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SKY & TELESCOPE December 2013 VOL. 126, NO. 6

On the cover: Comet ISON is keeping observers in suspense over what kind of sight it has in store for them.

COMET HYAKUTAKE: GERALD RHEMANN

FEATURES

OBSERVING DECEMBER

S&T TEST REPORT

ALSO IN THIS ISSUE

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December 2013 Digital Extra

Photo Gallery

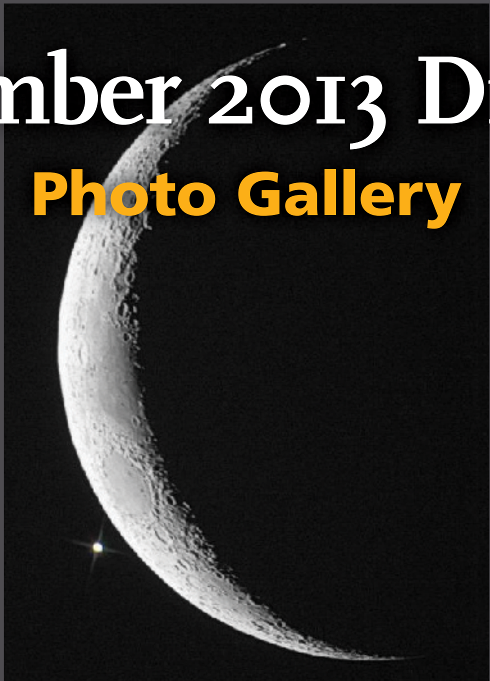

Image by Andrea V. Anfossi

BONUS WEB CONTENT

- **Latest ISON News**
  We'll post the newest updates about Comet ISON's activity.
- **High-Power Comet Observing**
  The tail is only part of a comet's structure — learn what else you can see.
- **Digging Deep in M33**
  This classic article guides observers through the star-forming regions of the Triangulum Galaxy.

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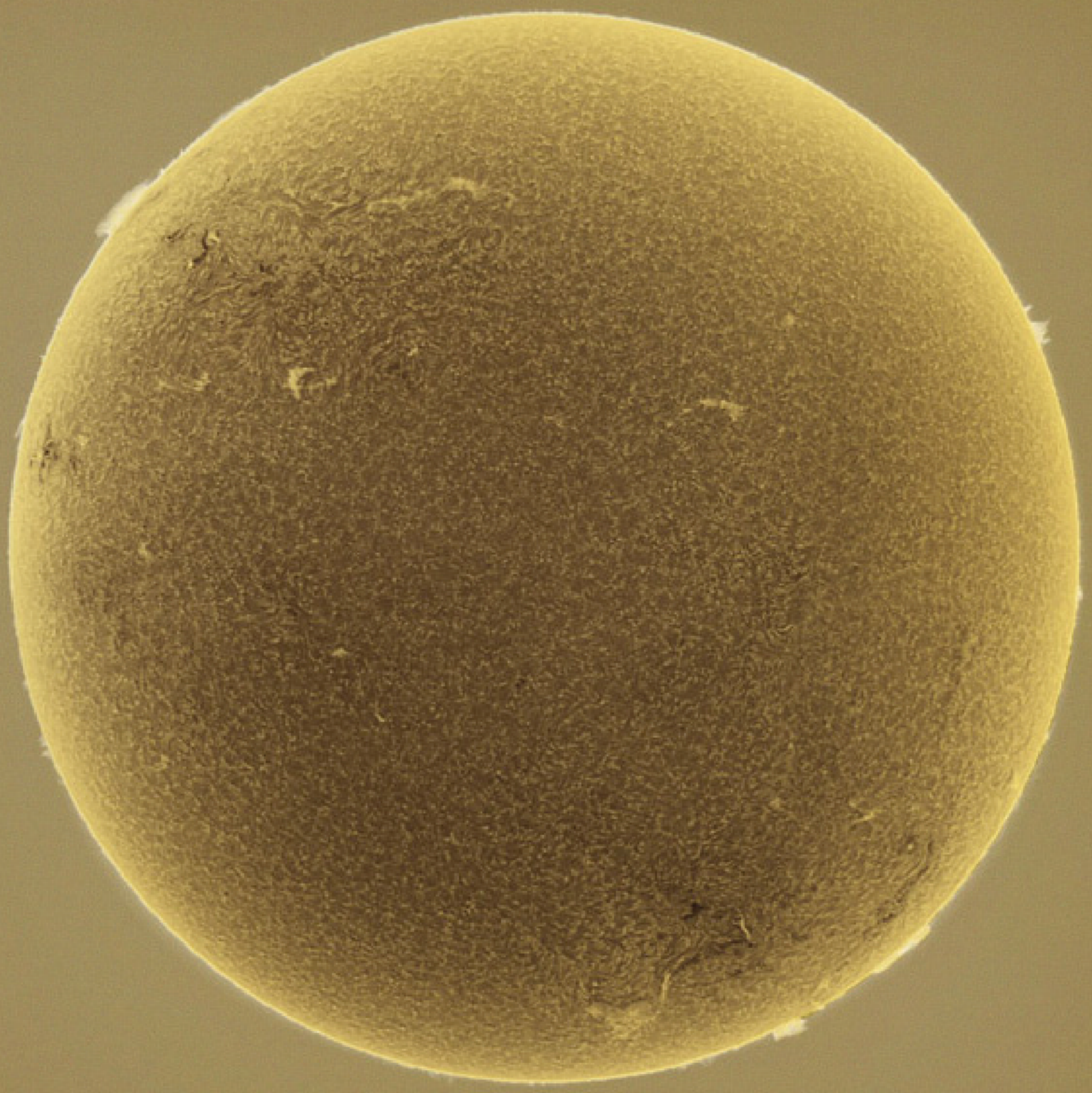

ONLINE PHOTO GALLERY

Brian Maynard imaged the solar disk with an H-alpha filter, displaying flares, prominences, and sunspots. View more beautiful images or submit your own to our online photo gallery.

Comet ISON Photo Contest

As of this writing in early October, we still don't know how well Comet ISON will perform in prime time. As my colleague Alan MacRobert quips, it could be a spectacle, a speck, or something in between. But taking an optimistic stance, and realizing that there are a lot of astrophotographers who will take great pictures no matter what, we're conducting a Comet ISON photo contest with Celestron's sponsorship and support.

The contest starts on October 25th, and we will accept photo submissions until midnight EST on December 31st. We welcome entries of all types, including high-power telescopic photos and wide-field nightscapes such as those found on The World at Night website (**www.twanight.org**). We require that Comet ISON must be in the original exposure(s). For example, we won't accept a photo of the comet over the Golden Gate Bridge if ISON is pasted into a photo taken several years ago.

Entries should be at least 640×480 pixels in size, but no larger than 1,600×1,200 pixels (the winners should be prepared to send us higher-resolution photos for later print publication). To submit entries, go to **skypub.com/photocontest**. We will accept as many as five entries per person, and there is no fee to participate. Please visit the contest website for full details and entry requirements.

Once the deadline has passed, the *S&T* editorial and art staffs will select about a dozen finalists. We will post them on our website on January 8, 2014, along with the photographers' names. The public can then cast votes for their favorite entries until January 22nd, and then we will tally the votes to determine first-, second-, and third-place winners. Each winner will receive a prize from Celestron, with the top prize being an 8-inch EdgeHD telescope, an Advanced VX mount, and a Skyris 274M camera. See the ad on page 42 for more details on the prizes.

All entrants will retain rights to their photos; we only ask for permission to publish the finalists and winning photos on our website and in the April 2014 issue of *S&T* (and future digital editions of this issue).

Knowing the tremendous creativity that exists in the astrophotography community, and with high hopes that this contest will inspire new people to enter the field, *S&T* and Celestron can't wait to see what kind of photos people submit. If you haven't tried comet photography before, check out Chris Cook's article on page 70. We encourage you to participate! ✦

Robert Naeye
Editor in Chief

SKY & TELESCOPE
Founded in 1941 by Charles A. Federer, Jr. and Helen Spence Federer
The Essential Guide to Astronomy

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Tragedy in Colorado

Some of your readers may be unaware that the wildfires in Colorado this June burned Van Slyke Instruments' machine shop to the ground. VSI has produced some of the finest ATM components available. Having purchased some of its products, I can attest to the fact that the design and quality are first rate. This is a terrible loss to the amateur astronomy community.

Robert Majewski
Las Vegas, Nevada

Editor's Note: *Several flash floods exacerbated the damage, inundating the property with ash and debris. Despite ardent support from the astronomical community and several generous offers of aid, VSI's creator Paul Van Slyke says he will not be able to rebuild. He thanks everyone for their kindness, and we honor him for his 25 years of hard work.*

Making Dermatologists Happy

Recently, I acquired a hydrogen-alpha solar telescope and was quite excited about using it — until I noticed the amount of sunlight exposure I was receiving while observing. I am a soon-to-be 65-year-old amateur astronomer with a history of minor skin cancers, so this is no lighthearted concern. Many solar observers employ a piece of cardboard, cut with a hole fitting the diameter of their scope, to reduce the glare in their eyes. It occurred to me that a larger shade might reduce both glare and protect me from the Sun. So I took a big golfer's umbrella made of ripstop nylon and cut a hole in it to fit around the scope. I also used Velcro straps to attach the umbrella shaft to the optical tube. As you can see from the photo, my upper body is thus shaded quite nicely.

Jim Hamilton
Redondo Beach, California

JIM HAMILTON

With an umbrella and a little ingenuity, this reader found a way to limit sunlight exposure to just his observations.

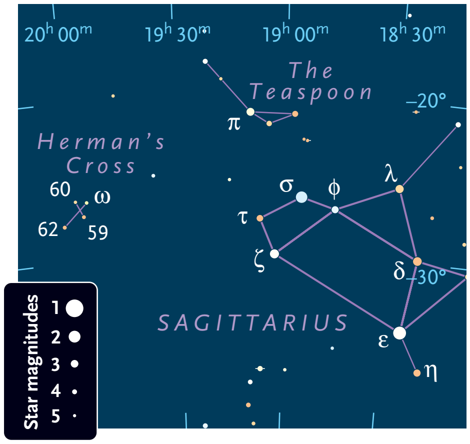
Eponymic Astronomy

On the July 2013 issue's cover, adjacent to the date, there is a small, four-star asterism. The stars, which to my eye are arrayed in a Latin cross, are all 4th-magnitude, and the shape spans about 2° lengthwise in eastern Sagittarius. In comparison, Crux stretches across roughly 6°.

The asterism caught my eye because I have a long-standing friendship with it. I first discovered it in my Comet Halley photographs of March 23, 1986 — it was a guide to many observers that month and appears in several Halley photos (*S&T*: June 1986, pages 560–1). Since 2006, I've taken to calling it Herman's Cross, because I had not seen the asterism named on any contemporary star maps.

Despite its smallness, the group has an ancient lineage. According to the late, great George Lovi in his Rambling Through the Skies column "Some Chinese Constellations of Summer" (*S&T*: July 1986, page 51), "To the Chinese it was *Kou*, the Dogs, referring to the legendary 'Dog People' with canine bodies who were supposed to live in mountain caves." In his massive compendium *Star Names, Their Lore and Meaning*, R. H. Allen wrote that for Ptolemy the group was τετρὰπλευρον (*tetrapleuron*), which translates to "quadrilateral." Subsequently, in his 1603 *Uranometria*, Johann Bayer converted Ptolemy's Greek into the low Latin *terebellum*, which appears in a few, later star atlases. Officially, the four stars are (clockwise) ω, 59, 62, and 60 Sgr.

Slightly east of the Teapot asterism and centered on right ascension 20 hours, declination –27°, the four stars (one of which is a red giant) are a good, mid-evening binocular asterism in late summer and autumn for Northern Hemisphere mid-latitude observers.



Herman M. Heyn
Baltimore, Maryland

Seeing the Sky Better

Thank you for your two recent articles "The Sky Within Your Eyes" by Salvador Bará (August issue, page 68) and "Eyepieces: Windows on the Universe" by Alan French (September issue, page 68). I am 63 years old with both Parkinson's disease and a Celestron 9.25-inch scope, and these two articles are helpful.

James E. Feickert
Marion, Iowa

I took a special interest in Bará's recent article on visual observing with eye aberrations. For several years I have experienced a different type of visual artifact, which I recently learned is caused by an anomaly known as *map-dot-fingerprint dystrophy*. The condition takes its name from its appearance during an eye inspection with the slit-lamp microscope commonly used by ophthalmologists. Roughly speaking, it arises from microcysts in the cornea, and the resulting visual artifact can be a combination of a smeared point-spread function (like those in Bará's article) and a degradation of visual contrast.

In my case, the microstructure in my eyes is placed somewhat away from the center of the pupil, so that under strong lighting conditions I don't notice the contrast smearing. However, when dark-adapted, my pupils dilate sufficiently to uncover the affected corneal area, resulting in a wispy smearing of point sources such as oncoming headlights and stars.

Readers suspecting the condition can do a simple test to see the aberration: put a very small drop of water on a dark surface illuminated by a lamp, then bring it close enough to your eye that it becomes the out-of-focus image of the pupil. Neglecting floaters (which move) and an intrinsic grainlike appearance, map-dot can be recognized from its name.

Aldo Cugnini
Long Valley, New Jersey

From Our Other Publications

In response to Robert Naeye's August Spectrum, I just wanted to say that I received your *Astronomy's 60 Greatest Mysteries* a couple of weeks ago and did a very atypical thing: I read every word. Every word! It delivered fascinating and mind-bending discussions as accessible stories, exactly as promised, and I devoured each and every one. What a collection!

Jane A. Green
Alfriston, East Sussex, UK

I would like to congratulate the *S&T* staff for the superb special edition *Astronomy's 60 Greatest Mysteries*. The edition is the finest single issue of an astronomy magazine I have read in over 50 years. Not only did you pull the likes of Lee Smolin, Martin Rees, and other prominent scientists, but also experts from various points in their careers who will inspire young readers trying to decide whether they want to go into astronomy. The articles' conciseness and clarity are brilliant. I am sure the magazine will be a ready reference on my reading stand for some time to come.

I also want to congratulate you on the news commentaries on your website. In addition to veteran Kelly Beatty, whom we have come to appreciate for his depth and range of astronomical knowledge, you have assembled a talented group of young writers. Their coverage of new developments, observations, and theoretical breakthroughs in the field is more than mere press-release regurgitation; they include clear and substantive explanations, analogies, and context in their articles. I especially enjoy Camille Carlisle's writing in this regard (as well as her sense of humor). I think that the mission of the Smithsonian's National Air and Space Museum in Washington, D.C., might well apply to today's *S&T*: "To educate, commemorate, and inspire."

Nick Anderson
Arlington, Virginia

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

For the Record

* *August issue, page 57: The star labeled Eta below the arc of three dark nebulae should be labeled 12. Eta is the nearby star in Scutum.*
* *September issue, page 58: GN 20.43.9 dangles from the star at the eastern corner of the 5-arcminute-tall kite, not the one at the western corner as stated.*
* *The ConVento group of stellar spectroscopists (September issue, page 30) was formed by a group of amateurs and professionals at a workshop in Portugal that included Thomas Eversberg and Anthony Moffat. The group took its name from the monastery where the meeting was held (Convento da Arrábida), not from the Italian for "with wind" as stated in the article. You can read more about this meeting at* **http://bit.ly/18ygJLj**.

75, 50 & 25 Years Ago

Roger W. Sinnott

December 1938

Aliens Invade "When Orson Welles and his Mercury Theatre started their broadcast on that night in October, little did they realize that a panic like the one they described would actually occur because of their broadcast. . . .

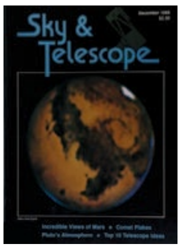
"Most astronomers are sure that no Martians will ever come. . . . There *is* air on Mars but it contains only one 1/1000th the amount of oxygen in the earthly air. There is water vapor on Mars but only 1/20th that upon the earth. . . . Mars is without question the wonder planet but there is nothing that can be observed with our present-day telescopes that would lead us to include men from Mars among its marvels."

Dorothy A. Bennett's assessment shows the strides astronomers had made since Percival Lowell speculated about Martian canal builders 30 years earlier.

December 1963

Arecibo Dish "A radar and radio telescope of novel design, with a collecting area of 18½ acres, has been completed near Arecibo, Puerto Rico, and was dedicated November 1st. This instrument was built by Cornell University and will be operated by it for the Department of Defense. . . .

"At least half the working time of the Arecibo radar-radio telescope will be devoted to observations of the earth's ionosphere . . . [as well as] radar studies of the planets and measurements of cosmic sources. The remainder of the operating time will be spent on researches related to military communications, ballistic missile detection, and tracking."

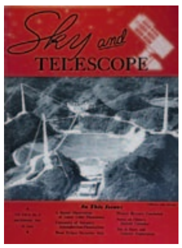


Six years later the giant dish transferred from the military to the National Science Foundation. Arecibo's targets now range from near-Earth asteroids to pulsars.

December 1988

An Amateur's Find "Dan Kaiser runs a one-man shoe repair shop in Columbus, Indiana. Thirteen years ago, the sight of Comet West in the winter dawn inspired him to become an amateur astronomer. He had no idea that he would eventually discover . . . the brightest large-amplitude Algol variable to be found in over a decade. . . .

"[On a] vacation to visit the Harvard Observatory plate collection . . . [he] found five previous fadings on six plates between 1902 and 1933. . . . If Kaiser is right, the next time the star will be at minimum light is September 2, 1991."



Right on cue, the 8th-magnitude star faded by nearly 2 magnitudes in early September 1991. Eclipses of the star, now called OW Geminorum, occur once every 3.45 years.

MISSIONS | Voyager 1 Reaches Interstellar Space

After a year of conflicting assessments, scientists for NASA's Voyager 1 spacecraft agree that the probe probably crossed into interstellar space in August 2012.

Launched in 1977, Voyager 1 now is more than 125 astronomical units away, more than three time's Pluto's average distance from the Sun. Scientists expected the spacecraft to eventually cross the *heliopause*, the outer limit of the Sun's solar-wind bubble, or heliosphere. But knowing exactly when has been difficult.

Voyager 1 started picking up radio static from the heliosphere's turbulent boundary decades ago, and in 2004 it noted that the solar wind had decelerated to subsonic speed. In August 2012 the craft relayed that the number of cosmic rays had jumped and the solar wind had plummeted — exactly the effect that space physicists expected to find in interstellar space. But, curiously, there was no corresponding change in the direction and intensity of the ambient magnetic field, which should have happened if the probe had passed out of the Sun's magnetic influence into that of the interstellar medium. So researchers convinced themselves that the spacecraft had merely reached a kind of on-ramp to the heliopause (*S&T*: March 2013, page 14).

This illustration shows the Voyager 1 spacecraft in deep space. Scientists agree that the craft appears to have left the heliosphere for good last year.

NASA / JPL-CALTECH

The magnetic field proved to be "something of a red herring," says Marc Swisdak (University of Maryland). In the September 1st *Astrophysical Journal Letters*, his team presents detailed simulations of the magnetic interactions along the heliopause. Paired with observations, the simulations show that the heliopause is a porous, multilayered structure, and that the solar and interstellar magnetic fields at this edge intersect at a very small angle. The work suggests that Voyager 1 crossed the heliopause around July 25, 2012.

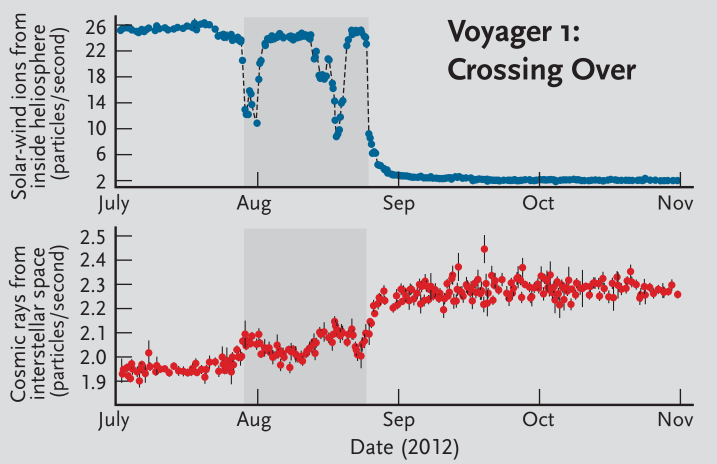
Now the Voyager team agrees that the changes seen in August 2012 truly did herald the long-awaited crossing. Mission scientist Donald Gurnett (University of Iowa) and colleagues report online September 12th in *Science* that the craft has recorded pronounced changes in surrounding plasma waves. These waves are sensitive indicators of how much plasma is present: if the waves' frequency increases, the plasma's density has gone up. The interstellar medium's plasma is denser than the tenuous solar-wind plasma at Voyager 1's distance, so an increase would indicate that the spacecraft had exited the heliosphere.

Voyager 1 detected this increase thanks to two strong solar-wind blasts that reached the spacecraft in October–November 2012 and April–May 2013. The blasts each triggered a pulse of waves in the plasma around the craft, but the more recent pulse had a higher frequency that implies a density almost exactly equal to what researchers expect in the interstellar plasma.

"We made it — while we still had enough power," says longtime project scientist Edward Stone (Caltech) with relief. The craft's plutonium-fueled power system should support current operations until about 2020. After that engineers will switch off the last instruments one by one.

Voyager 1 has not entirely left the Sun's realm: the comet reservoir known as the Oort Cloud extends to perhaps 50,000 a.u.

■ **J. KELLY BEATTY**



Midway through 2012, Voyager 1's instruments noted drops in the number of solar-wind particles recorded per second (*top*) and simultaneous surges in interstellar cosmic rays (both highlighted). The craft now seems to have left the porous heliopause for good.

S&T: LEAH TISCONE, SOURCE: NAND LAL / NASA GSFC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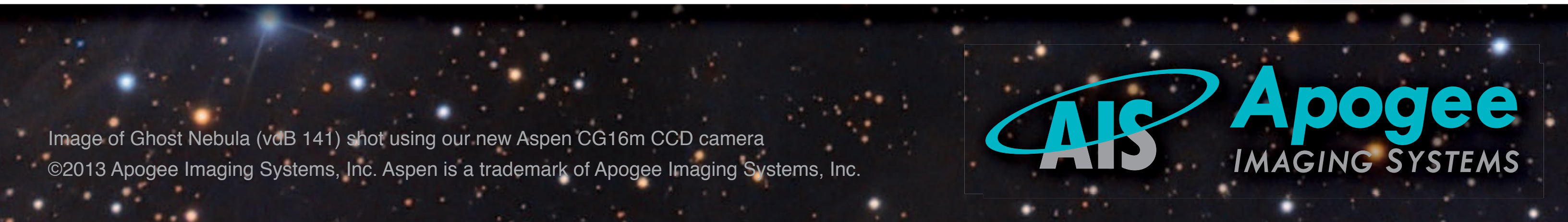
Image of Ghost Nebula (vdB 141) shot using our new Aspen CG16m CCD camera
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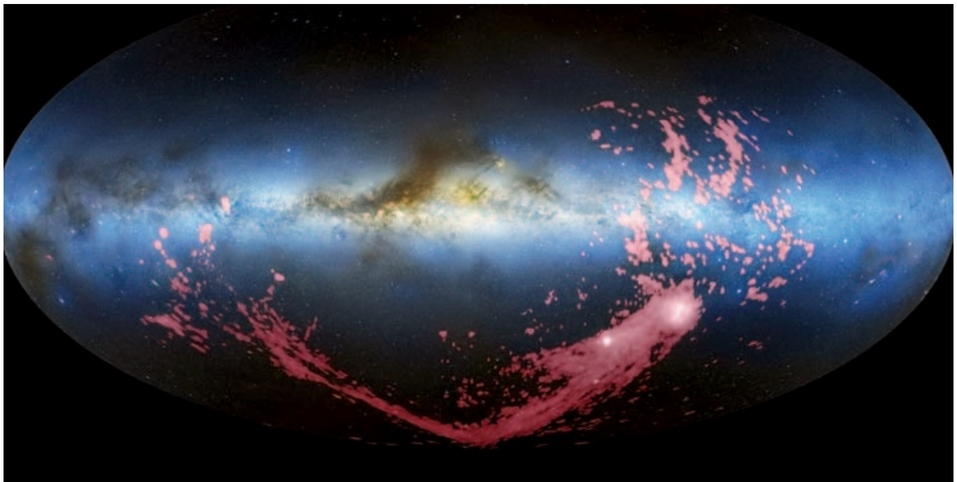
GALACTIC | Source Found for Magellanic Stream

New observations might reveal the origin of the Magellanic Stream, a long rivulet of gas encircling the Milky Way that is headed by the Small and Large Magellanic Cloud dwarf galaxies.

The stream is a monstrous cascade of gas spanning some 200° with the mass of several hundred million Suns, gas that might someday rain down on our galaxy and spark new star formation. Andrew Fox (Space Telescope Science Institute) and Philipp Richter (University of Potsdam, Germany) headed an international team that conducted an observing campaign to piece together the stream's history.


A radio image highlights the 200°-long Magellanic Stream (pink) against a visible-light backdrop showing the Milky Way. The Magellanic Clouds are the white regions lower right of center.

DAVID L. NIDEVER ET AL. / NRAO / AUI / NSF / AXEL MELLINGER / LAB SURVEY / PARKES / WESTERBORK / ARECIBO OBSERVATORY

Instead of observing the stream's faint, diffuse gas directly, the astronomers pointed ground- and space-based telescopes toward several quasars on the stream's far bank. Most of the light from these cosmic beacons pierces the fog, but specific wavelengths are absorbed as they pass through the gas. The more abundant a particular element, the more light it soaks up.

Sightlines through the stream's tail show low element abundances similar to those the SMC should have had 2 billion years ago, suggesting that section came from the smaller dwarf galaxy, perhaps during a tidal tussle with its larger sibling.

But the view toward quasar Fairall 9, close to the stream's head, shows high levels of sulfur comparable to those found in the Large Magellanic Cloud. The LMC must have contributed its share of gas more recently, stripped away as the dwarfs close in on the Milky Way and run headlong into our galaxy's spherical halo of hot gas, the team reports in two papers in the August 1st *Astrophysical Journal*.

The observations confirm recent work suggesting the Magellanic Clouds are only making their first pass around the Milky Way, says Gurtina Besla (Columbia University) (*S&T*: October 2012, page 28). If the galaxies had already made many passes around the Milky Way, all of the stream would be polluted with LMC gas, she says. But if they're just making their first pass, then the effects of traveling through the Milky Way's halo will only be seen in the youngest portions of the stream — the regions closest to the dwarf galaxies. That's exactly what the observations show.

■ **MONICA YOUNG**

BLACK HOLES | Milky Way's Central Beast Starves Itself

New high-resolution observations with NASA's Chandra X-ray Observatory reveal why emission from the Milky Way's supermassive black hole is fainter than it should be: like a maniacal self-denying dieter, the black hole is throwing over its shoulder almost all of the feast set before it.

Young, massive stars surrounding the black hole eject thick winds of particles, and these particles should feed the black hole at a rate of about an Earth mass each year. But that influx would make X-ray emission from the beast's tutu-like accretion disk 100 million times brighter than it actually is.

Chandra peered deep into the obscured galactic center for five weeks to find out why. The X-ray observations reveal emission from hot ionized gas, laid out in a shape similar to the disk of stars around the black hole. But only a weak signal appeared from ionized iron in the hot material spiraling through the innermost region down toward the event horizon, implying that there's not much gas there.

Q. Daniel Wang (University of Cambridge, UK, and University of Massachusetts, Amherst) and colleagues calculate that a measly 1% or less of the initially captured material makes it into the innermost region. The other 99% escapes as an outflow.

"The outflow [is] powered by a tiny fraction of the gas that (altruistically) sacrifices itself so that its fellow protons can escape to freedom," explains black hole researcher Roger Blandford (Stanford University). This theory has been one of several proposed to explain black holes' inefficient feeding habits.

Wang says that the 1% transfers energy to the outflow and, although the details are sketchy, the transfer probably involves magnetic fields. The inner disk is hotter and rotates faster than the outer disk, and this rotation would take the turbulent magnetic fields woven through the gas and wind them up. The tightly wrapped fields increase the gas pressure, which in turn pushes an outflow from the disk's outer regions that would carry with it some of the disk's energy.

■ **CAMILLE M. CARLISLE**

IN BRIEF

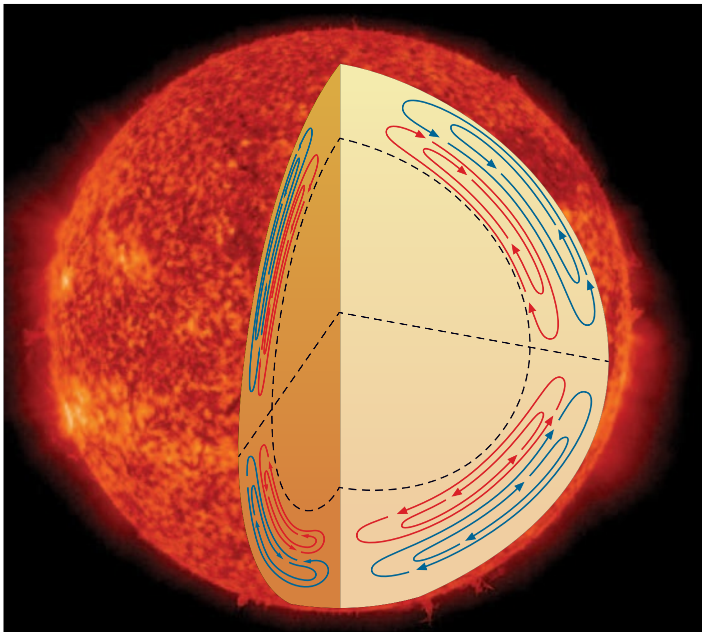
Lunar Orbiter Launched. At 11:27:00 p.m. local time on September 6th, NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) launched from the commercial Mid-Atlantic Regional Spaceport in Virginia. Observers across the Eastern Seaboard saw the fiery plume as the spacecraft shot into space. From its looping retrograde orbit, LADEE will study tenuous dust flurries that arise at dawn and dusk from the Moon's surface and have perplexed planetary scientists since the first lunar landers. After finishing science observations in February, the craft will crash-land on the Moon.
■ J. KELLY BEATTY

Infrared Eye Reopened. NASA is reviving the Wide-field Infrared Survey Explorer (WISE) to help its hunt for near-Earth objects. WISE shut down in 2011 after its successful sky mapping but will now start a three-year scan of the inner solar system. The objective is to spot and track potentially hazardous objects in Earth's vicinity, with an eye toward investigating small asteroids suitable for NASA's proposed asteroid retrieval mission (July issue, page 12).
■ J. KELLY BEATTY

Kepler KO'd. The prolific planet-hunting run is officially over for NASA's Kepler mission, the team announced August 15th. Engineers have abandoned efforts to salvage the telescope's full pointing ability, so scientists have turned to analyzing the as-yet-untouched last two years of observations. NASA is exploring alternative missions for the disabled craft; suggestions range from observing near-Earth objects to eclipsing binary stars. Alternatively, the agency might choose to close down operations completely.
■ MARK ZASTROW

Einstein@Home Helps Discover Pulsars. Using the combined computing power of 200,000 private computers, Benjamin Knispel (Max Planck Institute for Gravitational Physics, Germany) and colleagues discovered 24 Milky Way pulsars. The computer cloud analyzed archival radio data, revealing a variety of objects thanks to new search methods, the team reports in the September 10th *Astrophysical Journal*.
■ CAMILLE M. CARLISLE

SUN | Plasma Flows Befuddle Theorists



Solar Circulation

New observations suggest the Sun has at least two equator-to-pole circulation cells, instead of just one as long thought. The second cell is wreaking havoc for researchers, who don't know what it means for solar theory.

S&T: LEAH TISCIONE; SUN: NASA / SDO / AIA

A peek into the Sun's interior has undermined current models that attempt to describe our star's behavior. Instead of following a single circulation cell from the equator to the pole and back again, plasma (and its associated magnetic field) now appears to flow through at least two cells, Junwei Zhao (Stanford University) and colleagues report in the September 10th *Astrophysical Journal Letters*.

Scientists think that the 11-year cycle of the Sun's magnetic activity is governed by the equator-pole movement, called the *meridional flow*. The Sun's magnetic field is like a bar magnet, generated as charged particles inside the Sun circulate like water boiling inside a spherical pot. Because the Sun's equator rotates faster than its poles, the rotation twists and disrupts the magnetic field, creating sunspots, loops, and massive ejections of charged particles and radiation. The meridional flow is required to carry tangled magnetic flux from the equator to the poles and reset the field.

Scientists assumed the meridional flow follows a single circulation cell, traveling along the Sun's surface from the equator to the poles before sinking deep inside for the ride back. The return flow was supposed to be so deep and slow that it would take roughly 11 years to cycle back to the equator, explaining the length of the solar cycle.

But models based on this theory failed to predict the current solar cycle's weakness (November issue, page 10).

To investigate the flow, Zhao's team used NASA's Solar Dynamics Observatory to watch the gas in the Sun's photosphere swell and retract in response to sound waves passing through the interior. By timing the arrival of waves sloshing against the surface, the team indirectly glimpsed gas flows deep inside the Sun.

The observations show not one, but two circulation cells within the Sun, one stacked beneath the other. The first return flow from the pole back to the equator is relatively shallow, 62,000 km (39,000 miles) below the Sun's visible surface — half as deep as models had assumed. But the flow turns poleward again at 125,000 km down in a second cell. Even more cells could lie below these.

Solar researcher David Hathaway (NASA/Marshall Space Flight Center) says the results are "catastrophic" for current theory. "It indicates the need for revolutionary changes in our dynamo models for the sunspot cycle."
■ MONICA YOUNG

IN BRIEF

Strike Puts 17-Day Halt on ALMA Observations. Negotiations between the Atacama Large Millimeter/submillimeter Array's managing corporation and the workers' union broke down in late August, when the two sides disagreed over changes to contracts up for renewal. Operations resumed September 9th after a resolution that includes a reduced work schedule and an allowance increase for hours worked at high altitude — at 5,000 meters, the ALMA site poses unique health challenges. The strike sparked debate about how much Chile benefits from its international observatories, with Chilean scientists on both ends of the opinion spectrum.
■ MONICA YOUNG

Scopes Seek Budgetary Plan B. In August the 100-meter Green Bank Telescope signed a deal with West Virginia University to receive $1 million over the next two years in return for observing time. The agreement is part of an ongoing effort to keep running after the NSF divests funds by 2017; however, annual operations cost 10 times WVU's contribution. Meanwhile, the UK has extended funding for the United Kingdom Infrared Telescope (UKIRT) to December 31st (*S&T*: September 2012, page 14). The University of Hawaii will then take over legal ownership and responsibility for the Mauna Kea site and will partner with one of two potential parties to operate the telescope.
■ MONICA YOUNG

Deep Impact Spacecraft Meets Its End. NASA announced September 20th the end of operations for the successful comet observer. The mission team lost communication with the craft in mid-August, due to a software glitch that reset Deep Impact's computers to constant reboot mode. Without computers controlling its thrusters, the craft couldn't hold itself (or its antennas) still. Deep Impact survived eight years beyond its nominal mission's end, continuing after it hit Comet 9P/Tempel 1 with an impactor in 2005 (*S&T*: October 2005, page 34) to investigate other comets and exoplanets.
■ CAMILLE M. CARLISLE

SOLAR SYSTEM | Titan's Stiff Resistance . . .

Comparisons of Titan's surface topography and gravity field show Saturn's biggest moon has a relative rigid, highly eroded ice shell.

A low-density object (such as an iceberg) floating in a higher-density fluid (such as an ocean) will reach a point of buoyant equilibrium, called *isostasy*. The same holds true for Earth's continents and mountain ranges, which maintain their loftiness by having deep, buoyant "roots" that extend into the upper mantle.

If Titan's water-ice crust is in isostatic balance with the global ocean presumed to lie deeper down, the gravity field should increase modestly over high-standing plateaus and mountain ranges.

But as Douglas Hemingway (University of California, Santa Cruz) and colleagues report in the August 29th *Nature*, the opposite happens.

"Normally, if you fly over a mountain, you expect to see an increase in gravity due to the extra mass of the mountain," says coauthor Francis Nimmo (UC, Santa Cruz). "On Titan, when you fly over a mountain the gravity gets lower. That's a very odd observation."

The best way to explain this, the team contends, is that Titan's highlands have been partially eroded away, leaving the underlying, low-density ice "roots" locked in place by the outer shell.

The shell would need to be unexpectedly rigid and thick — at least 40 km — to keep the buoyant masses from pushing themselves upward. Depending on the layer's thickness, anywhere from 100 meters to 1 km of topography wore down. Much of this erosion must have occurred around Titan's midsection, where the present-day topography is generally higher and thus more easily worn down.

The erosion would help explain why the big moon has so few impact craters and such vast expanses of dunes (made of icy solid hydrocarbons) around its midsection.

The team offers three ideas to explain the crustal rigidity: it could arise (1) from an outer shell rich in an ice mixture called a *clathrate*; (2) from a subsurface ocean infused with ammonia, which would lower the freezing temperature; or (3) because the moon's interior never completely separated into discrete layers, which would skew Cassini's gravity measurements.
■ J. KELLY BEATTY

. . . and Methane Goes Missing on Mars

A super-sensitive instrument onboard NASA's Curiosity rover has found no methane on the Red Planet.

Methane (CH_4) is the most abundant hydrocarbon in the solar system. The trace amounts in Earth's atmosphere are unstable and must be constantly replenished, mostly by biological activity.

Over the past 15 years, various ground-based observers have reported spectroscopic evidence for spurts of CH_4 in the Martian atmosphere. But some researchers have worried that these are instead whiffs present in Earth's atmosphere. The come-and-go signals also don't make sense given that CH_4 should linger for centuries.

Still, detections from orbit by NASA's Mars Global Surveyor and ESA's Mars Express seemed to confirm the gas's existence at an abundance of roughly 15 to 30 parts per billion by volume (ppbv).

Reporting online September 19th in *Science*, mission scientist Christopher Webster (Jet Propulsion Laboratory) and colleagues reveal that the rover has found no trace of CH_4 in the Martian atmosphere. The Sample Analysis at Mars (SAM) instrument analyzed the thin Martian air's composition by gulping in six separate samples of the atmosphere over an 8-month stretch. The team reports an upper limit of just 0.18 ppbv. Given the uncertainty of ± 0.67 ppbv, they conclude there's been "no detection of methane."

SAM will next look for levels below 1 part per billion to confirm the result. ✦
■ J. KELLY BEATTY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Mysterious Travelers

Humans have been seeing comets for millennia, but we still have a lot more questions than answers.

Photograph by
Sebastian Deiries / ESO

COMET OVER PACIFIC Comet McNaught and its spectacular tail graced Southern Hemisphere skies in early 2007.

David Jewitt

Our knowledge of comets predates civilization. The brightest comets, infrequent and unnervingly unpredictable visitors to the inner solar system, were widely received by the ancients as omens of doom. Aristotle thought they were peculiar meteorological phenomena ("burning air"). At the dawn of modern science, Tycho Brahe demolished this notion by using parallax to show that the comet of 1577 was more distant than the Moon. Only in the past century have we come to understand the true significance of comets as icy relics from the epoch of planet formation. And only in the last few decades have we started to use comets as tools to understand the origin of our solar system.

Our modern view is best framed in terms of Fred Whipple's "dirty snowball" model. In this picture, a comet is a solid, ice-dirt conglomerate nucleus that sublimates (solid material vaporizing to gas) in the Sun's heat to form a transient, roughly spherical atmosphere, or *coma*. Radiation pressure from sunlight along with magnetic forces from the solar wind push dust and ionized cometary gases out of the coma, forming the dust and gas tails, respectively.

Beyond this broad-brush picture, our understanding of comets is very limited. Although the coma and tail can be very large and spectacular, most of the mass and scientific interest lies in the nucleus, which is small, faint, and very difficult to detect. A comet nucleus only a few miles in diameter sometimes produces a tail that stretches tens of millions of kilometers, comparable to the distances between the planets. The study of the nucleus is so difficult that the first reliable telescopic measurements were obtained only in the 1980s, at about the same time that the European Space Agency's Giotto spacecraft returned the first close-up pictures of Comet Halley's nucleus.

Even though people have been seeing comets for millennia, the meaningful scientific investigation of these iceballs is a comparatively new endeavor. These visitors from distant realms still present us with perplexing mysteries.

Fresh from the Freezer

Comet nuclei are small, but they can shed mass at prodigious rates. For example, Comet Halley, with an effective nucleus diameter of about 11 kilometers (7 miles), loses 50 to 100 tons *per second* at each perihelion owing to sublimation. At this rate, such a small body would run out of material in a few tens of thousands of years, far less than the 4.5-billion-year age of the solar system. In principle, this could mean that comets are young, but in practice there is no place in the modern-day solar system where comets can form.

Instead, comets are primordial bodies that formed at low

The Four Parts of a Comet

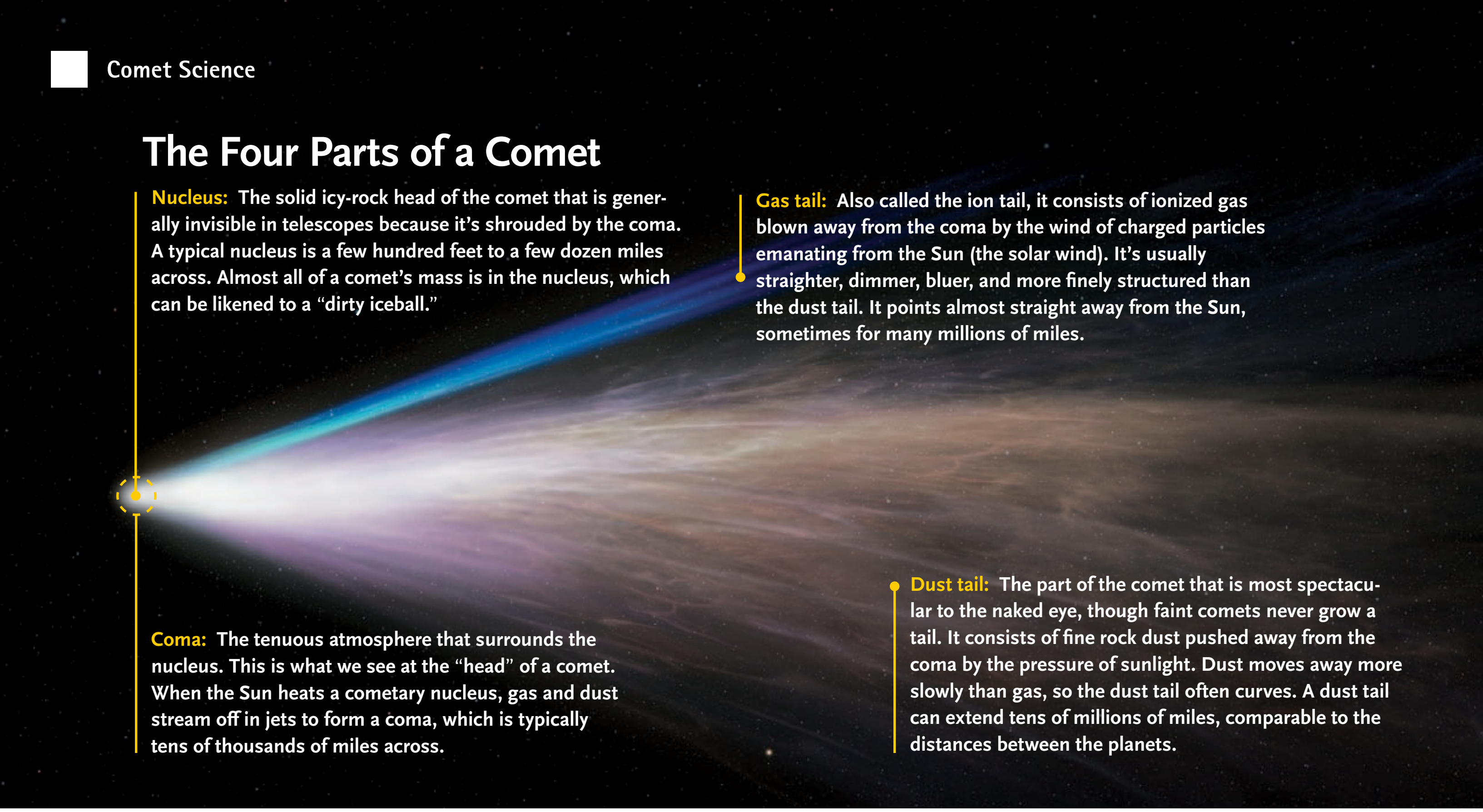


ILLUSTRATION: CASEY REED

temperatures in the outer solar system and have been stored in deep freeze ever since. Short-period comets come from the Kuiper belt (where temperatures are about –230°C, or –380°F) whereas most long-period comets originate in the Oort cloud (about –260°C). Comets are dislodged from these reservoirs by gravitational disturbances from the planets (in the case of the Kuiper belt) and from passing stars and the galactic tide (Oort cloud).

However, infrared spectral observations of comet dust seemingly contradict the idea that the nuclei are frozen remnants from the time of planet formation. Silicate dust grains in comets show clear evidence of having been heated to temperatures near 1000°C. This is even hotter than a mid-day on Mercury, yet the comets ejecting these grains have never been that close to the Sun. If they had, their water ice and other volatile materials would have vaporized long ago. Even more perplexing, NASA's Stardust mission found a calcium-aluminum inclusion (CAI) in dust from Comet Wild 2's coma. CAIs are minerals formed at high temperatures that were previously found only in meteorites from the asteroid belt. We recognize them as the first solids that condensed as the inner solar nebula's hot gases cooled.

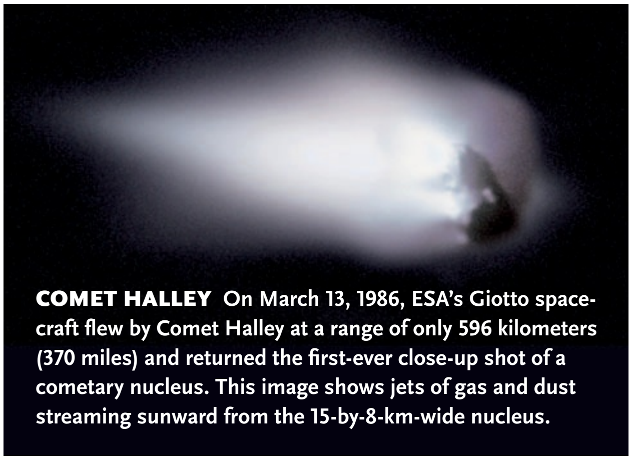
How could comets be ice-rich and yet contain dust that has been very strongly heated? The answer seems to be that the Sun's protoplanetary disk was strongly mixed; hot dust particles near the young Sun were somehow transported to the outer regions, where they were encased in ice and then trapped in cometary nuclei.

Geology on a Dirty Snowball

Although a dirty-snowball nucleus seems simple, it's replete with unexpected complexity. Telescopic comet images offer a hint of this by showing jets and other structures in the coma. We think jets erupt because sublimating ice is confined to limited active areas (vents), whereas most of the nucleus's surface is blanketed by inert material (probably rocks too big to be ejected from

SHORT- VS. LONG-PERIOD COMETS

Short-period comets are those that take less than 200 years to orbit the Sun. Long-period comets take 200 years or more to complete an orbit.



COMET HALLEY On March 13, 1986, ESA's Giotto spacecraft flew by Comet Halley at a range of only 596 kilometers (370 miles) and returned the first-ever close-up shot of a cometary nucleus. This image shows jets of gas and dust streaming sunward from the 15-by-8-km-wide nucleus.

ESA / MPAE / LINDAU

the nucleus by gas drag). During Comet Halley's 1986 apparition, for instance, jets fed the coma through only about 10% of the surface. But Halley was unusually active, and on many other comets the active regions can cover as little as 1%.

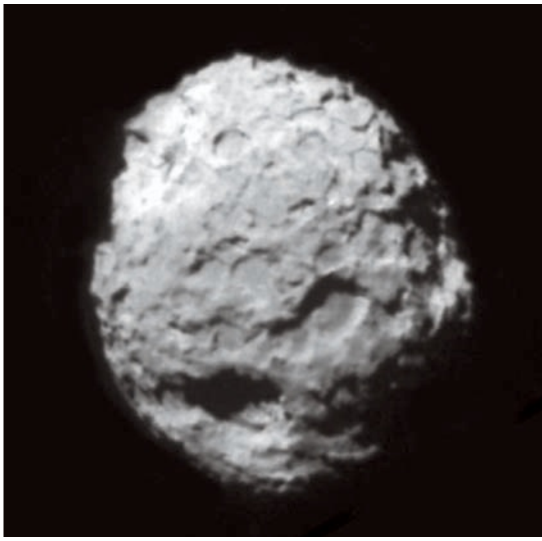
Moreover, the actual surfaces of cometary nuclei turn out to be very puzzling geologically. Features seen in high-resolution nucleus images are unlike those found anywhere else in the solar system.

The biggest surprise is that images of cometary nuclei show little evidence for vents or active areas. For example, in a picture of Comet Wild 2's nucleus from NASA's Stardust mission, one could not guess the locations of the jets in the coma. The same goes for a NASA Deep Impact spacecraft image of Comet Tempel 1. Wild 2's nucleus has so many craters that it's tempting to think they were formed by impacts, like those seen on the Moon or asteroids. But they are much deeper in proportion to their widths, they are not bowl shaped, and some even have vertical walls with overhangs. Conceivably, some of these strange features are the products of small projectiles striking very porous materials. More likely, the craters were not formed by impacts at all. They could represent collapse features, caused by the past loss of near-surface volatile materials in now-dead jets. We simply don't know.

Another surprise is that the spacecraft-imaged nuclei differ considerably from one another. Tempel 1 shows very few craters compared to Wild 2. Its surface is distinguished by smooth regions that resemble flows of low-viscosity material. We don't know what these flows are. In one model, they consist of dust fluidized by gas leaking from the nucleus that is unable to escape the comet's feeble gravity (the escape speed from Tempel 1 is so low — about 1 meter per second — that an overly enthusiastic astronaut could jump off without the aid of rockets). In contrast, Comet Hartley 2's nucleus exhibits a weird composite structure, suggesting that it was constructed when different objects stuck together.

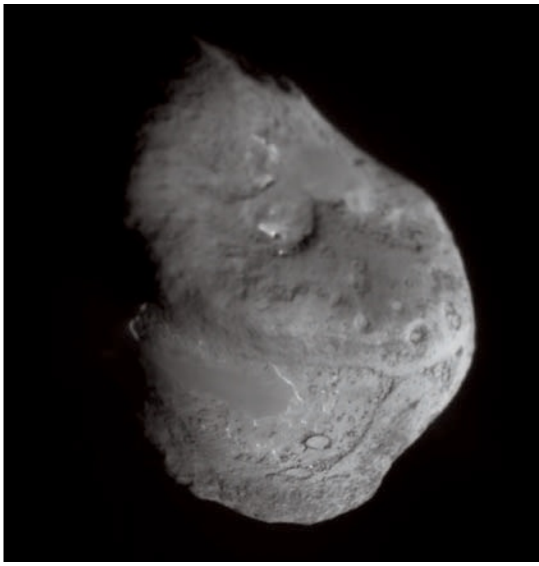
Exploding Ice

Another mystery concerns the physical form of the ice in comets. In the normal ice you find in your refrigerator, the water molecules are arranged in an orderly, hexagonal structure. We call that *crystalline ice*. But at the low temperatures typical of the Kuiper belt and Oort cloud, the ice can be *amorphous*, in which the water molecules occupy a chaotic jumble, devoid of any orderly arrangement. The difference between crystalline and amorphous ice might seem esoteric and unimportant. After all, ice is ice. In fact, the difference is potentially explosive! When amorphous ice is heated, for example in a comet moving closer to the Sun, it converts spontaneously to the crystalline form, releasing energy in the process. Moreover, the nooks and crannies between water molecules in amorphous ice offer excellent pockets for atoms and molecules



POCKMARKED COMET NASA's Stardust spacecraft took this close-up of Comet Wild 2's 5-km-wide nucleus on January 2, 2004. The many pits were probably formed by the collapse of solid material after venting rather than by impacts.

NASA / JPL-CALTECH



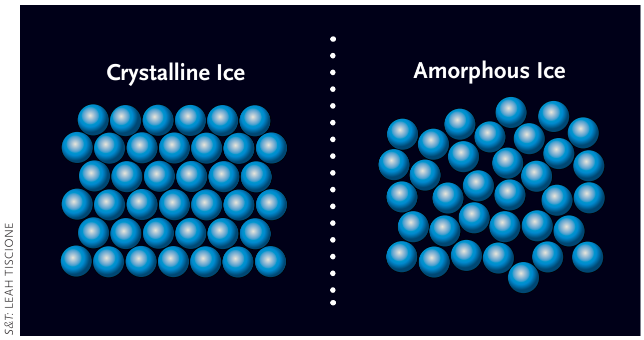
SMOOTH COMET When NASA's Deep Impact spacecraft flew by Comet Tempel 1 in July 2005, it revealed a remarkably smooth nucleus with only a few large collapse pits — a stark contrast to Comet Wild 2's nucleus. The longest dimension is 7.6 km.

NASA / JPL-CALTECH / UNIVERSITY OF MARYLAND

CONTACT BINARY After NASA's Deep Impact mission was renamed EPOXI, it flew by Comet Hartley 2 on November 4, 2010, and took this picture of what appears to be a contact binary: two pieces connected by a smooth, dust-covered bridge. The nucleus is only 2.2 km long. Note the venting jets at the far right.

NASA / JPL-CALTECH / UNIVERSITY OF MARYLAND

OUTBURST *S&T* imaging editor Sean Walker took this image of Comet Holmes with a 4-inch Newtonian astrograph on November 10, 2007. In just 42 hours in October 2007, Holmes brightened by nearly a million times, reaching magnitude 2. The cause of the outburst remains unknown, but it may have been due to amorphous ice spontaneously converting into crystalline form.



TWO FORMS OF ICE Water ice occurs in two forms. In its more familiar crystalline form (left), the molecules form an orderly, hexagonal arrangement. But in extreme cold, the molecules can be bunched together in a chaotic jumble (right). Various gases can become trapped in the gaps between molecules. When this amorphous ice is heated and spontaneously converts to crystalline form, it can explosively release the trapped gases.

of other gases to hide, making amorphous ice a kind of sponge for soaking up carbon monoxide, carbon dioxide, and other gases common in comets.

In addition to releasing energy, the rapid crystallization of amorphous ice squeezes out the trapped molecules, leading to potentially explosive outgassing. This might explain cometary outbursts such as that seen in Comet Holmes in 2007, which brightened nearly a million times in less than a day. Models suggest a runaway, in which heat released by the crystallization of one chunk of ice triggered the crystallization of adjacent ice, until all the nearby amorphous ice was consumed. Other comets have also exhibited outbursts (such as Schwassmann-Wachmann 1, which produces several outbursts per year), but not at the extreme level shown by Holmes. We don't know why this otherwise unremarkable comet produced such an atypically large outburst. Crystallization might also explain outgassing from comets that are too far from the Sun for crystalline water ice to sublimate.

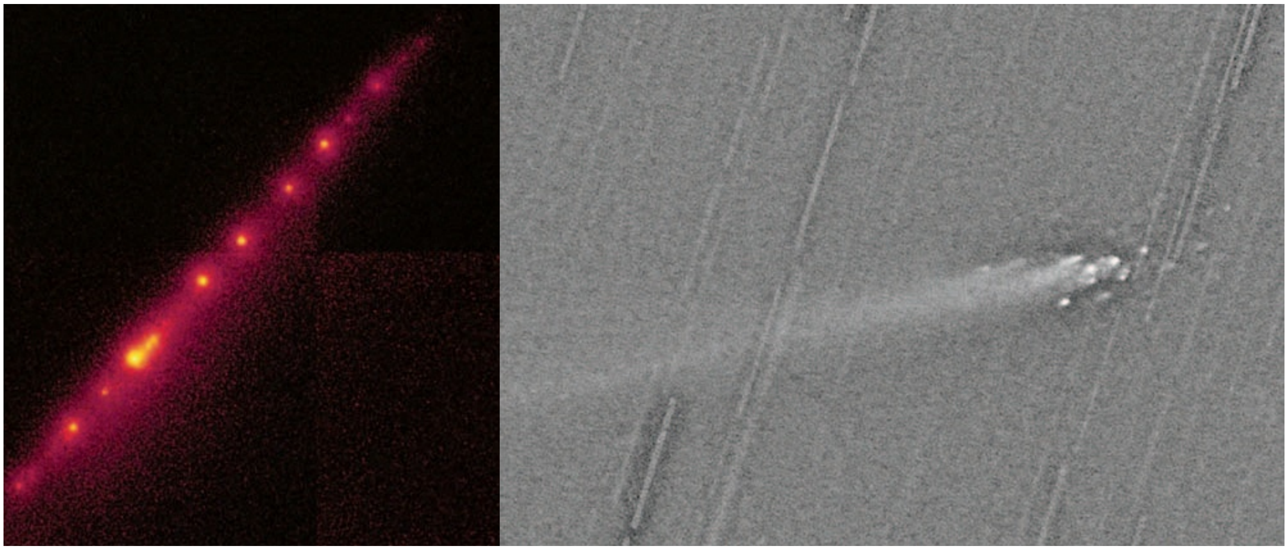
Unfortunately, we lack direct proof that comet ice is amorphous. If comets from the Kuiper belt contain amorphous ice, then it's reasonable to expect that the Kuiper belt objects themselves should be amorphous. Curiously, all reliable measurements of Kuiper belt objects show that their ices are in crystalline form.

When Breaking Up Is Easy To Do

Yet another cometary mystery is why nuclei break up, typically releasing a single companion object but sometimes disintegrating into a cluster of fragments or even a shower of dust. Our understanding of this phenomenon is negligible for most cometary disruptions.

We can explain a few cases by the breakup of the nucleus from gravitational stresses during a close flyby of the Sun or Jupiter. In the most famous example, Comet Shoemaker-Levy 9's "string of pearls" resulted from the nucleus of a comet that flew inside Jupiter's Roche limit and was ripped apart by gravitational stresses. Sungrazing comets, such as the recent and spectacular Comet Lovejoy, might also have suffered gravitational disruption. These mostly tiny objects, now numbering more than 2,000, are fragments of a large precursor nucleus that broke apart long ago. Models suggest that this nucleus was a rubble pile — a series of chunks held in contact by gravity and little else.

But other comets break up far from the planets or the Sun, where gravitational stresses are unimportant. One possible cause of these breakups is rotational disruption. A cometary nucleus vents gas preferentially on the dayside, exerting a net torque. Outgassing forces can be particularly strong for small nuclei, pushing the nucleus away from its Keplerian orbit and spinning it up in just a few orbits. Spin-up has been observed in several comets, most notably in Hartley 2. There, the torques exerted by sublimation changed the 18.3-hour rotation period at a



S-L9 IMAGE: HAL WEAVER / T. E. SMITH / STSCI / NASA; LINEAR IMAGE: ESO

COMET BREAKUPS Numerous forces can cause cometary nuclei to disintegrate. *Left:* In July 1993 the Hubble Space Telescope took this image of Comet Shoemaker-Levy 9's "string of pearls," kilometer-size fragments that resulted from the comet's tidal disruption by Jupiter about a year earlier. These fragments later rained down on Jupiter. *Right:* Europe's Very Large Telescope acquired this dramatic image showing the breakup of Comet LINEAR in August 2006. LINEAR's fragments are much smaller than those of S-L 9. The cause of LINEAR's demise remains unknown, since it was not passing near the Sun or a planet when it broke apart.

ROSETTA RENDEZVOUS In mid-2014, ESA's Rosetta spacecraft will rendezvous with Comet Churyumov-Gerasimenko. Rosetta will deploy a small probe that will attempt to land on the nucleus.
ESA / AOES MEDIALAB

rate of nearly 1 minute per day in 2011. This change is extremely rapid in astronomical terms and could spin the nucleus to break-up speed in only a few orbits. Rotational breakup is probably one of the dominant mechanisms by which comets fragment and die.

What's Inside?

Spacecraft images also raise questions about the internal structures of cometary nuclei. If comets are collisional shards of Kuiper belt objects, then we might expect them to have fragmented, rubble-pile-type interiors. Internal fractures would make the nuclei very weak in tension, consistent with their propensity to split and disintegrate.

However, other nuclei seem quite different. In Deep Impact images, Comet Hartley 2 resembles a smooth-waisted, asymmetric dumbbell, suggesting to some that it's actually a *contact binary* (two independently formed objects resting against each other), with dust collected in the neck between the components. Furthermore, the gases sublimating from Hartley 2 are different at the two ends, with the small end releasing more carbon dioxide (CO_2) than the other. The different compositions suggest that the two pieces formed at different locations in the protoplanetary disk, with the more-CO_2-rich end forming farther from the Sun.

Michael Belton (Belton Space Exploration Initiatives) has proposed a totally different structure for other cometary nuclei, based on the flat, plate-like structures seen on Tempel 1. In his TALPS model, the nucleus is built like a stack of pancakes, with each incoming cometesimal flattened against the surface of the stack upon impact (TALPS is "splat" spelled backward). In the absence of better data probing cometary interiors, we have no way to decide amongst these and other structure models.

These are still early days in the study of cometary nuclei. We know where these bodies have been stored in the solar system for billions of years. And we have characterized a few examples in enough detail to know that the physical properties of cometary nuclei are incredibly diverse. But we don't know why. How much of this diversity is primordial, and how much reflects modification of the nuclei on their long journeys from the Kuiper belt and the Oort cloud toward the Sun? Telescopic observations at different stages of their inward drift will shed light on this question in the coming decades.

A harder nut to crack is the question of how comet nuclei were built. Are they collisional shards from colliding Kuiper belt objects, are they rubble piles, Belton's pancakes, some combination of these models, or something entirely different? The answer will tell us how dirty snowballs accreted in the outer regions of the protoplanetary disk.

Resolving the internal structure might be possible with radar tomography, in which long-wavelength radio waves are transmitted through the nucleus to a detector on the other side. The first experiment of this type is planned for the nucleus of Comet Churyumov-Gerasimenko. If all goes well, a transponder on the landing portion of ESA's Rosetta spacecraft will send radio signals through the nucleus to be detected from the orbiter above. Never tried before, this measurement will open an entirely new and fascinating avenue for investigating comets. ✦

David Jewitt *is a professor of planetary science at the University of California, Los Angeles. He is interested in the solar system's small bodies, especially comets and Kuiper belt objects, and in planetary formation processes.*

For up to date information about Comet ISON, visit skypub.com/ISON.

NASA / ESA / LASCO

What Can We Learn from Comet ISON?

The long-period, sunskirting Comet ISON is headed toward a perihelion at 0.0125 a.u. (only 2.7 solar radii) from the Sun's center. If the nucleus survives its close encounter with the Sun, intense solar heating should produce a spectacular show, although the comet will be so close to the Sun that specialized instruments might be needed to view it. Most sungrazers do not survive beyond perihelion because they are only a few tens of meters across. ISON's nucleus is estimated to be 2 to 3 km in diameter, giving it a better chance. Planetary scientists will be watching to see how ISON's nucleus fares in the intense environment of the Sun's inner corona. Even if ISON's nucleus does not vaporize, it might break up or disintegrate from gravitational stresses imposed on it by the Sun. Careful measurements of the fragments will be useful in calculating the nucleus's internal strength.

SUNGRAZER The above image of Comet SOHO-6 is representative of many sungrazing comets discovered in SOHO pictures. Some comets barely survive their close encounters with our solar system's host star, whereas others disintegrate due to heat and/or gravitational disruption. SOHO-6 died a fiery death as it plunged into the Sun. It's an open question whether Comet ISON will survive its late November close encounter with the Sun.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The Comet ISON Story

With the most dramatic portion of Comet's ISON's apparition almost upon us, questions remain about what we'll see.

John E. Bortle

Like some hero in a Homeric epic, the story of Comet ISON has vacillated between the extremes of exaltation and the depths of despair. The comet was initially heralded as "the comet of the century" soon after its discovery more than a year ago. But by late last spring it had morphed into an object thought by some to be so small and fragile that it might even dissipate before reaching its rendezvous with the Sun. More recently, ISON has seemingly resurrected itself, offering hope that it may yet become the celestial spectacle everyone is dreaming about.

The swirl of controversy associated with this comet arose within days of its September 21, 2012 discovery by Russian amateur astronomers Vitali Nevski and Artyom Novichonok. They had noted the barely discernible diffuse spot on images made with a remote 16-inch telescope in the International Scientific Optical Network (ISON). The object's slow motion against the background stars suggested that the discovery was made when the comet was unusually far from the Sun. But what really set the astronomical community in a tizzy was the realization that Comet C/2012 S1 was headed for an extraordinary

ALL PHOTOGRAPHS BY DENNIS DI CICCO UNLESS OTHERWISE NOTED trip through the inner solar system in late 2013.

Recent decades have seen several comets become spectacular sights as they neared the Sun. Comet Hale-Bopp closed to within 85 million miles of our star in 1997, and Comet Hyakutake (1996) and Comet McNaught (2007) ventured to within about one-fifth that distance. But when Comet ISON sweeps around the Sun on November 28th, it will literally skirt our star's visible surface, missing contact by less than 750,000 miles (1.2 million km).

Unfortunately, initial reports of ISON's close pass to the Sun were accompanied by a flurry of extraordinary brightness predictions on various websites and online forums. Many suggested that Comet ISON would become brighter than the full Moon, making it possibly the greatest comet in history.

Nevertheless, there was a crucial bit of information missing from ISON's initial orbital calculations. Early observations gave no indication of whether ISON was a comet returning to the inner solar system or a brand-new one fresh from the Oort Cloud. Astronomers can only make such a determination after watching a comet long enough to get a true shape of its orbital path.

Knowing whether a comet is new or returning can prove critical in predicting how it may evolve as it draws close to the Sun. Dynamically old comets have had previous brushes with solar heating, so much of their volatile layers have been boiled off. This tends to make them more consistent performers during subsequent returns, allowing early predictions to hold throughout the apparitions.

Conversely, dynamically new comets are pristine objects widely thought to be coated with a thin outer crust of highly volatile icy material. This thin layer vaporizes when the comets are still very far from the Sun, so it temporarily generates misleadingly bright objects. When this outer layer is exhausted, the comet's initial brightness fades, revealing an intrinsically fainter and less active object. The apparition of much-hyped Comet PanSTARRS earlier this year, which disappointed many visual observers, exhibited the typical performance of a dynamically new comet.

Dynamically old comets such as Bennett (in 1970), West (1976), and Halley (1986), which have had multiple encounters with the Sun, are usually more consistent per-

***Facing page*: At the time of its discovery in June 2011, Comet PanSTARRS (C/2011 L4) was predicted to put on a dramatic show early this year. But it didn't live up to expectations, in part because it was a "new" comet making its first trip through the inner solar system. Many observers even had difficulty finding it in the March evening twilight (this shot is from March 20th).**

***This page*: Two comets that did live up to expectations and proved to be among the brightest of the 20th century were Comet West (*top*, photographed on March 8, 1976) and Comet Bennett (*bottom*, photographed on April 4, 1970). Both were "old" comets making return trips around the Sun.**

Many factors influence a comet's appearance. Comet Hyakutake briefly became a dramatic naked-eye sight even in suburban skies when it passed within 10 million miles (15 million km) of Earth on March 25, 1996.

formers throughout their apparitions. They tend to live up to their expectations in the eyes of amateur astronomers and the public.

Setting the Stage

Early predictions of ISON's performance were based on the idea that comets brighten and fade according to the inverse 4th-power law of their distance from the Sun. This idea largely evolved during the 20th century from observations of comets located between 0.3 and 2.5 astronomical units (a.u.) from the Sun. Now, however, it's generally accepted that this power-law formula is somewhat too generous. Furthermore, comets very far from the Sun at the time of their discovery tend to change brightness in a far less predictable manner than astronomers can anticipate by using any power-law formula.

Neglecting these facts, early writers and bloggers simply extrapolated Comet ISON's discovery brightness all the way to perihelion in the usual manner. This led to some outrageous predictions of the comet ultimately becoming brighter than the full Moon.

As observations of Comet ISON accumulated during the months following its discovery, it became clear that it was definitely a first-time visitor from the Oort Cloud. And true to that nature, this dynamically new comet brightened less than anticipated. On top of that, late last spring the comet ceased to increase in brightness for a time, leading some to suspect that it might already be dying out.

In this regard, Comet ISON was following very much in the footsteps of two previous objects dubbed "comet of the century." In 1940 Comet Cunningham was supposed to put on a grand Christmastime show, leading some to postulate that it might be the return of the Star of Bethlehem. It didn't and wasn't. Three decades later an almost identical scenario was played out by the infamous Comet Kohoutek (*S&T:* April 2013, page 32). When these comets reached their respective perihelia, they presented only mediocre displays, even for astronomy enthusiasts. Many readers will recall the press humorously dubbing Kohoutek "the flop of the century."

In the long history of comets, a vast majority of seemingly promising new ones have failed to live up to expectations. Only one dynamically new object comes to mind that radically differed from this pattern — Comet McNaught in 2006-07. Following a somewhat questionable start, it eventually became bright enough to be seen in broad daylight, and for observers in the Southern Hemisphere it was one of the grandest comet displays of our time.

A New Chapter Unfolds

After hiding in the Sun's glare earlier this year, Comet ISON was recovered in dawn skies in August, looking very much the way it did when last seen several months earlier. Although its intrinsic brightness was clearly less than initially predicted, it was also clear that the comet wasn't dying out. Furthermore, new predictions suggested that ISON could yet attain some degree of daytime visibility at the time of perihelion and would make a nice morning showing in the eastern skies of early December.

Nevertheless, the exact details of Comet ISON's upcoming display remain in doubt because of its extraordinary sweep around the Sun. Its perihelion distance is so small that there are very few comparable objects on which to base predictions. The only reasonable comparisons are a half dozen or so brighter members of the unique Kreutz family of sungrazing comets and the Great Comet of 1680, itself mistakenly thought early on to be related to Comet ISON. But all these objects experienced

For the latest Comet ISON updates, see skypub.com/ison.

previous encounters with the Sun.

Some years ago I established an empirical relationship between a comet's intrinsic brightness and its perihelion distance that governs whether or not it can survive its encounter with the Sun. If this relationship holds for Comet ISON and its 0.012 a.u. perihelion distance, the comet would require an intrinsic brightness of magnitude 7.0 to survive. The most recent estimates of ISON's brightness place it just above this threshold. If it survives, the nucleus could still break up due to solar heating and tidal forces. The dramatic appearance of Comet West in the March 1976 predawn skies was partly the result of the comet's nucleus breaking apart around the time of perihelion. This was also the case for Comet Lovejoy in 2012.

Based upon my five decades of observing comets, I feel that the predictions I made in last January's issue (page 57) will still largely be met. The comet should be briefly visible in daylight on November 28–29. To see it, observers will need to take adequate precautions because of the comet's proximity to the Sun (see page 32). ISON's brightness will quickly decline as it withdraws from the Sun, with the light from the waning Moon conspiring to dim the display after December 15th. By Christmas the head of the comet could well be nearing the limits of visibility with the naked eye.

It's the development of Comet ISON's tail that offers the biggest uncertainty. Historically, the Kreutz sungrazing comets and the Great Comet of 1680 unfurled enormously long, almost perfectly straight tails that rank among the longest ever seen. But these were old comets that also happened to be rich in volatile ices, as well as dust. We now know that ISON is a new comet that currently seems exceptionally dust-rich but perhaps ice-poor, leading one longtime comet scientist to characterize it as a "dust-ball" comet.

The recent Comet PanSTARRS was also a very dust-rich comet. Its anticipated sweeping naked-eye tail never developed, remaining quite stubby and visually unimpressive. Although early predictions suggested that Comet ISON would have a truly spectacular tail in the morning skies of December, recent estimates suggest a much shorter and more highly curved tail. As such, we may see a tail only half as long as I had envisioned when I wrote my ISON story in the January 2013 issue. Whatever comes to pass, I still think that ISON's December showing will impress many and perhaps might yet amaze more than a few of us! ✦

*Contributing editor **John Bortle** has been observing and writing about comets for more than five decades.*

Comet ISON was still two months from perihelion when Damian Peach captured this view on September 24th. The hopes and dreams of observers ride on how the comet evolves as it heads toward its November 28th rendezvous with the Sun.

S&T: SEAN WALKER

Although many visual observers were less than impressed with Comet PanSTARRS's appearance in twilight skies, photographers fared better, as demonstrated in this March 17th image.

Dazzle or Dud?

When, where, and how to watch whatever Comet ISON becomes.

Alan MacRobert

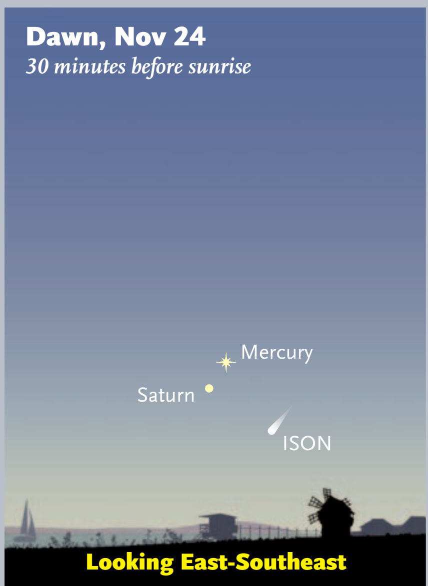
The future brightness of a promising comet is just about the toughest thing in naked-eye astronomy to predict. As John Bortle explains in the previous article, this is especially true for fresh, never-before-seen comets. So we're about to find out whether Comet ISON will come anywhere close to the inflated public expectations that were generated early on. (At one time it was billed as possibly becoming the greatest comet in history!) It's doing rather poorly as we go to press — 11th magnitude in early October — but it could yet become a fine sight during dawn in December.

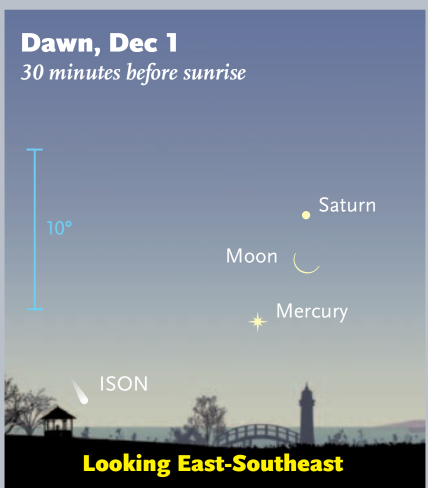
The reason is that Comet ISON still holds a wild card. It's going to swing right through the Sun's corona on November 28th, missing the Sun's photosphere (visible

Below: **The sungrazing Comet Lovejoy (C/2011 W3) put on a spectacular display for the Southern Hemisphere in December 2011 after its perihelion. If Comet ISON exceeds expectations, this is a good model for how it might appear early in December from mid-northern latitudes: displaying a long, narrow, almost straight tail pointing up from the eastern dawn horizon. Guillaume Blanchard took this shot from the Very Large Telescope site in Chile on December 22, 2011.**

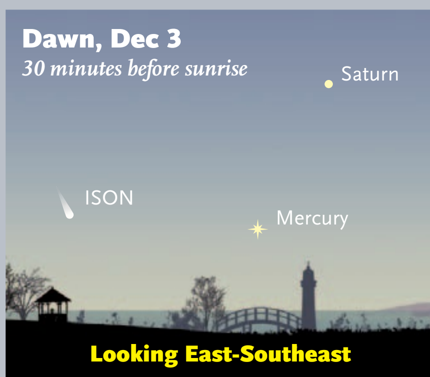
For the latest Comet ISON updates, see skypub.com/ISON.

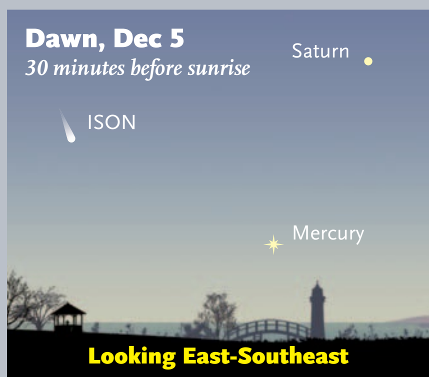
NOVEMBER As Comet ISON brightens in November, it will descend lower and lower into the brightening dawn. The comet symbols here are exaggerated; use them to pinpoint the location to examine with respect to the other plotted objects. Bring binoculars.





DECEMBER The comet emerges from perihelion back up into the dawn sky. It should fade as it climbs higher day by day. Its brightness is probably exaggerated here. The blue 10° scale bar is about the size of your fist held at arm's length. (Continued on page 33.)





surface) by less than the Sun's diameter. The intense broiling during this time — combined with the Sun's gravitational tidal effect, which will try to pull the solid nucleus apart into a line of rubble — means that anything might happen.

When and Where to Look: November

Comet ISON spends most of November diving ever lower in the eastern dawn sky as it heads toward the Sun. How much it will be brightening during this period is still anyone's guess — check the updates at **skypub.com/ISON** — but it could become dimly visible to the naked eye or more likely binoculars low in the east-southeast. Helping to guide your way will be Mercury, Spica, and Saturn, as shown in the November panels on the previous page. The comet symbols there are much brighter than anything you can probably expect to see. Use them to find the correct spot, with respect to Mercury, Spica, and Saturn, to examine as closely as you can. Mercury will be the brightest object in the area; start from there.

As November nears its end, the comet should brighten dramatically — just when it's becoming lost in the bright glare of late dawn. Ironically, it will be at its brightest very briefly in the worst of all light pollution, the daytime sky right next to the Sun! See the box below.

It will take another couple of days for the comet's head to re-emerge from the solar glare . . . whatever is left of it.

S&T: ALAN MACROBERT

Comet Spotting at Perihelion

Comet ISON will be physically closest to the Sun on November 28th (Thanksgiving Day in the U.S.) around 19^{h} Universal Time, or 2 p.m. EST. It will appear within one Sun diameter of the Sun's edge from about 17^{h} to 20^{h} UT. The comet's time of peak brightness should be from perihelion to perhaps a few hours after.

Will it be detectable then? If you block out the Sun's disk very cautiously and carefully with no momentary lapses — put the Sun behind a chimney or lamp post, not your wavering finger — you may possibly detect the comet's fuzzy pinpoint of a head with the unaided eye if the air is very clear. Do not attempt this with binoculars or a telescope!

The comet swings from due south of the Sun at 17:30 UT to closely southeast of it at 18:30, due east at 19:20, and farther northeast for several hours thereafter.

When and Where to Look: December

Again, dawn will be the time, and east-southeast will be the direction.

The comet, or its crumbled, elongated remains, will be very low in bright dawn for the first few days of December (the bottom three panels on the previous page). From about the 7th to 11th it will appear higher earlier in the dawn while the sky is beginning to lighten (facing page). After that it will be higher in a darker sky.

Unfortunately, it should fade rapidly as its viewing position improves. By the time you can see it in a dark pre-dawn sky (i.e. more than 90 minutes before sunrise), you're likely to need optical aid and the finder chart at far right. Moonlight interferes starting December 15th.

A crucial uncertainty after perihelion involves not just whether the comet's nucleus will break up, but when. Some comets crumble away to a diffuse, invisible rubble cloud while still far from the Sun. If that happens to ISON before perihelion day, don't expect much of anything at all to be visible afterward.

Comet expert Bortle says that a breakup even as late as 12 hours after perihelion will scatter the remains far enough apart to leave nothing very visible in December (page 26). But after that, the story reverses! A disintegration later in the game would be good news, because a rubble swarm would expose more icy surface to the solar broiling. "Such a post-perihelion breakup would very likely result in a strikingly bright and impressive tail for the comet," says Bortle, turning it into "a truly fine naked-eye sight." The hope is for a breakup to occur late enough that the fragments won't spread out to invisibility.

There's certainly precedent for this. Examples of a breakup turning a comet spectacular are Comet West in 1976 (top of page 27) and Comet Lovejoy in 2011 (page 30).

Another hopeful sign: a study last spring using the Hubble Space Telescope estimated Comet ISON's nucleus to be up to 3 miles (5 km) wide. That's probably several times the diameter of Lovejoy's nucleus. The bigger the nucleus, the more stuff there will be to blow off.

So expect little, be ready for a lot, and enjoy one of the few aspects of visual astronomy that's just not very predictable. ✦

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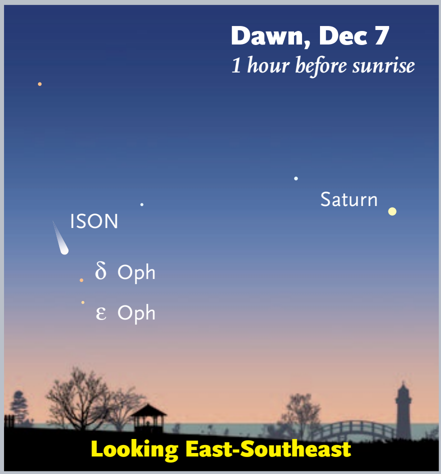
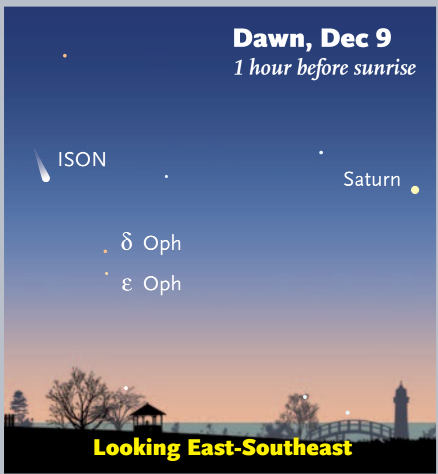
*Senior editor **Alan MacRobert** remembers the post-perihelion dazzle of the sungrazing Comet Ikeya-Seki in 1965 and the dud of Comet Kohoutek in 1973–74.*





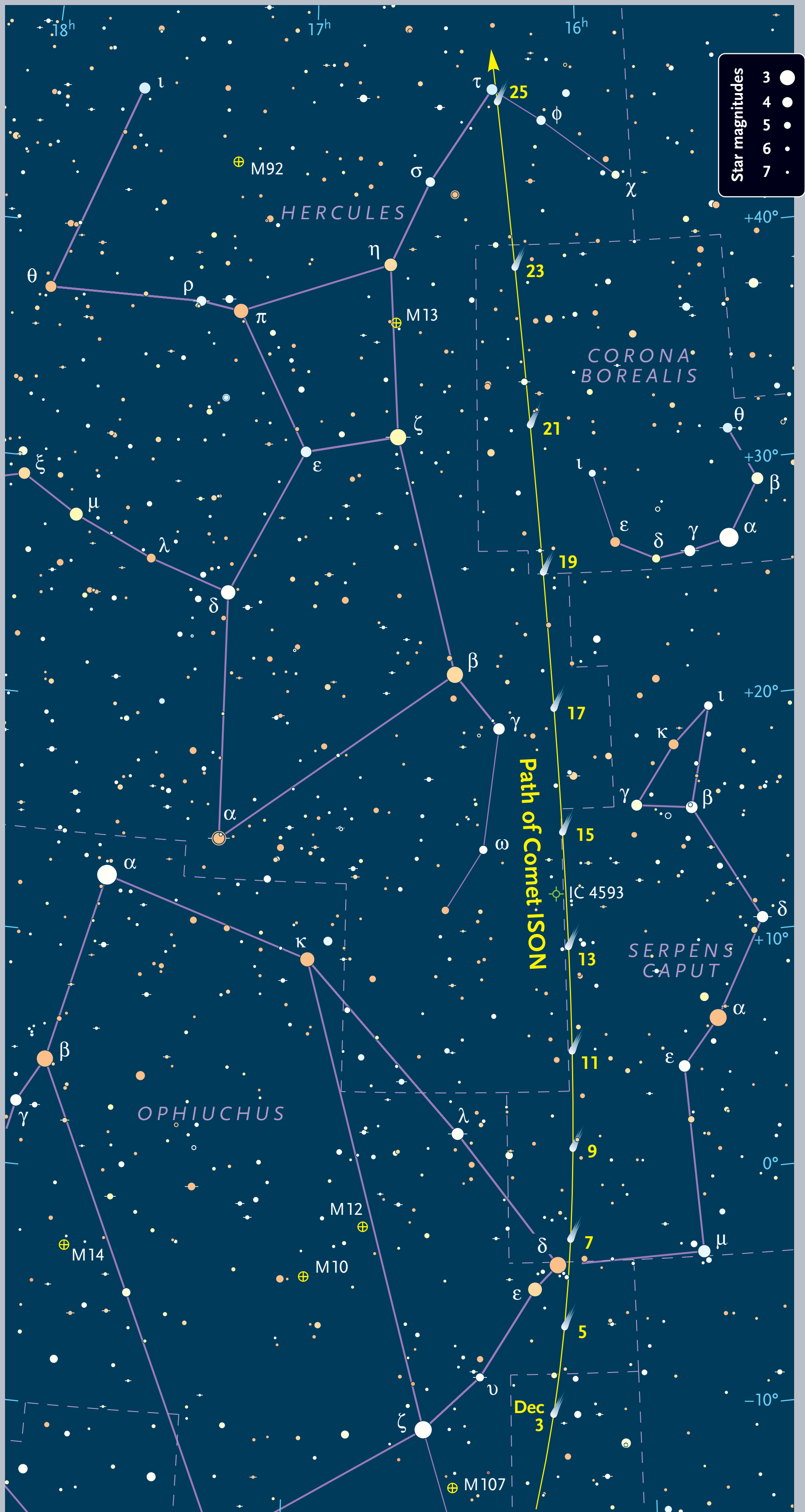


CHART AT RIGHT Only as the comet fades away will it finally climb high into the eastern pre-dawn darkness, crossing Serpens, Hercules, and Corona Borealis. The comet symbols here are plotted at 0:00 Universal Time on the dates indicated, about a half day before the pre-dawn observing time arrives in North America. Dawn's first light begins about 90 minutes before sunrise.

Exploring the Triangulum Galaxy

If you want to see a galaxy with beautiful spiral arms and a multitude of deep-sky treasures, it's hard to beat M33.

Ted Forte

Messier 33, the magnificent spiral galaxy in Triangulum, is a paradox. Inexperienced observers often cite it as one of the hardest objects in the Messier catalog, especially if they're observing in or near a city. Yet it's visible to the naked eye in locations far from urban lights — a benchmark for sky quality.

Charles Messier usually receives credit for discovering M33, although it's quite possible that the Italian astronomer Giovanni Battista Hodierna viewed the object a century earlier. In any case, Messier independently discovered it on August 25, 1764.

The Triangulum Galaxy resembles a child's pinwheel toy with two prominent spiral arms that curve away from the bright core in a backward S shape. So astronomers sometimes refer to it as the Pinwheel Galaxy, a nickname it shares with M101. It can be disappointing, even undetectable, in light-polluted urban environments. But under dark, transparent skies, even relatively small telescopes can reveal a remarkable degree of detail and structure.

In fact, M33 probably displays more detail through backyard telescopes than any galaxy besides our own Milky Way and the far-southern Magellanic Clouds. Its large angular size and face-on orientation give the impression of a giant, but it's actually quite modest when compared to M31 or our Milky Way. Scientists estimate it to be about 50,000 light-years across and to contain perhaps 40 billion stars, roughly one-fifth to one-tenth as many stars as in our home galaxy. It's highly probable that M33 is a gravitationally bound satellite of M31; just 650,000 light-years separate the two, and the Pinwheel exhibits some slight warping of its spiral disk, indicative of Andromeda's influence.

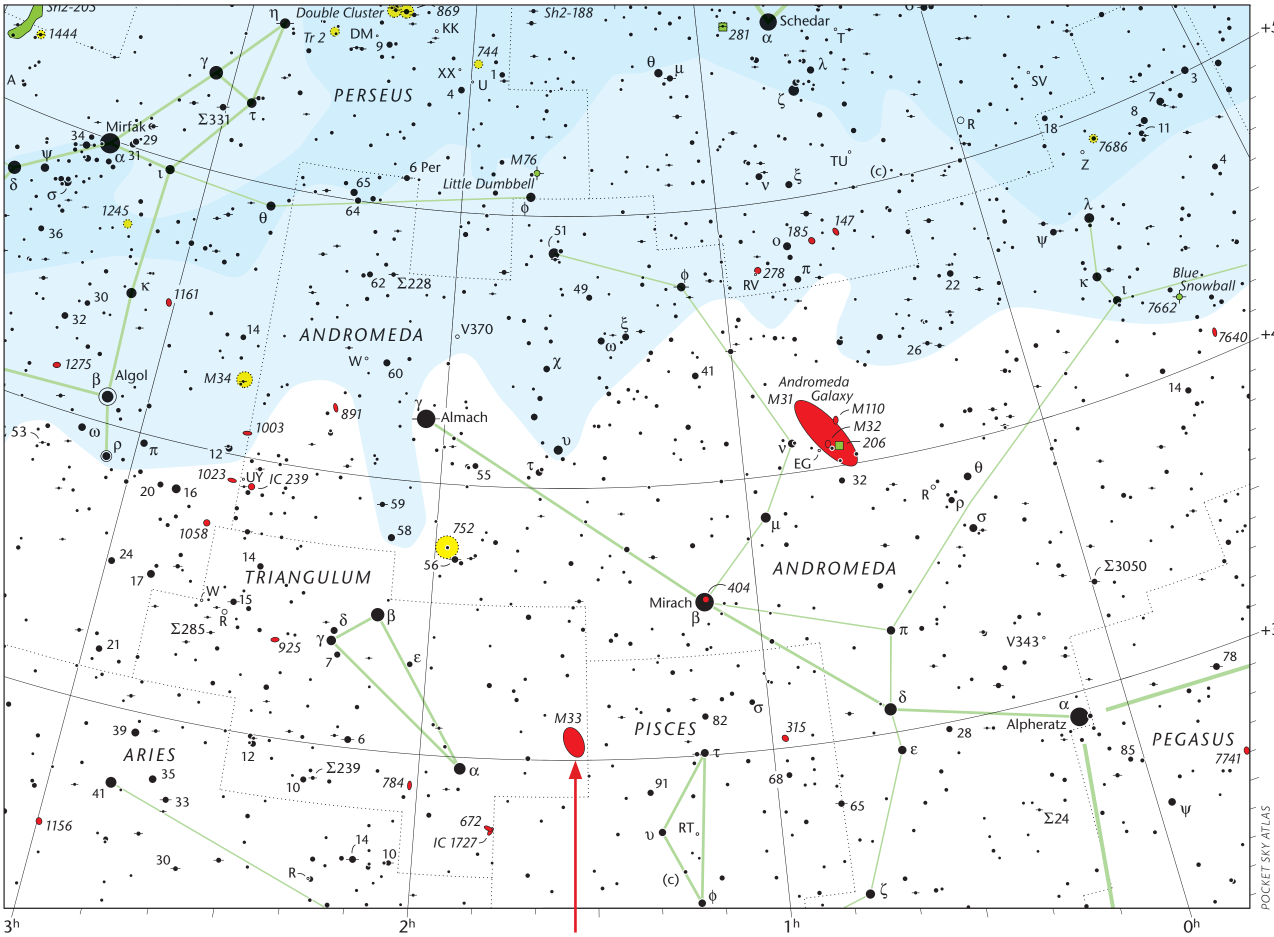
Under dark skies, my observing companions and I often detect M33 with our unaided eyes, usually using averted vision. Some naked-eye observers even report being able to discern the central condensation of the galaxy as separate from the object's overall glow.

M33's low surface brightness and large angular size suggest that it's easiest to detect through a telescope at low magnifications. Many novice observers fail in their attempts to locate the galaxy because they use too much magnification or expect to see a much smaller, brighter object. In fact, many find that M33 is easier to spot through 7× to 10× binoculars than through a telescope.

Most observers can detect the galaxy easily in a 60-mm scope, but I haven't seen any trace of spiral structure at that aperture. I need at least a 4-inch scope and excellent conditions to view even a hint of the pinwheel arms. At 8 inches of aperture, M33 is definitely mottled, and I can differentiate the larger H II regions (luminous clouds of partially ionized gas).

The largest and easiest H II region to spot is **NGC 604**, which lies near the tip of the galaxy's main northern arm. It appears disconnected, lying well beyond the brightest segment of the arm, but it's bright enough to be very obvious. A novice observer might easily mistake it for

M33 is the second-nearest spiral galaxy to our Milky Way. This image from the 8-meter Subaru Telescope in Hawaii shows far more detail than you can see at the eyepiece, but you can see many of the brighter star clusters and stellar nurseries. North is up. SUBARU TELESCOPE / NAOJ

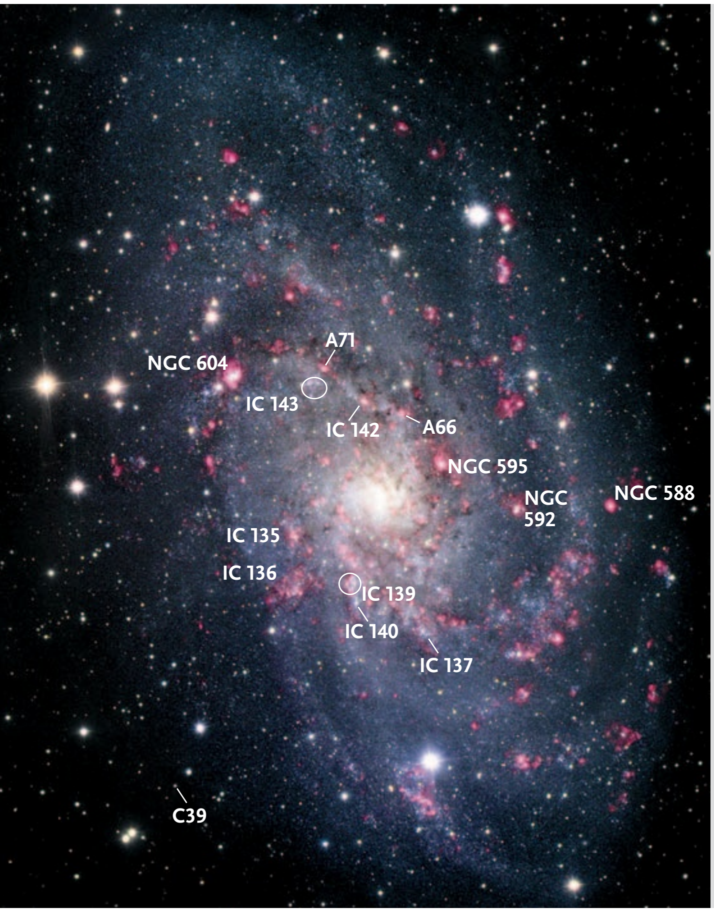


M33 is relatively easy to find between the brightest stars in Triangulum and Andromeda. M33 is close to the Andromeda Galaxy both in the sky and in space, and is probably gravitationally bound to its larger neighbor.

an unrelated object resembling an elliptical galaxy. This giant star-forming region is perhaps the largest stellar nursery in the Local Group, about 40 times larger than the Orion Nebula (M42) in terms of volume. William Herschel discovered NGC 604 two decades after Messier first observed M33. A narrowband nebula filter helps to define the cloud's boxy, irregular shape. The fact that a filter scarcely dims NGC 604 is evidence that we're really seeing an emission region, and not just the combined glow of the estimated 200 giant stars that comprise its core. Although several of the other large H II regions show some response to a nebula filter, I have not noted

LEFT: ADAM BLOCK / NOAO / AURA / NSF
RIGHT: NASA / HUBBLE HERITAGE TEAM (AURA / STSCI)

NGC 604 is the largest known star-forming region in our Local Group of galaxies. The nebula is about 1,300 light-years across, and its brightest stars contain 100 or more solar masses. The Tarantula Nebula in the Large Magellanic Cloud probably contains more stars, but it's smaller in size. NGC 604 is the reddish region in the upper center in the wide-field image on the far left. The zoom-in image on the near left was taken by the Hubble Space Telescope.



Objects Within M33 Described in This Article

Name	RA	Dec.	Author's Observation Notes (197× and 262× in an 18-inch telescope)
NGC 588 (A27)	$1^h 32.8^m$	+30° 39′	Round, less obvious than other NGC knots
NGC 592 (A59)	$1^h 33.0^m$	+30° 35′	Smallish, but easy to spot
NGC 595 (A62)	$1^h 33.8^m$	+30° 42′	Large and bright oval masked by nearby core
NGC 604 (A84)	$1^h 34.5^m$	+30° 47′	Very bright, visible in small scopes; see text
IC 135 (A100)	$1^h 34.3^m$	+30° 37′	Bright, elongated, isolated knot
IC 136 (A101)	$1^h 34.3^m$	+30° 34′	Larger, elongated, mottled knot
IC 137 (A12)	$1^h 33.6^m$	+30° 31′	Large, formless glow in the southern spiral arm
IC 139 (A4)	$1^h 34.0^m$	+30° 34′	Together with IC 140, bright knot in the combined glow
IC 140 (A5)	$1^h 34.0^m$	+30° 33′	Together with IC 139, bright knot in the combined glow
IC 142 (A67)	$1^h 33.9^m$	+30° 45′	Stellar knot in the northern arm
IC 143 (A75)	$1^h 34.1^m$	+30° 47′	Elongated knot in the northern arm
A66	$1^h 33.8^m$	+30° 45′	Large, bright patch in the northern arm
A71	$1^h 34.1^m$	+30° 48′	Bright spot adjacent to IC 143
C39	$1^h 34.8^m$	+30° 22′	Tiny, faint, very challenging. M33's largest and brightest globular cluster

The various objects described in this article are labeled. If located under dark skies, telescopes with apertures of 8 inches and larger can reveal most of these objects to a visual observer. The background image is courtesy of Robert Gendler.

very much improvement in their visibility.

Most casual observers will record M33 as a large oval glow of very low surface brightness, with a brighter, almost rectangular core that's elongated north-south, and NGC 604 appearing as a bright oval about 12′ northeast of the core. Observers blessed with larger apertures and/or pristine skies are sure to detect a mottled spiral structure. They can also trace two prominent arms that gracefully extend outward north and south for several arcminutes, with lesser arms appearing as a knotty, speckled halo with little definition.

But it's possible to go much deeper. The patient, persistent observer will be rewarded with a multitude of the Pinwheel's intricate and beautiful details. A pioneering guide, complete with an excellent labeled photograph, appeared in *Observing Handbook and Catalogue of Deep-Sky Objects* by Christian B. Luginbuhl and Brian A. Skiff (Cambridge University Press, 1990).

S&T contributing editor Alan Whitman observed three dozen of the more prominent knots with a 25-inch scope, summarizing the results in the December 2004 issue. Whitman's friend Guy Mackie also detected 12 of those objects through a 12.5-inch Dobsonian.

Luginbuhl and Skiff started the tradition of naming knots within M33 based on a paper published in the November 1980 *Astrophysical Journal Supplement Series* by Roberta M. Humphreys (University of Minnesota) and Allan R. Sandage (Carnegie Observatories). The names consist of the letter A followed by a number.

Five regions within M33 have also earned their own NGC designations. Four of those (NGC 604, 588, 592, and 595) are emission knots. NGC 603 is a triple star that Lord Rosse misidentified as a nebulous object. Ten features have IC numbers, based on observations in 1889 by French astronomer Guillaume Bigourdan. Bigourdan was attempting to identify nebulae whereas Humphreys and Sandage were concerned with stellar associations. Because most of these associations are involved in emission nebulae, the two lists have a strong, but not necessarily exact, correlation.

More than two-dozen individual clusters, stellar associations, and H II regions are visible as distinct objects in amateur-sized scopes, but many do not reveal themselves without effort. And since moderate to high powers are necessary to detect many of the objects, the observing conditions must allow for the higher magnifications required. A detailed finder chart will help you to mine M33's riches. There is detail enough to occupy an observer for many hours, or many nights. Isn't it incredible that so much structure can be gleaned from 2.6 million light-years away? If you're like me, you'll revisit M33 at every opportunity, building a collection of its tantalizing treasures over repeated sessions. What follows are some of the more accessible features.

After NGC 604, **NGC 595** is perhaps the brightest and largest of the H II regions, but it might be overlooked, because it lies just 4′ northwest of the galaxy's core. Reportedly discovered by Heinrich Ludwig d'Arrest on October 1, 1864, it too is a giant star-forming region, excited into visibility by the hot young stars embedded within. It appears oval with a slightly brighter center.

Howard Banich created this sketch while observing M33 through a 28-inch Newtonian at magnifications ranging from 106× to 1,210×.

NGC 592, smaller and more starlike, is easier to spot, lying in a blank area west of the core and inside the curve of the southern spiral arm. Farther west, on the outskirts of that arm, is the larger but fainter **NGC 588**, which appears round. D'Arrest discovered both of these regions as well.

Three fairly bright knots define the brightest part of the southern spiral arm. **IC 139** and **IC 140** are close together and only occasionally separate into discrete blobs. A little farther from the core, the southern arm turns west and is seemingly hinged on **IC 137**, a larger whorl that appears as a formless glow.

Conspicuous in their relative isolation, two nebulous stellar associations lie to the east of the southern arm, southeast of the core. **IC 136** and **IC 135** glow with the combined light of their component stars and surrounding gas. Both are a little elongated and nearly resolvable; in my 18-inch Dob they give me the distinct impression that with just a tiny bit more resolution, individual stars would pop into view.

The northern spiral arm traces a crescent-shaped arc of nebulosity from NGC 604 in the northeast to the galaxy's core, wrapping just east of NGC 595. The mottled appearance is punctuated by brighter snags that can be teased into discrete objects with effort. Chief among them, perhaps, are **IC 143** and **IC 142**. IC 143, an elongated glow, is less obvious than the brighter, smaller IC 142, which appears stellar. Other concentrations of starlight and nebulosity within the northern arm can appear as distinct knots. **A71** is a bright spot adjacent to IC 143; **A66** is another bright patch in the arm.

Farther from the galaxy's main body, nearly a dozen other stellar associations and star-forming regions are detectable. There isn't room to describe them all here, but let's explore one more area. NGC 603, the triple star that Lord Rosse noted as a nebulous object, lies 28′ southeast of M33's core. It can indeed appear nebulous and requires high magnification to resolve. In the same medium-power field is a 10th-magnitude double star that can point the way to M33's brightest globular cluster, designated as **C39**. You might need a detailed finder chart to pinpoint this very faint stellar spot. I can't think of a more distant globular cluster that can be seen in an amateur-sized instrument, so it's well worth the effort just to extend your personal record.

I enjoy these and many more of M33's features with my 30-inch Dobsonian reflector, which has extended my life's list of treasures. I hope I have whetted your appetite to do the same. ✦

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*Contributing editor **Ted Forte** enjoys the dark skies of his backyard observatory outside of Sierra Vista, Arizona. His column* The Backyard Astronomer *appears monthly in the* Sierra Vista Herald.

New Product Showcase

◄ **PORTABLE GO TO** The Danish company Track The Stars rolls out its TTS-160 Panther (starting at €3,887, or about U.S. $5,200), a modular Go To portable telescope pier. TTS-160 is an alt-azimuth tracking pier using an innovative counterweight system for maximum portability. The mount features 120-mm and 100-mm bronze worm gears in its altitude and azimuth axes for smooth tracking, driven by DC servo drives with optical encoders for precise slewing up to 3.5° per second. The mount can support telescopes up to about 50 pounds (23 kilograms), depending on the telescope's length, and accepts the popular Losmandy D-style mounting plate system. Its Go To computer includes all the Messier, NGC, and IC catalogs, plus all the planets, and it connects to a PC via a RS-232 interface using the LX200 protocol. The TTS-160 is capable of deep-sky astrophotography with the optional de-rotator attachment and accepts autoguider commands via a standard ST-4 port. See the manufacturer's website for additional options, accessories, and features.

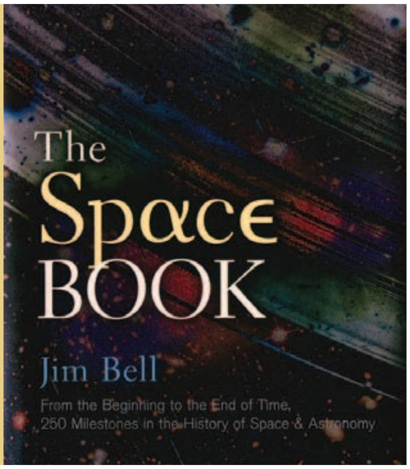
Track the Stars
Enghoejvej 17, 3660 Ganloese, Denmark
+45-5057-3550; www.trackthestars.com

▲ **WEB-READY CAMERA** Apogee Imaging Systems announces the Aspen Series of CCD cameras. The camera design features improved stray-light baffling, an anti-reflection-coated silica chamber window for maximum light throughput, and a robust shutter rated for more than 5 million cycles. The camera includes USB 2.0 interface and a built-in Ethernet interface with an internal web server for internet-ready remote operation. Its thermoelectric cooling with forced air is capable of temperatures of 70°C below ambient with ± 0.1°C stability. The Aspen is available with a wide array of detectors, including full-frame, interline transfer, or spectroscopy CCDs, and supports multiple binning modes. Each camera comes with a 12-volt power brick and is compatible with the company's filter wheels and other accessories. See the manufacturer's website for additional information.

Apogee Imaging Systems
151 N. Sunrise Ave. Suite 902, Roseville, CA 95661
916-218-7450; www.ccd.com

ASTRO FACTS Planetary Society president, Arizona State University scientist, and frequent *Sky & Telescope* contributor Jim Bell has a new tome, *The Space Book*, which explains 250 scientific milestones in an easy-to-understand format. Everything from the Big Bang up to and including the end of time are covered in a beautifully illustrated, chronological format. Subjects include the birth of the Sun and planets, the invention of the telescope, and the Milky Way's inevitable collision with the Andromeda Galaxy (M31) in the distant future. Each of the 250 milestones is distilled into single-page summaries accompanied by picturesque (and occasionally amusing) illustrations or photographs on its facing page. Sterling, ISBN 978-1-4027-8071-4, hardcover, 528 pages.

Sterling Publishing
387 Park Ave. South, New York, NY 10016
212-532-7160; www.sterlingpublishing.com



New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information contact the manufacturer or distributor. Announcements should be sent to nps@SkyandTelescope.com. Not all announcements can be listed.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Deadline for submissions: Midnight EST December 31, 2013
Finalists posted on our website for voting: January 8, 2014
Voting ends: January 22, 2014
Winners announced: April 2014 Issue
SkyandTelescope.com/photocontest
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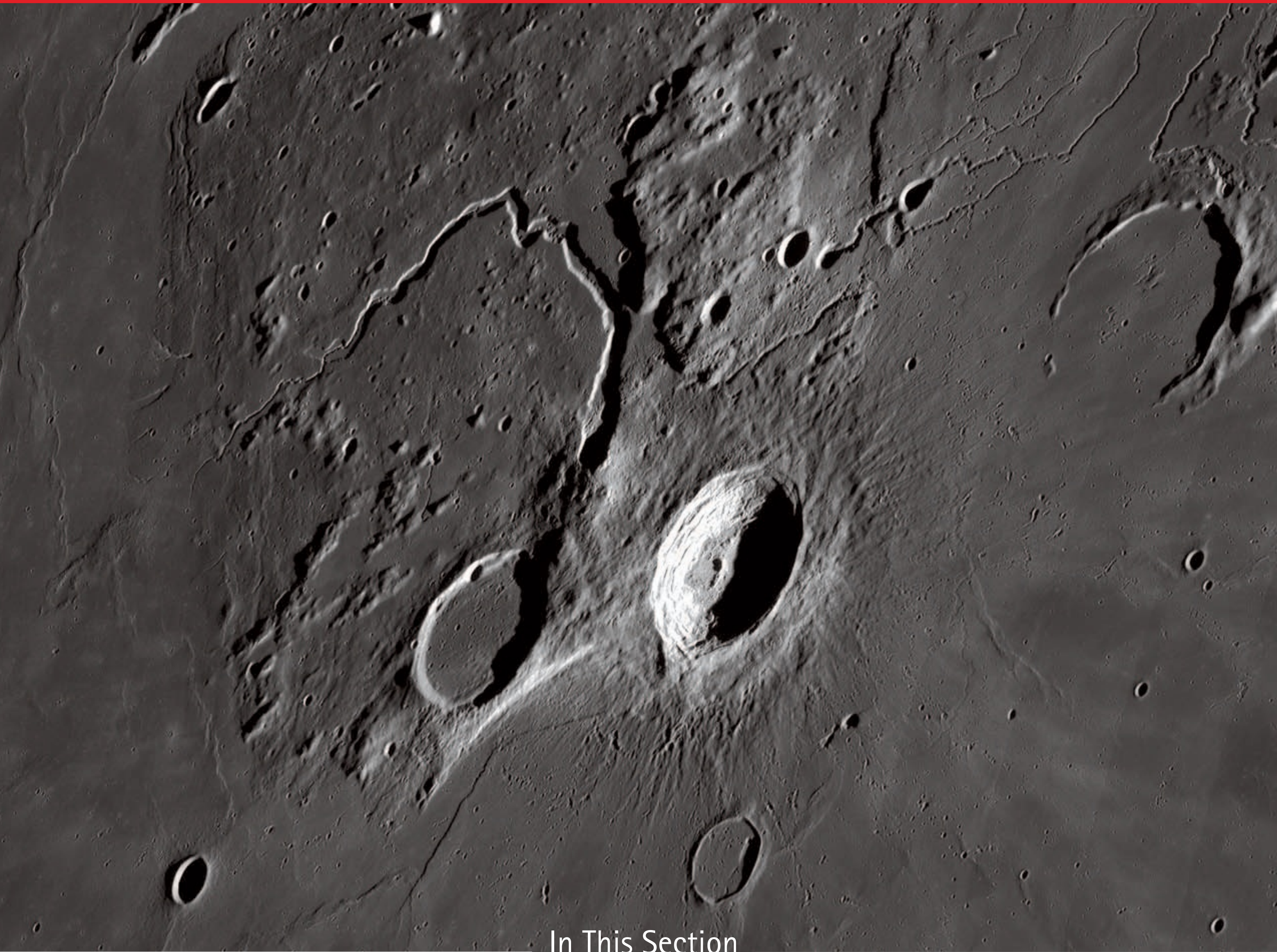


In This Section

Transient lunar phenomena have often been reported in and around the bright crater Aristarchus; see page 54.

PHOTOGRAPH: NASA / GSFC / ASU

Sky at a Glance

DECEMBER 2013

1 **DAWN:** The thin waning crescent Moon shines a little below Saturn and upper right of Mercury low in the east-southeast 60 to 30 minutes before sunrise. And the long, curved tail of Comet ISON may be visible to their left, as shown on page 31.

5 **DUSK:** Venus shines lower left of the waxing crescent Moon; see page 48.

9, 10 **EVENING:** Jupiter shines just 15′ from the 3.5-magnitude star Delta (δ) Geminorum.

13–14 **ALL NIGHT:** The Geminid meteor shower peaks this night. The best viewing time is the hour between moonset and the first light of dawn on the 14th; see page 50.

15 **EVENING:** Aldebaran shines 2° to 4° lower right of the Moon (for North America).

18 **EVENING:** Jupiter shines about 5° left of the just-past-full Moon.

21 **THE SHORTEST DAY OF THE YEAR** in the Northern Hemisphere. Winter begins at the solstice, 12:11 p.m. EST (9:11 a.m. PST).

25–27 **DAWN:** The waning Moon passes Mars on the 25th and 26th and Spica on the 26th and 27th.

27–30 **DAWN:** Mars shines within 1° of the famous double star Gamma (γ) Virginis, also known as Porrima.

28 **DAWN:** Alpha (α) Librae, also called Zubenelgenubi, shines 1° to 3° lower left of the waning crescent Moon in North America, with Saturn 5° farther left. The Moon occults (covers) Alpha Librae for Hawaii.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

Planet	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	Visible November 9 through December 7		SE
Venus	SW		
Mars		E	S
Jupiter	NE	S	W
Saturn			E SE

Moon Phases

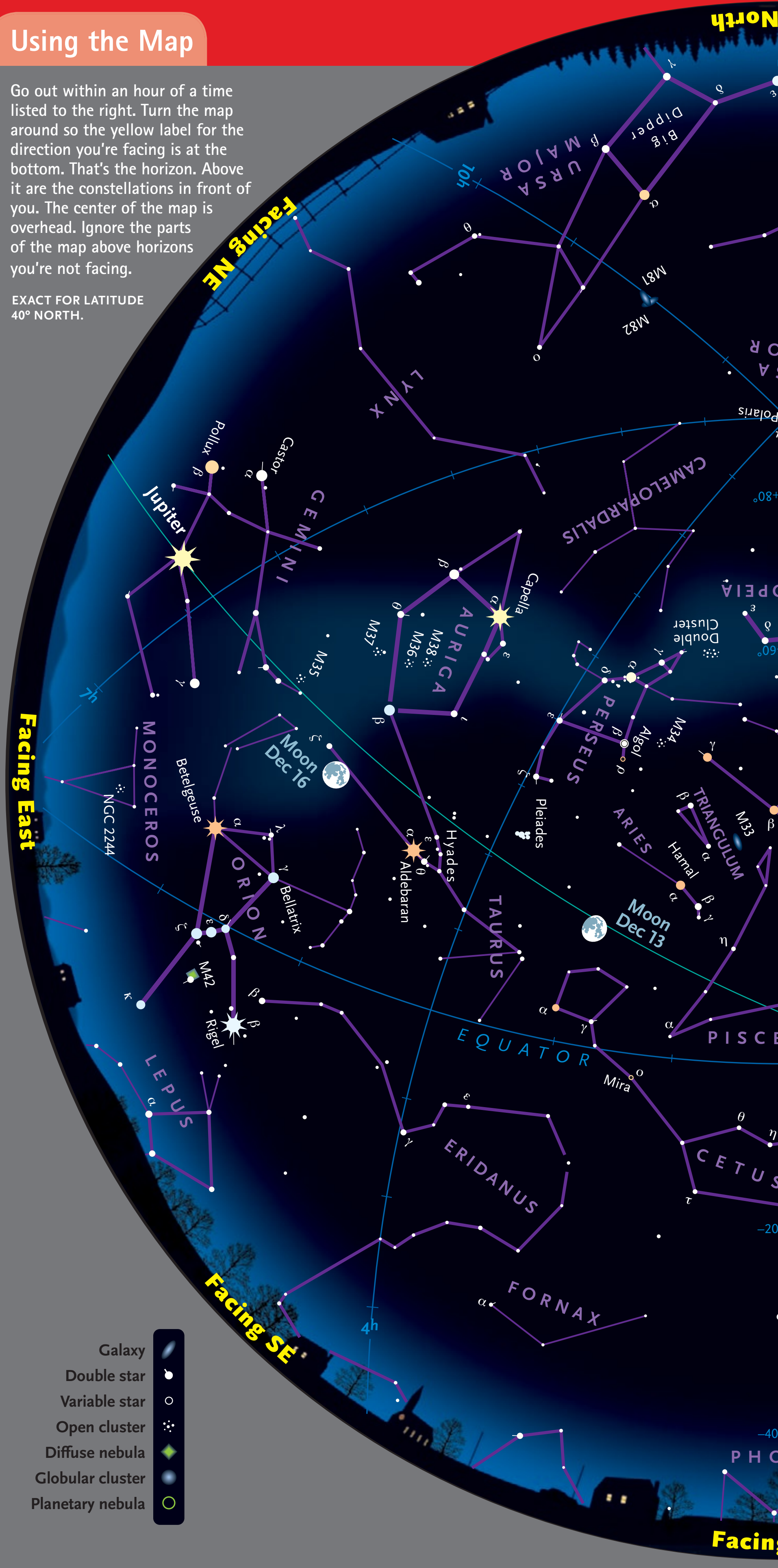
New	December 2	7:22 p.m. EST	
First Qtr	December 9	10:12 a.m. EST	
Full	December 17	4:28 a.m. EST	
Last Qtr	December 25	8:48 a.m. EST	

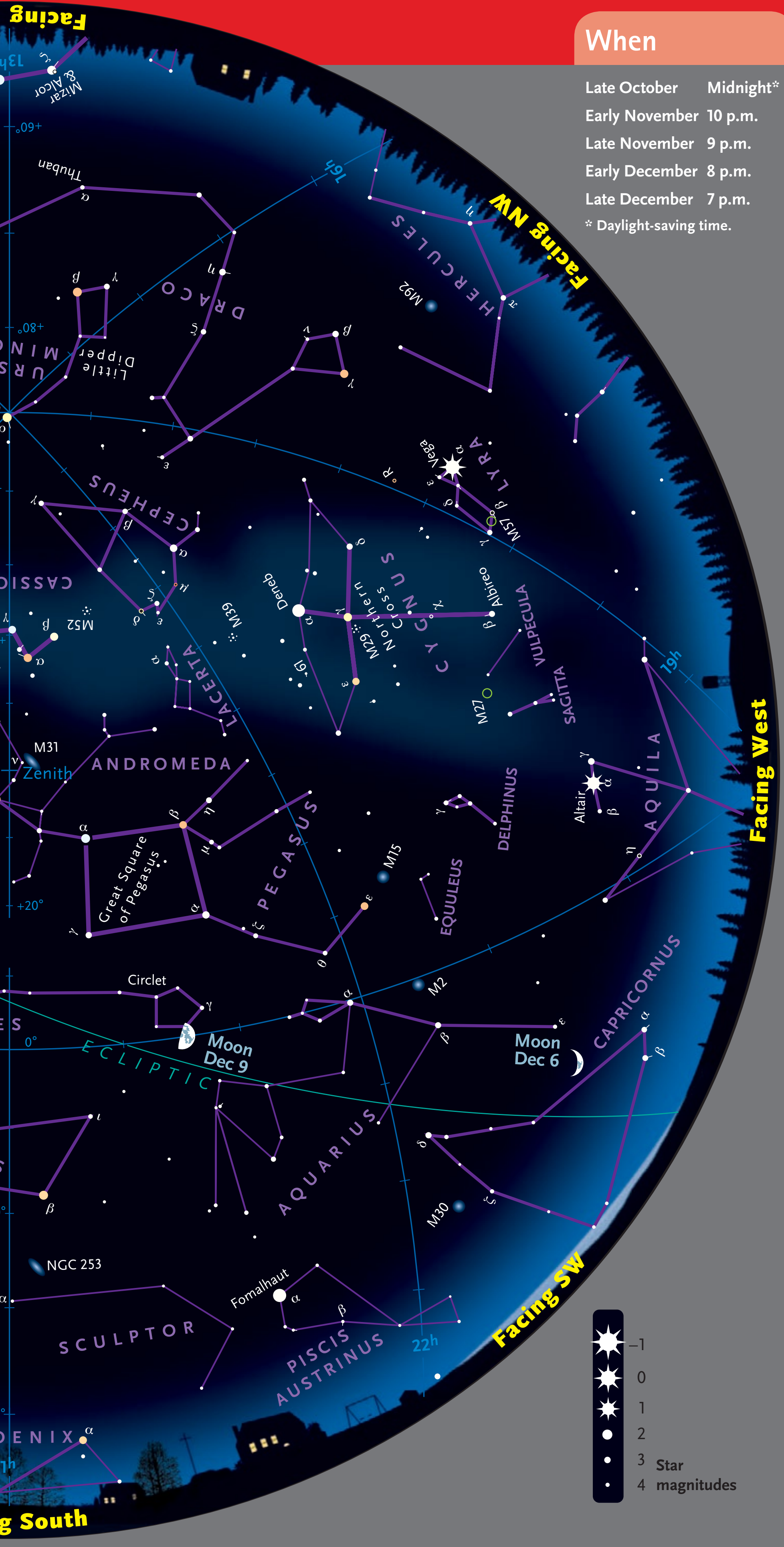
SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

Late October	Midnight*
Early November	10 p.m.
Late November	9 p.m.
Early December	8 p.m.
Late December	7 p.m.

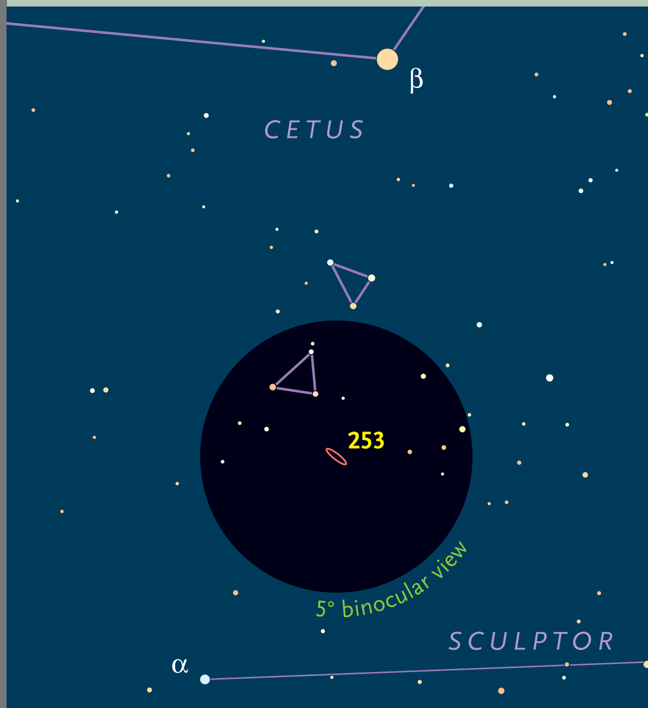
* Daylight-saving time.

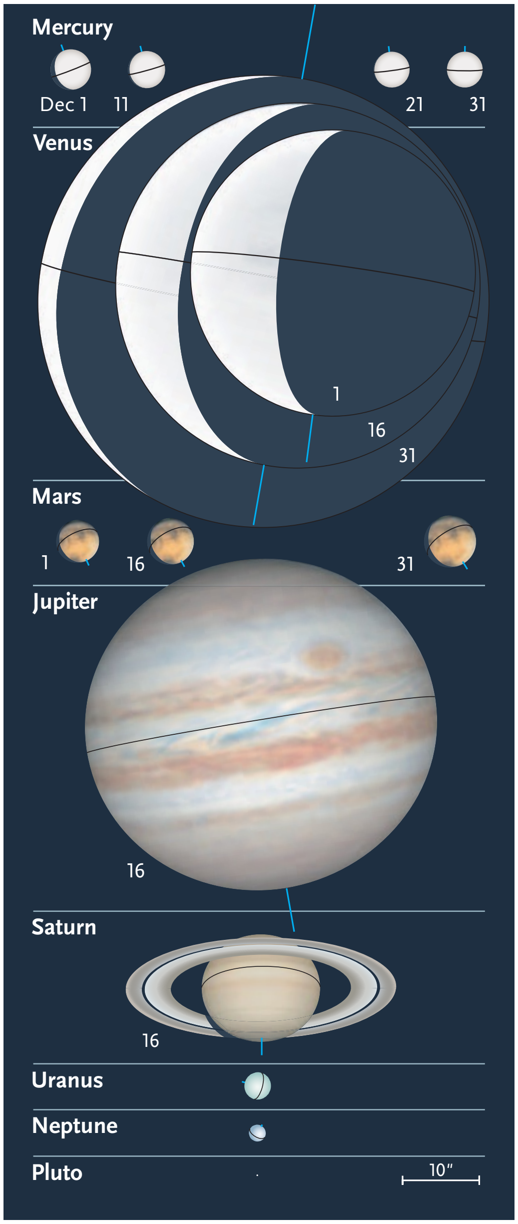
Remarkable NGC 253

Imagine you're at a crowded cocktail party and find yourself standing with the gathering's hostess while she chats amiably with another guest. "Yes," she says, "that's him, in the gray suit, standing next to the potted plant." Surprised, her friend replies, "But he just seems so undistinguished and ordinary — are you sure he's the one?" "Certainly," the hostess replies, "he's truly a remarkably interesting fellow once you get to know him!" In the celestial cocktail party of the night sky, the guest list is loaded with individuals that are more impressive than they might first appear. Galaxy **NGC 253** in Sculptor is a good binocular example.

You can locate it off Beta (β) Ceti by gliding south past a pair of small triangles of 5th- and 6th-magnitude stars. The galaxy is a little south and west of the second triangle. In my 15×45 image-stabilized binos under dark skies, NGC 253 shows up as a small but distinctly elongated streak of pale light. Even my 10×30s are sufficient to show the 7.8-magnitude galaxy's shape and orientation. Interesting, if not impressive.

So let's get to know NGC 253 a little better. For one thing, it has a couple of aliases, including the Silver Dollar Galaxy and Caldwell 65. Perhaps its biggest claim to fame is that it's a so-called starburst galaxy — an island universe glittering with a bumper crop of fresh, newly formed stars. It was discovered in 1783 by Caroline Herschel, William Herschel's sister and devoted observing partner. NGC 253 is also something of a big shot, being the brightest member of the Sculptor Galaxy Group, the nearest gathering to our own Local Group. A rather interesting fellow, I'd say. ✦





Sun and Planets, December 2013

	December	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$16^h\ 28.1^m$	–21° 46′	—	–26.8	32′ 26″	—	0.986
	31	$18^h\ 40.3^m$	–23° 07′	—	–26.8	32′ 32″	—	0.983
Mercury	1	$15^h\ 26.1^m$	–17° 26′	15° Mo	–0.6	5.3″	89%	1.267
	11	$16^h\ 28.7^m$	–21° 42′	10° Mo	–0.7	4.8″	96%	1.386
	21	$17^h\ 35.5^m$	–24° 20′	5° Mo	–1.0	4.7″	99%	1.440
	31	$18^h\ 45.3^m$	–24° 50′	2° Ev	–1.3	4.7″	100%	1.437
Venus	1	$19^h\ 33.9^m$	–24° 41′	43° Ev	–4.9	37.3″	31%	0.447
	11	$19^h\ 55.7^m$	–22° 38′	38° Ev	–4.9	43.8″	22%	0.381
	21	$20^h\ 03.7^m$	–20° 27′	30° Ev	–4.8	51.5″	13%	0.324
	31	$19^h\ 54.7^m$	–18° 26′	18° Ev	–4.5	58.9″	5%	0.283
Mars	1	$11^h\ 49.0^m$	+3° 12′	73° Mo	+1.2	5.6″	91%	1.664
	16	$12^h\ 17.5^m$	+0° 17′	80° Mo	+1.1	6.1″	91%	1.523
	31	$12^h\ 43.8^m$	–2° 22′	88° Mo	+0.9	6.8″	90%	1.375
Jupiter	1	$7^h\ 23.9^m$	+22° 05′	139° Mo	–2.6	44.9″	100%	4.392
	31	$7^h\ 09.7^m$	+22° 36′	173° Mo	–2.7	46.8″	100%	4.214
Saturn	1	$15^h\ 00.4^m$	–14° 52′	22° Mo	+0.6	15.4″	100%	10.782
	31	$15^h\ 12.9^m$	–15° 40′	49° Mo	+0.6	15.8″	100%	10.494
Uranus	16	$0^h\ 31.9^m$	+2° 41′	104° Ev	+5.8	3.6″	100%	19.768
Neptune	16	$22^h\ 19.5^m$	–11° 09′	69° Ev	+7.9	2.3″	100%	30.323
Pluto	16	$18^h\ 44.8^m$	–20° 16′	17° Ev	+14.2	0.1″	100%	33.504

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

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

The Sun and planets are positioned for mid-December; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

Fred Schaaf *welcomes your comments at fschaaf@aol.com.*

Fred Schaaf

The Unextinguished Hearth

The fire of human imagination mirrors the fire of the stars.

Drive my dead thoughts over the universe
Like withered leaves to quicken a new birth!
And, by the incantation of this verse,

Scatter, as from an unextinguished hearth
Ashes and sparks, my words among mankind!
Be through my lips to unawakened earth

The trumpet of a prophecy! O Wind,
If Winter comes, can Spring be far behind?
— Percy Bysshe Shelley, *Ode to the West Wind*

Last month, I began this column quoting just the last sentence of the poem above. This time, I present several stanzas to give context to the truly magical phrase that Shelley uses. This phrase can be applied to the unending wonder that pours down to us from the starry universe and which we in turn find stirred up from within us: the "unextinguished hearth."

December and the universal hearth. I've written before how each year when I'm stargazing on late-autumn evenings I start smelling the smoke from my neighbor's fireplace. I've told how the thin Milky Way band around Cassiopeia hangs high in the north like smoke from the fire that I'm smelling. It continues to the northwest, where it puffs into the descending Cygnus Star Cloud.

By around 9 p.m. in early December, Perseus flies high above the linked patterns of Auriga the Charioteer and Taurus the Bull. Below Taurus and Auriga, radiant Orion and Gemini are ascending the eastern sky, and Procyon and Sirius have recently risen. As we stare at them, it's easy to imagine these brightest stars in the heavens to be the glowing ashes and sparks blowing up from a hearth. It's a hearth that's unextinguishable — at least for untold billions of years.

Even when there's no aroma from a human fireplace, we can imagine something lighting up the universe and sending the fire forth in the form of stars. As scientists, we say that "something" is nuclear fusion, mostly hydrogen atoms being fused together into helium, and in the process releasing great amounts of radiant energy. By following this system of understanding called science, we can learn more and more about the otherwise undiscoverable nature of stars, about their long, strange lives and bizarre, transformational deaths.

NASA / HUBBLE HERITAGE TEAM / STSCI / AURA

Our galaxy forges several new stars every year. This false-color image from the Hubble Space Telescope shows a bow shock around a very young star in the Orion Nebula.

We can also look at the stars with our unaided eyes and be thrilled by the direct experience of these hearts of fire shining in darkness. This puts us in the state of pure wonder that young children feel — young children and perhaps our greatest scientists, who rethink our most basic concepts and sometimes come up with fundamentally new ways to visualize the truths of nature. Humans in a state of wonder tend to put forth their own glowing ashes and sparks: creative ideas, insights, and appreciations that can fire up the people around them.

The hearth within. Whatever fire is within our minds only begins to fade if we grow tired of our experience of the world. But in astronomy, some sights are so amazing that it seems impossible to tire of them: Venus at peak brightness (as it is at dusk in early December), Sirius, Orion, the Pleiades, Saturn in a telescope.

Do you want another example? Each great comet is unique — an individual, varying every night, sporting a potentially constellation-spanning tail that gives the impression of a vast extended flame. Let us hope that the universe's unextinguished hearth gives us such a comet in December 2013. ✦

A Month for Bright Planets

Jupiter rises before Venus sets on December evenings.

Will Comet ISON be a spectacle or a disappointment in December? Even if it's a disappointment, other solar system objects will be putting on unusually good shows as 2013 comes to an end.

At dusk, Venus is at its brightest in the first part of the month. Then in the last week of December it starts setting dramatically earlier each evening, while displaying its skinny, tall crescent in telescopes and binoculars. Jupiter rises early in the evening and remains splendidly high for the rest of the night. Mars appears above the east horizon a little after midnight and is highest in the south at dawn. By then Saturn is well up in the southeast. And Mercury and Saturn may or may not be accompanied by a fine-looking comet.

DUSK

Venus is a glorious beacon low in the southwest, shining at its stunning maximum magnitude of –4.9 in early December. It starts the month setting almost 3 hours after the Sun for viewers at latitude 40° north, though it's only about 20° high at sunset. Even by December 22nd, when the interval between sunset and Venus-set has shrunk to about 2 hours, the northward-trekking planet remains almost as high and still shines at magnitude –4.8.

What does change dramatically in the first three weeks of December is Venus's phase and apparent diameter. Its phase thins from 30% to 11% sunlit, while its diameter — the length of the crescent — increases from 38″ to 53″. Late in this period is a good time to try to detect Venus's phase with mounted or steadily held binoculars. A few keen-eyed people have even seen the crescent with their unaided eyes.

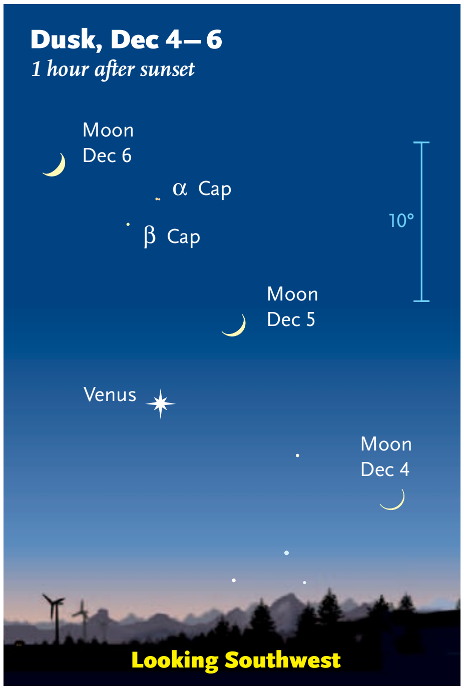
By New Year's Eve, Venus sets less than 1½ hours after the Sun and is almost 1′ wide and just 4% illuminated. The planet will go through inferior conjunction with the Sun on January 11, 2014.

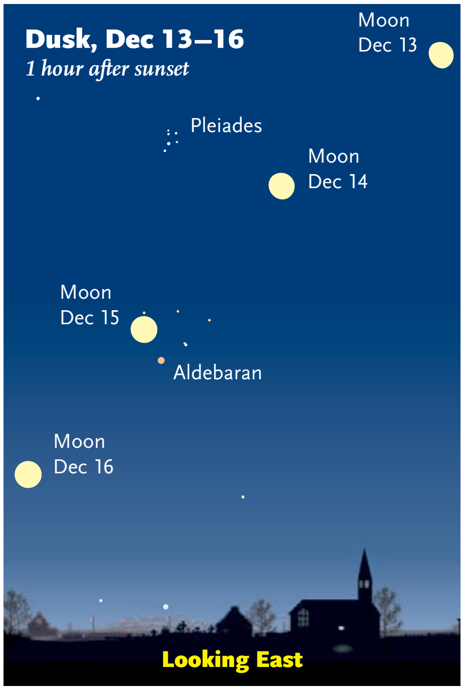
As evening twilight fades, **Uranus** (near the Pisces/Cetus border) and **Neptune** (in Aquarius) are visible in the south and southwest, respectively. See **skypub.com/urnep** for finder charts.

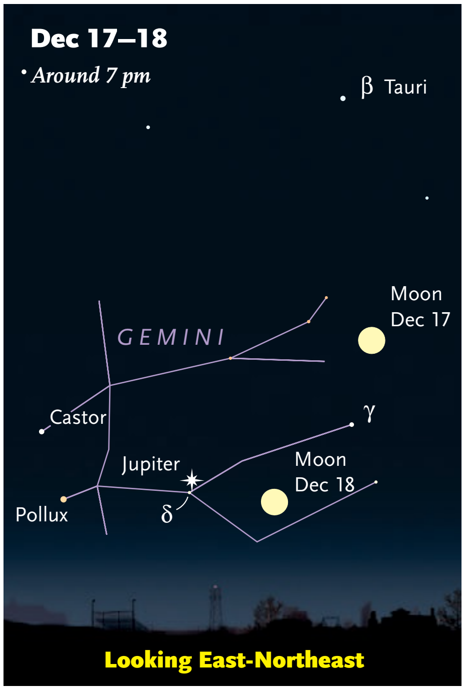
If **Comet C/2012 S1 ISON** survives its close encounter with the Sun on November 28th, it will shoot almost due north in the sky. So it might be visible both after sunset and before dawn. However, it's very low in evening twilight for the first three weeks of December, and much higher before dawn.

EVENING AND NIGHT

Jupiter, in Gemini, rises around 7 or 8 p.m. as December starts, but it rises in bright twilight, less than a half hour after sunset, at month's end. By late evening

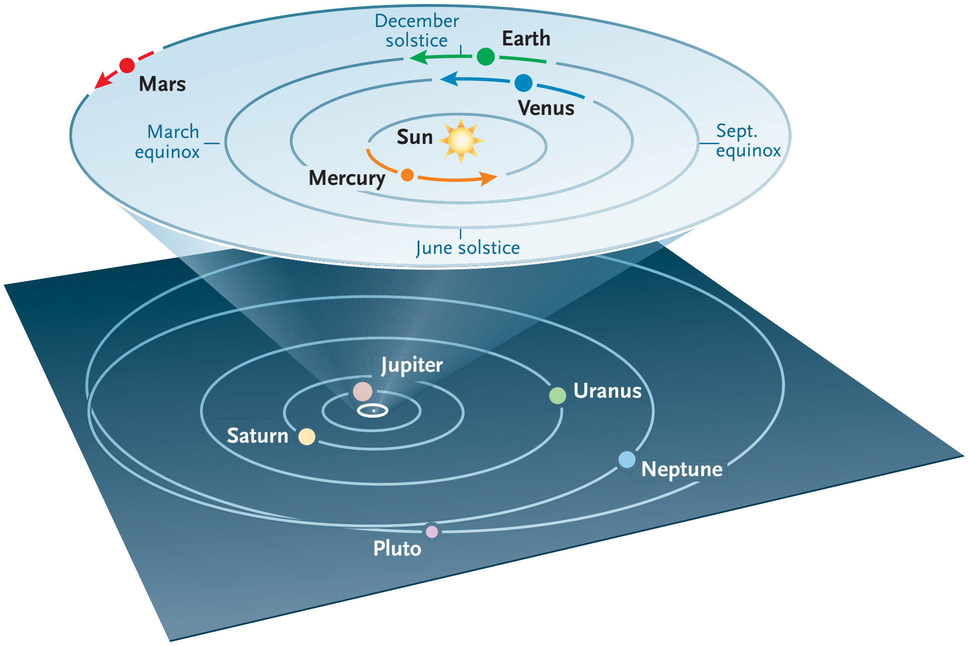






ORBITS OF THE PLANETS

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



it dominates the eastern sky. The giant planet doesn't reach opposition this year but will do so on January 5, 2014. It brightens to magnitude –2.7, and telescopes show it swelling to 47″ wide.

On the American evenings of December 9th and 10th, binoculars help show 3.5-magnitude Delta Geminorum (Wasat) just 15′ south of the retrograding Jupiter — not as close as they were back on October 4th.

DAWN

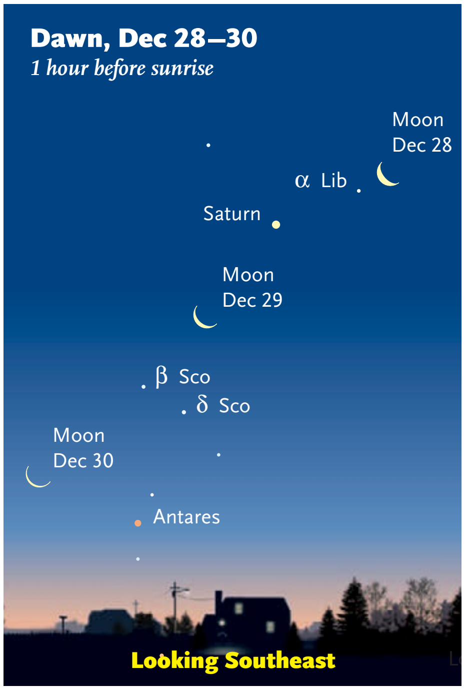
Mars comes up a little sooner after midnight each week. And as December progresses, its brilliance increases from magnitude +1.2 to +0.9. Watch the orange-yellow planet march a little more than 1° north of 3.6-magnitude Beta Virginis (Zavijava) early in the month, about ¾° north of 3.5-magnitude Eta Virginis (Zaniah) on the 17th and 18th, and a similar distance south of 2.7-magnitude Gamma Virginis (Porrima) on December 28th and 29th.

Mars is highest for telescopic observations during morning twilight, but its globe grows only from 5.6″ to 6.8″ in diameter — still too small to see much detail in most telescopes.

Comet ISON, heading rapidly north, rises higher and higher before sunrise for viewers in the Northern Hemisphere as December progresses. But how quickly will the comet's head and tail be fading? Will the tail be an intense sungrazer ribbon until at least mid-month? See page 30 for our best current prediction.

Saturn rises around 5 a.m. as December starts and 1½ hours earlier as it ends. The golden planet shines at magnitude +0.6 and is moving eastward deeper into Libra, and farther from Alpha Librae (Zubenelgenubi). Even in morning twilight Saturn is rather low in the southeast, but its rings this month open up to a glorious 21° from edgewise.

Mercury on December 1st is still in view at dawn, to Saturn's lower left. The innermost planet brightens from magnitude –0.6 to –0.8 in the first half of the month, but also appears lower each morning, and is soon lost from view. Mercury reaches superior conjunction with the Sun on December 29th.



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.

SUN AND MOON

The **Sun** reaches the December solstice at 12:11 p.m. EST on the 21st. This marks the beginning of winter in the Northern Hemisphere and summer in the Southern Hemisphere.

The **Moon** is a waning crescent between Mercury and Saturn at dawn on December 1st and a waxing crescent well to Venus's upper right at dusk on December 5th. The waxing gibbous Moon floats near Aldebaran and the Hyades on the evening of December 15th and rises not far to the right of Jupiter three nights later, now just past full. The waning lunar crescent is well to the upper right of Saturn at dawn on December 28th. ✦

The Moon and the Geminids

Rocks from a fried asteroid will streak through the mid-December moonlit sky.

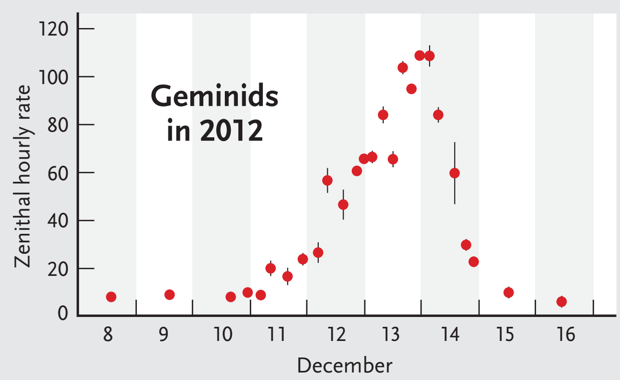
Around December 14th every year, Earth passes through the Geminid meteoroid stream. The resulting meteor shower is unusual in several ways. It's often the richest reliable shower of the year, and it seems to be strengthening over the decades. It becomes nicely active as early as mid-evening, so you don't have to wait until after midnight as with many other showers. Its meteors are relatively slow, arriving at 36 kilometers per second (80,000 mph), hardly more than half the speed of the Perseids, Orionids, and Leonids. The meteors often appear yellowish. Their deep plunges into the atmosphere betray them as dense bits of rock rather than fluffy dust clods like most cometary meteors.

And in fact they come not from a comet but a tiny asteroid, 3200 Phaethon, which is itself an oddball. It's in a small, highly elongated orbit that, every 1.43 years, brings it three times closer to the Sun than Mercury's average distance. So the Sun repeatedly shines on it 50 times more intensely than sunlight does on Earth.

BABAK TAFRESHI / DREAMVIEW.NET

The annual Geminid meteor shower is as reliable as they come. On the morning of December 14, 2009, it sent this fireball streaking over the back of Canis Major while Babak Tafreshi was waiting with an open camera shutter in the Zagros Mountains of Iran. The brightest star is Sirius. Orion at right is preparing to set.

This year the Geminid shower should peak around 6^h Universal Time on Saturday morning December 14th (1 a.m. Eastern Standard Time), ideal for North Americans, especially easterners. But the waxing gibbous Moon will be bright, just three days from full and shining for most of the night. The Moon finally sets one hour before the first glimmer of dawn on the morning of the 14th, affording a dark window for serious meteor observers.



INTERNATIONAL METEOR ORGANIZATION

Last year's Geminid shower acted normally, rising for a few days to a peak zenithal hourly rate of about 109, then dropping off faster. The dates are UT. Zenithal hourly rate is the number you would see if the shower's radiant were near the zenith and the sky was dark enough for 6.5-magnitude stars to be visible.

The shower is also active for a few days before then, and the Moon sets about an hour earlier for each day before the 14th. The Geminids drop off more steeply after maximum. This is seen in last year's activity profile at left, which was compiled by the International Meteor Organization from 22,892 Geminids observed by 160 counters around the world.

Bundle up as warmly as you can, using the cold-weather tips starting on page 66, and bring a reclining lawn chair. A sleeping bag provides further protection from the late-night radiational cooling under a clear sky. I observe near my house, so I can button a 50-watt electric hot pad on a long extension cord inside my coat.

Find a spot with an open view of the sky and no lights to get in your eye. Lie

back in the lawn chair, facing away from the Moon. Gaze into the stars, and be patient. You might see a Geminid every minute or two on average. The shower's radiant point is in Gemini near Castor, and the higher that is the better, but the meteors themselves will appear anywhere in the sky. So watch wherever it's darkest.

A "Rock Comet" Crumbles

What exactly creates the Geminid meteoroid stream? Small-body researchers David Jewitt and Jing Li (UCLA) say they've figured it out. For 30 years astronomers have thought that Phaethon — discovered in 1983 and only 3 miles (5 km) wide — must be a dead comet nucleus. During its close loops around the Sun its surface roasts to more than 700°C (1300°F), so all water and other volatiles must have been baked out of it ages ago. Then how can it continue to shed any particles at all? The Geminid stream is too compact to be very old.

Jewitt and Li have found proof that Phaethon is still shedding. NASA's two STEREO spacecraft, designed to observe the Sun, are also able to see Phaethon when it's nearest the Sun. STEREO found that the asteroid brightens unexpectedly and emits a dust tail when it's in the most intense heat. With no volatiles left to vaporize and carry dust away, the two propose that Phaethon's bare rock cracks and crumbles by thermal fracturing. Jewitt calls Phaethon a "rock comet."

"While this is the first time that thermal disintegration has been found to play an important role in the solar system," the two write, "astronomers have detected unexpected amounts of hot dust around some nearby stars that might have been similarly produced." So, count it as another way the Geminids are unusual.

Become a Meteor Counter

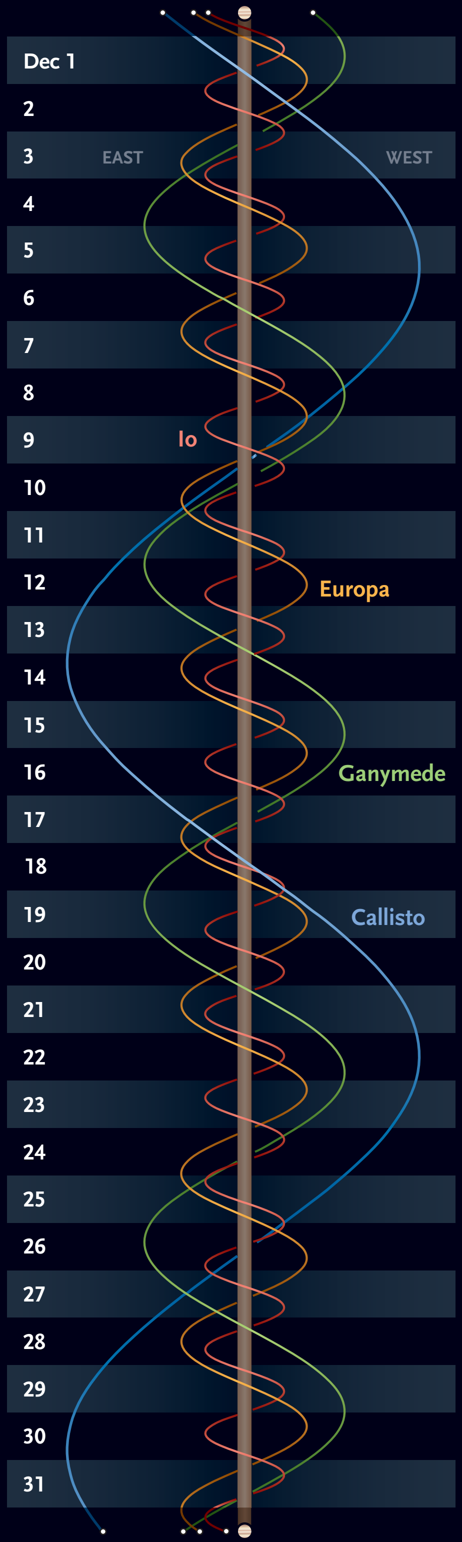
Have you ever done a scientific meteor count? The International Meteor Organization always wants more observers around the globe. You'll need to follow the IMO's standardized procedures so that your counts can be meaningfully compared with others. See **www.imo.net/visual** and also **skypub.com/meteors**, "Advanced Meteor Observing."

Phenomena of Jupiter's Moons, December 2013

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

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

All December, Jupiter is just about as big and close as it will appear at its January 5th opposition. Stay up late in the evening to observe it telescopically when it's high in steady air, shining down from Gemini.

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

Listed on the previous page are all the December interactions between Jupiter, its shadow, and the satellites and their shadows. A 3-inch telescope is generally enough for watching these events.

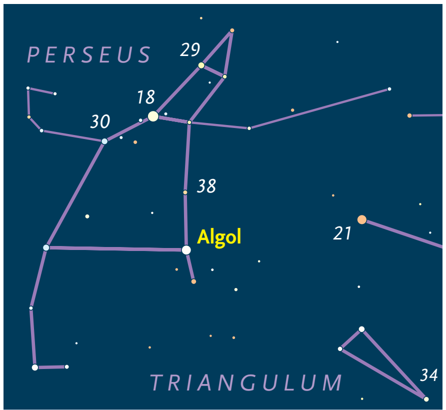
Here are the times, in Universal Time, when Jupiter's Great Red Spot (actually pale orange) should cross Jupiter's central meridian. The dates, also in UT, are in bold:

November 1, 3:12, 13:07, 23:03; **2**, 8:59, 18:54; **3**, 4:50, 14:46; **4**, 0:41, 10:37, 20:32; **5**, 6:28, 16:24; **6**, 2:19, 12:15, 22:11; **7**, 8:06, 18:02; **8**, 3:57, 13:53, 23:49; **9**, 9:44, 19:40; **10**, 5:36, 15:31; **11**, 1:27, 11:22, 21:18; **12**, 7:14, 17:09; **13**, 3:05, 13:01, 22:56; **14**, 8:52, 18:47; **15**, 4:43, 14:39; **16**, 0:34, 10:30, 20:25; **17**, 6:21, 16:17; **18**, 2:12, 12:08, 22:04; **19**, 7:59, 17:55; **20**, 3:50, 13:46, 23:42; **21**, 9:37, 19:33; **22**, 5:28, 15:24; **23**, 1:20, 11:15, 21:11; **24**, 7:06, 17:02; **25**, 2:58, 12:53, 22:49; **26**, 8:44, 18:40; **27**, 4:36, 14:31; **28**, 0:27, 10:22, 20:18; **29**, 6:14, 16:09; **30**, 2:05, 12:00, 21:56.

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

These times assume that the spot is centered at about System II longitude 204°. If it's not following predictions, it will transit 1⅔ minutes early for every degree of longitude less than 204°, or 1⅔ minutes later for every degree more.

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



Minima of Algol

Nov.	UT	Dec.	UT
1	2:35	2	15:34
3	23:24	5	12:23
6	20:12	8	9:12
9	17:01	11	6:01
12	13:50	14	2:50
15	10:39	16	23:39
18	7:28	19	20:28
21	4:17	22	17:18
24	1:06	25	14:07
26	21:55	28	10:56
29	18:44	31	7:45

Use the comparison-star chart above to estimate Algol's changing brightness. The geocentric predictions of mid-eclipse in the table are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy Gerry Samolyk.

Looking Back on a TLP

A controversial observation continues to spur interest 50 years later.

Fifty years ago, lunar cartographers James Greenacre and Edward Barr made the most well-documented observation of transient lunar phenomena (TLPs). A TLP is an unusual coloration, flash, obscuration, or other anomalous observations of the Moon. One of the earliest TLP reports was the 1787 observation by William Herschel of a fluctuating brightness at the crater **Aristarchus**, seen in earthshine. Herschel thought he had witnessed a volcanic eruption, but astronomers with more familiarity observing the Moon under various illumination conditions politely informed him that Aristarchus normally looked like that in earthshine.

This early TLP observation had two things in common with many of the hundreds that followed: it concerned Aristarchus, the brightest large crater on the Moon, and it was erroneous.

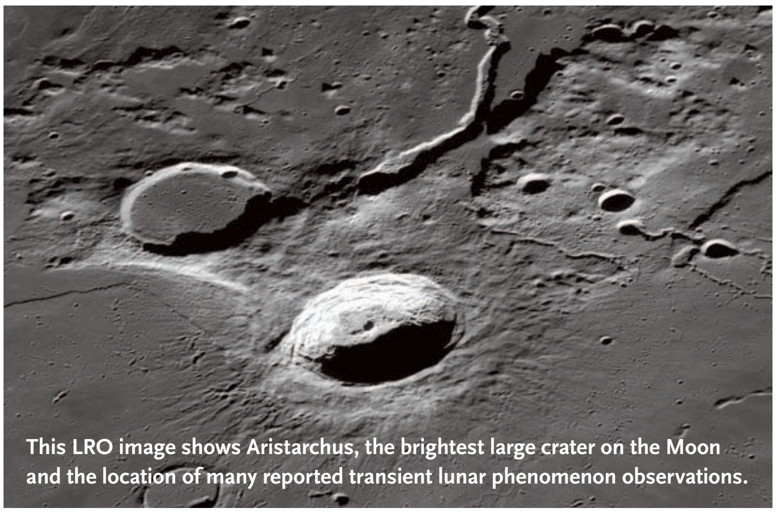
The observation by Greenacre and Barr, professional cartographers, occurred while they were performing routine observations with the Lowell Observatory 24-inch refractor to add details to maps being prepared for the Apollo missions. The pair observed a conspicuous pinkish streak inside the rim of Aristarchus and two red spots near the Cobra Head portion of Vallis Schröteri on the evening of October 29, 1963. Three hours later they saw a bluish glow envelop the northern rim of Aristarchus.

This report attracted considerable publicity at the time — partially due to its appearance in the December 1963 issue of *S&T* (page 316) — and is still considered the best example of a TLP. The observation has also been widely criticized for being made when the Moon was low in the sky (29°), under poor seeing conditions, and with very high magnification. Additionally, the 24-inch refractor was a poorly corrected achromat, so atmospheric dispersion or chromatic aberration are likely explanations.

Recently, Bob O'Connell and Tony Cook, members of the British Astronomical Association have gathered together virtually all documents related to this observation, including letters and telegrams previously unpublished. They also interviewed Greenacre's son and others with knowledge of Greenacre and the events. All of this information is presented in an article in the August 2013 *Journal of the British Astronomical Association* and online at **www.the1963aristarchusevents.com**.

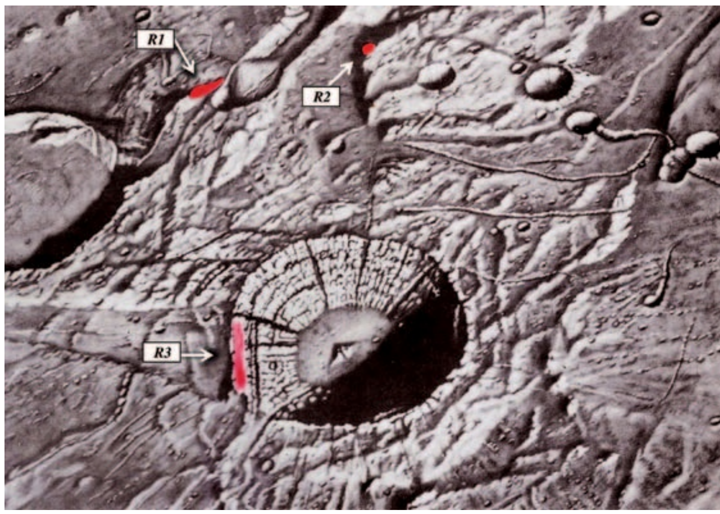
Of particular value is the additional documentation of Greenacre's career, which demonstrates that he was a well-trained scientist and experienced cartographer with two years of background using the 24-inch by the time of the Aristarchus observations. That adds considerable support to the interpretation that what he saw was a true anomalous event; Greenacre was also known to be skeptical about TLP's in general.

At the same time, all the criticisms about the observa-



NASA / GSFC / ARIZONA STATE UNIVERSITY

This LRO image shows Aristarchus, the brightest large crater on the Moon and the location of many reported transient lunar phenomenon observations.



Patricia M. Bridges produced this detailed illustration of the positions of Greenacre and Barr's October 29, 1963 observations (marked in red) with a great deal of input from the observers.

Contributing editor ***Charles A. Wood*** *(lpod.wikispaces.com) is coauthor of the book* 21st Century Atlas of the Moon.

tions remain indisputable: observing conditions were quite poor, with terrible seeing, and the Moon was only 29° above the horizon when Greenacre first noticed the red spots. But the spots were visible even through a Wratten 15 yellow filter, used to suppress the telescope's significant chromatic aberration. And the red spots were first seen in darker areas near the Cobra Head, regions where spurious color should have been less pronounced. Although Greenacre and Barr saw the red glow around the bright western rim of Aristarchus, they did not detect it anywhere else in and around the crater. Based on the limited distribution of red regions and the fact that they were so much more conspicuous than anything Greenacre had observed before, he and Barr felt certain they had observed some kind of lunar activity.

Today we can use the recent high-resolution images from NASA's Lunar Reconnaissance Orbiter (LRO) to look for any possible changes. O'Connell and Cook report that the LRO images don't show evidence for any recent deposits that might be associated with the event. Searching the LRO Narrow Angle Camera images at the location of the observations reveals veneers of dark material in the areas, but they all contain numerous small craters that attest to the deposits being millions of years old. If some physical event on the Moon caused the TLP, it left no detectable deposit. We can thus eliminate the eruption of a lava or ash deposit.

The high-resolution LRO images do not rule out the escape of gases. How gases would cause the colors seen is not completely understood. And four different events scattered across tens of kilometers seems geologically unlikely, though not impossible.

The Lowell observers reported another TLP at Aristarchus one month later under similar observing conditions. That is suspiciously consistent with the TLPs being visible only in certain observing conditions, strengthening the argument that these anomalies were simply artifacts. On the other hand, a monthly recurrence might be expected if gases only can escape during monthly periods of maximum tidal stresses.

Fifty years later, we still don't unequivocally know whether the Aristarchus TLP was something on the Moon or an illusion. The recent discoveries of water buried in shadow-filled south polar craters and in lunar magmas that erupted billions of years ago demonstrate that the Moon still has secrets — but those ancient hydrous signatures are located far away from Aristarchus. I accept that Greenacre and Barr observed an anomalous event, but in my opinion it most likely was an unusual display of atmospheric dispersion due to poor seeing, augmented by the 24-inch refractor's poor color correction. Other explanations simply must remain speculation.

How does this famous observation and history relate to amateurs? First, the compilation of all relevant information by Bob O'Connell and Tony Cook provides an excellent model for others to follow in documenting the historical record of unusual observations. Second, at least one prominent amateur observer who doubts that anything happened on the Moon 50 years ago fully admits that the excitement about that event inspired his fascination with the Moon that continues to burn brightly today. ✦

The Moon • December 2013

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

S&T: DENNIS DI CICCO

Phases

NEW MOON December 3, 0:22 UT	FIRST QUARTER December 9, 15:12 UT
FULL MOON December 17, 9:28 UT	LAST QUARTER December 25, 13:48 UT

Distances

Perigee 223,832 miles	December 4, 10^h UT diam. 33′ 10″
Apogee 252,444 miles	December 20, 0^h UT diam. 29′ 25″

Librations

Pontécoulant (crater)	December 7
Gum (crater)	December 9
Gibbs (crater)	December 12
de Sitter (crater)	December 18

Local Group Dwarf Galaxies

Observing nearby galaxies is always rewarding though often challenging.

It's nice to know your neighbors. We dwell within a vast spiral galaxy known as the Milky Way. Together with the Andromeda Galaxy (Messier 31), it dominates a minor cluster known as the Local Group. Although its flashiest constituents usually garner the most press, let's turn our attention to some of the little guys. A recent paper in the *Astronomical Journal* (Alan McConnachie, 2012) lists 75 "definite or very likely members of the Local Group," most of them dwarf galaxies.

Local Group Dwarf Galaxies from Cassiopeia to Cetus

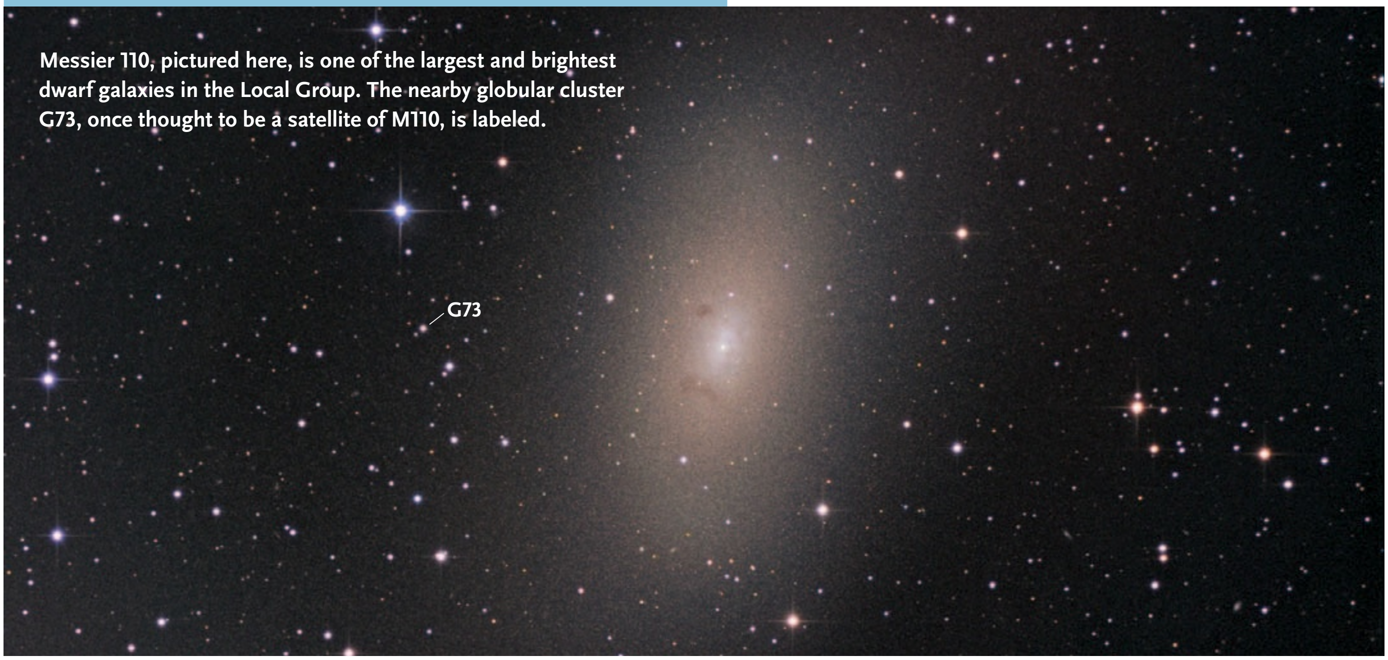
Object	Dist. (M ly)	Mag. (v)	Size/Sep.	RA	Dec.
M110	2.7	8.1	21.9′ × 11.0′	0^h 40.4^m	+41° 41′
And I	2.4	12.7	2.5′ × 2.5′	0^h 45.7^m	+38° 02′
NGC 185	2.0	9.2	11.7′ × 10.0′	0^h 39.0^m	+48° 20′
NGC 147	2.2	9.5	13.2′ × 7.8′	0^h 33.2^m	+48° 31′
IC 10	2.6	10.4	6.8′ × 5.9′	0^h 20.3^m	+59° 18′
Peg dSph	2.6	13.2	4.0′ × 2.0′	23^h 51.8^m	+24° 35′
Peg dIrr	3.0	12.6	5.0′ × 2.7′	23^h 28.6^m	+14° 45′
And II	2.1	11.7	3.6′ × 2.5′	1^h 16.5^m	+33° 25′
IC 1613	2.5	9.5	16.2′ × 14.5′	1^h 04.8^m	+2° 07′

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. Distances are from Alan McConnachie's 2012 *Astronomical Journal* article, expressed in millions of light-years.

Some Local Group dwarfs have respectably high total magnitudes, but they all have stingily low surface brightnesses. Viewing them entails a magnification balancing act. Although you can discern more detail when studying a large image, galaxies can become too dim to see if you spread their light out too much.

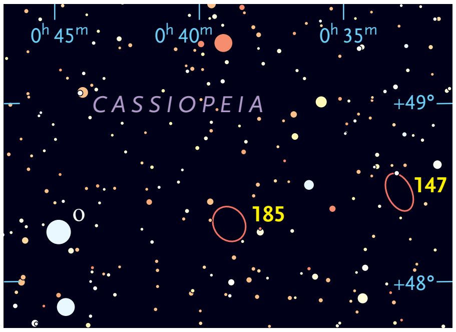
From mid-northern latitudes, the easiest Local Group dwarf to see is **Messier 110**, which hovers over the northwestern flank of the great Andromeda Galaxy. M110 is visible as a moderate-size oblong glow through 14×70 binoculars in my semirural sky. It's a lovely sight in the same field of view with its giant neighbor and M32, the little galaxy on the Andromeda Galaxy's opposite flank. Despite its diminutive size, M32 is not a dwarf galaxy, as evidenced by its high surface brightness.

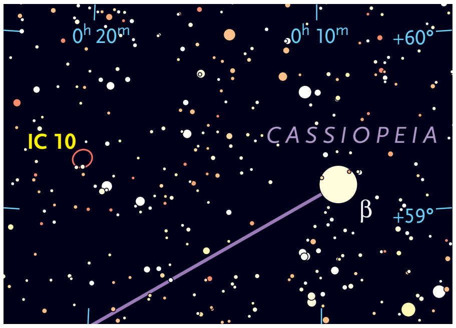
In my 130-mm refractor at 63×, M110's oval profile leans slightly west of north and brightens steadily toward the center. The galaxy is enshrined in stars, with two

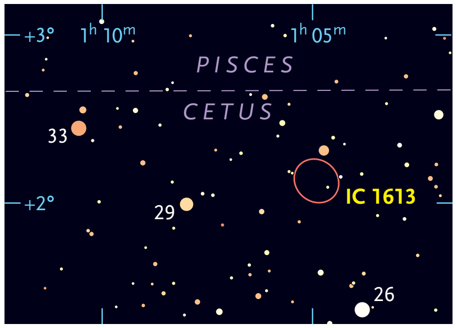


Messier 110, pictured here, is one of the largest and brightest dwarf galaxies in the Local Group. The nearby globular cluster G73, once thought to be a satellite of M110, is labeled.

JOHANNES SCHEDLER







***Above*: These detailed charts show stars to magnitude 11.5, deep enough so that each of the images on the following page includes two or more charted stars. *Lower right*: The galaxies discussed in this article stretch from Cassiopeia nearly down to the celestial equator. Detailed charts for the four brightest galaxies are shown above. Charts for the remaining galaxies can be downloaded at www.faintfuzzies.com.**

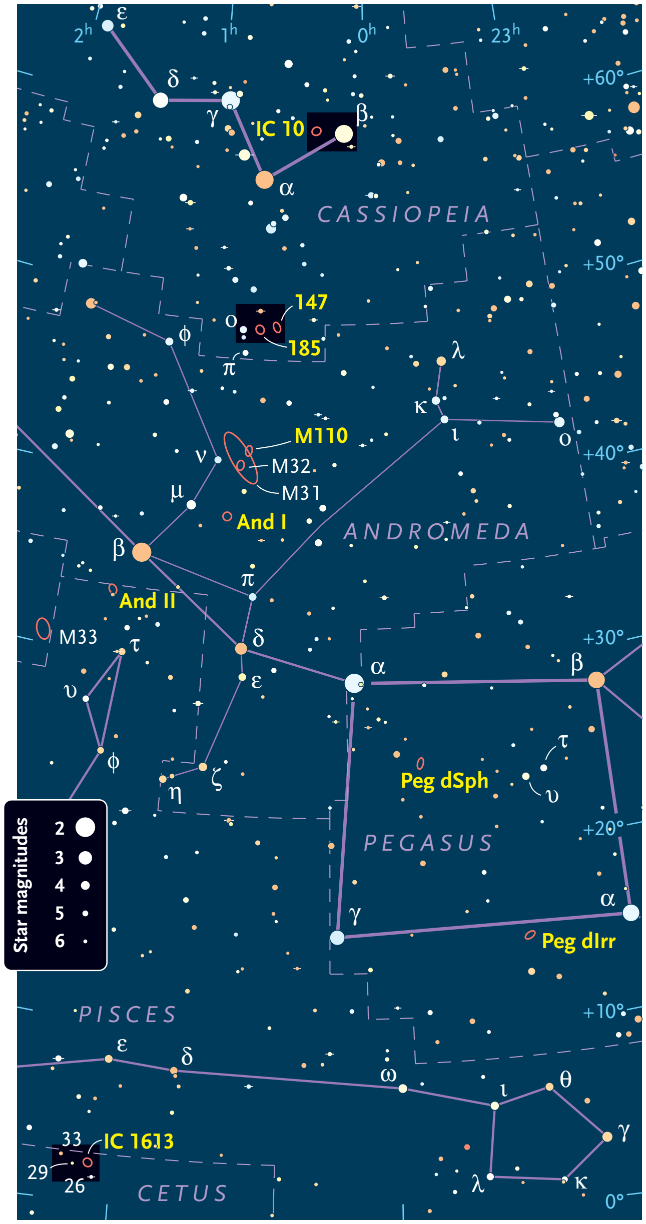
11th-magnitude suns tacking down its southwestern verge. M110's outer halo fades so gradually that it's difficult to tell where it ends, but I estimate its apparent size at roughly 13′ × 6½′. The galaxy is fairly bright within dimensions of about 3′ × 2′.

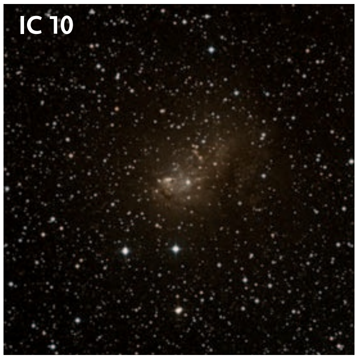
M110 boasts an intriguing feature, a tail created by the Andromeda Galaxy's tidal pull on the dwarf's stars. My 10-inch reflector at 70× shows an extremely dim extension to M110's halo that reaches out toward the Andromeda Galaxy and is slightly bent clockwise. The tail weakens as it nears its giant neighbor, fading to invisibility about 8′ from M110's apparent edge.

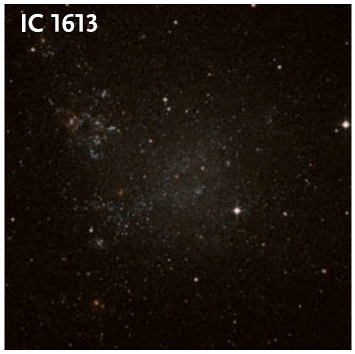
Having read that the extragalactic globular cluster **G73** (Bol 20) might belong to M110, I added it to my observing list. I've since learned that recent journal papers assign G73 to the kingdom of the Andromeda Galaxy, but as the brightest globular near M110, it's still enjoyable to hunt down. With my 10-inch scope at 220×, it simply looks like a 14.9-magnitude star — but knowing what I'm looking at makes it exciting. G73 and other Andromeda Galaxy globulars are discussed on page 58 of last month's issue.

Also in Andromeda, but not for the faint of heart, is exceedingly dim **Andromeda I** (PGC 2666). At first I only suspected something as I slowly swept across this galaxy with my 15-inch scope at 133×, but with study a ghostly presence made itself known. To me it appeared roundish and about 2′ across, with a 13th-magnitude star at its western edge. Detailed charts for finding Andromeda I and all the other Local Group galaxies in this article can be downloaded from Alvin Huey's website **www.faintfuzzies.com**.

Crossing the border into Cassiopeia, we come to two easier dwarf galaxies. **NGC 185** sits 58′ west of Omicron (ο) Cassiopeiae, and **NGC 147** is 58′ west and a bit north of NGC 185. They share the field of view through my 130-mm scope at 23×. NGC 185 is a readily visible 8′ × 6′ milky oval that gently brightens toward the center. Several stars enwrap the dwarf, including a faint one at its northeastern tip with a bright, golden-hued one beyond it.







POSS-II / CALTECH / PALOMAR OBSERVATORY

These images are synthesized from red and blue plates from the second Palomar Observatory Sky Survey. They show the huge variety of morphologies evidenced by Local Group dwarf galaxies. Each image covers a 15′ × 15′ square of sky, and they have all been processed identically.

The western side of the galaxy grazes an imaginary line between the golden star and another of similar brightness 20′ west-southwest. Considerably dimmer and more elongated, NGC 147 leans north-northeast and is watched over by an east-west scattering of stars floating north of it.

At 48×, NGC 185 is very pretty. More stars join the wreath encircling it, and faint stars jewel the halo. NGC 147 appears about 9′ long and half as wide, revealing a slightly brighter, relatively large, elongated core that grows very softly brighter toward the center.

Also in Cassiopeia, **IC 10** lies 1.4° west of Beta (β) Cas. Through my 130-mm refractor at 63×, it's a very faint glow with averted vision. It hosts a relatively large, somewhat brighter center and a 12.8-magnitude star superposed on its western edge. A 2½′ right triangle of 10th- and 11th-magnitude stars sits just south of the galaxy. At 117× the brightest region is visible with direct vision, but nicer with averted vision. The galaxy looks a bit patchy and spans about 1¾′. This portion of IC 10 inhabits the southeastern end of a 3½′-long, mottled fog when examined through my 10-inch scope at 115×. Two faint stars pin opposite sides of the galaxy's northwestern end, and a fuzzy spot is moored in the eastern side of the bright area. The perceived fuzz is a blend of an intense star-forming region and a faint foreground star.

The **Pegasus Dwarf Spheroidal** (Andromeda VI) makes its home in the constellation Pegasus 1.5° west-southwest of orange Psi (ψ) Pegasi. With my 15-inch scope at 133×, I see an insubstantial roundish haze cradled by four faint stars. At 216× the galaxy is about 2′ across and centered 2′ away from the 10th-magnitude star near its southwestern edge. Its exceptionally feeble glow brightens only slightly in the middle. Three of the dim stars nuzzle the galaxy's tenuous rim — one southeast, one northeast, and the closer star of the pair northwest.

The dwarfs we've visited so far have been satellites of the Andromeda Galaxy, but the status of the **Pegasus Dwarf Irregular** (UGC 12613) is less certain. McConnachie states that it's "extremely distant from Andromeda, but could arguably be dynamically associated."

UGC 12613 is located 2.0° north of yellow 70 Pegasi. It takes some study to see it in my 10-inch reflector at 115×, and it looks rather strange. The galaxy takes the form of a narrow wedge that widens as it stretches 3′ west-northwest from a 14th-magnitude star, with its southern side extending out to a 13th-magnitude star. Through my 15-inch scope at 133×, the wedge is enveloped in a diaphanous oval mist with dimensions of about 4′ × 1½′.

The 16th-magnitude galaxies **PGC 71549** and **PGC 214961** that sit off the Pegasus Dwarf Spheroidal's eastern tip and southern side, respectively, can be seen with telescopes upward of 16 inches in aperture.

Now we'll move into far northern Pisces, where we find another Andromeda Galaxy satellite, **Andromeda II**, 2.6° south-southeast of Beta (β) Andromedae. This gauzy dwarf is weakly visible through my 15-inch scope at 216×, and it appears roughly 2½′ across. A curve of four stars, magnitudes 10.5 to 12.6, hugs its eastern edge, and three dim stars are superposed on its western side.

Our final target is a Local Group member-at-large, being neither a satellite of the Andromeda Galaxy nor our own Milky Way. **IC 1613** is located in northern Cetus, 47′ north-northeast of the double star 26 Ceti, whose components are white and deep yellow. My 105-mm refractor at 87× shows a little smudge that makes a southward-flying kite with two faint stars to the west and a 7th-magnitude orange star 11′ north-northwest. My 130-mm scope at 102× reveals this patch more readily and discloses a larger, detached glow between it and the southernmost star of the kite. Inspecting the galaxy with my 15-inch scope at 102×, I see that these patches are merely brighter regions in a fat ovoid that's 9½′ long and tipped northeast. The northeastern bright patch is blocky, and the larger, southwestern one is elongated southeast-northwest.

Although many of our neighboring galaxies are shy, barely showing themselves, it's fun to try to bring them out of their shells and into the light of our questing backyard telescopes. ✦

 Dennis di Cicco

Meade's LX850 Astro-Imaging System

Can this mount's full-time automatic autoguiding make everyone a deep-sky astrophotographer?

ALL PHOTOGRAPHS BY THE AUTHOR

Meade LX850 Astro-Imaging System

U. S. Price: From $5,999.00
Available from dealers worldwide
meade.com

THERE ARE MORE ACTIVE deep-sky astrophotographers today than ever before. We have digital imaging and an abundance of commercial gear to thank for that. But there are also many would-be astrophotographers waiting in the wings. The reasons why they've yet to take the plunge vary, but I know that for some it's the complexity of assembling a deep-sky photography system. Just deciding what telescope, mount, autoguider, camera, and software to buy is difficult enough, but even more daunting is getting everything to play together nicely. Many see it as an overwhelming challenge, and it's these people that Meade must have been thinking about when the company set about creating what is now sold as the LX850 Astro-Imaging System.

On paper the LX850 sounds simple — a German equatorial mount with a built-in autoguider (called StarLock) that autonomously begins tracking the sky whenever you point the mount at a celestial target. It's completely self-contained; you don't need any external hardware or software. Just add the telescope and camera of your choice, open the shutter, and you'll be on your way to making deep-sky masterpieces.

But as everyone who has done it knows, autoguid-

***Above*: Meade's LX850 Astro-Imaging System with full-time, 100% automated autoguiding is a major leap forward for deep-sky astrophotographers, especially beginners. It does for long-exposure astrophotography what Go To telescopes did for observing. Although the 12-inch model pictured here weighs more than 200 pounds, it breaks down into manageable pieces.**

ing can be difficult even with careful human oversight. Meade has successfully tackled difficult technological challenges in the past (the self-aligning LightSwitch telescopes are a good example), so it's not surprising that the company attempted this one. But for the LX850 to be deemed a real success, the system has to work for its target audience — people with little or no experience doing deep-sky astrophotography. And that's definitely a tall order.

Nevertheless, after extensively testing the LX850 this past summer and fall with a Meade 12-inch f/8 ACF telescope, I'm comfortable saying that the company hasn't just been successful in achieving its goal; it's been *stunningly* successful. To understand why and how I've come to that conclusion requires a bit of backstory. So bear with me for a moment while I explain.

Deep-sky Guidelines

There are no unbreakable rules for deep-sky photography. Even my long-standing quip about having to do it at night isn't true in an age when astrophotographers use the internet to control telescopes half a world away. But some generalizations do apply. Foremost is that digital photography allows us to assemble great images of faint celestial targets with individual exposures that are relatively short. With just about any telescope and camera combination, the world of deep-sky photography is wide open to you if you can make exposures up to 10 minutes long.

Some form of guiding is needed to consistently make usable 10-minute exposures, and traditionally astrophotographers have done this by tracking a guide star in or around the field being imaged. Crosshair eyepieces and push-button hand paddles are all but extinct now that today's deep-sky photographers have switched to electronic autoguiders.

But autoguiding is a complex melding of hardware, software, and technique. I started out in the late 1980s with the original SBIG ST-4 autoguider (which is like telling someone you learned to drive with a Ford Model T). And after nearly 25 years I still consider myself lucky if I can shake most of the autoguiding bugs out of a new deep-sky setup in only a night or two. And that's just the mechanics — there's still the "art" of selecting a suitable guide star and setting an autoguider's "soft" parameters (exposure time, aggressiveness, etc.) every time I switch to a new target. This is why Meade faced an uphill battle to create a system that could do everything autonomously with equipment that beginning astrophotographers could easily master.

Hardware

Meade offers the LX850 as a package deal with four telescopes: a 130-mm f/7 apo refractor, and 10-, 12-, and 14-inch f/8 Advanced Coma Free Schmidt-Cassegrains. We borrowed the 12-inch scope for this review since its

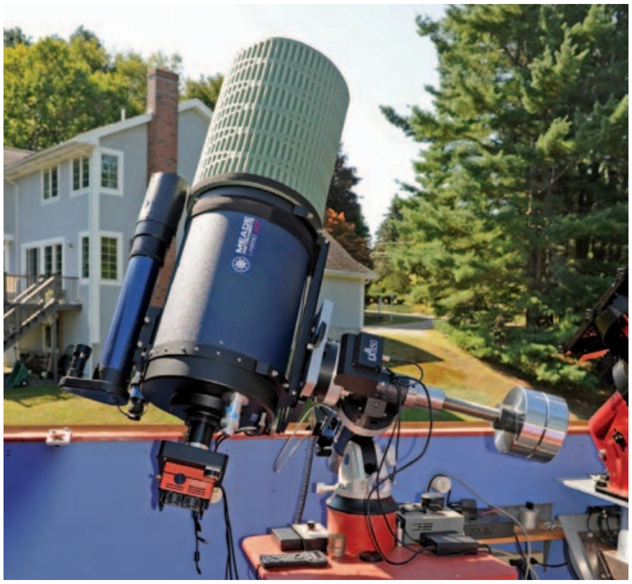
Left: The heart of the StarLock system is a pair of digital imagers that you can attach directly to the mount (shown here) or to the main telescope. The author never had StarLock fail to automatically find and track a guide star. It also assists with the LX850's polar alignment, high-precision pointing, and periodic-error reduction in the mount's drive.

Right: The LX850's electronics are completely self-contained and built around Meade's time-tested Autostar II hand controller. The mount is also plug-and-play compatible with any modern autoguider that is connected to the "aux autoguider" port. StarLock automatically defers to commands from an external autoguider when it senses signals sent to this port.

56-pound (25-kg) weight places a significant load on the mount (the 14-inch is only 7 pounds heavier). This scope's 2,400-mm focal length also places significant demands on the autoguider, since it greatly magnifies even tiny guiding errors.

I was as amused as my colleagues when a freight truck arrived at our offices to unload the LX850; the shipment included nine boxes (one of them huge) totaling 379

The author captured the Cocoon Nebula, IC 5146 in Cygnus, with an SBIG STT-8300 CCD camera using red, green, and blue filters and sixteen 10-minute StarLock–autoguided exposures made through each filter.



After weeks of testing the LX850 as a portable setup in his driveway, the author moved the scope to a pier in his backyard observatory where it was more convenient to work with the SBIG STT-8300 CCD camera seen here and its associated computer equipment. He used StarLock for a "drift" polar alignment (see the text for details), on the first night and then just "parked" the scope after each observing session. As such, he could begin on subsequent nights without having to align the scope again.

pounds. Nevertheless, when everything was unpacked, all the gear fit in the back of my small sports coupe with the rear seats folded down. The complete scope, as pictured on page 60, weighs nearly 250 pounds, but it breaks into components that are relatively easy to transport and assemble (the heaviest piece is the 68-pound equatorial head).

For the first month or so of testing, I stored the LX850 in my garage. Even when stripped of the most massive pieces, the tripod with the equatorial head attached was too heavy and awkward for me to drag from the garage to my observing spot just a few feet away in the driveway. Everything had to be broken down to be moved.

There is, however, a dividend associated with all this weight — the LX850 is a remarkably solid mount, and it handled the 12-inch scope with ease. Flexure, the bane of many autoguiding systems that use a separate guide scope, was all but nonexistent. The LX850 is also very well engineered and equally as well manufactured. Because of careful design, the only tools needed to assemble the mount are two Allen (also called hex) wrenches. Meade supplies them along with a special tool that fits the two sizes of hand knobs on the mount, but you can still turn these knobs without the tool. The heavily illustrated user's manual gives very clear instructions for putting everything together and roughly adjusting the mount in preparation for a night of observing. My biggest complaint about the mount is the short, coiled cord on the hand control — it could easily stand to be three times longer than it is.

WHAT WE LIKE:

Automatic autoguiding

Solid, heavy-duty mount

Automated setup features

WHAT WE DON'T LIKE:

Documentation needs work

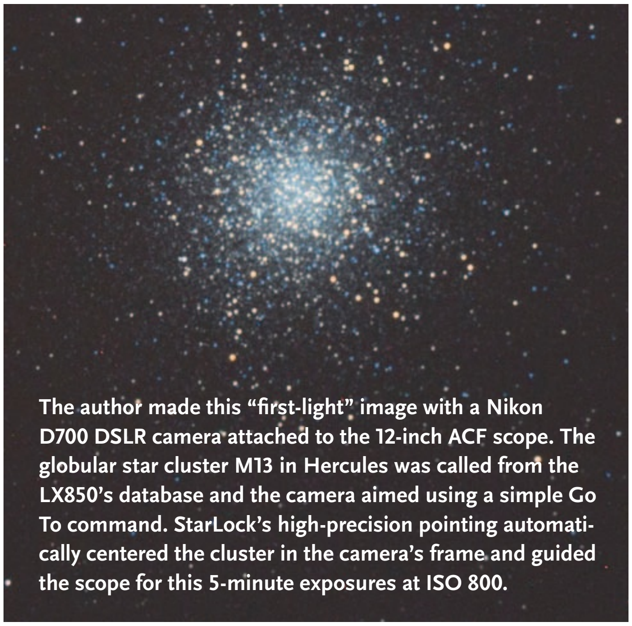
Hand-control cord too short

StarLock

Once I was familiar with the scope and working at a leisurely pace, I could assemble everything in less than half an hour (on many nights I did it in about 15 minutes). As stars emerged from the evening twilight, I would power up the LX850 and spend about 15 minutes working through the mostly automated steps needed to polar align the mount. This requires having a clear view of Polaris (or another suitable polar star in the Southern Hemisphere). Without a clear view of the celestial pole, observers will need to use alternate alignment methods.

Pressing a few more buttons on the hand control let me slew to any of thousands of objects in the scope's database. The LX850's default setting uses the pair of sensors built into the StarLock autoguider to precisely center each deep-sky object by offsetting from nearby bright stars — the process, which can be turned off, is completely automated and adds less than a minute to the time needed for a regular Go To slew to a target. It's very accurate, and a boon to anyone working with a camera (or eyepiece) that has a small field of view.

Within 15 or 20 seconds of slewing the LX850 to a target, StarLock would automatically find and begin tracking a guide star. I could then open my camera's shutter and make successful 5-minute exposures. If, during the setup procedure, I took the additional 15 minutes or so needed for a more-accurate "drift" polar alignment (another process that's highly automated by the StarLock system,



The author made this "first-light" image with a Nikon D700 DSLR camera attached to the 12-inch ACF scope. The globular star cluster M13 in Hercules was called from the LX850's database and the camera aimed using a simple Go To command. StarLock's high-precision pointing automatically centered the cluster in the camera's frame and guided the scope for this 5-minute exposures at ISO 800.

as well as one that can be used when Polaris is blocked from the observer's location), I could easily make successful 10-minute exposures. This didn't happen on just a few "lucky" nights; it happened *every* night.

Throughout the summer and early fall I photographed dozens of objects, making hundreds of 5- and 10-minute exposures. On a microscopic level some images had stars that weren't perfectly round. But when stacking individual exposures to create final images, I never rejected a single frame because of the guiding. Never! Not one!

This is an astounding track record for the LX850, especially because I always used StarLock's default settings. There are only a few things that advanced users can do to tweak StarLock's autoguiding, but none that I tried gave better results than when I just let StarLock do its own thing. It's a system that beginners can use out of the box and consistently get good results.

Smooth Sailing?

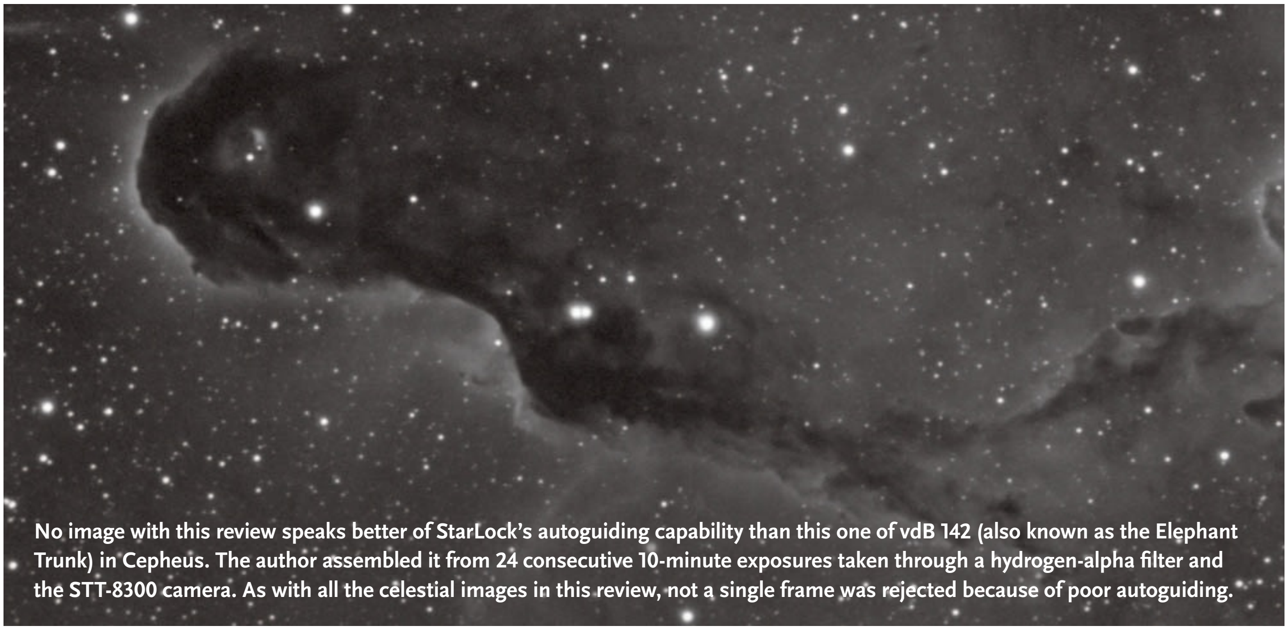
So, were my experiences with the LX850 all smooth sailing? The short answer is no. And the reason why can also be summed up in a single word; documentation. I approached the LX850 with the mindset of a beginner, and as such I relied heavily on the instructions in the manual and, more importantly, those that scroll across the hand control's display and are thus easiest to use in the dark. I found some of the instructions confusing. But a far bigger problem was the conflicting and misleading information shown on the scrolling display compared to that in the printed manual. It took several frustrating hours spread across two nights for me to sort it all out and realize that the manual, and not the scrolling display, had the more accurate instructions for initializing and polar aligning the mount. And you have to properly execute these steps before you can use the LX850.

Hindsight made this seem even more ironic, since what you need to know to get started with the LX850 is really quite straightforward. In my opinion, it's no exaggeration to say that a beginner equipped with a good "quick-start" guide could power up an assembled LX850 for the first time and have the system ready for autoguided exposures in less than 30 minutes. The good news is that Meade says it's working on an updated manual.

The space here limits my comments mainly to the mount's unique autoguiding capabilities. But even with a review five times this size I couldn't cover all of the features of the LX850 Astro-Imaging System. Many of them, however, are found in all of Meade's Go To telescopes equipped with the time-tested Autostar II controller (see, for example, our review of the 8-inch LX200GPS in the March 2003 issue, page 50). Likewise, the 12-inch f/8 Advanced Coma Free Schmidt-Cassegrain scope I tested has the same optics that were in the RCX400 scope that we reviewed in the February 2006 issue, page 78.

In the history of amateur astrophotography, autoguiding turned a lot of people on to deep-sky photography (it was a rare breed of individual who could tolerate hours of manually guiding a telescope). Today's autoguiders are far easier to use than the early models, but they are still challenging to master. So by that standard, the LX850 Astro-Imaging System is a quantum leap forward. It has done for deep-sky astrophotography what Go To telescopes did for observing, turning what many consider a daunting task into something that can be done with push-button ease. It's quite an accomplishment. ✦

Senior editor ***Dennis di Cicco*** *has been guiding telescopes for deep-sky photography since the 1960s.*



No image with this review speaks better of StarLock's autoguiding capability than this one of vdB 142 (also known as the Elephant Trunk) in Cepheus. The author assembled it from 24 consecutive 10-minute exposures taken through a hydrogen-alpha filter and the STT-8300 camera. As with all the celestial images in this review, not a single frame was rejected because of poor autoguiding.

Chuck Lott's "Pseudo-Ball" Newtonian Reflector

Here's an easy way to build a ball-and-socket telescope.

READERS ARE LIKELY familiar with the ball-and-socket telescope design popularized by commercial offerings such as Edmund Scientific's venerable Astroscan or Mag 1 Instrument's PortaBall. Several home-built versions have also been featured in this magazine, including Jerry Oltion's super-sized Astroscan clone (*S&T*: September 2011, page 64). These telescopes have one thing in common that limits both their size and their popularity among telescope makers: they require some kind of rigid ball or hemisphere. Oregon amateur Chuck Lott, however, has found a way around this construction obstacle.

TED TOUW

Chuck Lott built this nifty 4½-inch f/8 instrument based on a concept suggested by fellow ATM Tom Conlin. Unlike traditional ball-and-socket scopes, this one uses a "pseudo" ball consisting of three arcs.

Chuck is a member of Skope Werks, an informal group of Oregon ATMs that also includes Jerry Oltion. As Jerry explains, "The group's name is a play on Lockheed Martin's famous Skunk Works, which designs many odd airplanes — and we're definitely good at odd telescopes." Chuck's scope may be unconventional, but it's also elegantly functional. "We first heard about the pseudo-ball concept from Tom Conlin, who described how to pare the scope's back end down to a set of arcs that would ride inside a ring," Jerry recalls. Chuck and his Skope Werks colleague David Davis took the ball (so to speak) and ran with it, both producing working telescopes.

Chuck's scope is a 4½-inch f/8 Newtonian with a tube assembly that is rather straightforward — a hexagonal plywood upper section joined by three lengths of 5/8-inch doweling to the lower tube made from scrap plastic pipe. What sets his scope apart is the mount. "To try out Conlin's concept, I made a small model with three half-circles of Plexiglas positioned at 120° intervals set in a ring," Chuck explains. "I reasoned that three blades would self-center like a tripod — indeed the model proved so stable I immediately set to work on this proof-of-concept scope."

The three blades are cut from ¾-inch plywood and faced with plastic countertop edging purchased from a local cabinet shop. Chuck made full-scale drawings to get an idea of how large to make the circles and to figure out how far back he could position the scope's primary mirror, while leaving enough wood for strength.

The main components in the scope's base are two pieces of cookware. Chuck found a nonstick skillet of the right diameter at a thrift store and cut the bottom out of it. "As luck would have it," he adds, "the skillet fit nicely onto the lip of an old pot we used for boiling crabs." The skillet's Teflon coating makes a smooth bearing surface for the countertop edging to ride on. A coat of paint and three wooden legs finished up the base.

CHUCK LOTT

A length of surgical tubing serves as a spring to prevent the scope from nosediving when aimed near the horizon.

As those who have used a ball-and-socket scope know, the Achilles' heel of the design is balance, especially when even a small amount of weight is added to the scope's front end. This is because the bearing surfaces lie near the rear of the scope. To get around this problem, counterweights are often tucked behind the primary mirror — a solution that not only leads to a heavier scope, but also one potentially burdened with poor thermal performance. Chuck, however, took a different approach. The pot's depth enabled him to attach a "spring" made from a length of surgical tubing between the bottom of the scope and the bottom of the pot. He put hooks on both ends of the surgical tubing to connect to eye bolts attached to the scope and the bottom of the pot. That way, as the scope is aimed toward the horizon, the spring tension increases. Having several anchor points on the bottom of the pot enables fine-tuning the scope's response.

Chuck's scope has proven to be more than just a proof-of-concept project, since it is a source of enjoyable viewing experiences. As he also reports, "This project brings back fond memories of my first scope, which was also a 4½-inch. It reminds me of how much fun it was to discover the universe for the first time!"

Readers wishing to contact Chuck directly to learn more can e-mail him at **clott@casco.net**. ✦

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

Dress for Stargazing

It's easy to stay toasty warm when it's cold outside.

Tony Flanders

Astronomy tends to be a chilly hobby. Everywhere outside the tropics gets cold at night in some seasons, and many places can get cold at any time of year. There are three possible strategies for dealing with this fact: stay inside when it's cold, pretend it's not cold and suffer accordingly, or dress appropriately. You can probably guess which strategy I prefer!

The problem with staying inside is that it rules out many of the best times and places for stargazing. In much of the temperate zone, summer features biting insects, hazy skies, and just a few hours of full darkness per night. Autumn and winter, by contrast, have reliably long nights, and in many areas they also have very clear air. Moreover, in the Northern Hemisphere they feature the glorious Milky Way constellations from Cassiopeia through Orion and Canis Major, which contain a disproportionate share of the sky's brightest stars and deep-sky objects.

As for location, the very best stargazing sites feature high altitude and clear air — precisely the conditions that lead to the coldest nights. Some sites in the American West can fall below freezing even in summer, and I always bring a down jacket to Vermont's famous Stellafane star party, which is usually held in August.

Do I really wear a down jacket in August? You bet I do! I've done enough winter hiking, climbing, and camping that I have no need to prove how tough I am. People may think I look ridiculous wearing a down jacket and winter hat at 50°F (10°C). And indeed, they may be quite happy wearing just a sweater for 15 minutes. But two hours later they're shivering and I'm still toasty warm. The key is to put on plenty of clothing *before* you need it; it's much easier to stay warm than to get warm once you're cold.

One thing's for sure: you'll need to wear a lot more while stargazing than you did the previous day. That's partly because the temperature falls at night but also because you remain inactive for hours. That makes a huge difference. I wear more for stargazing at 50°F than I do for hiking uphill on a sunny, windless day at 0°F (–18°C).

Take all of my advice with several grains of salt; people's reactions to cold vary tremendously. And differences in attitude and culture may be even more important than physiological differences.

If you watch lots of westerns, you know that people in Arizona used to wear plenty of warm clothing. But that

Success

Illustration by Leah Tiscione

changed when offices replaced ranches and the focus of life shifted indoors. Now Phoenix is marketed as a place without winter — even though it gets quite chilly on January nights. People couldn't ignore that fact when they had to ride their horses home from the saloon, but it's easy to do without a winter jacket if you just walk a few steps to your car. So stargazers in southern Arizona tend to suffer greatly when they head up to high-altitude observing sites.

Conversely, stargazers in Canada and Scandinavia have a relatively easy time because these places have cultures that embrace winter — and people dress accordingly.

Principles of Cold-Weather Clothing

Before discussing specific clothes, let's get two basic principles straight:

- A chain is only as strong as its weakest link.
- Thick is good, thin is bad.

There's a widely held myth that you should always wear a hat in the winter because "you lose 80% of your heat through your head." The part about wearing a hat is

The author is dressed for a windless night at 50°F (10°C) on the left, and in full winter regalia on the right.

ALL PHOTOGRAPHS BY DENNIS DI CICCO

spot-on, but the 80% is nonsense. It actually comes from an Army study that found soldiers losing 45% of their heat through their heads. But that's because they were warmly dressed everywhere else, and had nothing on their heads. If you wear a fur hat, fur leggings, and a T-shirt, you'll lose most of your heat through your torso and arms.

In short: you lose a large fraction of your heat through whatever part of your body is least insulated. In the U.S. and Western Europe, where hats have been out of fashion since the 1960s, that's often the head.

The other place that's routinely neglected is the legs. The best hat and jacket in the world won't keep you warm at 20°F if you're wearing nothing but cotton slacks or blue jeans. I'll discuss specific solutions to this later, but for now just remember the general principle: a chain is only as strong as its weakest link.

What kind of insulation works best? It doesn't really matter; to a good first approximation the thickness is all that counts. All one-inch-thick jackets are roughly equal, whether they're stuffed with down, polyester, or wool. In fact homeless people, who are true experts on coping with cold, often stuff their clothes with newspaper. It's not very comfortable, but it works fine as long as it stays dry.

The other thing that matters is having a windproof outer layer; loose-weave wool won't keep you very warm when the wind is whipping through it. But pop a 6-ounce (170-gram) department-store windbreaker over a thick wool sweater, and you have a startlingly warm garment. Ideally you want a thin, tight-weave shell on the outside, with loose, fluffy insulation inside.

Buying Clothing

You don't necessarily need to rush out and buy lots of cold-weather clothing. Quite often, you can stay warm just by layering stuff that you already own.

For instance, legs are one place where most people's wardrobe is likely to fall short. Wearing two pairs of pants, one over the other, is twice as warm, but it's probably not very comfortable unless the outer pair is cut extra large. Two pairs of sweatpants might work better, even though they violate the windproof-outside principle.

Likewise, a couple of sweatshirts under a regular winter jacket will boost its warmth greatly — assuming that the jacket isn't too tight. And if the sweatshirts have hoods, they help keep your oh-so-important head warm as well.

If you do buy clothing, avoid ski shops. Ski clothing tends to be fashionable, overpriced, and not very warm. Stores for hunters and snowmobilers are better bets; like stargazers these people spend long periods inactive in the cold, and they tend to be cost-conscious. Stores for hikers and climbers usually have excellent gear, but ignore any advice about ventilation and dressing in layers; those are relevant only if you're alternating between strenuous activity and rest. Department stores and army-navy stores have some wonderful stuff for cheap and also a fair amount of junk; they're great if you can tell which is which.

One very important place where your current gear might not work is your feet. Foot warmth varies hugely from one person to another, but my feet never stay warm for long if I'm wearing regular street shoes when the temperature is below freezing. And don't try stuffing extra socks inside regular shoes — that's a classic recipe for frostbite. It's absolutely essential for footwear to be loose. Wearing too many socks will cut off the blood flow to your feet, making them colder rather than warmer.

Hiking boots are much better than street shoes. But for serious cold weather I always wear boots with built-in insulation. Boots with removable wool-felt liners, popularized by L.L. Bean in the U.S. and Sorel in Canada, are excellent. But there are many alternatives.

For your legs, long underwear is great, and shouldn't cost a fortune. Silk, high-tech synthetics, and old-fashioned cotton and wool all work well. Hikers don't use cotton because it loses insulating value when it's drenched with sweat. But that's rarely a problem for stargazers.

I wear fleece-lined pants all winter long, both indoors and out. They look just like regular trousers but are much warmer — try a web search to see examples. Having worn lined pants so long, I can't imagine how 99% of the population can tolerate a New England winter in regular street pants. It's miserable to walk outside and instantly feel the cold on your legs. And totally unnecessary!

Left: Down mittens are extremely warm, but they're ill suited for manipulating small objects. *Right:* Open-palm mittens allow you to poke out your fingers for fine work and retract them for warmth. They work well in conjunction with chemical hand warmers.

TIPS FOR STAYING WARM

There are lots of tricks and techniques to keep warm. For instance, an eyepatch helps preserve your dark adaptation if want to come into a lighted house to warm up. See skypub.com/cold for additional tips.

Left: The author prefers to stay inside when the wind is howling and the temperature hovers around 0°F. But when some special event makes observing really enticing on such a night, a face-mask is necessary to avoid frostbite. *Right*: Like many stargazers, *S&T* senior editor Dennis di Cicco favors the Mad Bomber hat, which provides full coverage for the ears and neck.

Many people swear by insulated bibs or coveralls, which eliminate the potentially problematic gap between jacket and pants. Both are readily available in stores that cater to construction workers or snowmobilers.

If you want to buy a jacket especially for stargazing, down is best. That's not because it has magical insulating properties but because it's light and compressible, so it doesn't inhibit movement. Put on a 2-inch-thick wool jacket and you'll feel like a stuffed puppet. With a 2-inch-thick down jacket, you barely know you're wearing it.

Jackets can never be too thick. I consider a standard down jacket over a thick pile jacket to be a bare minimum for temperatures around freezing, and inadequate when it's colder than that. I usually wear either a special expedition down jacket (wonderful but expensive) or two regular down jackets, one over the other.

The author's favorite boots are extra-warm Sorels (left) and U.S. Army insulated rubber boots, better known as Mickey Mouse Boots (right). Many other options are available; the one thing they all have in common is that they're really, really thick.

Avoid jackets with weatherproof shells. They're heavy and not very flexible — and who wants to stargaze when it's snowing? Short jackets that end at your waist rather than well down your hips are asking for trouble.

For your head, you need a thick hat that completely covers your ears, and as much of your neck and face as possible. Insulated hoods are even better. And best of all is a warm hood over a warm jacket.

That leaves hands, the final frontier. Everywhere else on your body is easy, but hands are a real challenge. For binocular stargazing I sometimes use a pair of thick down mittens that keep my hands toasty in a stiff breeze at 0°F, but they're far too clumsy for tightening the set screw on a focuser or typing on a keyboard.

Everybody works out his or her own compromise. One popular solution is thin gloves under thick mittens. Take the mittens off for fine work and put them back on whenever you can. I'm a fan of mittens with slits in the palms so that I can poke my fingers out when needed.

But in really cold weather I find that my own body heat isn't sufficient to keep my hands warm, so I supplement it with chemical hand warmers. Many people also like chemical heat packs for their feet. Just remember that they need oxygen to work — and also that the warmer they are, the more heat they put out. Keep them in a warm pocket before you open them, otherwise they'll take forever to get started.

Some people also swear by electrically heated gloves, boots, and even jackets, which are popular among motorcycle riders. I don't use these because I don't like to be dependent on electricity. But if you're already using a deep-cycle 12-volt battery to drive your telescope, why not use it to keep you warm at the same time? And if you can run an extension cord from your house, try a heating pad.

Or use the old-fashioned low-tech alternative: the hot-water bottle. Slip it under your jacket while your seated and you'll feel a glow of warmth radiating through your whole body. Cold hands? Just grab onto that hot-water battle, and they won't stay cold for long. ✦

Like most children, ***Tony Flanders*** *loved to play in the snow when he was young. Unlike most grownups, he never lost his sense of wonder about winter — or anything else.*

Capturing Comets

Chris Cook

Come home with a trophy of Comet ISON using these helpful techniques.

The promise of a bright comet always excites a certain breed of astrophotographer. These icy visitors from the edge of the solar system swoop into the inner solar system on extremely elongated orbits, put on a memorable show, and then (if they survive) return to the frozen depths of space.

Ever since observing and photographing Comet Bradfield (C/1987s), I've been enamored with these unique objects. Though technically members of our solar system, comets require their own special treatment in order to be captured in all their extended glory. Here are some tips that can help you get the most out of your equipment for Comet ISON's late autumn apparition.

Gather Your Equipment

The easiest way to capture a bright comet is to use a good DSLR camera with a tripod. I suggest avoiding point-and-shoot cameras because of their current trend toward smaller pixels, which are less sensitive to low light levels.

Although any current DSLR will produce good results, popular brands such as Canon and Nikon offer the widest array of bodies and high-quality lenses to fit in most budgets. Whatever camera you choose, make sure it has a bulb (B) mode, which enables you to take exposures longer than 30 seconds. While 30-second exposures are long enough for untracked wide-field nightscapes, you'll want to take longer images if you use a tracking mount to capture a bright comet's extended tail.

Your next consideration should be a lens. Comets vary in size and are unpredictable. If ISON turns into a great comet, its tail might stretch anywhere from 10° to 50° across the sky. You'll want to have a few lenses on hand that give you the flexibility to shoot at various focal lengths. For wide-angle nightscape photos or for comets with very long tails, lenses ranging from 8 to 85 millimeters work best.

Generally, you'll capture your best results through prime lenses (lenses with fixed focal lengths). These lenses usually produce sharper photos than their zoom counterparts and are often "faster" (utilizing a shorter f/ratio), too. Any camera lens you choose should have an f/ratio of at least f/4 and preferably f/2.8. Because comets are relatively dim subjects compared with objects shot in the daytime, the lower the f/ratio, the more light gets into the camera's sensor in a shorter time frame, allowing deeper exposures before the stars trail noticeably.

The next accessory essential to taking good DSLR comet photos is a shutter-release cable or digital intervalometer. These devices will enable you to fire the shutter without introducing vibrations during the exposure, which might ruin your image. A simple cable release will hold your shutter open until you release the cable. A programmable version will enable you to set the exposure length and number of repeated exposures without having to touch your camera again for the evening.

With your camera and lenses selected, your next requirement is a tripod. Any tripod will work as long as it can support about 8 pounds (3.6 kg). Sturdy aluminum models such as those manufactured by Manfrotto will assure wiggle-free images even in high winds.

Comets are unlike any other deep-sky or solar system object: faint ones require long exposures with complex guiding methods. Fortunately, bright comets are a welcome exception to that rule. When Hale-Bopp swung by in 1997, the author grabbed this 40-second exposure on Fujicolor Super G 800 Plus film with a 50-mm f/2 lens. Unless otherwise noted, all images are courtesy of the author.

Choosing Your Exposure

Today's DSLRs enable you to adjust the camera sensor's sensitivity. Just like in the days of film, an ISO of 100 is less sensitive than an ISO of 200, and so on. For most comet imaging, you'll want a fast ISO setting of 800 or greater. ISO settings of 2000 and higher produce more noise in older camera models. However, the newer DSLRs, such as the Canon 6D and 5D Mark III and the Nikon D800, are exceptions to that rule. These high-end DSLR bodies produce low-noise images all the way up to ISO 6400 compared with their older counterparts. With most DSLRs, though, the noise in fast ISO settings increases to the point where it will erode fine detail in your images. I prefer shooting untracked exposures at ISO 800 to 1600. This gives me a good balance between speed and noise with fast lenses and reveals fainter extended objects such as the Milky Way in relatively short exposures.

Speaking of exposures, what would be best for an untracked comet photograph? That depends on a number of factors: how big and bright the comet is, the local light pollution, and your lens's focal length and f/ratio. One of the best aspects of today's digital cameras is that they let us instantly examine our images on the camera's LCD screen. If an exposure is too dark or too light, we can easily adjust it on the spot. When shooting a bright comet, I suggest exposures ranging from 5 to 30 seconds with wide-angle lenses on a fixed tripod to avoid noticeable trailing of the comet and stars. The longer the focal length, the shorter the exposure you can take before trailing becomes objectionable.

Take some time before starting your exposures to compose the image; try including something that the average viewer can relate to. A foreground subject also gives a sense of scale. Placement of the comet and a foreground object within the camera's frame is important — putting the comet on the left side of the frame and the foreground object on the right will create a more balanced image than having your subject dead center in the frame.

Finally, when you're ready to shoot, set your camera to save the images in RAW mode. RAW files contain all the information that the camera's sensor has recorded and lets you adjust everything afterward. If you shoot JPEG, you'll have a smaller file size but the camera will make processing decisions for you.

Tracking the Sky

If you want to take deeper images of a comet that show more detail, you'll need to track your exposures. You can apply some of the same camera settings as before, but insert a tracking head between the camera and tripod to follow your target as it moves across the sky. This will enable you to record the stars as sharp points of light, not streaks. Additionally, you can take longer

The author poses in his observatory with his current deep-sky astrophotography setup: an Astro-Physics 130-mm StarFire EDF Gran Turismo with an SBIG ST-8300 CCD camera, riding atop a Losmandy G-11 German equatorial mount.

exposures to reveal the faintest extent of the comet's gas and dust tails, as well as faint deep-sky objects nearby. Tracking also allows you to use longer telephoto lenses to record finer details in the comet's tail.

In recent years, quite a few lightweight tracking heads have appeared on the market, including the Vixen Polarie, the iOptron SkyTracker, and the AstroTrac TT320X-AG. These compact mounts will hold up to 15 pounds, which will accommodate any DSLR with a telephoto lens as long as about 400 mm. You may need to experiment to see how long your particular tracking mount and lens combination will shoot before periodic error becomes apparent. In general, these tracking heads will enable you to capture dozens of 1-minute exposures that can then be stacked together using popular software programs to give you a smooth, colorful image much deeper than you can take without tracking.

If you want to shoot Comet ISON through a telescope, you'll need to consider moving up to an equatorial mount. These will allow you to take much longer exposures than you could with a tracking head. Heavy-duty models will enable you to mount multiple scopes and introduce a new level of sophistication — autoguiding — that will result in superior comet photos.

Comets not only move across the sky but also relative to the background stars. This becomes a problem both when the comet is passing close to Earth and when shooting long exposures. At a focal length of around 1,000 millimeters, even faint, distant comets will trail in a 5-minute exposure, while the stars are tracked perfectly. So how do we keep the comet sharp in the image?

There are two well-established techniques you can use; both require an autoguider. The first is to take many short images tracked on the background stars and then combine the images, registering each on the comet's coma. The stacked result will have a sharp comet image with an extended dust tail surrounded by streaks of the background stars. This can be accomplished by using an off-axis guider, or an additional guidescope.

If you use a guidescope and the comet is bright enough, you can track your images directly on the comet's head, as if it were a star. You'll need to experiment to find the best tracking exposures for your particular setup, depending on the comet's brightness. Both methods produce excellent close-up images, but by introducing a pause between exposures, you can use an additional post-processing method to obtain a result that makes both the comet and stars appear round, as we'll see shortly.

Processing Your Results

Once you've captured your images, you'll want to perform some processing to achieve your best results. Rarely is an astrophoto complete as soon as it comes out of the camera. The bare minimum necessary for untracked nightscape images is to adjust the color balance and perhaps boost the visibility of the comet and other deep-sky

Bright comets such as PanSTARRS (C/2011 L4) are easy to shoot with a camera and tripod. This image featuring the author and his young son was a single 2-second exposure at ISO 1250 with a 70-to-200-mm zoom lens at f/2.8.

objects. *Adobe Photoshop* has a great tool for this known as the Shadows/Highlights tool (Image / Adjustments / Shadows/Highlights). The highlights portion will recover some detail near the comet's bright head, while the shadow slider brings up everything in the darker regions of your image. Experiment with this tool until you're happy with the results.

If you tracked your images, you can combine many of the exposures to greatly increase your target's signal while also reducing noise. To do this in *Photoshop*, open the images to be combined, then use Select / All from the drop-down menu, then Edit / Copy. Now click on your base image and paste the copied one on top using Edit / Paste. Repeat this step for each image you're combining. Once you've pasted all the images, open the layers window (Window / Layers), and hide all the layers except the background and Layer 1 by clicking the eye icon to the left of each layer. Next, set the blending mode opacity of Layer 1 to 50%. You'll probably have to move the layer around slightly if there was some drift between your frames, or if the comet moved noticeably between exposures. Select the Move tool from your tool palette and nudge this top layer into place with your arrow keys. Once you're satisfied with the registration, hide it and repeat the same process for every layer until they're all aligned with one another.

Now let's blend these layers together. Show all the layers and change the opacity of each to progressively lower values, so that each layer contributes equally to the final image — Layer 1 should be set to 50%, Layer 2 to 33%, Layer 3 to 25%, and so on. Once you've changed each layer's value, you should have a very smooth image ready for further enhancement. Combine the layers using Layer / Flatten Image in the pull-down menu and save this file as a TIFF or PSD file. Now you can make any final adjustments using Curves, Shadows/Highlights, and Levels, or you can perform sharpening.

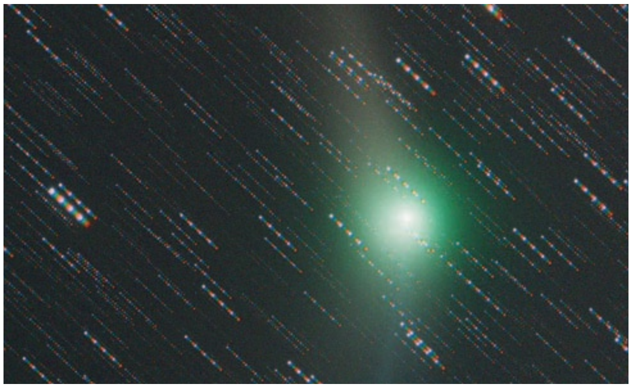
Combining Close-ups

If you plan on shooting close-ups of the comet through a telescope, a little advanced planning can help set your images apart from the rest. Shortly after perihelion, Comet ISON will be moving quickly in the dawn skies, which will require you to either shoot short exposures or track on the comet's nucleus (if it survives perihelion) to capture good tail details while avoiding trailing of the nucleus. Whether you're using a DSLR or CCD camera, add a pause of a minute or so between your exposures.

S&T: DENNIS DI CICCO

Left: **Adding a tracking head to your tripod and camera will enable you to record longer exposures, revealing more of a comet's extended tail in your photos.**

Right: **Using a tracking mount also lets you use longer telephoto lenses to record delicate wisps in a bright comet's gas tail. This author image of Hale-Bopp was a single 8-minute exposure using a 200-mm Nikon lens at f/4.**

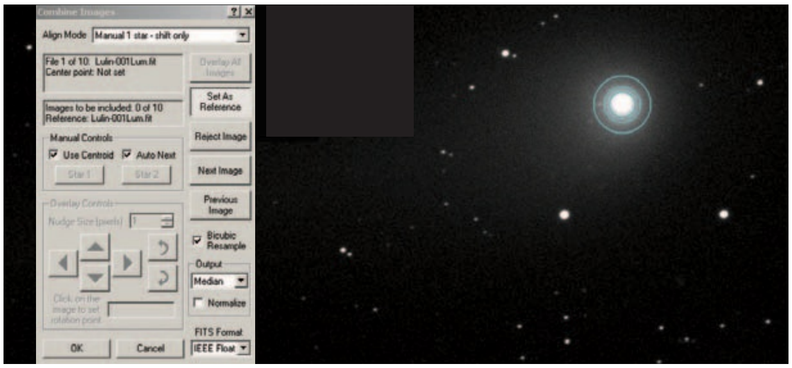


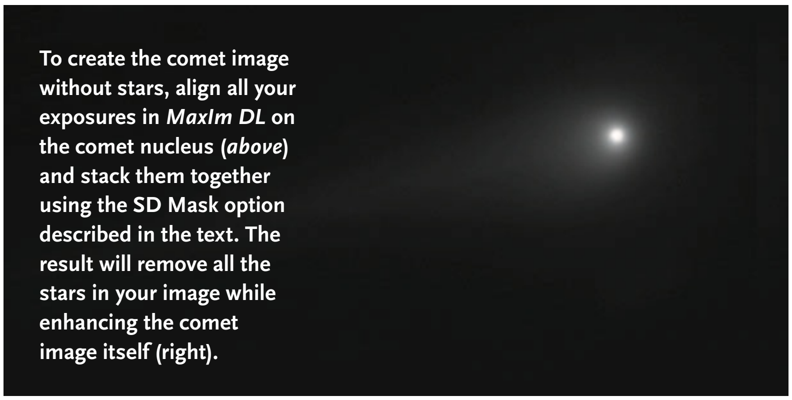
Above: **Stacking many short exposures taken through color filters will reveal faint details in a comet's tail, such as the widely spaced dust and gas tails in this photo of Comet Garradd (C/2009 P1). The red, green, and blue stars are due to the comet's motion through space during the 80 minutes of exposure.**

Below: **Shooting shorter exposures through a telescope allows more complex processing. The author produced these two images of Comet Lunin (C/2007 N3) using the same data. For the image with trailed stars, he registered all the exposures on the comet, whereas for the second image he used the technique described in the article to "freeze" the comet's motion.**

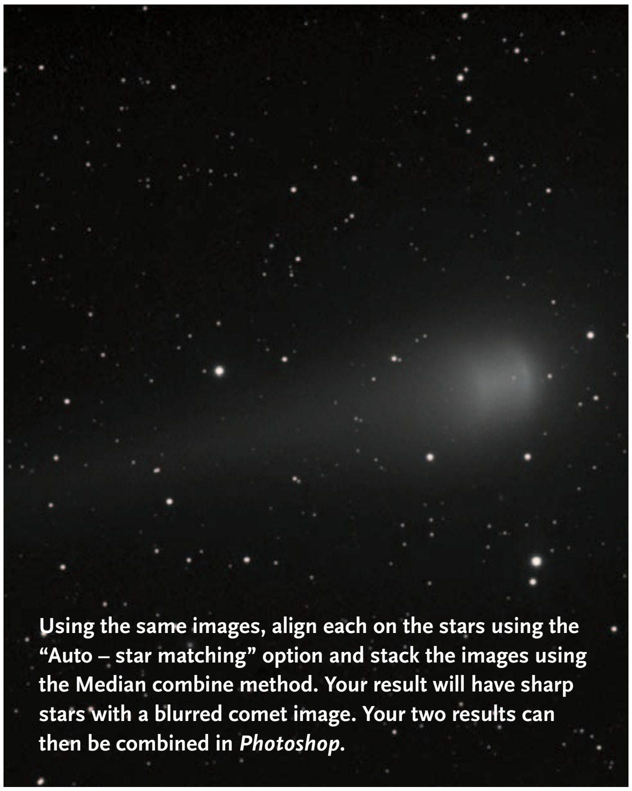
You'll want to process the images using software written specifically for astronomical images, such as *MaxIm DL*, *CCDStack 2*, *PixInsight*, *AstroArt*, or *Images Plus*. I use *MaxIm DL*, though most of the steps I use can be duplicated in the other programs.

To create an image with a sharp comet with trailed stars, begin by calibrating your exposures the same way you would for deep-sky images using darks, biases, and flats. In *MaxIm DL*, open Process / Stack in the pull-down menu. A new window opens, where you'll select the images to combine. Once you've selected them, click the Align tab and change the mode to "Manual 1 star – shift only." Using the cursor, select the very center of the comet's coma on all the images (you may have to perform a screen stretch to see the actual comet head) and zoom in at least 200%. Once you've selected every image, click the Combine tab, select Sum as the Combine Method, and click the Go button. You should end up with an image that contains star trails with a sharp comet. Save the file as an IEEE Float uncompressed FITS file to avoid clipping any of the signal. You can now stretch the image using DDP or Curves to enhance the tails and inner coma.





To create the comet image without stars, align all your exposures in *MaxIm DL* on the comet nucleus (*above*) and stack them together using the SD Mask option described in the text. The result will remove all the stars in your image while enhancing the comet image itself (right).



Using the same images, align each on the stars using the "Auto – star matching" option and stack the images using the Median combine method. Your result will have sharp stars with a blurred comet image. Your two results can then be combined in *Photoshop*.

This guided exposure displays multiple streamers in the tail of Comet Ikeya-Zhang (C/2002 C1). Total exposure was 25 minutes tracked on the comet's bright coma, and was shot through a Tele Vue TV-102 with Fujicolor Press 800 film on the evening of March 9, 2002.

If you shot the comet through individual color filters, repeat these steps for each of the red, green, and blue image groups and then combine them using Color / Combine Color in the pull-down menu. When complete, you'll have a color image of the comet surrounded by red, green, and blue stars, as seen on the previous page.

In order to produce an image with a stationary comet floating among sharp stars, you'll need to create two separate images using a slightly modified version of this same workflow. Follow the same steps as earlier, but change the Combine Method to SD Mask instead of Sum. Change the number of passes to 3, Sigma Factor 0.5, and switch the Normalization to "Linear" with an area of 50%. Also click the "Ignore Black Pixels" box, and then hit Go. You should end up with an image that is devoid of all the stars and contains only the comet. Save the file as an IEEE Float uncompressed FITS.

Next, we want to create the star-field image that will be composited with this photo. Simply combine the same individual images again, but change the alignment mode to "Auto – Star Matching," and also change the Combine method to Median. When you click Go, you'll end up with an image with sharp stars but a severely blurred comet. Again, save the file as an IEEE Float uncompressed FITS.

Open the two FITS files you just created and apply the same values of Digital Development Processing (DDP) to each image to bring out the comet's fainter regions while avoiding overexposing the coma details. Then save both results as 16-bit TIF files to combine in *Photoshop.*

To combine the two images, first open the image with sharp stars in *Photoshop*. Select Layer / Duplicate Layer from the pull-down menu. Now with the top layer selected, choose Filter / Noise / Dust & Scratches. A new window appears with the settings of the filter; choose a radius of about 10 and a threshold of 10, though you may want to experiment to find the best settings. Next, use the Clone Stamp tool to remove any remaining stars. Apply a Gaussian Blur with a radius of about 11. Now hide the top layer you have been working on and select the background layer. We'll combine the two layers using Image / Apply Image in the pull-down menu. Select the Background Copy as the layer, and change the target blending mode to Subtract, then click OK. You should now have an image that is devoid of the comet.

Now open the comet image without stars, and Select / All, then Edit / Copy. Click on your star field image and choose Edit / Paste. In the Layers window, change Layer 1 blending mode to Lighten. You should now have a stationary comet surrounded by round stars. You can make final adjustments to brightness, contrast, levels, and so forth.

Whatever techniques you choose to capture Comet ISON, remember that you are capturing a once-in-a-lifetime event: ISON will not return to the inner solar system for thousands of years. So whatever performance the comet gives, use these tips to make the most of it. ✦

__Chris Cook__ routinely images the night sky from his backyard observatory on Cape Cod in Massachusetts. Check out more of his images at ***www.cookphoto.com***.

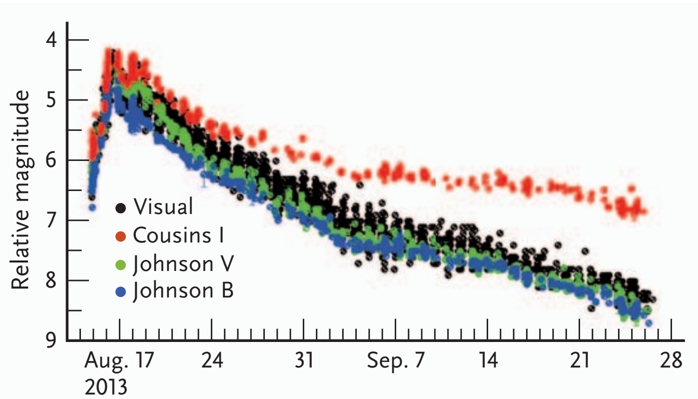
Naked-Eye Nova Shines in Delphinus

ROBERT NAEYE Professionals and amateurs are following Nova Delphini 2013.

At 14:58 UT on August 14th, using a 7-inch reflector and a CCD camera, Koichi Itagaki of Yamagata, Japan, caught a 6.8-magnitude star in the constellation Delphinus that wasn't there in an image taken the previous day. This "new star," or nova, brightened rapidly, peaking two days later at about magnitude 4.3, making Nova Delphini 2013 (also known as V339 Del or Nova Del) the brightest nova since Nova Scorpii 2007, and one of the 30 brightest on record.

The nova was visible to the naked eye for about a week. It has declined steadily ever since, and was shining at magnitude 9.7 on October 6th, as this article was going to press. When subscribers receive this issue in late October, the nova will probably have faded to around magnitude 10.

News of the nova spread rapidly over the internet. The American Association of Variable Star Observers was flooded with tens of thousands of brightness estimates in the following weeks, many from first-time nova observers.



These light curves include data submitted to the AAVSO by hundreds of observers from around the world. They show how the nova behaved at different wavelengths during its first six weeks.

These images from amateur Rolando Ligustri show how Nova Delphini 2013 faded and reddened over nearly a month. They were shot from the CAST Observatory in Talmassons, Italy.

"The big difference between this nova and earlier ones is the large contingent of amateur spectroscopists," says AAVSO director Arne Henden. A number of professional telescopes, including Hubble, also swung into action. But many of the largest scopes were unable to observe Nova Del because its sheer brightness would saturate their detectors.

Nova Del is a classical nova. These stellar explosions occur in a tightly orbiting binary system in which a relatively normal star pours a stream of hydrogen onto the surface of a companion white dwarf. When the layer of fresh hydrogen on the white dwarf's surface grows thick and dense enough, the bottom of the layer explodes in a runaway fusion reaction — a hydrogen bomb in the shape of a thin shell roughly the size of Earth. The white dwarf survives, and as new hydrogen builds up, the process may repeat in a few years to tens of thousands of years.

Nova Delphini 2013 is behaving like a typical nova. As Brad Schaefer (Louisiana State University) says, "Nothing unusual or surprising has been discovered for Nova Del so far." Spectra reveal numerous lines of iron in a low state of atomic excitation, so Nova Del appears to belong to the Fe II class. The nova ejected the hydrogen layer at about 2,000 km/second, which is in the middle of the range for these events.

But future surprises may emerge. As Sumner Starrfield (Arizona State University) explains, "Nova Del is being followed at all wavelengths by both professional and amateur astronomers. The AAVSO has been a big help." ✦

Robert Naeye is Editor in Chief of Sky & Telescope.

▲ **THE GRAND NEBULA**

Harel Boren

The Eta Carinae Nebula (NGC 3372) is a massive starbirth region in Carina that is easily visible to the naked eye under dark skies.

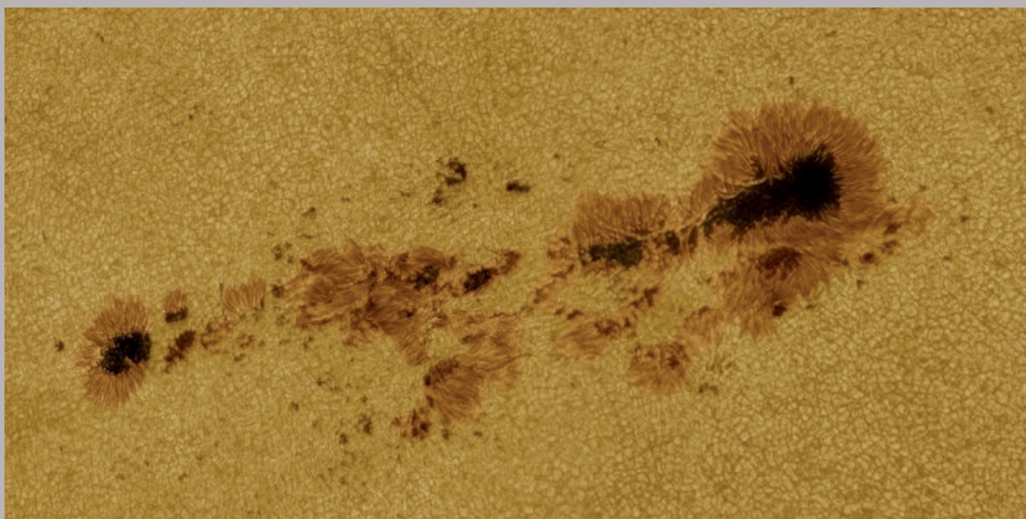
Details: *Officina Stellare Veloce RH 200 astrograph with SBIG STL-11000M CCD camera. Total exposure was 4 hours through Astrodon Gen II color filters.*

◀ **CONTRASTS OF SAGITTARIUS**

Kfir Simon

Reddish emission nebula IC 1284 in Sagittarius is paired with the blue reflection nebulae NGC 6590 and 6589.

Details: *Dream Telescopes & Accessories 16-inch astrograph with Apogee Alta U16M CCD camera. Total exposure was 2⅘ hours through color filters.*



▲▲ **EAGLE OVER TURKEY**

Tunç Tezel

The constellation Aquila the Eagle, with its bright star Altair, arches high above Keles Lake in Bursa Province, Turkey.

Details: *Canon EOS 5D DSLR camera with 24-mm f/1.4 lens. Mosaic of four images, each exposed for 30 seconds at ISO 1600.*

Visit skypub.com/gallery to see more of our readers' astrophotos.

▲ **SUNSPOT SMEAR**

Damian Peach

Among the largest sunspot groups so far this year, AR 1785 and 1787 are surrounded by the ever-churning granulation of the photosphere on July 6th.

Details: *Celestron C14 with Baader AstroSolar safety film and ZWO Design ASI120MM video camera. Stack of multiple exposures.*

Gallery showcases the finest astronomical images submitted to us by our readers. Send your very best shots to gallery@SkyandTelescope.com. We pay $50 for each published photo. See skypub.com/aboutsky/guidelines.

NARROWBAND WESTERN STATE
Robert Fields
The California Nebula (NGC 1499) in Perseus displays faint wisps of gases that extend far beyond the familiar boundaries of this well-known object.
Details: *Takahashi Epsilon 180 astrograph with SBIG STL-4020 CCD camera. Mosaic of four frames totaling 36 hours of exposure through Astrodon narrowband filters.* ✦

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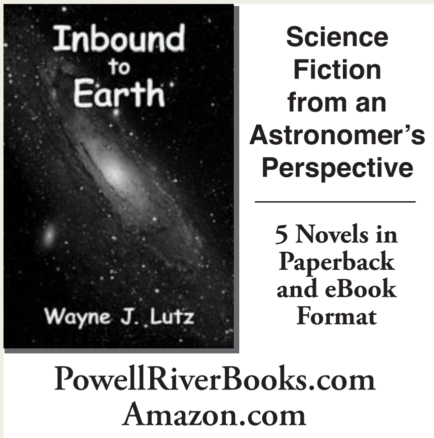

BOOKS

CCD EQUIPMENT

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DRIVES / MOUNTS

MISCELLANEOUS

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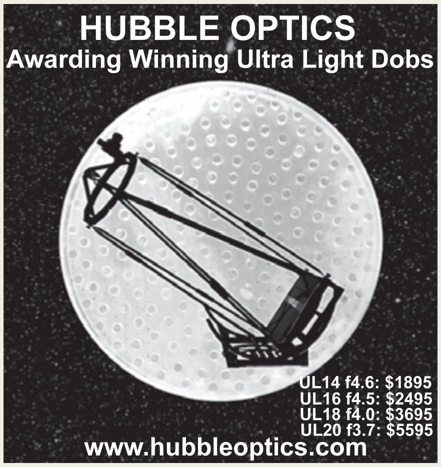
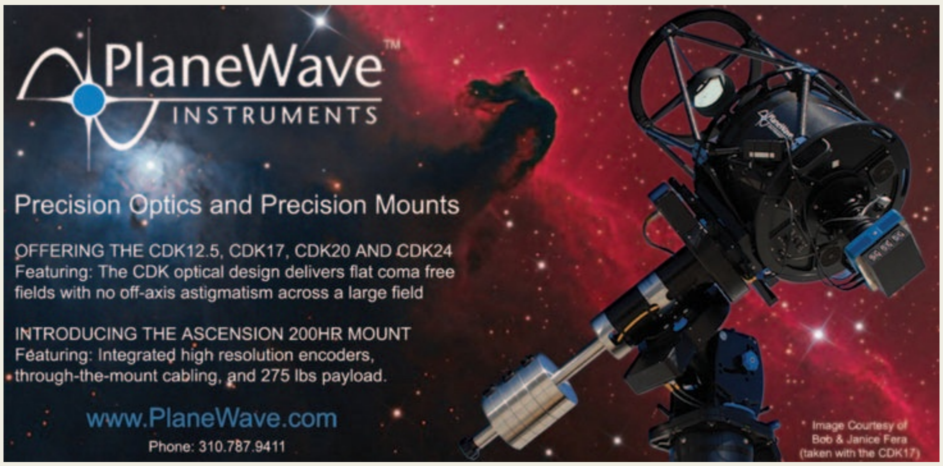


TELESCOPES

TELESCOPES



TELESCOPES

TELESCOPES

TRAVEL

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HAVE OVER 1,000 Sky & Telescope and Astronomy magazines dating back to 1956. First $200 takes them. Pickup in Candor, NY. donyeier@frontier.com .

TELESCOPE FOR SALE: 36" F4.9 folded Dobsonian. The scope is becoming too big for me and needs a younger astronomer! It can be used as a 3 mirror unit with an eyepiece height of some 7ft 3" or as a pure Dobsonian with a height of 13ft 2". The basic design is for observatory use but is currently mounted on a carriage so it can be wheeled out of my garage. It is transportable as is; sub assembled in a small hire truck and is quick re-assembly. Won first prize for workmanship at the Star Party, primary by Intermountain Optics. Set up for encoders and designed to take photography adaption. The price is US$25,000 to include finders and components plus shipping & taxes ex Sydney Australia at cost. Please e-mail josroberts2@gmail.com – serious inquiries only please.

FOR SALE: Beautiful 2,000 sq-ft single-story Pueblo-style home, between Las Vegas and Kingman AZ, 12' automated clamshell dome, 4BR, 3BA, 5 car garage, very dark clear skies, $195,000, for pictures and details email: easton6@roadrunner.com . Phone: 702-595-8535.

REAL ESTATE: Land and homes for sale in Southern Utah's high desert – the second darkest place in North America. Noted for deep sky viewing. Properties are located between Bryce Canyon and Capitol Reef National Parks. Small remote communities surrounded by 97% government lands. Electricity, water, internet access and complete comfort while living in the wilderness! Homes on the market now ranging in price from $190,000 to $470,000. Land ranging in size from 2 to 47 acres priced from $48,000 to $350,000, all with exceptional views of the landscape and the sky. For more information, visit www.bouldermountainrealty.com or call Cathy Bagley, Broker, Torrey, Utah, 435-425-3200.

FOR SALE: Classic A-frame, 2x10 construction, 33 mountaintop acres at 6,200' altitude, dark-sky laws in effect. Fort Davis, TX. 250K; matthewoller@yahoo.com.

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WEST TEXAS DARK-SKY site 40 miles from McDonald Observatory. A mile high on 4 acres in the Davis Mountains, 12x12 roll-off observatory with electric, phone, pier and C-8. 2,023 sq-ft 3br turnkey house built 1990. Agent website: http://jwcarpenter.com/Z170.htm, phone: 432-837-3325. Owner phone: 314-209-1515.

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SKY & TELESCOPE

Inside This Issue

Specialty astronomy equipment dealers and manufacturers are an important resource for amateur and professional astronomers alike — patronize our advertising dealers in this issue and enjoy all the benefits of their expertise.

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b. Paid and/or Requested Circulation	(1) Paid/Requested Outside-County Mail Subscriptions Stated on Form 3541. *(Include advertiser's proof and exchange copies)*	58,571	57,774
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c.	Total Paid and/or Requested Circulation *[Sum of 15b. (1), (2), (3), and (4)]*	66,640	65,724
d. Free Distribution by Mail *(Samples, complimentary, and other free)*	(1) Outside-County as Stated on Form 3541	643	696
	(2) In-County as Stated on Form 3541	0	0
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e.	Free Distribution Outside the Mail *(Carriers of other means)*	250	0
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Planetary Self-Awareness

The author reflects on the 45th anniversary of "Earthrise."

Psychologists use the term "self–awareness" to describe a conscious being who possesses the capacity for introspection. It's the understanding that you are one consciousness, separate from others. Self-aware individuals recognize that others have thoughts that they are not aware of. If you own certain types of animals as pets, you have no doubt realized that they are not self-aware: they think that others in the household exist solely for their benefit. Such pets cannot grasp why one leaves the house each morning to go to work and they generally think that the world revolves around them. The litmus test for being self-aware is recognizing oneself in the mirror; many higher mammals have passed this test.

Forty-five years ago this month, on December 24, 1968, the astronauts aboard the Apollo 8 mission (Frank Borman, James Lovell, and William Anders) captured one of the most iconic images of the century — Earth rising over the Moon's surface. With this image, humans could finally see our home planet from afar. Earth's blue face helped accelerate the environmental movement, it gave our species an accurate portrayal of our fragile home, it sparked our collective curiosity, and it became a hallmark of space exploration.

It's ironic that perhaps the most memorable aspect of our journey outward into space was looking back upon our planet. By journeying into the starry sky we found a mirror and recognized ourselves. This was the dawn of our species' planetary self-awareness.

From this time onward, the stars were no longer gods and myths for us alone. The sky did not exist solely for our benefit. We saw in the clockwork of the universe our relative insignificance amidst the immensity of space and the depth of time. We recognized the elements in interstellar clouds as being the building blocks of our bodies: carbon and calcium, sulfur and sodium, iron and oxygen. We could imagine, and indeed we have found, numerous worlds somewhat like our own planet, spinning at their own pace, revolving around different stars. Our planet was not the only reality.

This perspective of planetary self-awareness has profoundly changed our species. The journey to get here stretches back through the ages. Newton was there along the way, as were Aristarchus, Copernicus, Galileo, and Kepler. We are fortunate to be alive at this time of awakening.

Yet the starry sky's endowment to our species may not always endure. Light pollution and the expanding urban and indoor culture threaten to separate us from the understanding of the larger whole. Like the people of Lagash in Isaac Asimov's sci-fi story *Nightfall*, there is no guarantee that our technology can replace the profound perspective that the stars offer our species. To paraphrase the Ralph Waldo Emerson quote that inspired *Nightfall*, let us preserve for many generations the remembrance of this great moment in the history of humanity. ✦

NASA

On December 24, 1968, Apollo 8 astronaut William Anders caught Earth rising over the Moon's eastern limb. This famous "Earthrise" photo is rotated 90° clockwise above to match the iconic view.

***Chad Moore** founded the U.S. National Park Service Night Skies Team — a group of scientists dedicated to preserving natural darkness and sharing the starry sky.*

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