadow transits of the Galilean satellites especially interesting (see page 53).

Jupiter sets after 2:30 a.m. at the start of February but around 1 a.m. at month's end.

MIDNIGHT TO DAWN

Saturn takes over the stage from Jupiter in the small hours of the morning, rising about 2 hours before Jupiter sets. Saturn brightens a trace from magnitude +0.5 to +0.4 this month as it hovers about 18° east of Spica and 4½° northwest of the wide double star Alpha Librae (Zubenelgenubi).

Saturn's rings are tilted a wide 19.3° from edge-on, their maximum for the year. The planet is at western quadrature on January 30th, so February is a good month to look for the shadow of the planet's globe on the rings. Unfortunately for viewers at mid-northern latitudes, Saturn is now well south of the celestial equator, so it rises less than halfway up the sky even when it's highest, shortly before the sky begins to brighten.

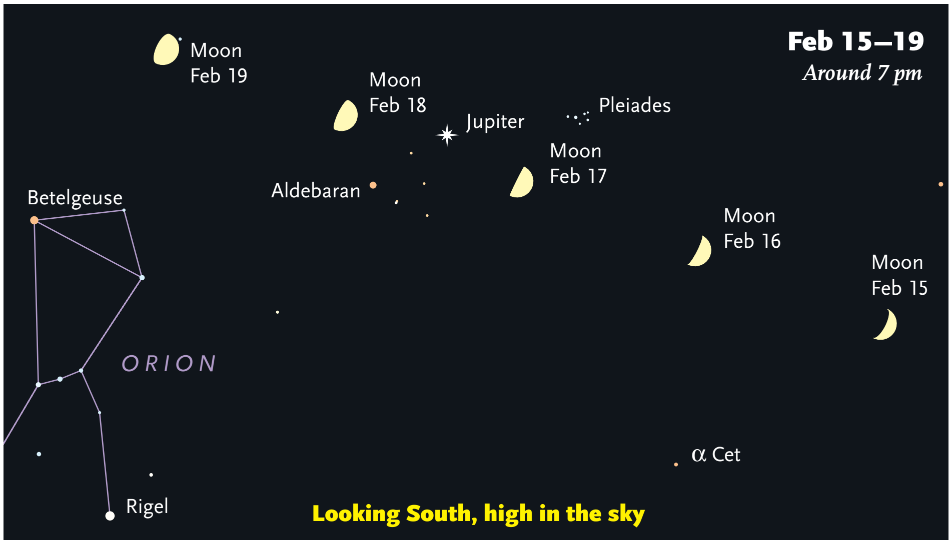
DAWN

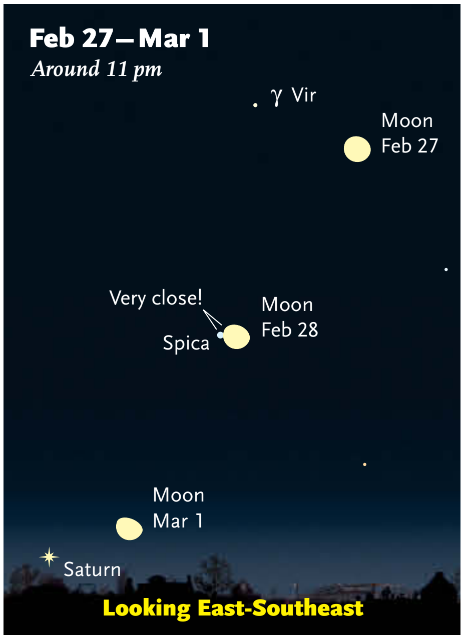
Venus can be glimpsed shortly before sunrise in early February, very low in the east-southeast. But it soon disappears into the Sun's glare on its way to conjunction on March 28th.

MOON PASSAGES

The **Moon** is at last quarter when it glows lower left of Saturn at dawn on February 3rd. About 30 minutes after sunset on February 10th, an extremely thin lunar crescent hangs well to the lower right of tightly paired Mercury and Mars. The next night, the Moon is closer to their upper right.

The waxing gibbous Moon shines well to either side of Jupiter on February 17th and 18th as seen from the Americas. On the evening of February 28th, the waning gibbous Moon passes extremely close to Spica for North American viewers and occults the star from parts of Mexico, Central America, and South America (see **www.lunar-occultations.com/iota**). ✦





Comet PanSTARRS: Early Alert

Get ready for the first of the two bright comets expected in 2013.

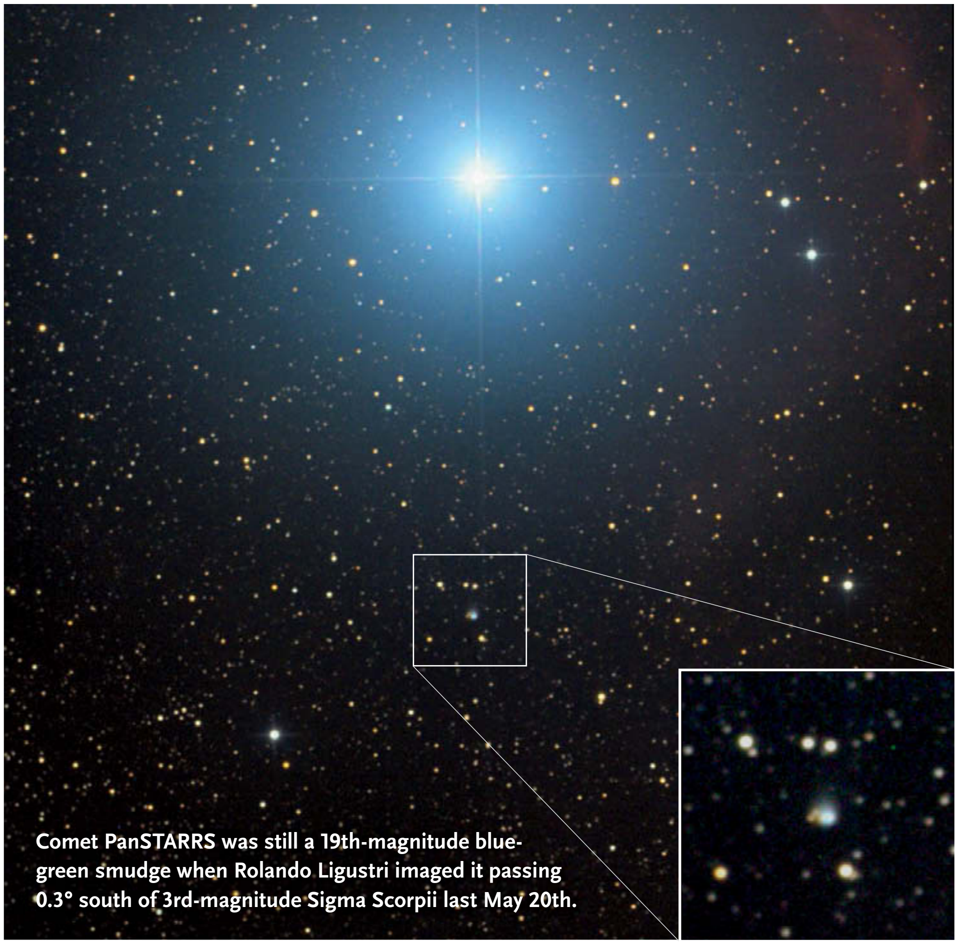
The great comet of the coming year is likely to be Comet ISON (C/2012 S1), which may turn into a long-tailed, naked-eye spectacle in December 2013; see last month's issue, page 57. But ranking not far behind, by current predictions, will be Comet PanSTARRS (C/2011 L4) coming in March. It's on course to glow at magnitude zero or brighter low in the western evening twilight around the middle of March for viewers at mid-northern latitudes.

Discovered in June 2011 by the automated PanSTARRS sky-survey project in Hawaii, the comet will swing fairly close by the Sun (0.30 a.u.) on March 10th. It's likely to grow a large, bright tail by that time. It's nearest to Earth just five days earlier, though at a moderately distant 1.10 a.u. Its best showing for mid-northern skywatchers should be from about March 8–22, especially the week of March 12–18. But it will be quite low in the dusk, only about 16° from the Sun then.

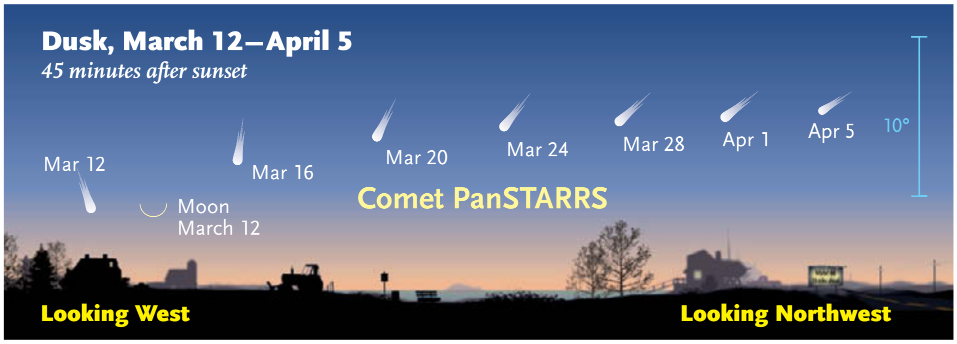
And that's assuming it doesn't fizzle out. Comet PanSTARRS is on a slightly hyperbolic orbit, which means it seems to be a fresh body newly arriving from the distant Oort Cloud. Comets that have never before been warmed by the Sun have a way of brightening early, suggesting great things to come, and then dwindling after a virgin coating of especially volatile material bakes off the nucleus.

PanSTARRS was about magnitude 19.5 when discovered. In mid-October it was brightening on schedule at magnitude 10, though still a cold 2.8 a.u. from the Sun. During January and February it's predicted to brighten from magnitude 8 to 4. But during that time it remains south of the Sun, crossing the tail of Scorpius, Telescopium, Indus, and Grus. Not until the start of March does it pop up our way.

We'll have more to report next month.



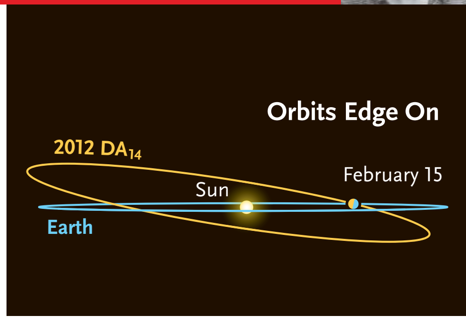
Comet PanSTARRS was still a 19th-magnitude blue-green smudge when Rolando Ligustri imaged it passing 0.3° south of 3rd-magnitude Sigma Scorpii last May 20th.

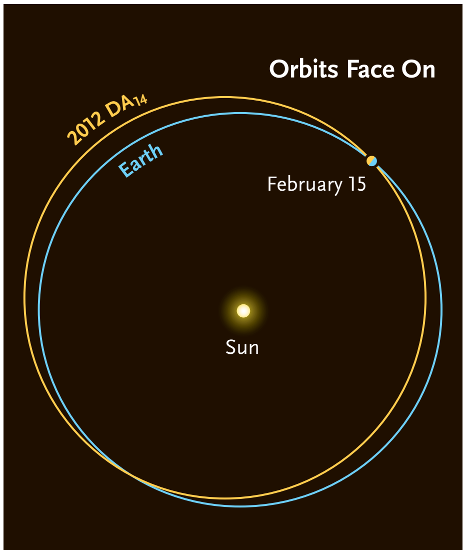


For observers near 40° north latitude, Comet PanSTARRS may be a naked-eye object when it emerges from the glare of sunset in early March. It will fade in the following weeks as it moves northward, still low. The tails of the comet symbols here point away from the Sun. The actual tail will probably be longer and curved — or perhaps barely visible at all.

Alan MacRobert

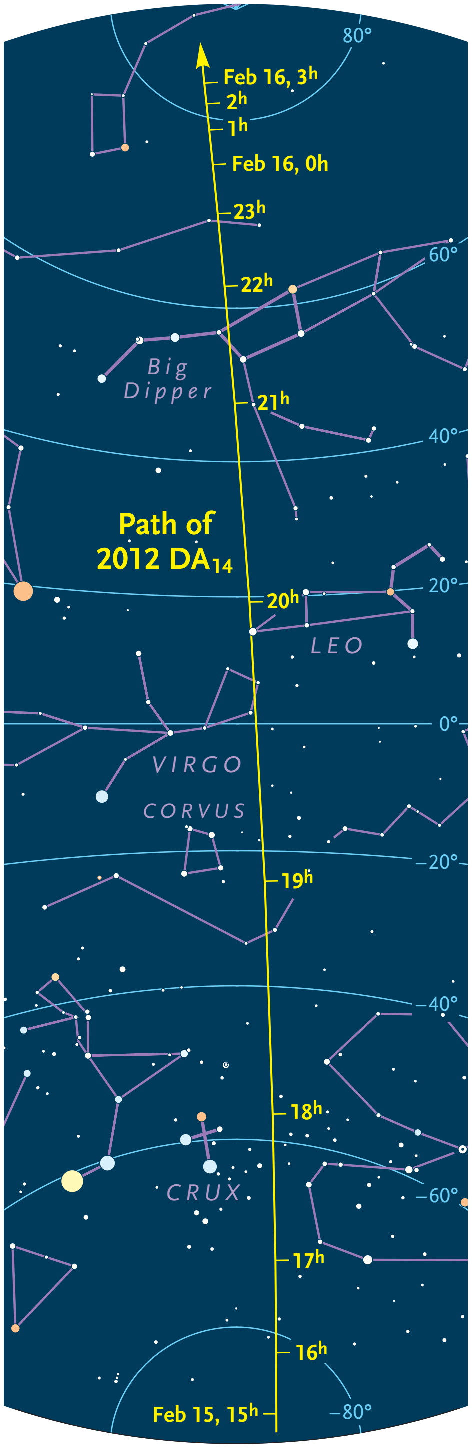
A Record-Close Asteroid Zips By





The asteroid 2012 DA_{14} is currently in an orbit similar to Earth's. The orbits are shown face on and nearly edge on.

S&T: LEAH TISCIONE



The little asteroid 2012 DA_{14} will move south to north across nearly half the celestial sphere in just a few hours, passing the Southern Cross, Corvus, the head of Virgo, the tail of Leo, and the Big Dipper until dwindling away near Polaris.

Expect a small asteroid to make big news on February 15th. The gymnasium-sized 2012 DA_{14}, 40 or 50 meters (130 to 160 feet) across, will make the closest Earth flyby of a natural object ever predicted far in advance. It will pass within 28,500 km (18,000 miles) of Earth's surface around 19:25 UT February 15th, reaching 8th magnitude as it whizzes north across the stars at a rate of 0.8° per *minute*.

But not for our part of the world. At that time it will be near the head of Virgo, which will be up in a dark sky for longitudes from easternmost Europe (in late evening) across Asia to Australia (before dawn).

In North America, darkness won't fall on the East Coast until about 0^h February 16th UT (7 p.m. February 15th Eastern Standard Time), by which time the asteroid will be down to magnitude 11.1 and moving much more slowly near the Little Dipper. By nightfall on the West Coast three hours later, it will have faded to 12.4.

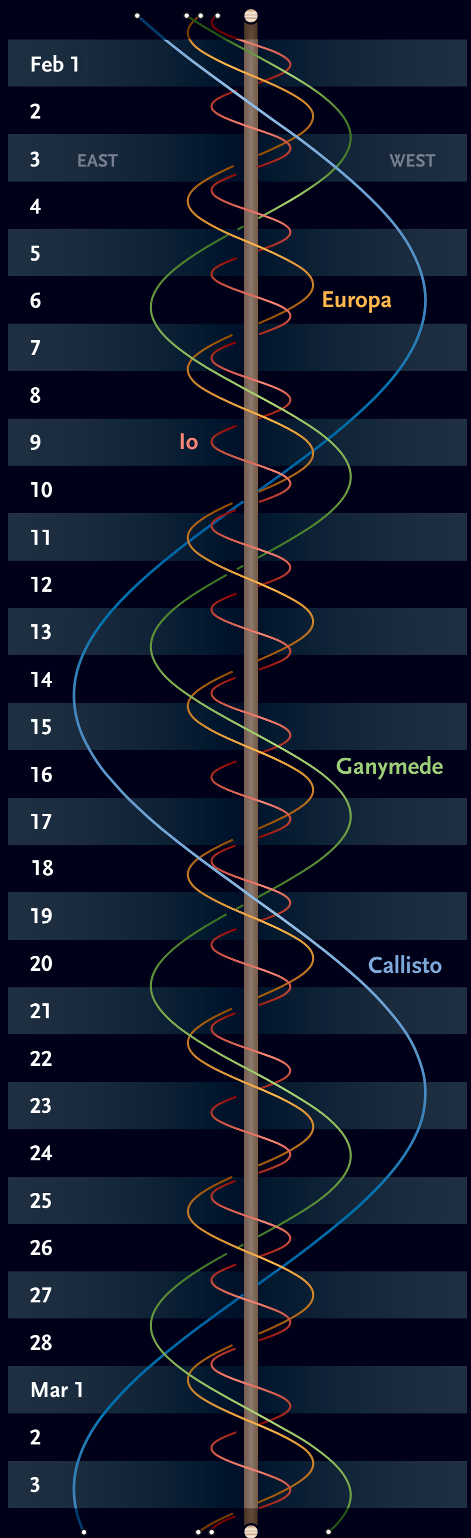
The constellation chart at left shows the asteroid's race from practically the south to north celestial poles in just 12 hours.

Locating 2012 DA_{14} in a telescope (or big binoculars!) will not be simple. It will be so close that your location on Earth will greatly affect its apparent path across the stars, due to topocentric parallax. There's one way to go about this. Go to the precise JPL Horizons ephemeris utility at **ssd.jpl.nasa.gov/horizons.cgi**. For Target Body enter 2012 DA14, for Observer Location enter your latitude and longitude, and for Time Span enter your planned observing period in UT and a time interval of perhaps 1 minute. In Table Settings include Astrometric RA and Dec., as well as Visual Mag. Click Use Selected Settings, then Generate Ephemeris. You'll get a custom list of minute-by-minute positions.

Then, using a detailed sky-charting program, print out a star chart to an appropriately deep magnitude centered on one of the equinox-2000.0 RA and Dec points you got. Be looking there with your scope at the correct minute.

The last time I watched an asteroid pass close enough to show real-time motion in my 12-inch scope, I had the eerie feeling that we were dodging a bullet — rather different from the usual all-is-peaceful observing experience. Astronomers estimate that if 2012 DA_{14} hit our atmosphere it would release 2.4 megatons of energy, comparable to the 1908 Tunguska event, which has been estimated at 3 to 20 megatons. Not a world-killer, and possibly harmless over an empty ocean, but you wouldn't want to be nearby.

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.

Action at Jupiter

In February Jupiter shrinks from 43 to 39 arcseconds across at its equator. And be sure to set your scope up early in the evening now; Jupiter is high in its best observing position right after dusk.

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually reveal at least two or three. Identify them with the diagram at left. Listed in the table on the facing page are all of the moons' many interactions with Jupiter's disk and shadow during February, fascinating events to watch.

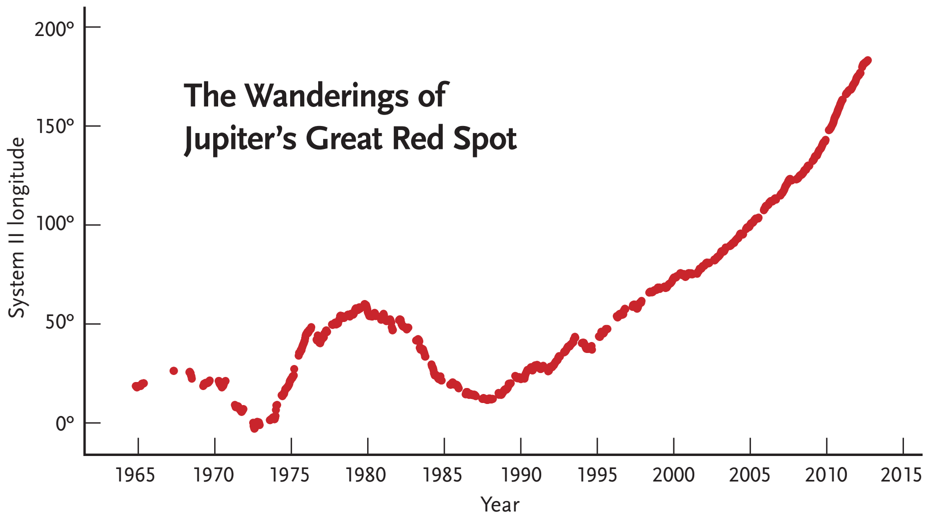
Jupiter's Great Red Spot is the planet's most famous feature but can be hard to see in small and medium-size scopes. It's currently pale orange-tan, not exactly high contrast against its surroundings, and the spot has been slowly shrinking for decades. It gained its name and fame during a time in the late 19th century when it was longer, judging by drawings at the time, and strikingly brick red.

Like other Jovian features, The Great Red Spot drifts eastward and westward in the planet's winds. Amateurs have tracked its motions for many decades — first by timing its central-meridian crossings visually, and nowadays more accurately (and at more flexible times) by measuring images.

The graph below shows the spot's movements from 1964 to 2012 with respect to Jupiter's System II longitude. Defining longitude on a gas planet is somewhat arbitrary; system II is defined as having a rotation period of 9 hours, 55 minutes, 40.63076 seconds, more or less the long-term average for cloud features in Jupiter's mid-latitudes.

Following are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. The Red Spot appears closer to the central meridian than to the limb for 50 minutes before and after these times:

January 1, 0:29, 10:25, 20:20; **2**, 6:16, 16:11; **3**, 2:07, 12:03, 21:58; **4**, 7:54, 17:50; **5**, 3:45, 13:41, 23:37; **6**, 9:32, 19:28; **7**, 5:24, 15:19; **8**, 1:15, 11:11, 21:06; **9**, 7:02, 16:58; **10**, 2:53, 12:49, 22:45; **11**, 8:40, 18:36; **12**, 4:32, 14:27; **13**, 0:23, 10:19, 20:14; **14**, 6:10, 16:06; **15**, 2:01, 11:57, 21:53; **16**, 7:48, 17:44; **17**, 3:40, 13:36, 23:31; **18**, 9:27, 19:23; **19**, 5:18, 15:14; **20**, 1:10, 11:05, 21:01; **21**, 6:57, 16:53; **22**, 2:48, 12:44, 22:40; **23**, 8:35, 18:31; **24**, 4:27,



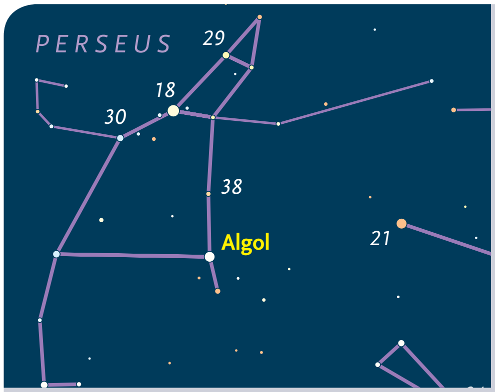
The ever-drifting Great Red Spot reversed direction several times from 1964 to 1988, then it began a gradual speedup toward increasing longitudes that continues today. Each dot is a 60-day mean of amateur measurements of the Red Spot's position, taken from the database of Jupiter-feature positions maintained by the JUPOS project; see jupos.org.

Our new Jupiter app shows the Galilean moons and the Great Red Spot at any time. Go to the iTunes store and search for JupiterMoons.

14:22; **25,** 0:18, 10:14, 20:10; **26,** 6:05, 16:01; **27,** 1:57, 11:53, 21:48; **28,** 7:44, 17:40; **29,** 3:35, 13:31, 23:27; **30,** 9:23, 19:18; **31,** 5:14, 15:10.

February 1, 1:07, 11:03, 20:59; **2,** 6:54, 16:50; **3,** 2:46, 12:42, 22:37; **4,** 8:33, 18:29; **5,** 4:25, 14:20; **6,** 0:16, 10:12, 20:07; **7,** 6:03, 15:59; **8,** 1:55, 11:50, 21:46; **9,** 7:42, 17:38; **10,** 3:34, 13:29, 23:25; **11,** 9:21, 19:17; **12,** 5:12, 15:08; **13,** 1:04, 11:00, 20:55; **14,** 6:51, 16:47; **15,** 2:43, 12:38, 22:34; **16,** 8:30, 18:26; **17,** 4:22, 14:17; **18,** 0:13, 10:09, 20:05; **19,** 6:00, 15:56; **20,** 1:52, 11:48, 21:43; **21,** 7:39, 17:35; **22,** 3:31, 13:27, 23:22; **23,** 9:18, 19:14; **24,** 5:10, 15:06; **25,** 1:01, 10:57, 20:53; **26,** 6:49, 16:45; **27,** 2:40, 12:36, 22:32; **28,** 8:28, 18:23.

To obtain Eastern Standard Time from UT, subtract 5 hours; for Pacific Standard Time subtract 8. The times above assume that the spot is centered at about System II longitude 188°. ✦



Algol, the prototype eclipsing variable star, fades every 2.87 days from its usual magnitude 2.1 to 3.4. It stays near this minimum for two hours, and it takes several more hours to fade and to rebrighten. Shown above are magnitudes of comparison stars with decimal points omitted. The geocentric predictions at right are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy Gerry Samolyk, AAVSO.

Minima of Algol

Jan.	UT	Feb.	UT
1	4:02	1	17:05
4	0:52	4	13:54
6	21:41	7	10:44
9	18:30	10	7:33
12	15:20	13	4:23
15	12:09	16	1:12
18	8:58	18	22:01
21	5:48	21	18:51
24	2:37	24	15:40
26	23:26	27	12:29
29	20:16		

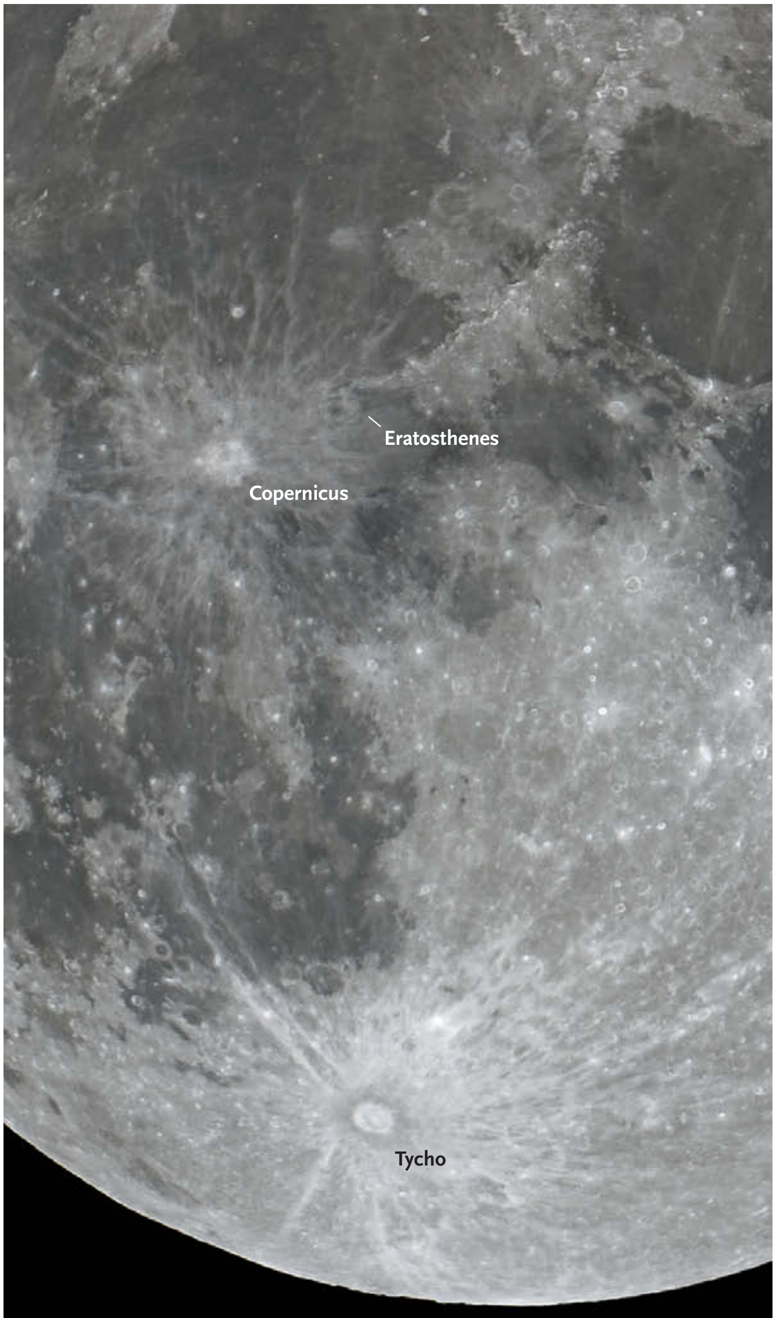
Phenomena of Jupiter's Moons, February 2013

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard 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.

A Brighter Moon

Solar rays aren't the only things that make the lunar surface bright.



The Moon's fully illuminated phase is the best time to observe its largest rayed craters. The most obvious is Tycho in the Southern Hemisphere, with its far-flung ray system spanning hundreds of miles.

S&T: SEAN WALKER

Many lunar observers tend to put away their telescopes during full Moon. But little do they know that they're missing out on some important clues to the history of our satellite. The clues lie in the brightest features of the full Moon: the interiors of young craters and the ejecta rays that extend considerably beyond them.

Let's begin by focusing our attention on **Tycho**, the most famous of the rayed craters. Tycho's structure can be broken down into three bright components. First are the crater's central peaks and the interior edges of its rim. Second is the broad region surrounding the crater that's almost completely covered by bright ray material. And finally, there are the long crater rays themselves. So Tycho's bright 52-mile-wide (85-km) crater is surrounded by a bright annulus 100 to 120 miles across, with rays extending hundreds of miles beyond the crater rim and across the lunar surface.

Other conspicuous rayed craters on the lunar nearside are Copernicus, Aristarchus, Kepler, Theophilus, Thales, and Anaxagoras. It's a fairly short list for two important reasons. First, large craters didn't form on the Moon very often. In fact, there was a steep drop-off in the number of projectiles hitting the Moon about 3.8 billion years ago. The maria don't have many craters because few large projectiles hit the Moon over the last 2.5 billion years, when most lava eruptions had ceased.

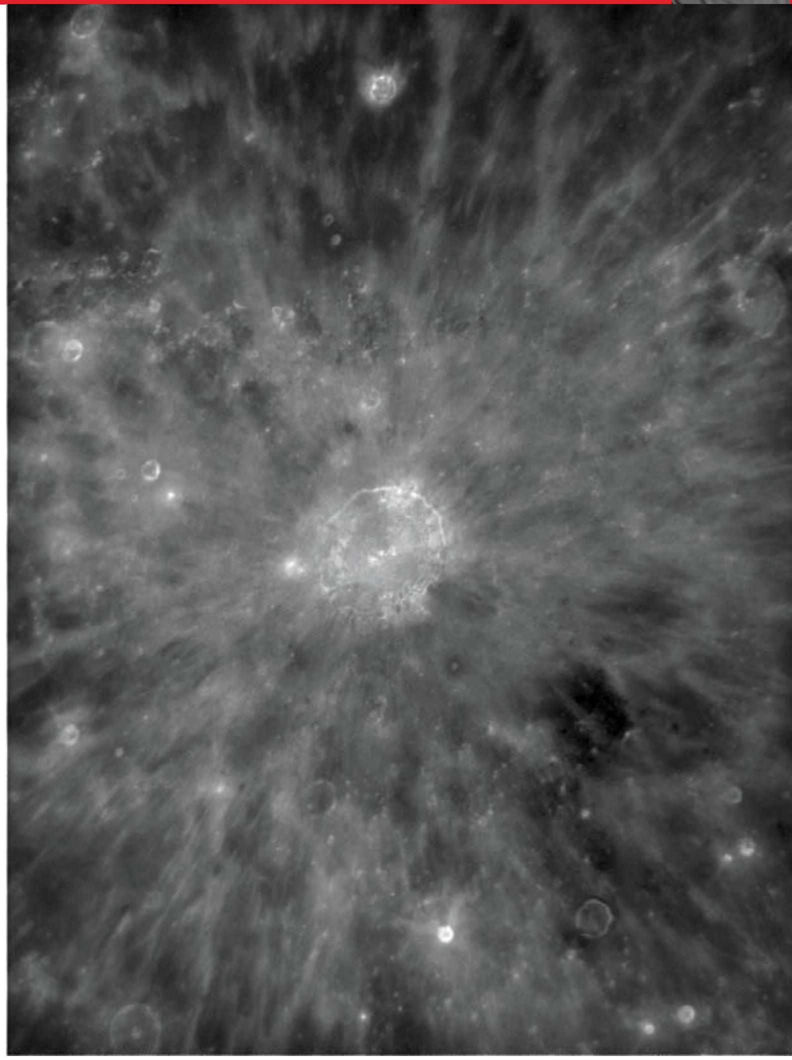
The second reason there aren't many rayed craters is that rays darken and fade over time. Rays are made of lunar rocks that were pulverized during the impact process. This fresh material is initially bright, but over time it darkens due to weathering by the solar wind. This weathering allows scientists to roughly date these craters. Tycho is about 100 million years old and its rays are bright; **Copernicus** is about 800 million years old and its rays are duller (though still conspicuous), while **Eratosthenes** is even older and has only a few hints of rays.

When initially formed, every crater had a bright interior, a surrounding annulus of bright ejecta, and rays that stretched five to ten crater diameters beyond its rim. At the end of the period of intense cratering, the Moon must have had hundreds of bright craters, making it significantly brighter at full Moon than it is today (the Moon was also closer to Earth). Imagine the spectacle if every crater were as bright as Copernicus, Tycho, or Aristarchus, and the Moon were crisscrossed by hundreds of rays.

After constructing this picture of an ancient brilliant Moon, I must admit it might not be completely true. We know from samples brought back during NASA's Apollo program that the giant collision that formed the Imbrium impact basin occurred about 3.8 billion years ago, and the Orientale basin probably formed soon afterwards. These two huge impacts would have covered much of the lunar surface with massive ejecta deposits. This ejecta would have buried most pre-existing rays (and many of the craters that formed them), so only the craters that were formed after these basins, in the waning days of intense cratering, would have had visible rays.

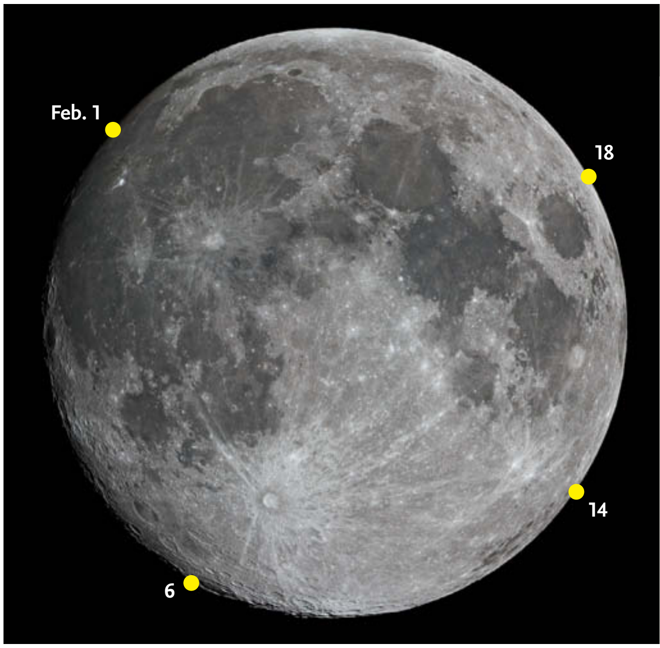
The basins' massive ejecta deposits would include vast amounts of freshly pulverized lunar rock and perhaps even streamers of rays. Scaling up from Tycho, the bright annulus that surrounded Imbrium might have extended roughly 1,500 miles in all directions, with rays stretching thousands of miles. Indeed, some of the ejecta would have smacked into Earth; other bits probably traveled across the inner solar system, cratering planets and burning up in the Sun. The Moon would have glowed from the heat of this giant impact, and much of it would have been covered by bright ejecta.

Unfortunately, there was no one to witness this stupendous natural firework, for nearly all life on Earth was still billions of years in the future. But with the benefit of data from Apollo missions, we can still vividly imagine it. ✦



HOWARD ESKILDSEN

***Right*: Copernicus's ray system is striking, but not as bright as Tycho's. That's because Copernicus is much older.**



S&T: DENNIS DI CICCO

The Moon • February 2013

Phases

LAST QUARTER
February 3, 13:56 UT

NEW MOON
February 10, 7:20 UT

FIRST QUARTER
February 17, 20:31 UT

FULL MOON
February 25, 20:26 UT

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

Distances

Perigee	February 7, 12^h UT
226,998 miles	diam. 32′ 43″
Apogee	February 19, 6^h UT
251,327 miles	diam. 29′ 32″

Librations

McLaughlin (crater)	February 1
Inghirami (crater)	February 6
Furnerius (crater)	February 14
Lacus Spei	February 18

Puppis, the Stern

Northernmost Puppis is rife with star clusters and planetary nebulae.

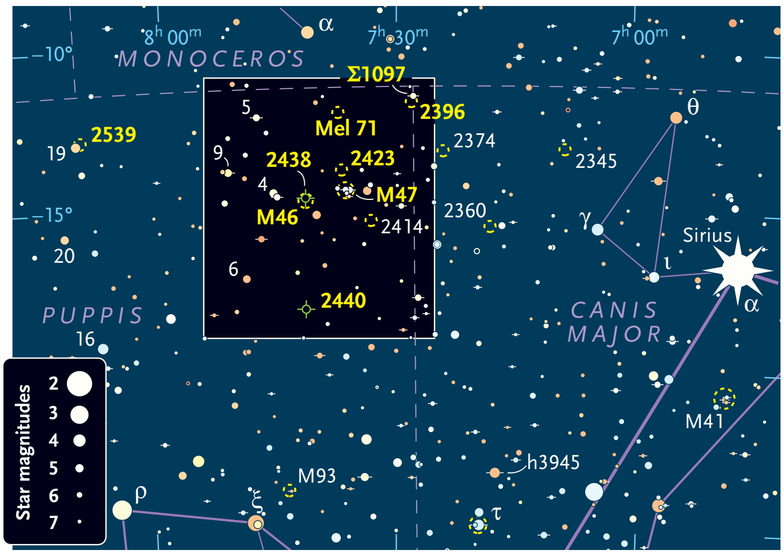
Stern-foremost; no path of onward speeding ship her path.
Sternwards she glides, like to a ship whose helm
Her crew have turned to landward,
Coming to anchor; all the oars back-water,
And lapping surges splash upon the strand.
— The Skies and Weather-Forecasts of Aratus, 1880

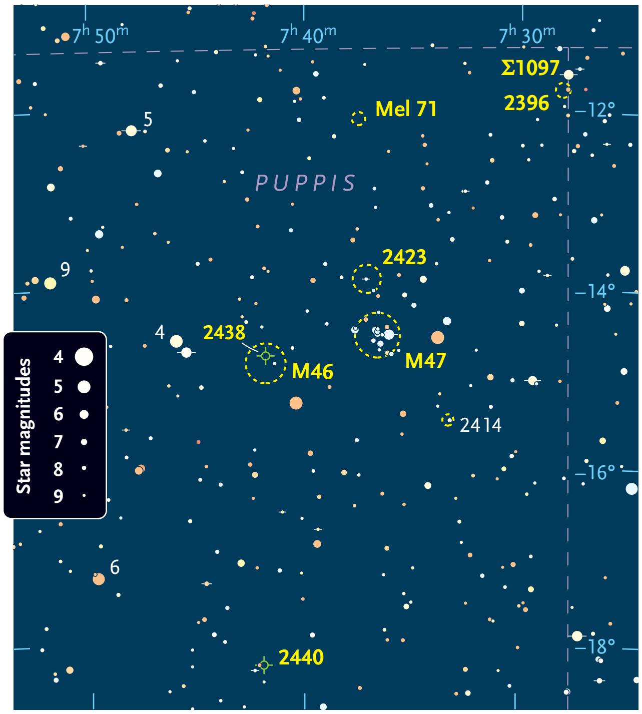
The great ship Argo floats stern first across the sky for stargazers who can see the three constellations that comprise her: Carina, the Keel; Vela, the Sails; and Puppis, the Stern. From my home latitude of 43° north, only Puppis is clearly visible. Most of Vela and all of Carina remain below the horizon, as if the ship were sinking into the watery depths.

Far northern Puppis holds one of the prettiest sights the constellation has to offer, the lovely open-cluster trio **M46**, **M47**, and **NGC 2423**. They charmingly adorn a single field of view through my 130-mm refractor at 23×. M46 is a gorgeous cluster crowded with diamond-dust stars and accented with a few brighter sparks. The cluster's densely packed, 15′ core wears a wide fringe of more loosely scattered stars, many in rambling chains that trend outward and swell the cluster to 23′. A 5th-magnitude orange sun watches over M46 from the southwest. Markedly different from its fine-grained companion, splashy M47 boasts about 50 mixed bright and faint stars in a coarse group spanning about ½°. A slightly awry five-spot pattern catches attention near the center of the cluster, with the southernmost spot being a close double of nearly matched stars. To the north-northeast of M47, NGC 2423 is a fine gathering of many faint to very faint stars covering about 15′.

Our Sun dwells in a spiral-arm segment of the Milky Way Galaxy that's known as the Orion Spur. The star clusters featured above also bead this spur, lying farther outward along it. When observing them, note the apparent brightness of their stars, which is a clue to their relative distance from us. Showy M47 is closest at 1,600 light-years; then we come to NGC 2423 at 2,500 light-years; and finally M46, whose minute points of light are 4,500 light-years distant.

M46 holds a welcome surprise if we look a little closer. Increasing the magnification of my 130-mm scope to just 37× teases out **NGC 2438**, a planetary nebula in the northern edge of the cluster's core. One of the cluster's stars glitters at the planetary's southeastern edge. At 117× the nebula displays a wide-rimmed annulus with a weakly filled central hole. Wretchedly dim and contending with the nebula's light, NGC 2438's 17.7-magnitude central star isn't visible in backyard telescopes. As a consolation prize,





The rich star cluster Messier 46 (lower left) and splashy M47 form a magnificent pair. Note the planetary nebula NGC 2438 superposed on M46's northern outskirts and the delicate cluster NGC 2423 north of M47.

a cluster star superposed a tad northwest of center makes a nice stand-in for the planetary's unseen sun.

Despite coincidence on the sky, NGC 2438 does not reside within M46. They're not moving together through space, but rather have a radial velocity difference of 30 km/sec. Current data don't completely rule out the possibility that the nebula's progenitor could be a runaway star ejected from the cluster. But if so, the separation between the nebula and cluster must be increasing by at least 1 light-year every 10,000 years.

Climbing 1.8° north from NGC 2423 takes us to **Melotte 71**, another fetching star cluster. My 130-mm scope at 23× shows a highly granular, 9′ haze with brighter points at the east-southeast and west edges. The base of a skinny, south-pointing, isosceles star-triangle abuts Melotte 71's southwestern edge. A magnification of 117× demonstrates that the eastern star of the triangle's base and the star at the cluster's east-southeast edge are double, while the cluster itself resolves wonderfully into many sparkling faint to very faint stars. At 164× I count 50 pinpricks of light within the group.

The nicely contrasting star pair **Struve 1097** (Σ1097, STF 1097) sits 2.4° west-northwest of Melotte 71. The 6.0-magnitude primary is easy to spot because it's the brightest star for more than a degree in any direction.

Clusters, Nebulae, and a Double Star in Far Northern Puppis

Object	Type	Magnitude	Size/Sep.	RA	Dec.
M46	Open cluster	6.1	26′	$7^h\ 41.8^m$	-14° 49′
M47	Open cluster	4.4	30′	$7^h\ 36.6^m$	-14° 30′
NGC 2423	Open cluster	6.7	19′	$7^h\ 37.1^m$	-13° 52′
NGC 2438	Planetary nebula	10.8	64″	$7^h\ 41.8^m$	-14° 44′
Mel 71	Open cluster	7.1	9.0′	$7^h\ 37.5^m$	-12° 03′
Σ1097	Multiple star	6.0, 8.9	20″	$7^h\ 27.9^m$	-11° 33′
NGC 2396	Open cluster	7.4	10′	$7^h\ 28.0^m$	-11° 43′
NGC 2440	Planetary nebula	9.4	70″	$7^h\ 41.9^m$	-18° 13′
NGC 2539	Open cluster	6.5	21′	$8^h\ 10.6^m$	-12° 49′

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.

KEITH NOLL / NASA / ESA / STSCI

Through my 105-mm refractor at 28×, the bright star appears yellow-white, and its 8.9-magnitude, blue-white companion sits northwest. The primary is actually a very close pair composed of a blue star and a yellow star with a difference of about one magnitude. They're aligned nearly north-south and only 0.7″ apart. Can you split this teasingly tight twosome?

NGC 2396 is centered 9.8′ south-southeast of Struve 1097. Although it doesn't look much like a star cluster to me, NGC 2396 assumes an amusing shape through my 130-mm refractor at 63×. I see it as a curvy line that waves across 10′ of sky and traces out the neck and humps of a Bactrian camel. The brightest star, where the front hump joins the neck, shines with a golden hue.

Despite appearances, NGC 2396 is thought to be a true cluster 1,900 light-years distant, 300 million years old, and at least 15 light-years across.

The intricate planetary nebula **NGC 2440** sits 3.4° due south of M46 and just 3′ west of an 8th-magnitude, yellow-orange star. Through my 130-mm scope at 23×, the star offers a striking contrast to the planetary's tiny, blue-green disk. At 164× the nebula sports a bright, blue-green center and faint wings that elongate it west-southwest to east-northeast. The core appears to be elongated perpendicular to the wings at 234×, and a dark belt slashes across its waist. NGC 2440 looks a bit different through my 10-inch reflector at 299× with an O III filter. The wings grow to about ¾′, and they now seem to extend southwest-northeast. The dark band worn by the core looks somewhat lopsided. I estimate the nebula's width as roughly ⅓′.

Deep images of NGC 2440 reveal a remarkably complex structure. Many planetary nebulae are bipolar, showing opposing lobes of ejected material. NGC 2440 is multipolar and has two, or possibly three, pairs of lobes with different orientations. These pairs are thought to have been created during different episodes of outflow from the dying star at its heart. Although shining feebly at magnitude 17.6, NGC 2440's central star has a blazing surface temperature of 200,000°C. Its phenomenal heat makes it 2,000 times more luminous than our Sun, despite the fact that it's only 3.7% as big across.

"For a last glimpse at celestial splendors for the night, let us turn to the rich cluster 1630, in Argo, just above the place where the stream of the Milky Way — here bright in mid-channel and shallowing toward the shores — separates into two or three currents before disappearing behind the horizon. It is by no means as brilliant as some of the star clusters we have seen, but it gains beauty and impressiveness from the presence of one bright star that seems to captain a host of inferior luminaries."

Let's take the above advice, beautifully written by Garrett P. Serviss in his delightful 1901 book, *Pleasures of the Telescope*. Serviss is describing object number 1630 from John Herschel's monumental 1864 *General Catalogue*, but nowadays we know it better as **NGC 2539**. The star he mentions is deep yellow, 4.7-magnitude 19 Puppis, which gilds the cluster's southeastern edge and makes it fairly simple to locate.

Through 8×32 binoculars from my semirural home, NGC 2539 is a softly glowing ball of mist, like a mystic's cloud-filled crystal ball seen from afar. "Inferior luminaries" precipitate from the haze through 14×70 binoculars, showing me a pretty sprinkling of faint stars. And at just 68×, my 105-mm scope unveils a loosely gathered congregation of 60 faint to very faint stars haphazardly splashed across 20′ and closely watched by their golden captain. ✦

You can read *Pleasures of the Telescope* as an online Project Gutenberg e-book at gutenberg.org/files/28752/28752-h/28752-h.htm.

▲ **BINOVIEWING DELUXE** Denkmeier Optical announces its most advanced binoviewer, the Binotron-27 Super System (introductory price $1,099). It features high-quality 27-millimeter prisms that fully illuminate 1¼-inch eyepieces. A wide range of eyepiece spacing can accommodate most observers' interpupillary distance. The unit utilizes new patent-pending Collitron eyepiece holders that allow the user to precisely collimate the unit without tools, and both sides focus with non-rotating helical motion. The Binotron-27 fits in telescopes with 2-inch focusers, and incorporates the company's popular Power X Switch that allow users the versatility of three different magnifications with a single set of eyepieces, and an integrated optical corrector with 45-mm clear aperture.

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▼ **EVERYONE'S UNIVERSE** Author Noreen Grice updates her book *Everyone's Universe: A Guide to Accessible Astronomy Places* ($27.95). In this expanded second edition, Grice presents comprehensive educational strategies to make astronomy fun and accessible to everyone, including those with physical or neurological disabilities. The book also includes a comprehensive travel guide to accessible observatories and planetariums throughout the United States. *Everyone's Universe* is particularly targeted toward teachers, planetariums, and other astronomy outreach programs. Paperback, 336 pages, ISBN 978-0-9833567-3-8.

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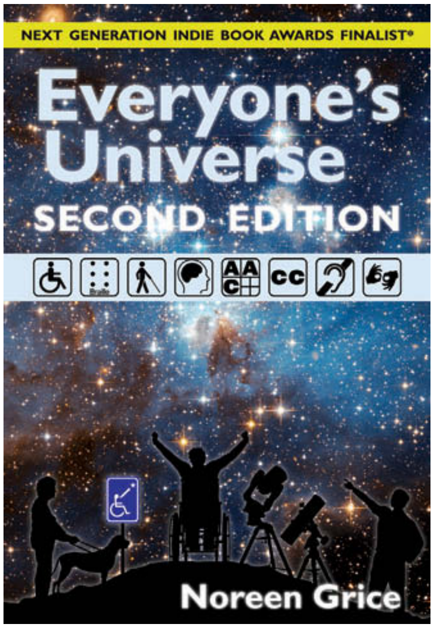

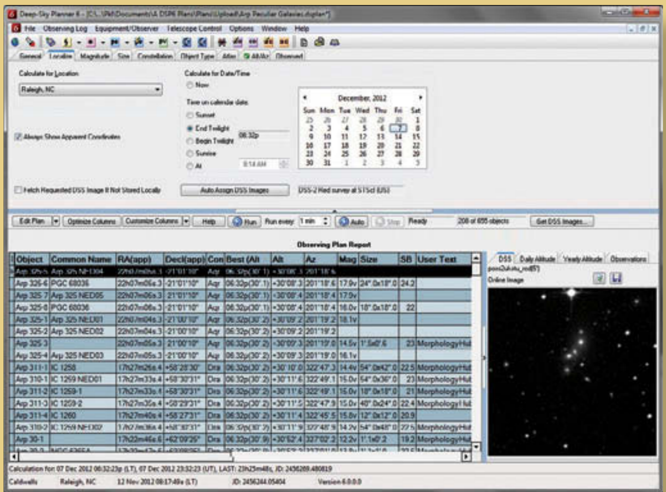

◀ **OBSERVING AID** Take advantage of unproductive cloudy nights and daylight hours by planning your evening observing sessions with *Deep-Sky Planner 6* ($80.95). This software package allows you to search through more than 1.25 million objects in its extensive database, with accurate positions for each object and the best time to observe particular objects from your location. *Deep-Sky Planner 6* includes numerous improvements to the user interface, and allows you to export your custom observing plans directly to telescope navigation programs including *Argo Navis*, *Sky Commander*, and *SkySafari*. The program can also drive Go To telescopes using the ASCOM 6 protocol, and works in conjunction with your favorite planetarium programs. An upgrade from version 5 is available for $42. Requires *Microsoft Windows XP* through *Windows 8*.

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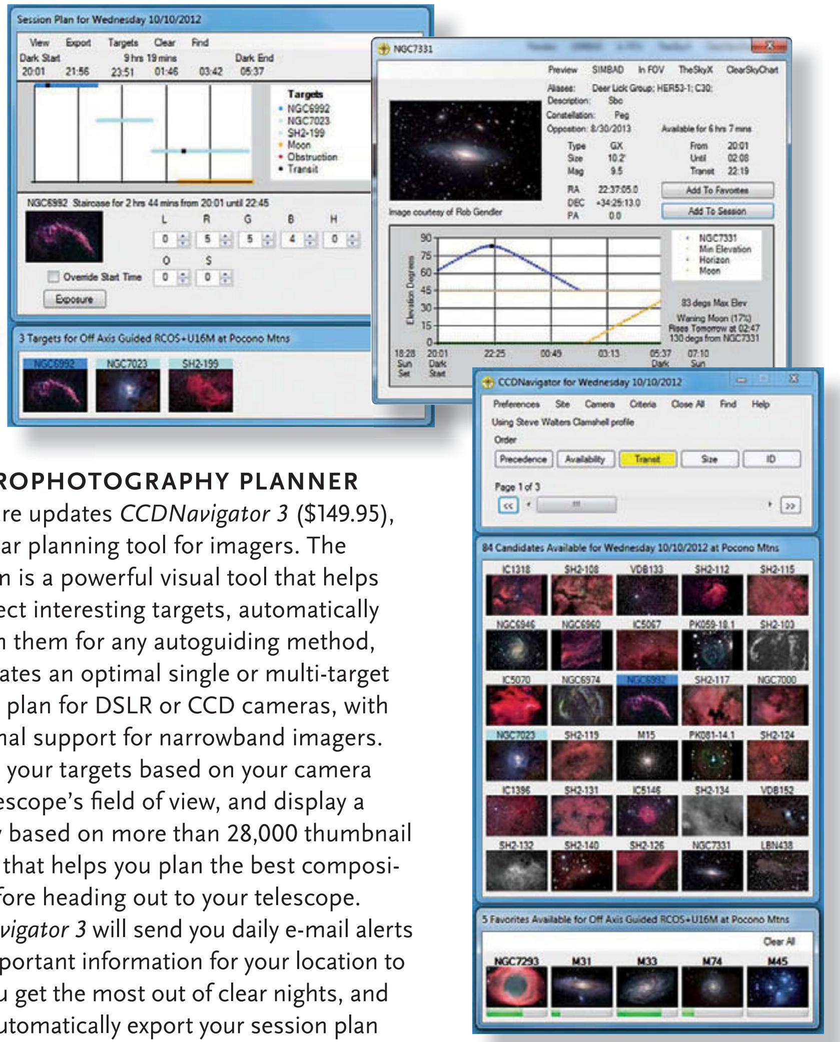

▲ IPHONE TELESCOPE ADAPTER

Arcturus Labs introduces the Magnifi ($79.99), a novel adapter that allows you to connect your iPhone 4 and 4s (it also works with the iPhone 5) to an eyepiece and take pictures through your telescope or microscope. Magnifi is a slip-fit case that holds your iPhone snugly in place, while an additional adapter clamps around your eyepiece and attaches with a sturdy bayonet mount to place your iPhone's camera as close to the ocular as possible. The unit is manufactured from impact-resistant polycarbonate plastic, and accommodates phones with screen protectors. Magnifi works with eyepieces from 1- to 1½-inch diameter, using custom-molded silicone sizing bands.

Arcturus Labs
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▶ ASTROPHOTOGRAPHY PLANNER

CCDWare updates *CCDNavigator 3* ($149.95), a popular planning tool for imagers. The program is a powerful visual tool that helps you select interesting targets, automatically position them for any autoguiding method, and creates an optimal single or multi-target session plan for DSLR or CCD cameras, with additional support for narrowband imagers. Choose your targets based on your camera and telescope's field of view, and display a preview based on more than 28,000 thumbnail images that helps you plan the best composition before heading out to your telescope. *CCDNavigator 3* will send you daily e-mail alerts with important information for your location to help you get the most out of clear nights, and it can automatically export your session plan directly to popular automated acquisition programs such as *CCDAutoPilot 5* and *ACP*. See the manufacturer's website for additional details.

CCDWare
www.ccdware.com

◀ NEW XPRESS CCD

Starlight Xpress takes advantage of Sony's new large CCD detectors in its SXVR-H694 anti-blooming CCD camera ($2,995). The camera features a Sony ICX694ALG monochrome sensor with a 2,750-by-2,200 array of 4.54-micron-square pixels. This highly sensitive detector boasts a peak quantum efficiency of 77% at 580 nanometers. Full-frame image downloads take approximately 5 seconds via a USB 2.0 interface. The camera weighs 500 grams (1.1 pounds) and measures 70-by-75-mm long. It also includes regulated thermoelectric cooling down to 30°C below ambient temperature. A adjustable faceplate allows you to square the chip to your telescope's optical axis. The SXVR-H694 is available with monochrome or color sensors. See the manufacturer's website for additional details.

Starlight Xpress Ltd.
Unit 3, Brooklands Farm, Bottle Lane,
Binfield, Berkshire, U.K. RG42 5QX
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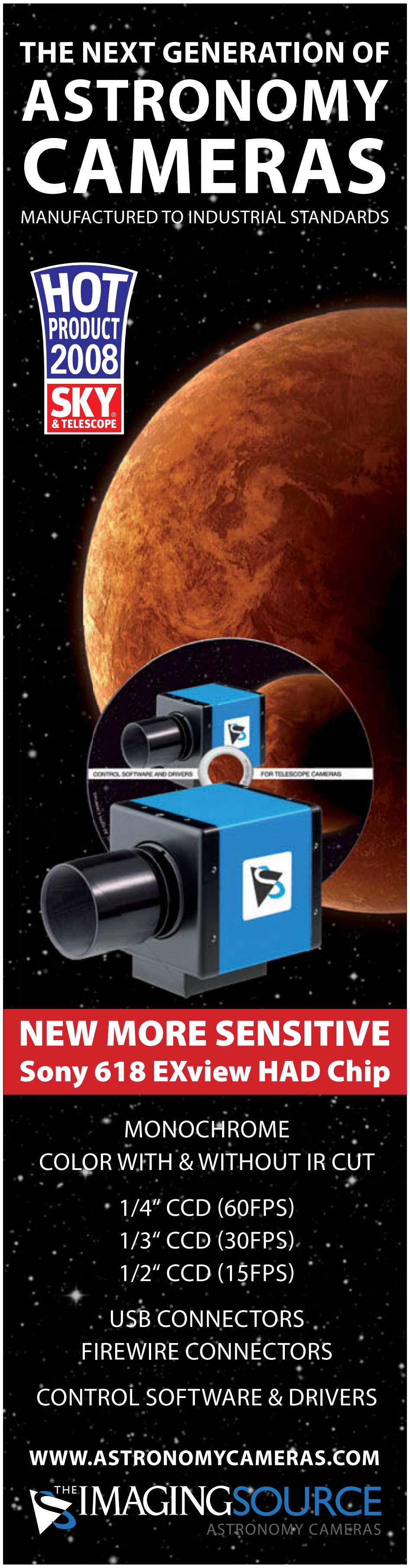
New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information contact the manufacturer or distributor. Announcements should be sent to nps@SkyandTelescope.com. Not all announcements can be listed.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Making Scopes the Highe Way

Philosophy and photons meet in carefully planned and executed telescope designs.

Telescope evolution is an interesting topic, not least because it's still happening. Considering that it was 1668 when Isaac Newton cobbled together the instrument that bears his name, it's surprising that nearly 350 later amateur telescope makers (ATMs) are still tweaking his design. A whole new branch on the Newtonian family tree sprang to life in the late 1960s when John Dobson revealed his unconventional variant.

As the ATM community began embracing Dobson's design concepts, innovators started tinkering with ways to make the scopes bigger, then ways to make them big and portable. Now we're making them big, portable, and lightweight. One telescope maker who is very active in this latest trend is Albert Highe.

We've featured Albert's work in this magazine before (for example, April 2008, page 80). His new 24-inch f/3.3 reflector, pictured at right, has all the hallmarks of his earlier efforts — elegant design, note-perfect functionality, and lightweight construction. But scopes as good as this aren't simply the product of skilled craftsmanship; they also depend on a disciplined, thoughtful approach that hinges on a few important principles.

Define your goals. Why do you want to build a scope in the first place? This is crucial. As Albert puts it, "If you don't know what you want, there is little likelihood that you'll get it." When you consider the amount of time and effort involved in making a scope, it's striking that we often dive right in and start cutting wood before really taking stock of our specific needs and circumstances. How large a scope does it have to be? How portable? Will you use it at home, or transport it to a remote observing site? "For my 24-inch," Albert says, "I spent a great deal of time identifying, prioritizing, and quantifying my goals and constraints."

Challenge the status quo. Form often follows function in telescope construction, but not always. Sometimes form follows tradition instead. For example, generations of telescope makers believed the best location for mirror-support points was under the 70% zone. That assertion stood until Toshimi Taki's September 1994 article in this magazine showed there was a better way based on finite-element analysis. Savvy telescope builders have been putting their mirror supports nearer the 50% zone ever since. "I review and analyze existing designs," Albert explains. "In particular, I try to assess performance and identify the assumptions the designers made and discover if they're truly valid."

Innovation and change aren't the same thing. Although it's perfectly valid (and fun) to make a scope with a stand-out look, that's not the same as making an instrument that looks different because it actually is different. "Creative minds can generate lots of ideas, but different doesn't necessarily mean better," Albert notes, adding, "The innovations I appreciate most are those where a

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Albert Highe (pictured on the following page) made this 24-inch f/3.3 Newtonian, which weighs only 142 pounds (64 kg). Much of the scope's design philosophy is outlined in the accompanying story. And many of its features, including the novel mirror support, were adapted from the 20-inch reflector described in Highe's new book from Willmann-Bell.

MICHELLE STONE

Tilting the focuser back toward the primary mirror by 11° relative to the primary's optical axis allowed Highe to shave 4 inches off the eyepiece height when the scope is aimed at the zenith. The spider assembly for the scope's secondary mirror, like the support system for the primary, is a significant departure from traditional designs. Its construction is also carefully described in his book, which includes software and Excel worksheets for modifying the design for other telescopes.

new or different form provides improved functionality." Although the idea didn't originate with him, the tilted-back focuser on Albert's scope is a good example. It not only looks cool, but it also confers the significant benefit of lowering the eyepiece position by about 4 inches when the scope is aimed at the zenith.

Let the data guide you. "Common practices often are reiterations of personal opinions and/or extrapolations from limited testing," Albert says. "Just because an opinion or design is often repeated doesn't mean it's correct or that it's the optimum solution." If there's something that can be tested, test it. Ever wonder why so many Dobsonians ride on textured Ebony Star Formica and Teflon? Experimentation has revealed this combination to be superior to others for smooth Dobsonian motion.

The low-profile rocker box and ground support for Highe's 24-inch scope help keep the eyepiece accessible for observers without requiring a ladder. For transport, wheels and a pair of handles attach to the rocker box.

Embrace the change. If you've built a scope or two previously, you have a great opportunity to assess your past efforts to see how well they satisfy your current observing interests and circumstances, which tend to evolve over time. "I review my design goals to see if my priorities have changed," explains Albert. "I also critique my previous designs and ask myself if the assumptions I made are still valid."

While true innovation is a rare thing, it never occurs if we don't engage in thoughtful design and execution. Not every ATM is going to advance the evolution of the Newtonian reflector, but for most of us, that's more of a big-picture concern. Of greater importance is taking the time to assess our individual needs and letting them guide us to an instrument optimized for the kinds of observing we enjoy.

Readers wishing to learn more about designing and building scopes like Albert's should check out his new book, *Engineering, Design and Construction of Portable Newtonian Telescopes* (available from **www.willbell.com**). ✦

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*Contributing editor **Gary Seronik** has built a series of scopes customized to specific tasks and circumstances. Some of them can be seen at his website, **www.garyseronik.com**.*

Fulfilling a Lifelong

AS A YOUNGSTER GROWING UP in Illinois, I developed an interest in amateur astronomy. In high school I made 6- and 10-inch Newtonian telescopes, including grinding the mirrors. Although I went on to study physics and astronomy in college and even did graduate work in astronomy at the University of Chicago, I ultimately took another career path and became a psychologist (or, as I like to put it, I switched from outer space to inner space). When I made that change, I promised myself that someday I'd build an observatory for the viewing enjoyment of myself and my community.

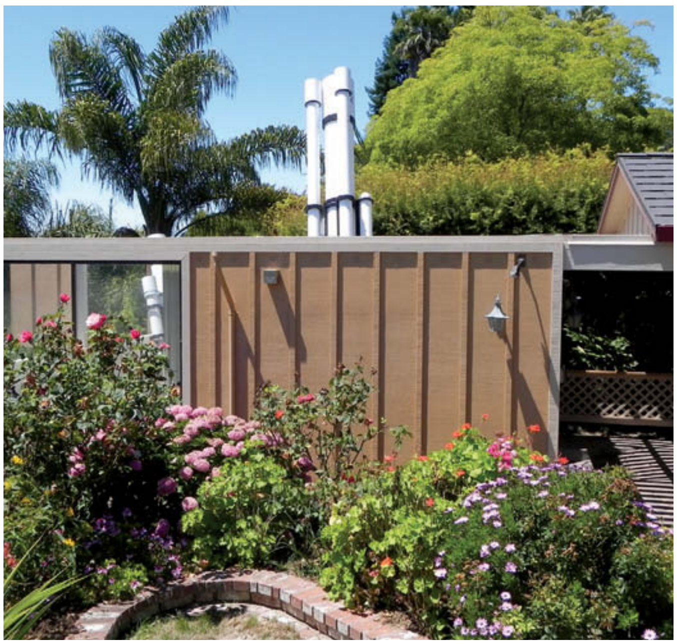
Observatory Design **and Construction**

The climate at my rural home near Monterey Bay in California is mild and frost-free, so I decided to build a roll-off-roof observatory rather than a domed structure. While I'm also blessed with relatively stable atmospheric conditions and a reasonably dark sky, some light pollution still spills over from nearby Santa Cruz and Silicon Valley. I felt that refracting telescopes, rather than large reflectors, would prove optimal for my conditions, and my observatory was designed for them.

Overall the observatory, which was built by David Frybarger, has the look of a conventional detached garage — except for the exterior beams along the patio and the roof that moves back and forth!

The structure sits on a sandstone knoll with an almost unobstructed 360° view of the sky. With the help of Ed Byers, who made the German equatorial mounts for my telescopes, I established a central north-south line for the observatory. Along this line two 4-foot cubical holes were jackhammered into the extremely hard sandstone and filled with concrete. These serve as bases for the concrete telescope piers, which were isolated from the building's concrete-slab floor to prevent vibrations being transferred from the floor to the telescopes.

All told, 42 cubic yards of concrete were poured for the observatory, piers, two walkways, and an adjacent patio on the north side of the building. There are embedded conduits for electrical lines and for cables used for computer



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Edward B. **Noffsinger**

Dream

This home observatory grew from a personal promise made long ago.

and video hookups. The roll-off roof slides northward over the patio, providing a shady place to relax on hot summer days when I use the telescopes for solar observing.

The observatory's outside dimensions are 16 by 20 feet, and the 9-foot-tall walls are conventional wood framing with 2x4 studs on 16-inch centers. The outside is covered with plywood siding, and the inside is finished with sheetrock. To ensure that the temperature inside the observatory remains in close equilibrium with the outside ambient temperature, no insulation was used in the walls. There are also 4-inch circular vents along the top and bottom of the exterior walls between each set of studs and at the top and bottom of all interior cabinets.

Seeds were sown for the author's observatory when he switched career paths from astronomy and physics to medicine in the early 1970s. The facility and its array of eight refractors (described in the accompanying text) were recently completed after more than two decades of planning and construction. Their design was driven, in part, by the mild climate and sky conditions at the author's Santa Cruz, California, home.

Roll-Off **Roof**

Two horizontal 4x8 beams topped with 1x4 lath extend northward from the upper north corners of the observatory along the east and west sides of the patio. Each beam is supported by three 4x6 redwood posts, and 2x8 redwood joists on 2-foot centers running between the beams keep them straight and parallel. A pair of 4x4 diagonal cross braces further stabilizes the beams at the end away from the observatory. The beams support barn-door tracks that are turned upside down for the roll-off roof.

The rolling roof consists of a rectangular, welded-steel frame with the same footprint as the observatory. There are a total of 24 barn-door "trucks" mounted along the east and west sides of the frame, and these roll on the inverted tracks. The frame carries 11 conventional roof trusses made from wood and covered with ½-inch exterior plywood sheathing. This is topped with lightweight metal roofing shingles that are designed to look like asphalt shingles.

The roof is powered by a gearmotor and chain drive that turns a steel shaft extending the width of the building at the top of the observatory's northern interior wall. The shaft has four garage-door cable drums mounted to it. Stainless-steel cable winds around the drums and attaches to each end of the roof through pulleys and guides. Magnetic switches limit the roof's motion.

The top half of the observatory's southern wall is a pair of bi-fold sections that swing outward to expose the southern sky to the telescopes. There are also large sliding windows on the building's north, east, and west walls.


MIKE NOFFSINGER

The author's daughter-in-law, Olga Ramirez Noffsinger, lends scale to the observatory and its battery of eight refractors, several of which are specially made for solar observing. The instruments are carried on a pair of German equatorial mounts built by Ed Byers.

Telescopes and Mounts

The observatory's primary instrument is a 12-inch f/12.2 refractor custom made by D&G Optical in Manheim, Pennsylvania. Barry Greiner thinks that the scope, which took more than a decade to complete, is the best large refractor his company has made. The achromatic objective is constructed with proprietary crown and flint glasses that are fully multicoated.

The 14-inch-diameter tube is oversized for better cooling and thermal properties. It was custom rolled and welded, and all the seams were ground and smoothed before the tube was powder-coated on the outside and its interior painted flat black. Extra baffles inside the tube minimize reflections, ensuring that views of the night sky through the instrument have a velvety black background. A 24-inch-long, 16-inch-diameter dew cap is fitted with a heater and an adapter that accepts various aperture stops and filters.

A cluster of four companion refractors and a finderscope are mounted along with the 12-inch. These include a pair of D&G Optical 5-inch f/30 achromats in oversized tubes that are intended primarily for solar observing. The other two scopes have 3-inch f/30 single-lens objectives and oversized tubes. Internal fans promote laminar airflow within the tubes to reduce air turbulence. They were custom made by the late Bob Mortimer for full-disk solar observing with hydrogen-alpha and calcium K-line filters. Hexagonal tube rings with collimation adjustments support the 12-inch refractor and auxiliary telescopes, enabling them to be accurately aligned to one another.

For solar observing, I typically configure the 12-inch scope with a Baader Planetarium 2-inch Herschel Safety Wedge Solar Prism for white-light observations. One of the 5-inch scopes is fitted with a Daystar 2-inch hydrogen-alpha filter that has a very narrow, 0.25-angstrom bandpass. The other 5-inch refractor is used for either calcium K-line or hydrogen-beta observing.

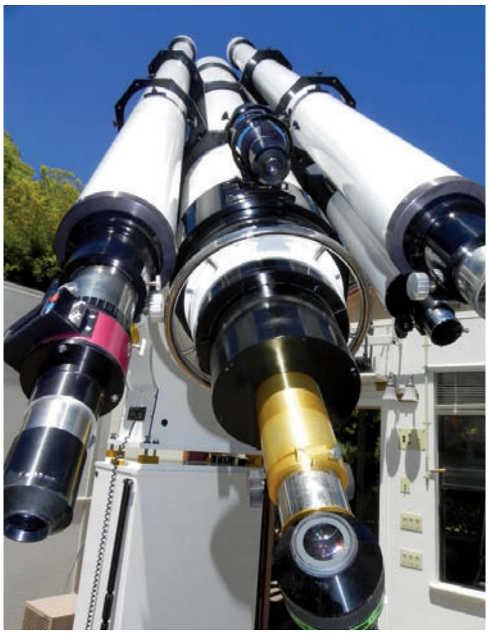
The scopes ride on a Byers Series III German equatorial mount attached to the larger of the observatory's two cement piers. The mount has 5-inch-diameter bearings at the top of the polar and declination axes. Both axes are driven by large worm gears, which are diamond lapped for maximum tracking accuracy. The gear on the polar axis is 18½ inches in diameter with 584 teeth, while the declination gear is 15 inches with 480 teeth. Both have worms that are spring loaded to eliminate backlash. The drives use DC servo motors, which have a greater speed range, more power, and are smoother than stepping motors. The electronics provide accurate solar, lunar, and sidereal tracking rates.

The mount has traditional setting circles as well as a digital readout for right ascension and declination. The highly accurate 18½-inch-diameter right ascension circle is unusual for having its own electronic sidereal drive system that keeps it synchronized with the sky. As such, I can initialize the setting circle at the beginning of an observing session and then point the scope to any object by dialing in the object's right ascension directly on the circle. I don't have to worry about making hour-angle calculations or having the setting circle lose its accuracy when I manually slew the telescope with its drive motors. The digital setting circles are initialized using any of six stars, three of which are always visible at any given time.

The smaller pier in the observatory is for an 8.2-inch f/8 semi-apochromatic refractor with an oil-spaced objective made by Fred Mrozik. It is mounted along with 5-inch and 4-inch Takahashi fluorite refractors on a Byers Series II½ mount. Rounding out my observing arsenal is a 16-inch f/5.5 Newtonian reflector on a Byers Series II mount with a custom pier on wheels. I prefer observing with the refractors because of their black sky background, but the reflector does have greater light-gathering power.

My home observatory is the culmination of a lifelong dream that began almost a half century ago. It is hard to describe the pure joy of observing with your own telescopes. I've held many stargazing parties here and look forward to many more. It's a thrill to see the looks on people's faces — children and adults alike — as they view through a large telescope for the first time. The observatory has become a major source of enjoyment for my family, friends, and community. I wish every success to others who have a similar dream of building a home observatory. I'm certain they will find it to be a fulfilling pursuit that provides great personal satisfaction. ✦

An enthusiastic amateur astronomer, ***Edward B. Noffsinger*** *spent 40-plus years as a psychologist, administrator, and consultant to national and international medical groups. He can be contacted through his website,* ***www.GroupVisits.com****.*



The business end of the 12-inch refractor includes a very large stainless-steel "yacht steering wheel" made by Ed Byers. It allows the observer a convenient handhold for swinging the big telescope and its auxiliary instruments around the sky.

Observing *with* Astrovideo Cameras

Video can boost your telescope's reach by leaps and bounds.

By Rod Mollise

A few years ago the approach of another birthday got me feeling philosophical. Not just about life in general, but about amateur astronomy. How far had I seen? What is really out there in deep space? I had observed many amazing objects, but I felt like I'd only scratched the surface.

ALL IMAGES BY THE AUTHOR

I didn't just want another look at the same old clusters, nebulae, and galaxies; I wanted to dig deep and see what lies beyond the bright showpieces.

How would I do that? I could do it visually with a large telescope. It's not unusual anymore to see amateurs using 20-, 30-, or even 40-inch Dobsonian light buckets. The problem with that idea was I'd have to haul one around whenever I had the hankering to observe. Innovative designs have made large amateur telescopes lighter than ever (see page 63), but you can only make a 25-inch Newtonian so small. A long time ago I decided I would not let my choice of telescope dictate my choice of vehicle.

What about astrophotography? I've been down the imaging road a time or two with film cameras, CCD cameras, and DSLRs. I love taking pictures of the sky, but that

Astrovideo observing has become a popular way to enjoy astronomy. Detailed views of targets such as the Lagoon Nebula (above and left) are within reach using modest equipment from less-than-ideal locations.

Astrovideo observing is not geared toward producing stunning astrophotos. Its primary goal is simply to reveal faint targets on a video monitor or laptop screen. These images of M27 *(left)* and M51 were recorded in only 15 and 28 seconds, respectively, through an 8-inch Celestron C8 Schmidt-Cassegrain telescope.

was not quite what I had in mind. Doing a good job with a conventional camera means concentrating on one or two objects an evening. Given my weather in the South, that meant I might “see” eight or ten new objects over the course of a year. And I wanted to go way beyond that in my explorations.

Then I remembered video. I had done a little experimenting, shooting the Moon and planets with my camcorder. I liked the results but hadn’t been able to image dimmer objects. A standard video camera’s exposures don’t allow enough time for the light of a distant galaxy to build up. I wondered, though, what would happen if I could take longer exposures with a video camera?

I didn’t have to wonder long. Several of my friends had embraced “astrovideo,” as they were calling it, and were routinely capturing the dimmest objects with video cameras. They viewed them in near real-time with no computer required, just a camera and a monitor. It was even more appealing that they were doing it from light-polluted suburban sites! My buddies were using special cameras from Mallincam (**mallincam.com**), Cosmo-Logic Systems (formerly StellaCam, **cosmologicsystems.com**), and Orion Telescopes & Binoculars (**oriontelescopes.com**). These cameras had several things in common that

Augmenting your observing gear with an astrovideo camera is almost like tripling the aperture of your telescope. This 22-inch Starstructure Dobsonian, combined with a MallinCam Xtreme, routinely reveals galaxies fainter than those plotted in popular star atlases.

Above: Astrovideo cameras are very compact, often smaller than a wide-field eyepiece. Popular models shown above or those available from Orion Telescopes & Binoculars come with a 1¼-inch nosepiece to fit directly in your telescope's focuser.

Left: Besides the camera, you'll need a video monitor to display your exposures as they come off of the camera. When in remote locations, the author uses a small, portable DVD player that includes a video input. The player's internal battery is adequate for displaying images throughout an entire evening.

Video camera detectors are by their very nature small due to the format of analog television. Although this makes placing your target on the detector difficult, the tiny field of view is too narrow to reveal any off-axis distortion inherent in most telescope optical designs.

allowed them to capture deep-sky objects.

The most important difference between astrovideo cameras and camcorders is the astronomy cameras' ability to take longer exposures. The less-expensive astrovideo cameras can expose for 5 to 10 seconds. That may not sound like much, but it's enough to reveal amazingly faint objects. My first astronomy video camera was limited to 10-second exposures, but had no difficulty revealing 15th-magnitude galaxies with an 8-inch telescope.

I found I liked the astrovideo experience: it was more like visual observing than sweating over a CCD camera and computer. Video cameras begin a new exposure as soon as the previous one is completed. With a new frame flashing onto the screen automatically every 10 seconds, I felt like I was seeing objects in real time. An additional bonus was the camera's good performance from my less-than-perfect site, thanks to the wide dynamic range of its CCD detector.

What really fired me up, though, was astrovideo's ability to reveal the dim and distant. How deep can one go? I've heard it said that an astrovideo camera can multiply a telescope's aperture three times, but this may be a conservative estimate. I have visually observed faint objects such as the Horsehead Nebula in Orion with large scopes, but even a 42-inch has never delivered at the eyepiece the level of detail visible with my video camera and 11-inch Schmidt-Cassegrain telescope (SCT).

I loved my first camera, the discontinued StellaCam 2. Although it was able to image objects such as the Horsehead Nebula with fair ease, to do that I had to crank up the gain (sensitivity) on its wired hand control to levels that made the image on the video screen noisy, with ugly, uneven backgrounds. The answer to this minor annoyance is to consider moving up to a more sensitive camera. More advanced models such as the StellaCam 3 or the MallinCam Xtreme are capable of exposing for hours (not that you'd ever want to do that).

When it was time to replace my StellaCam 2, I turned to the MallinCams, since they feature color sensors. I settled on the MallinCam Xtreme, which was a big step up from my earlier camera.

Even with the gain set at low levels, images from astrovideo cameras, like those of still CCD cameras, show considerable thermal noise. Internal heat causes electrons to be liberated from the imaging chip, and these electrons show up in pictures as "false stars." The MallinCam Xtreme includes electronic cooling to reduce thermal noise, just like a dedicated CCD camera.

The results I quickly achieved with the Xtreme were nothing short of amazing. Going from 10-second to 1-minute exposures made a huge difference. Not only was I able to keep the gain setting low, resulting in smoother-looking images on the monitor, I could see more detail than with short exposures no matter how high the gain was set on the StellaCam.

On first-light night for the Xtreme, Orion was hanging in the sky, so I naturally slewed the 11-inch SCT to the Horsehead, set the exposure to 56 seconds, and let fly. What was displayed when the first image came in made my jaw drop! IC434, the "background," was bright red. The reflection nebula to the northeast, NGC 2023, was icy blue. But what most impressed me was the dark nebula itself.

One benefit of the small detectors in astrovideo cameras is they can utilize strong focal reducers without producing objectionably distorted star images, allowing you to convert your f/10 SCT into an f/3.3 wide-field instrument.

Details were visible that I had only seen in long still-camera exposures, and I was seeing them without a computer and hours of image processing.

In addition to letting me see faint objects, I found that astrovideo cameras fulfilled my other requirement: seeing plenty of good stuff each and every night. The simplicity of my setup allowed me to cover lots of ground in a single evening. When I was doing The Herschel Project (*S&T*: August 2012, page 60), my quest to see all 2,500 of William and Caroline Herschel's deep-sky objects, I often logged 100 or more faint fuzzies a night.

So is astrovideo for you? It might be if your goals are similar to mine. If you are more interested in pretty pictures, however, it might not be your cup of tea. Stills made from video will never look as attractive as images from astronomical CCD cameras, though some video users have come close using frame grabbers to transfer cameras' analog video into a computer for processing.

Astrovideo may also not be for you if you don't like a fair amount of somewhat expensive technology coming between you and the sky. You'll need a camera, a monitor, a power supply, and cables for a minimal setup. If you want to record your videos for later viewing, you'll also need a video recorder. How much money is involved? The best cameras are relatively inexpensive compared to astronomical CCD still cameras (about $500 to $2,000 depending on the make and model), but you'll still need to factor in the cost of the additional items.

Most cameras come with a small AC power supply, but often that won't do much good at a dark site out in the sticks. I power my camera with a DC power cord supplied by the manufacturer and a 12-volt automotive battery. Furthermore, I've found that running the camera off a battery results in less-noisy video than if I power it from the typical "wall-wart" AC power supply.

The sort of monitor you'll want depends on your

Pixel Count *and* Pixel Size

How can deep-sky video cameras produce recognizable pictures of galaxies in 10 seconds when a DSLR would need a minute or more? It's all a matter of pixel size. The bigger the pixels on the light sensor, the more light falls on each pixel in a given period, and the better the low-light sensitivity.

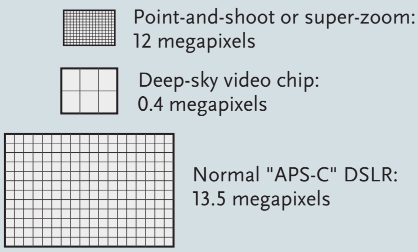
Point-and-shoot and super-zoom cameras are poor choices for deep-sky photography because they have tiny sensors (to keep their long zoom lenses compact) divided into huge numbers of pixels — which is largely a marketing gimmick. A full-page photo in this magazine needs just 6 to 8 megapixels.

DSLRs have about the same pixel count as point-and-shoots, but their sensors are much bigger. That makes each pixel bigger, giving the camera very good sensitivity when operating in low light levels.

The sensors in deep-sky video cameras are small, but they have very low pixel counts. That results in huge pixels, making them extremely sensitive to faint light, but at the cost of resolution.

— ***Tony Flanders***

Typical Camera Sensor Chip and Pixel Sizes



Chips are shown at true size.
Each small square represents 250 x 250 pixels.

Observing with an astrovideo camera like the one here doesn't require much additional equipment to tow into the field. Besides the camera, you'll need a DC power source and a video monitor or laptop computer to display your exposures. You can also use a variety of Barlows and focal reducers to tailor your field of view to each target, just like switching eyepieces when visually observing.

M16

Left: Setting up an astrovideo camera couldn't be easier — simply replace your eyepiece with your astrovideo camera. Your telescope then becomes the camera's lens.

observing site. If you are working from home with AC power available, you can use any TV/monitor with a standard composite video input. At a remote location, you'll usually need one that runs on DC. I use one of the ubiquitous portable DVD players, one with an input jack for external video that allows me to use it as a monitor. The screen is small, but it looks good and runs a long time on the internal battery.

I preserve the video that comes out of my camera with a solid-state video recorder that saves my shots to an SD memory card. It will run a whole evening on its battery, and it's small and convenient. I have used a home DVD recorder, and that worked fine, but I had to power it with an inverter and a large marine battery that was heavy and was quickly discharged by the inverter.

Silly me. I forgot to mention the No. 1 accessory you need: a telescope. What kind of scope? To go beyond the Moon and planets (most current astrovideo cameras are competent planetary imagers, too), you need a telescope that fulfills three requirements: it needs wide-field optics, it must be able to reach focus with a camera, and it must have a motor drive — preferably one with Go To pointing.

Some Newtonian reflectors don't have enough focus travel to allow the use of a camera of any kind when the camera is inserted directly into the telescope's focuser. Refractors will usually work without any modifications. Telescopes that move their primary mirrors to focus, like Schmidt-Cassegrains and Maksutov-Cassegrains, rarely have focus problems with cameras thanks to their wide focus range.

The imaging chips on astrovideo cameras are small, so a scope with a wide field of view is needed to satisfactorily frame most objects. The perfect focal length for a video telescope is around 500 to 1,000 mm. Is yours longer than that? If so, it's easy to fix with a focal-reducing lens. I use an f/3.3 reducer to change my way-too-long 2,000-mm SCT to a video-friendly 660 mm.

I'm often asked if you can start out in video with a simple Dobsonian telescope that doesn't have a drive to track the stars. Unfortunately, the answer is no. The tiny sensor chips of astrovideo cameras make tracking objects (even planets) by hand an exercise in frustration. The good news is that inexpensive Dobsonian reflectors can be purchased with alt-az drives or after-market tracking platforms. The small video chips also make it difficult to find and track objects, so a Go To telescope that locates objects automatically is much more efficient and less aggravating for video use.

So now you've got a telescope and a video camera. How do they work together? That's easy. The camera goes right into the focuser. No eyepiece is required, and astrovideo cameras don't come with lenses — your telescope becomes the lens. Most cameras come with a 1¼-inch nosepiece that allow them to be inserted directly into the focuser.

There's still the question of the choice of camera model. I won't say that a beginner isn't well-served by a top-of-the-line MallinCam Xtreme or StellaCam 3, but it's possible to start out simply and inexpensively. Both the Orion StarShoot Deep Space Video Camera and the MallinCam Jr are easy to use and give excellent results right out of the gate. They are limited to exposures of 4 seconds, but I was able to image hundreds of objects with similar exposures with my StellaCam 2.

I've seen plenty using astrovideo cameras from places like my humble backyard and our light-polluted club site. Although I still like looking through an eyepiece, I see much more with video. My cameras have more than fulfilled my wish to see what's out there, helping me look beyond the Messier and NGC catalogs to the hordes of dim galaxies that form the backdrop of the universe. ✦

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*Contributing editor **Rod Mollise** observes faint fuzzies from Chaos Manor South, most often using catadioptric telescopes.*

NGC 7331

Sean Walker

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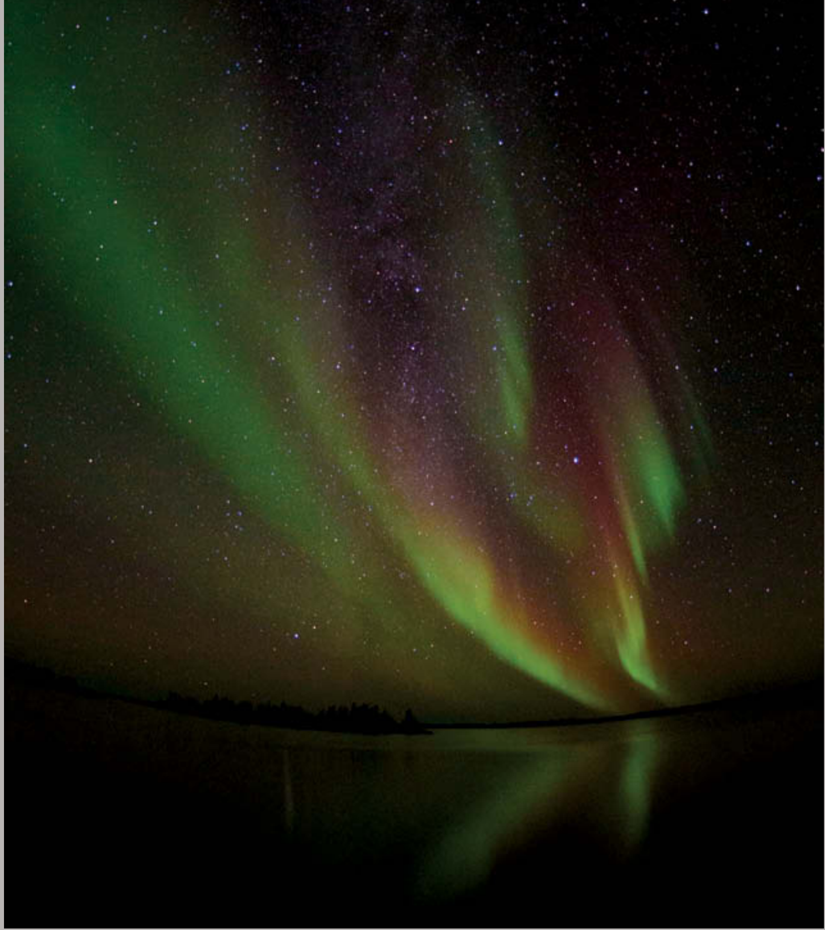
▲ **NEBULOUS CHRYSALIS**
Fabian Neyer
The famous Cocoon Nebula, IC 5146, is surrounded by reddish hydrogen gas and brownish dust in this extremely deep photograph.
Details: *Telescope Engineering Company APO140ED refractor with SBIG STL-11000M CCD camera. Total exposure was just shy of 30 hours through Baader Planetarium color and hydrogen-alpha filters.*

▶ **SUNSET RIMS**
Alessandro Bianconi
Northern lunar craters Aristoteles (top) and Eudoxus appear in stark relief as both catch the last rays of the setting Sun.
Details: *Celestron 14-inch EdgeHD telescope with Basler Ace acA640-100gm video camera. Mosaic of two frames, each a stack of multiple exposures.*

Visit SkyandTelescope.com/gallery for more gallery online.



◀ **LAKESIDE AURORA**

Philip Kwok

A vibrant display of northern lights dances among the stars of Cygnus as seen from Great Slave Lake in the Northwest Territories of Canada on the evening of September 21, 2012.

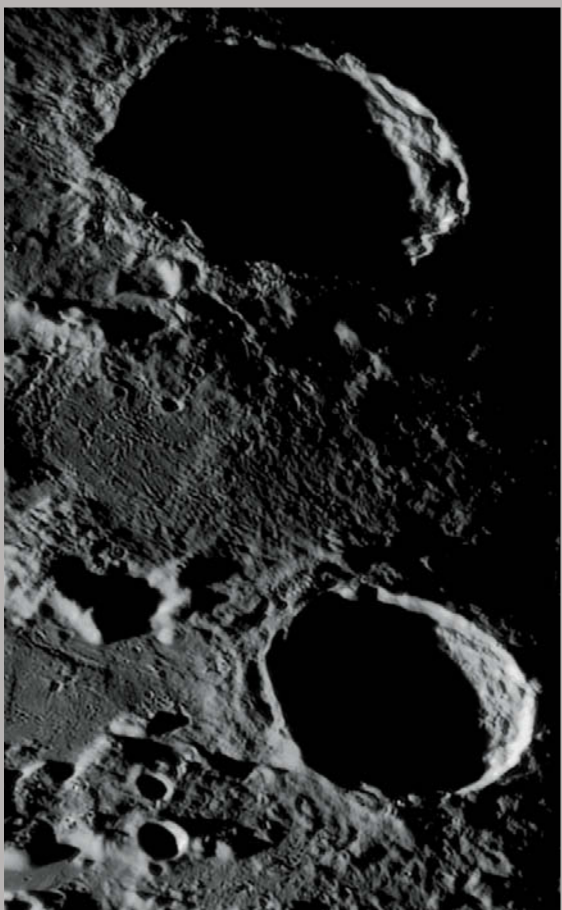
Details: *Nikon D800 DSLR camera with a 10.5-mm fisheye lens. Total exposure was 13 seconds at f/2.8, ISO 3200.*

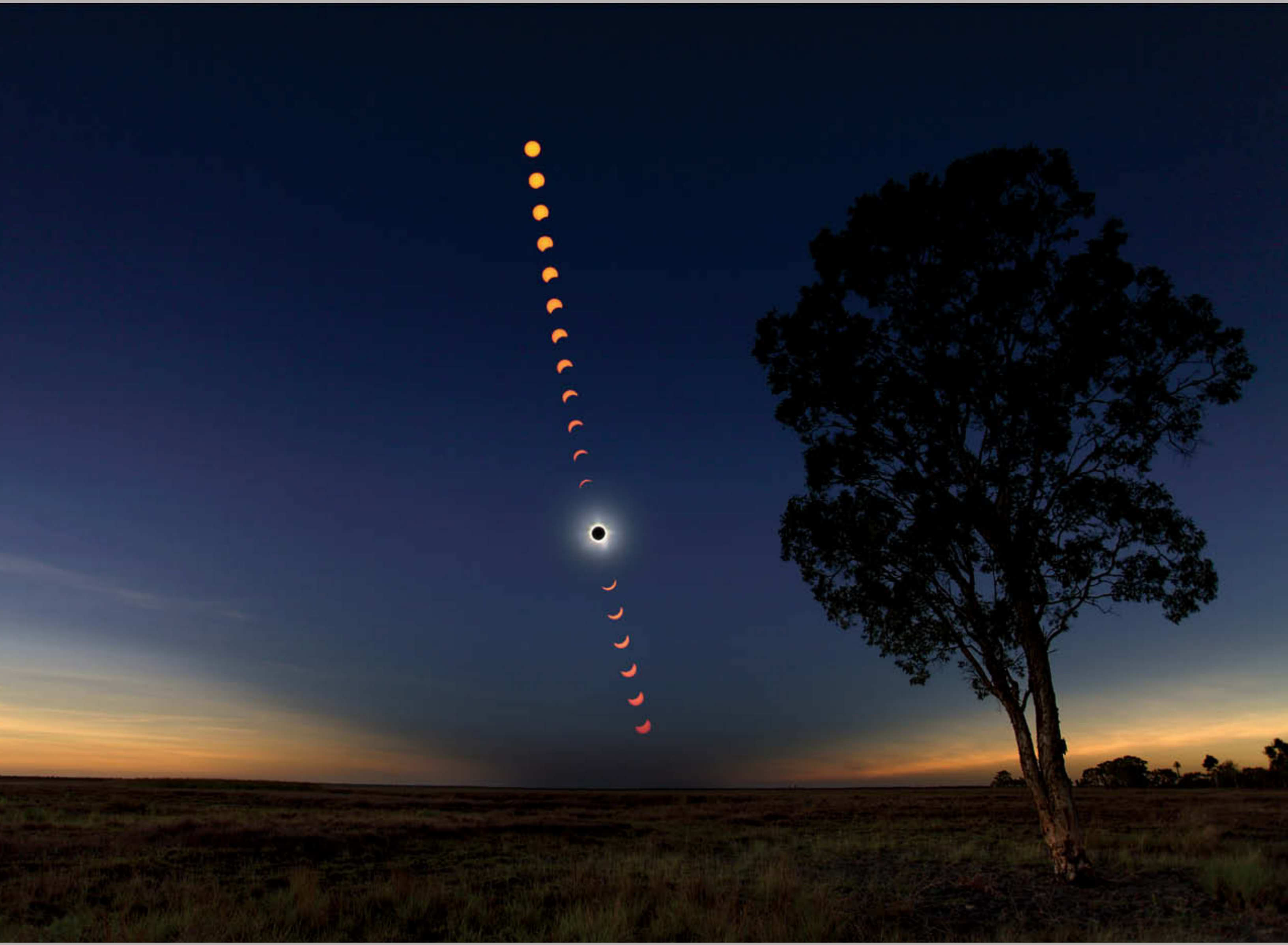
▼ **WANING LUNA**

Howard Eskildsen

The waning Moon a few days past full phase offers observers an opportunity to explore craters in stark relief. Also visible are the extensive rays of Tycho (lower left) and Copernicus (upper left).

Details: *Meade ETX-125 Maksutov-Cassegrain telescope with Canon EOS 60D DSLR camera. Composite of two snapshots.*





▲ **POMPURAAW ECLIPSE**

Geoff Sims

The total solar eclipse of November 14th (local time) appears with the well-defined lunar shadow in this composite image.

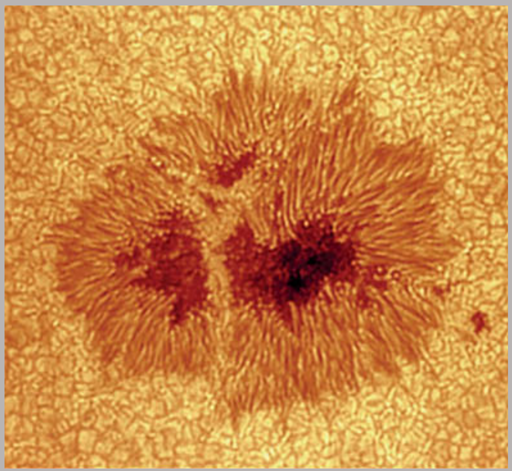
Details: *Canon EOS 5D Mark II DSLR camera with 17-to-40-mm zoom lens. Composite of multiple exposures captured from Pormpuraaw, Queensland, Australia.*

► **CHURNING SPOTS**

Alessandro Bianconi

The dark umbra of sunspot AR1575 is surrounded by filamentary structure in this high-resolution view recorded last September 25th.

Details: *Celestron 14-inch EdgeHD telescope with Basler Ace acA640-100gm video camera. Stack of multiple exposures through a Baader AstroSolar Safety Film solar filter.*



▸ **GALACTIC RIFT**
Lorenzo Comolli
The dark nebula complex known as the Pipe Nebula includes Barnard 59, 65, 66, 67, and 78, and is readily visible as a seeming absence of stars within the southern portion of the constellation Ophiuchus.
Details: *Canon EOS 5D DSLR camera with Sigma 180-mm lens. Total exposure was 1 hour at f/4, ISO 800.*

▾ **LIFTOFF!**
Hap Griffin
A Delta IV heavy-lift rocket takes off from the Cape Canaveral Air Force Station launch complex on June 29, 2012.
Details: *Canon EOS 40D DSLR camera with 18-to-55-mm zoom lens. Exposure was 1/4000 second at f/8, ISO 800.* ✦

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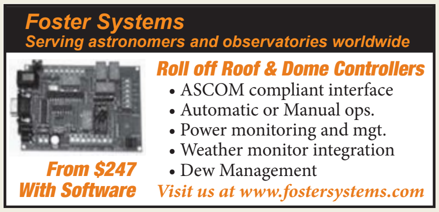

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PHOTOS BY THE AUTHOR (3)

ON A COOL, clear night in November 2011, I set up my telescope in the front yard, hoping to catch a glimpse of asteroid 2005 YU_{55} as it whizzed by. Much to my dismay I couldn't find it, so I refocused my attention on Jupiter and a nearly full Moon. The dazzling Moon, coupled with the fact that my iPhone 4S was in my hand, gave me the idea to simply hold my phone to the eyepiece and take a snapshot. The resulting photo was more detailed and gorgeous than I expected.

Given one easy success, I tried again with Jupiter. Although the Jupiter image was fuzzy and overexposed, it still showed the planet's equatorial belts and Galilean moons. It made me wonder what would happen if I made a serious attempt at using my iPhone for astrophotography. Could I capture beautiful, detailed images of the planets? What about deep-sky objects? Could I really take quality astronomical images with my iPhone?

I conducted an exhaustive internet search to see what others had done, but I only found images that looked like the ones I had taken. Disappointingly, much of astronomy forum discussions suggested that smartphone cameras were only useful for taking Moon snapshots or low-resolution photos of Jupiter and Saturn.

Knowing I had a state-of-the-art smartphone camera, I decided to try anyway. I built an inexpensive but highly functional adapter to attach my eyepieces to my iPhone, and over the next six months I developed a number of useful imaging and processing techniques for creating quality astrophotos. Some of these techniques will be familiar to many astrophotographers, while others relate specifically to the use of a smartphone camera. These latter techniques include effective "touch" focusing, exposure lock, overexposure elimination through the use of filters and high magnification, minimizing telescope jiggle, and the selection of useful camera apps including *Slow Shutter Cam* and *Magic Shutter*.

Once I've recorded my images, I copy the files to my computer and then convert them to a format compatible with the image-stacking programs *RegiStax 6* (**www.astronomie.be/registax**) or *DeepSkyStacker* (**http://deepskystacker.free.fr**).

With my iPhone/Nexstar 8 combination, I managed to image all the planets (sorry, Pluto), including surprisingly detailed and colorful pictures of Mars, Jupiter, and Saturn, as well as star clusters, contrasting binaries, and the Orion Nebula. My planetary images captured much more detail than I could ever see visually, to the point where I could track features on Jupiter from night to night and see Martian clouds. You can see my best images at **www.flickr.com/photos/artcole/** along with commentary on how they were created, as well as photos and specs of my homebuilt iPhone adapter.

My hope is that when other smartphone-wielding amateurs see these images and know what's possible, they'll give it a try, too. As the technology gets better, the quality will continue to improve. Smartphone astrophotography is admittedly a challenge, but it's fun, rewarding, inexpensive, and for me personally, it brought a whole new dimension to a beloved pastime. ✦

***Art Cole** is an amateur astronomer and satellite ground system engineer from Halifax, Nova Scotia, who has spent the last 25 years trying to find objects with his telescope. He welcomes feedback at **artcole3000@yahoo.ca**.*


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