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PL16803 image of Comet Lovejoy courtesy of Gerald Rhemann.

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SKY & TELESCOPE

November 2015 VOL. 130, NO. 5

On the cover: This composite image from NASA's Solar Dynamics Observatory shows a bright flare (white) and coronal mass ejection (filament) on the Sun on August 31, 2012.

IMAGE: NASA / GSFC / SDO, MODIFIED BY PATRICIA GILLIS-COPPOLA

FEATURES

NASA / BILL INGALLS

OBSERVING NOVEMBER

S&T TEST REPORT

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November 2015 Digital Extra

Photo Gallery

Image by Scott Champion

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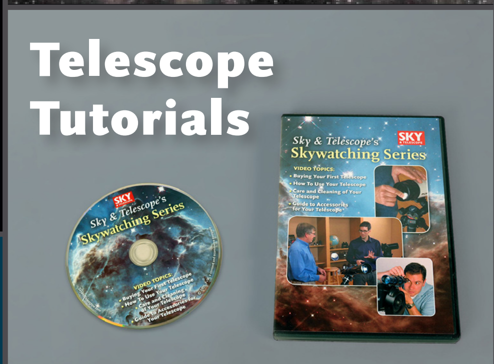

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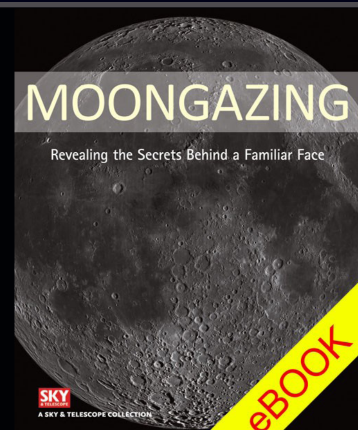

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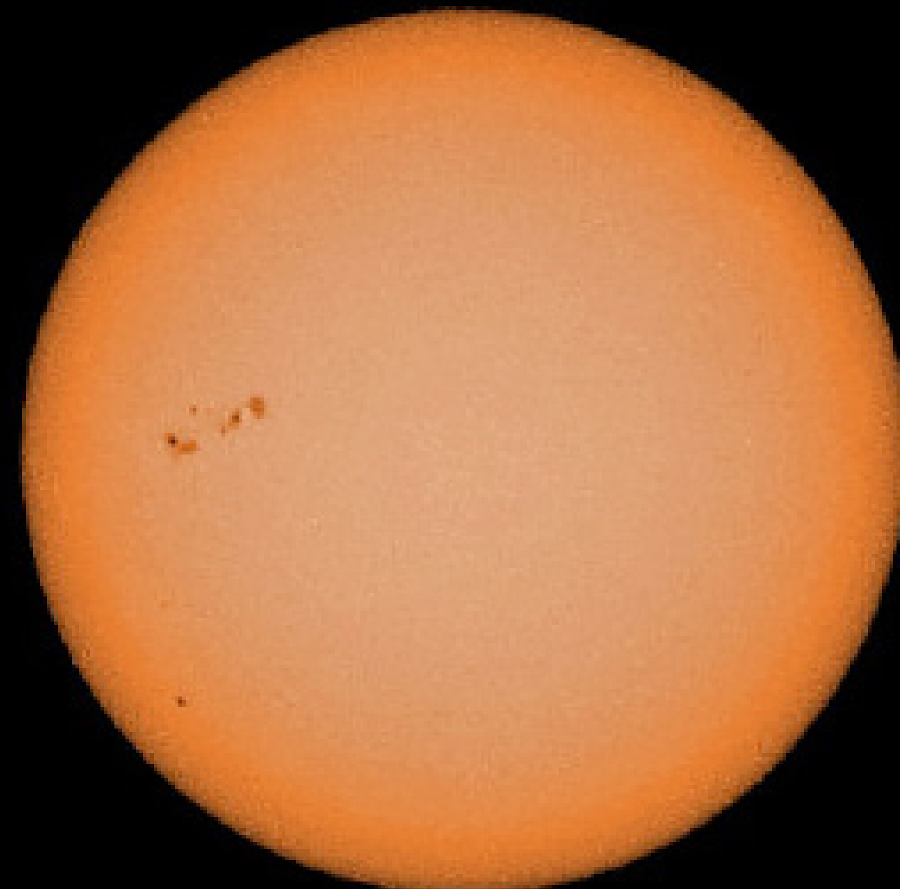

ONLINE PHOTO GALLERY

Joanna Wojtowicz photographed this view of the Sun showing Active Region 2339.

Celestial Balm

OLIVER SACKS, the neurologist and author, wrote recently of seeing the night sky "powdered with stars" (in Milton's phrase) while spending a night in the countryside. Witnessing this dark-sky grandeur made Sacks, who this year has been chronicling his battle with terminal cancer, realize how little time he had left. "My sense of the heavens' beauty, of eternity, was inseparably mixed for me with a sense of transience — and death," he wrote in the July 26th *New York Times*.

Did this awareness cause him to despair? Just the opposite. Sacks told friends he would like to see such a sky again when he is dying. He noted that, since he first publicly discussed his condition in the February 19th *Times*, the hundreds of letters he has received expressing appreciation for his life and work have brought him comfort. "I remain very glad and grateful for all this — yet none of it hits me as did that night full of stars," he wrote.

Why, as he stands on the brink of the beyond, does Sacks find solace gazing at the vault of heaven? Sacks recounts how he has long coped with bereavement by turning to the nonhuman. The chemical elements — "little emblems of eternity," he dubs them — are one such source of succor. For his 81st birthday last year, friends gave him a small box containing thallium, element 81.

S&T: SEAN WALKER

To me, Sacks' reaction that night in the countryside makes perfect sense. All those elements that he treasures, that comprise his body and each of ours, originated out there amongst the stars. We talk of Mother Earth, but Mother Supernova might be more apt. From the human perspective, the firmament, like the elements, is constant, whereas everything here on our planet — save the elements it consists of — is ephemeral, as Sacks understood that summer evening.

And what is so universally inspiring as a night sky powdered with stars? Sacks is not an astronomer, nor even a physical scientist. Yet he, like most of us no matter our field of interest, nor our age, background, or beliefs, is struck dumb by their resplendence and mystique.

I for one am grateful to Sacks for so graciously and sensitively sharing his observations in this last stage of his life. Each of us will reach that moment when we, too, are staring at eternity. Sacks' words offer their own consolation that death is not something to be feared, in part because it couldn't be more natural: our elements returning to the cosmos from which they sprung. ✦

Editor in Chief

Postscript: Oliver Sacks died on August 30th, as this issue went to press. May he rest in peace amongst the stars.

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GOTO

GOTO PANDIA II HYBRID
Replaces Large Format Film

Digitized scene from original large format film

Sahoto Benibana,Kahoku Civic Cultural Center Center
PANDIA II HYBRID

Twenty years ago, when the Sahato Benibana, Kahoku Civic Cultural Center in Kahoku-cho Japan opened, the only way to put dramatic, colorful, animated images onto a planetarium dome was to use large format film running through an oversized cinema projector with a special lens. But today, high-cost, high-maintenance film is essentially a "dead" technology. Video is able to replace much of what the old large format projectors used to do. The Kahoku-cho staff knew that it was time to replace the obsolete large format film projector with fulldome video.

However, the Kahoku-cho staff also knew that video does a very poor job of reproducing the pin-sharp, bright starry sky of an opto-mechanical planetarium projector. So for their renovation technology, they chose a GOTO PANDIA II HYBRID system. The stars are created by the very compact PANDIA II. This LED-powered 19 inch starball shows a gorgeous sky in the tilted, 15 meter dome, including a Milky Way made up of 40,000,000 micro-stars.

Synchronized with the motions of the PANDIA II is GOTO's own VIRTUARIUM X fulldome video system. And the entire system is controlled by GOTO's unique HYBRID control console, which enables everything from simple cueing of automated movie playback to rich, yet effortless live programming.

Finally with the turnkey equipment package installed, the planetarium's original "safflower city" movie was cleaned, scratches were removed, and the movie was digitally enhanced for optimal color reproduction and stability on the dome. So the large format film that ran when the theater opened in 1995, now digitized, can be seen better than ever before. The total conversion from large-format film theater to modern GOTO PANDIA II HYBRID Planetarium is now complete. And the public loves it.

Note: PANDIA II is called PANDORA II in Japan.

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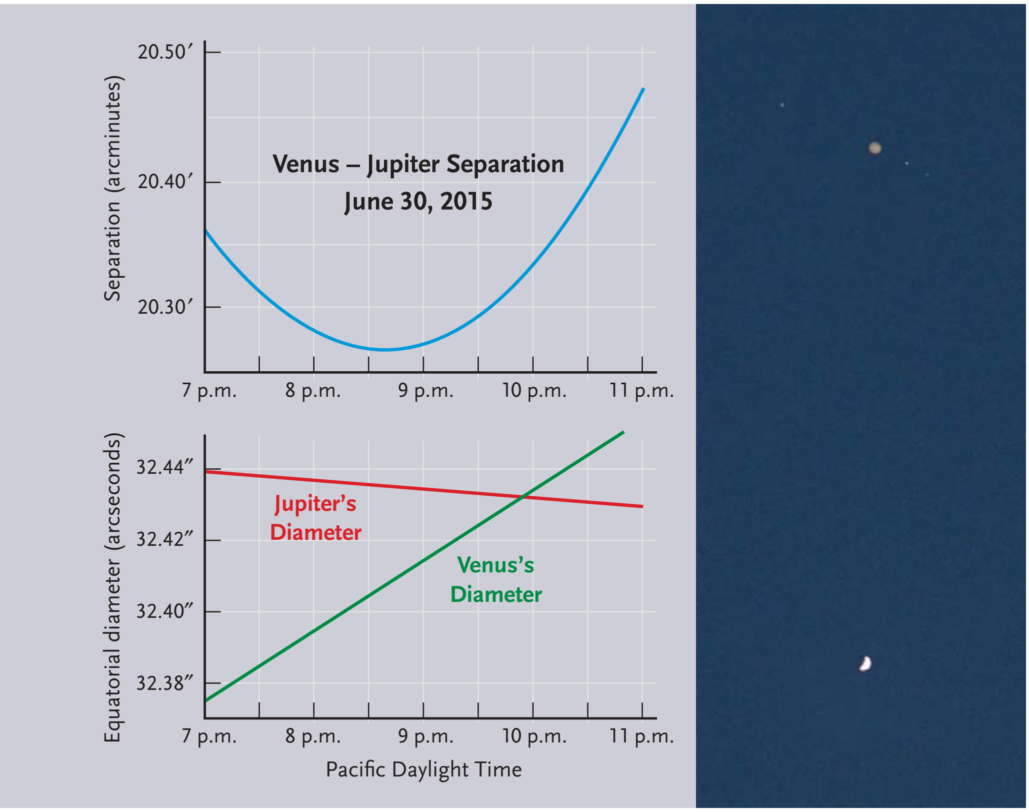


CHART SOURCE: DON BRUNS; IMAGE: RICHARD TRESCH FIENBERG

***Left:* The dramatic convergence of Venus and Jupiter in the late-June sky (upper graph) coincided almost exactly with the two planets having the same apparent diameter (lower graph). *Right:* When closest on June 30th, Jupiter (at top) and a crescent Venus appeared in the same field of an 80-mm f/6 refractor. This is a composite of a 1⁄160-second image of the planets' disks and a 0.8-second exposure to bring out Jupiter's moons.**

Coincidental Conjunction

I enjoy coincidences and unusual numeric combinations, such as 3/14/15 at 9:26:54 a.m. or celebrating with my wife, Carol, at our "1/3 century" wedding anniversary. While I knew the recent close conjunction of Venus and Jupiter (*S&T:* June 2015, p. 48) might generate some pretty photos, it did not otherwise attract my attention — until I looked a little closer.

It turned out that, as seen from my home in San Diego, Jupiter and Venus would appear closest to each other only 70 minutes before the two planets had the same apparent diameter. That was a rare coincidence worth watching! I don't know if many other amateurs noted this rare occasion, but I was happy for clear skies so that I could enjoy it.

Don Bruns
San Diego, California

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.

From Fiction to Fact

At the end of his excellent article on the novels *De la Terre à la Lune* (*From the Earth to the Moon*) and *Autour de la Lune* (*Around the Moon*) by Jules Verne (*S&T:* June 2015, p. 32), Dean Regas states, "It's difficult to measure what impact the fictional writings of Jules Verne had on the real NASA missions that would follow." I note that rocket pioneers Hermann Oberth, Robert H. Goddard, and Wernher von Braun all referred to these novels as sources of inspiration in their youth. Verne's impact on space travel was real and widespread!

Ken Rumstay
Valdosta, Georgia

Leonov's Near-Fatal Spacewalk

Your comment regarding the first-ever spacewalk in 1965 (*S&T:* May 2015, p. 10) — "Only decades later did the world learn that the spacewalk nearly killed Leonov." — is not quite correct. This episode is well documented in *The Russian Space Bluff* by Leonid Vladimirov, published in 1971. This book was only available to me after I emigrated from communist Czechoslovakia, but it confirmed rumors that circulated soon after the flight among those who were following the space race closely and were not blinded by propaganda.

Pavel (Paul) Otavsky
Woodstock, Vermont

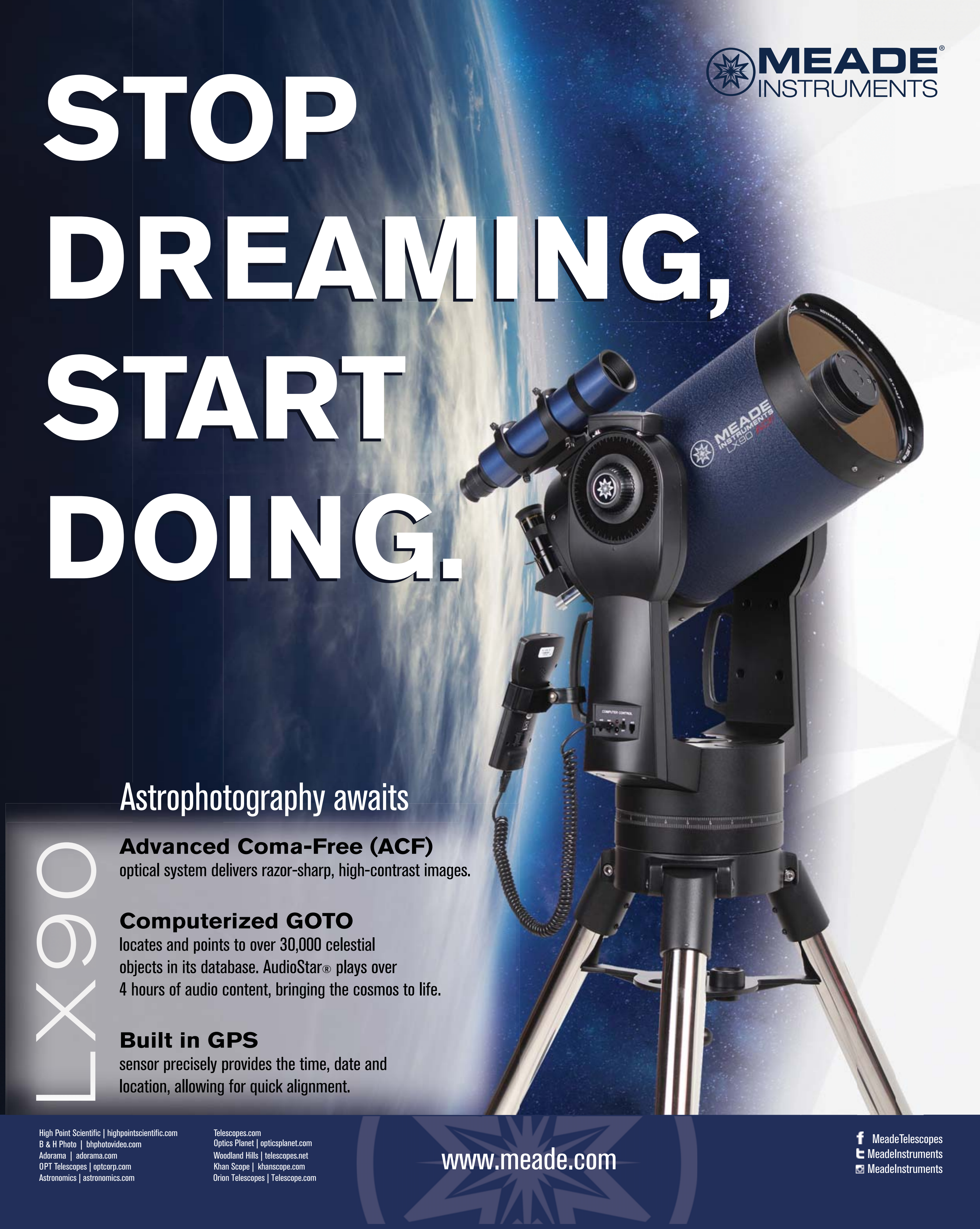
Size of Earth's Umbra

I was intrigued by Roger Sinnott's article about crater timings made during lunar eclipses (*S&T:* June 2015, p. 28), especially the variations in the size and shape of Earth's umbra due to our atmosphere. He details how an "occulting layer" of mesosphere, about 87 kilometers thick, can account for the apparent added "oblateness" of the shadow when averaged over thousands of measurements and many eclipses. Yet certain eclipses yield larger values: 91 km for the one on July 6, 1982, and 92 km for the eclipse of September 27, 1996.

Has anyone studied whether Earth's topography, at the leading or receding edge of the umbra, has any effect? In the case of the July 1982 eclipse, the Earth-Moon geometry put Africa's Atlas Mountains (which crest at 13,700 feet or 4.2 km) near one of the umbral edges. At the start of the September 1996 eclipse, the edge of Earth's shadow contained the Rocky Mountains. I can't imagine that a giant mountain range would have no effect if it happened to be in the right place at the right time.

Tom Sales
Somerset, New Jersey

Roger Sinnott replies: *You've raised an intriguing question. Any theory of the umbra's size needs to consider* everything *that happens to the sunlight as it grazes the*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Earth's limb on the way to the Moon. Our database includes, for each timing, the corresponding position angle around the umbra, so in principle one could look for a topographic effect. But cloud formations around Earth's limb also block sunlight below 10 km, and obtaining the weather data for a proper study would be challenging.

Astronomical Numbers

I smiled while reading Peter Tyson's "Take a Number" (*S&T:* June 2015, p. 6). During 35 years of teaching secondary chemistry, physics, and astronomy, I spent a great deal of time helping students understand the meaning of large and small values. The numbers and measurements mentioned by Tyson include some that I stressed because they are particularly significant.

Take, for example, the distance to the Moon. I'd start by asking my students if they knew the distance around Earth's equator. Although I considered my students to be some of the best on the planet, very few could answer quickly. We did some math, spent some time "estimating" (guessing), and finally arrived at the idea that the Moon's distance could be expressed in terms of Earth circumferences (it's roughly 10).

Then we tackled the speed of light. Together we concluded that in one second, with "space mirrors" strategically placed, light would travel around Earth roughly seven times.

I particularly enjoyed discussing the Earth-Sun distance with them. We agreed that 93 million of *anything* is too much to grasp. Then I'd ask, "What is the easiest number to think about?" Eventually they'd settle on "1," so we identified the Earth-Sun distance as one "something" — 1 astronomical unit.

Frank Lock
Gainesville, Georgia

A billion seconds is about 31.7 years. Assuming that a galaxy has 200 billion stars, and you counted them at a rate of 200 per second starting in 1983, you'd be finishing right about now. To me, that's more understandable and even more overwhelming. As for Abell 2065, well, if one could cover 1 light-year in 1 second, then 35 years later . . .

Reinhard Oberberger
Calgary, Alberta

For the Record

✷ *June 2015, p. 55: The angular diameters of the Moon at apogee and perigee were inadvertently interchanged.*

75, 50 & 25 Years Ago

Roger W. Sinnott

November-December 1940

Kindred Orbits "Most astronomers . . . are as much annoyed at the continued existence of Encke's Comet as at its peculiar behavior. Moving in such a small orbit, almost like that of an asteroid, the comet is activated by fairly intense sunlight at all times. . . . How it can continue to show indefinitely as a hazy diffuse object and not be completely dissipated is truly a mystery. We now add to its list of peculiarities an association with the extensive Taurid stream of meteors [even though] the planes of the orbits are tipped about 12° with respect to each other. . . .

A new mathematical theory for the perturbing effect of Jupiter's attraction showed that Encke's Comet does *not* keep the same plane for long periods of time. In less than six thousand years the orbit plane tips around like the rim of a wobbling top. . . . The most reasonable conclusion . . . is not that the Taurid meteors arise from Encke's Comet but rather that they both have a common ancestor, some large comet that broke up . . . some five thousand to fifteen thousand years ago."

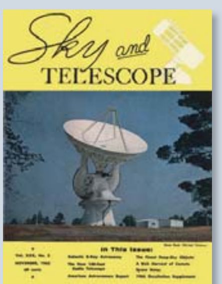
Harvard astronomer Fred Whipple was famous for such linkages. Some 43 years after writing these words, he startled other astronomers when he tied the Sun-approaching asteroid 3200 Phaethon to the annual Geminid meteor shower.

November 1965

Tree Rings "It has long been known that there is a correlation between the sunspot cycle and the growth of trees, as measured by the thickness of their annual rings. Now another association between solar activity and tree rings is suggested in *Science* by Minze Stuiver of Yale University's Radiocarbon Laboratory. . . .

"Dr. Stuiver has analyzed various wood specimens, but especially a section from a Douglas fir which grew between 1687 and 1951 at an altitude of 6,000 feet. . . . His measurements show a clearcut negative correlation: the radiocarbon content of tree rings tends to be high in years when sunspots are few.

"There is an obvious explanation of this. When solar activity is low, more cosmic rays from outside the solar system can reach the earth, increasing the production of neutrons in the upper atmosphere. The neutrons combine with nitrogen nuclei to make more C14."

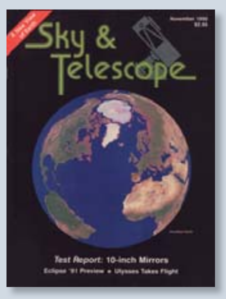


The negative correlation still holds true, though energetic particles from solar "superflares" can trigger carbon-14 creation; see page 22.

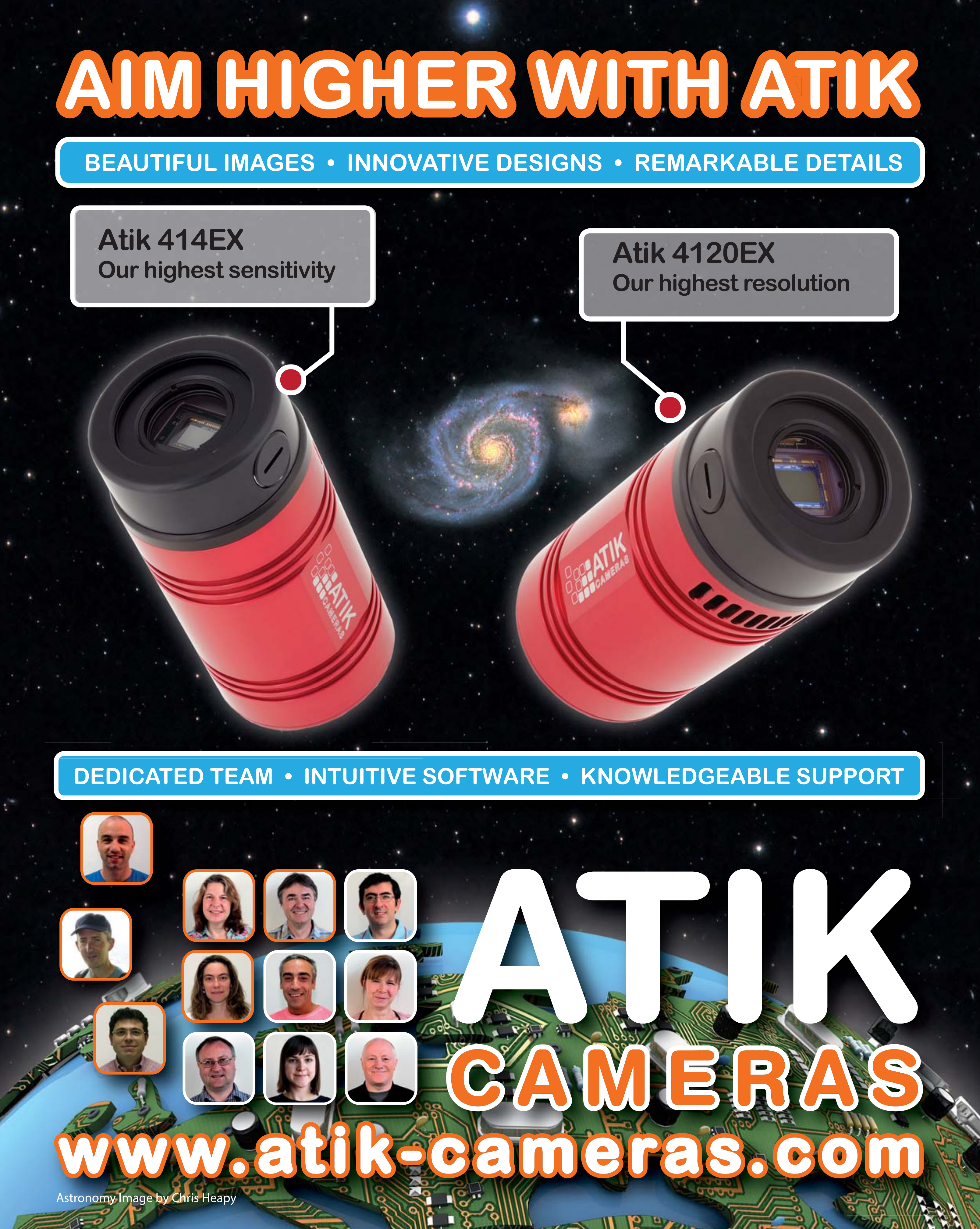
November 1990

Cosmic Steppingstone "The Virgo cluster is the nearest rich collection of galaxies. [Hence] its precise distance is a critical link in determining the distance scale of the universe. . . . Recent estimates, using a wide variety of 'standard candles,' range from just under 40 million light-years to somewhat over 70 million. (The first estimate, that made by Edwin P. Hubble and Milton L. Humason in 1931, was a mere 6 million light-years!) . . .

"Now George H. Jacoby and Robin Ciardullo (Kitt Peak National Observatory) and Holland C. Ford (Johns Hopkins University) have derived a new distance of 48 ± 3 million light-years, using planetary nebulae as their distance indicators. . . . "



The uncertainty in the Virgo Cluster's distance seems to be settling down. In 2007 a clever statistical technique, based on surface-brightness fluctuations in the cluster's elliptical galaxies, yielded 54 million light-years.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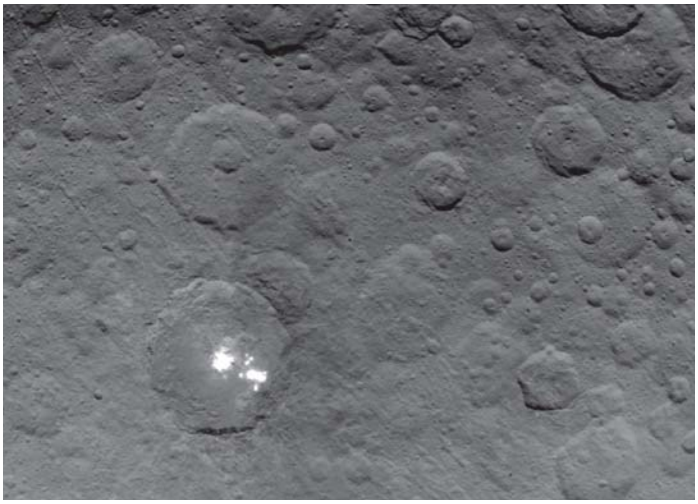
MISSIONS | Dawn Reveals Ceres' Bright Spots, Haze



NASA / JPL-CALTECH / UCLA / MPS / DLR / IDA

Mysterious white spots dot the floor of Occator, a crater on Ceres that's 92 km (57 miles) across. NASA's Dawn spacecraft has seen haze inside the crater that appears to be linked to the spots.

New observations from NASA's Dawn orbiter (*S&T:* Apr. 2015, p. 20) show bright spots, a pyramid-shaped mountain, and a mysterious haze on the dwarf planet 1 Ceres.

Mission scientists first saw bright spots on the surface as the spacecraft approached its destination. These spots veritably shine inside Occator, one of Ceres' large craters, and also appear elsewhere on the surface. Dubbed *faculae* by Dawn principal investigator Christopher Russell (University of California, Los Angeles), after the bright spots that appear in the Sun's photosphere, they might be exposures of ice or salt. Dawn's upcoming spectral measurements should settle the question.

"The lifetime of ice is quite short at the surface of Ceres, so if it's ice it must have been very recently exposed or be constantly replenished," says asteroid specialist Andrew Rivkin (Johns Hopkins University Applied Physics Laboratory).

"Anything that bright and that small indicates to me transient behavior," confirms Russell, who reviewed the mission's findings on July 21st at the 2015 NASA Exploration Science Forum in Moffett Field, California.

Dawn also detected what looks like a haze inside Occator, visible at noontime when observed at a glancing angle. It doesn't extend or flow over the crater's rim. If real, it's the first-ever haze observed on a body in the asteroid belt. Haze suggests the presence of sublimating ice, which could point toward geologic activity that is somehow dredging water ice up from the dwarf planet's interior. A curious network of shallow fractures, called *catanae*, also slices through the region. One of them cuts directly through Occator and its central bright spot.

The surface of Ceres is peppered with impact craters, though few are very large — Yalode, 271 km (168 miles) across, tops the list. Most fall into three types: simple, central-peak, and central-pit craters. Many show evidence of landslides and flow features, which again provide tantalizing hints of past geologic activity. This theory is further bolstered by observations from ESA's Herschel space observatory, which in 2011–13 found evidence for water vapor hovering over specific regions.

Ceres even has a lonely mountain, dubbed "The Pyramid" for its strange, steep-sloped geometry. It measures 30 km across at its base and 5 km high. Some sides are stained white. "We don't understand it," admits Russell. The Dawn team is still waiting on spectra of the surface to analyze the quasi-faceted peak, which will come in January 2016, when Dawn enters its closest (and final) orbit over Ceres.

■ **EMILY POORE**

SETI | "Breakthrough" Projects Push E.T. Search Forward

On July 20th, Russian internet investor Yuri Milner announced he's committing $100 million to an ambitious SETI endeavor for the next 10 years. The project, named Breakthrough Listen, is a spinoff of Milner's Breakthrough Prize Foundation, which bestows awards for innovative work in fundamental physics, life sciences, and mathematics.

The Breakthrough Listen team will use two radio-search strategies. The first is a targeted search, using the 100-meter Green Bank telescope in West Virginia and the Parkes 64-m antenna in Australia to examine the nearest 1 million stars for radio-emitting civilizations. The second is a shallower, wide-sky sweep of the Milky Way's center and midplane to encompass more than 100 billion stars. The instruments will also take protracted stares at 100 of the nearest galaxies. One-third of the funds will go toward developing powerful new receivers and processors.

The plans call for an optical SETI search as well, using data from Lick's 2.4-m Automated Planet Finder telescope.

Also announced was $1 million for Breakthrough Message, an open competition for ideas about what, if anything, Earth should transmit if the team finds another civilization. Breakthrough Initiatives says it will not dispatch any message until a global debate has decided whether calling extra attention to ourselves this way is a good idea.

Read more about the projects and watch a video of the press conference at **http://is.gd/leapseti**.

■ **ALAN MACROBERT**

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GALAXIES | Gigantic Protogalaxy in the Cosmic Web

Astronomers have found that a massive filament of gas in the early universe is actually a humongous, galaxy-forming disk of cold gas.

One way that galaxies grow — and possibly the predominant way in the early universe — is from cold gas funneled like a pipeline into wells of dark matter (*S&T:* Sept. 2015, p. 16). These dark matter wells are dense filaments in the weblike cosmic structure, along which galaxies form. Although computer simulations suggest that many galaxies could have gotten their start as cold-flow-grown disks, observing this accretion in action is difficult because the gas is diffuse and faint.

Last year, astronomers detected a large, bright filament of gas called UM 287 shining at us from about 11 billion years ago (*S&T:* May 2014, p. 14). It's fluorescing thanks to the intense ultraviolet radiation of a nearby quasar. At the time, the team estimated that the structure was about 10 times more massive than expected, given simulation results.

But it turns out the filament *isn't* too massive, because it's not merely a filament. Christopher Martin (Caltech) and colleagues took a second look with the Palomar Cosmic Web Imager, a high-tech spectrograph they built and installed on the 5-m (200-inch) Hale Telescope on Palomar Mountain in California. The spectrograph homed in on the wavelength Lyman-alpha, which comes from cold neutral hydrogen that's been irradiated by ultraviolet light. By analyzing the filament's spectra, the team discovered that one part of the filament is moving toward us, while another section is moving away from us. In other words, the structure is actually a fuel line feeding a gigantic disk.

The disk is about 400,000 light-years across, or three to four times the size of the Milky Way's spiral disk. As the team reports August 5th in *Nature,* the object's rotational velocity suggests it's sitting in a halo of 10 trillion solar masses' worth of dark matter, an order of magnitude larger than the halo our galaxy inhabits. There's even a hint of star formation in its center, but the researchers aren't sure of that yet.

"Overall, it's hard to say with certainty that they're definitely seeing a cold-flow disk — as opposed to some other phenomenon that just happens to look like a cold-flow disk," says Kyle Stewart (California Baptist University), whose team has simulated the growth of these objects. "But when you look at all the observable properties of cold-flow disks from the simulations to determine what they *should* look like in the real universe, in my opinion, it's amazingly similar to what these authors have just observed."

■ **CAMILLE M. CARLISLE**

SUPERNOVAE | Lonely Explosions Between Galaxies

Researchers have confirmed that three white dwarfs went supernova in intergalactic space.

The space between galaxies is not entirely empty. Sometimes observers come across stars that have been ejected from their hosts and left to drift alone. Although solitary, they're still important for understanding how much mass the universe contains and where that mass is.

But it's difficult to see individual stars in the distant universe. So astronomers turn to supernovae, which are easier to spot. In 2011, researchers conducted a survey of 23 exploding white dwarfs in and near distant galaxy clusters. They discovered four of them were in the space between galaxies. But they couldn't resolve the images clearly enough to confirm that the white dwarfs truly floated in solitude.

Now, using Hubble images, Melissa Graham (University of California, Berkeley) and colleagues have confirmed the solitary nature of three of the supernovae — the fourth belongs to a dwarf galaxy. Given these statistics, the team calculates that roughly 11% of normal matter floats in intergalactic space. The result appears in the July 1st *Astrophysical Journal.*

■ **ANNE MCGOVERN**

IN BRIEF

Most Luminous Supernova Yet. Astronomers have discovered an exploding star that tops the "superluminous" charts. Dubbed ASASSN-15lh, the supernova was found on June 16th at magnitude 17 as part of the All-Sky Automated Survey for Supernovae (ASAS-SN). Follow-up observations suggest it shines with the luminosity of 572 billion Suns, and spectra confirm its bluish light has been traveling toward Earth for the past 2.8 billion years (redshift of 0.2326). The debris lacks hydrogen emission lines, meaning the star lost its outer layers prior to exploding.

■ **MONICA YOUNG**

Astronomers Spot Five-Star System. A rare four-star system turns out to have a fifth wheel, Marcus Lohr (The Open University, UK) and colleagues report in the June *Astronomy & Astrophysics.* Although multiple-star systems are common, systems containing more than three stars are rare. In 2013 Lohr's team discovered the quadruple system 1SWASP J093010.78+533859.5 in Ursa Major. It contains two eclipsing binaries, the two pairs separated from each other by 140 astronomical units (21 billion km). The fifth star revealed itself when the team took spectra to study the stars in more detail. The system is 9 to 10 billion years old.

■ **ANNE MCGOVERN**

Aurora on a Dwarf Star. Astronomers have detected auroral emission on a star. *Ultracool dwarfs* (UCDs) are the runts of the stellar family: they include both the least massive stars and brown dwarfs. Several UCDs emit periodic, aurora-esque radio signals, and a few even show signs in optical wavelengths. Now, Gregg Hallinan (Caltech) and colleagues report in the June 30th *Nature* that they've detected these telltale radio and optical variations simultaneously from a UCD called LSR J1835+3259. This object is an *M*8.5 star, right at the transition point between stars and brown dwarfs. The pulsations' period matches the dwarf's 2.84-hour day, suggesting the aurora is rotating in and out of view. A magnetically controlled stream of electrons, somehow dumped into the star's lower atmosphere, likely excites atoms and incites them to emit the auroral photons.

■ **CAMILLE M. CARLISLE**

EXOPLANETS | Microlensing World Confirmed

Astronomers have confirmed the existence of an exoplanet originally found via microlensing — the first time they've been able to successfully follow up on this investigative method.

In a microlensing event, one star passes in front of another from our perspective, and this alignment — within a fraction of a milliarcsecond (1⁄3,600,000°) — boosts the light of the background star like a magnifying glass would. If the closer, magnifying star has a planet around it, this planet can add an extra blip to the light curve of the boosted signal.

Observers have found about three dozen exoplanet candidates via microlensing. But to confirm these one-shot events, astronomers generally must wait several years until the stars move far enough apart to see them separately. Only then can they determine each star's physical characteristics, which they need in order to confirm the blip's nature.

Virginie Batista (Astrophysics Institute of Paris) and colleagues used images from the Hubble Space Telescope and the Keck II telescope on Mauna Kea to study the stars involved in the microlensing event OGLE-2005-BLG-169. Collaborating amateur and professional astronomers discovered this system in 2005. Since then, the stars have moved farther apart in the sky, finally separating enough for astronomers to split them.

The analysis, reported in two papers in the August 1st *Astrophysical Journal*, shows that the host star is a *K*5 main-sequence star (still fusing hydrogen in its core, as the Sun does), with a mass about two-thirds that of our star. It also confirms that the planet is 12 to 15 Earth masses (about equal to Uranus) and orbits its star roughly 4 astronomical units out.

■ **CAMILLE M. CARLISLE**

EXOPLANETS | Earth Cousin Really Earth-like?

On July 23rd, the Kepler team announced the discovery of Kepler-452b. This exoplanet has a radius 1.6 times that of our home world and orbits its *G*-type star every 385 days. That puts it well within the star's habitable zone, the (fuzzily defined) region where liquid water could exist on a planet's surface.

Kepler-452b is the first planet to meet the three criteria of being an Earth-size planet in the habitable zone around a truly Sun-like star. But whether it's really Earth-like remains unknown. The planet is too small and faint for ground-based observers to determine its mass and therefore its density and likely composition. (It was confirmed using statistical methods rather than additional observations.)

Given the masses of other, comparably sized exoplanets, Jon Jenkins (NASA Ames Research Center) and colleagues estimate Kepler-452b has 3 to 7 Earth masses. The size measurement and mass estimate put the planet on the dividing line between super-Earths, which have rocky surfaces, and sub-Neptunes, which have a significant gaseous envelope. As Jenkins put it, "This planet has a somewhat better than even chance of being rocky." The team reports the discovery in the August *Astronomical Journal*.

The announcement comes as part of Kepler's seventh data release, which netted 521 new planet candidates, including 12 that are less than twice Earth's diameter and in their stars' habitable zones. The tally of confirmed planets has risen to 1,030, with about two dozen of those in their stars' habitable zones.

■ **MONICA YOUNG**

COSMOCHEMISTRY
Buckyballs Help Solve Interstellar Mystery

Soccer-ball-shaped molecules lurking in the dusty corners of the Milky Way explain part of a spectral mystery, Ewen Campbell (University of Basel, Switzerland) and colleagues report in the July 16th *Nature*.

Diffuse interstellar bands (DIBs) have haunted astronomers for almost a century. First discovered in 1922, these absorption lines (more than 400 of them) are seen any time astronomers look toward dust-reddened stars. But no ions or molecules tested in the lab have provided a good spectral match.

Campbell's team decided to test ionized buckminsterfullerene molecules (a.k.a. "buckyballs") to see if they might explain some of the bands. Buckyballs link 60 carbon atoms into a stable, quasi-spherical cage. Astronomers have already detected them in space in gaseous and solid forms, but neutral buckyballs don't absorb light at the right wavelengths to explain DIBs.

When cooled to interstellar temperatures, however, the ionized buckyballs' spectra provide an exact match to two diffuse interstellar bands, the team found. Other carbon-bearing molecules may explain the remaining lines.

■ **MONICA YOUNG**

IN BRIEF

Closest Rocky Exoplanet Discovered. Using the ESO's 3.6-m telescope in the Canary Islands and NASA's Spitzer Space Telescope, Fatemeh Motalebi (University of Geneva, Switzerland) and colleagues discovered a transiting rocky planet in the constellation Cassiopeia. The planet orbits HD 219134, a 5th-magnitude orange dwarf 21 light-years from Earth. The team also found hints of two additional super-Earths and a giant planet, via the gravitational tugs they exert on their parent star. The confirmed planet, b, is the innermost. It's a super-Earth 4 to 5 times more massive and about 1.6 times larger than Earth, whipping around its star every 3 days. Its density is thus somewhere between 4.7 and 7.0 g/cm^3, similar to Earth's density of 5.5 g/cm^3, confirming the planet is likely rocky, the team reports in *Astronomy & Astrophysics*.

■ **MONICA YOUNG**

Alfredo Garcia Jr.
Lomita Ca

Photo taken by:
Jason Ware

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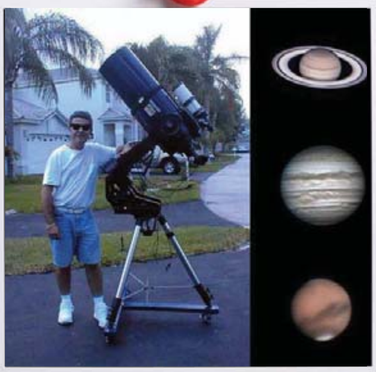
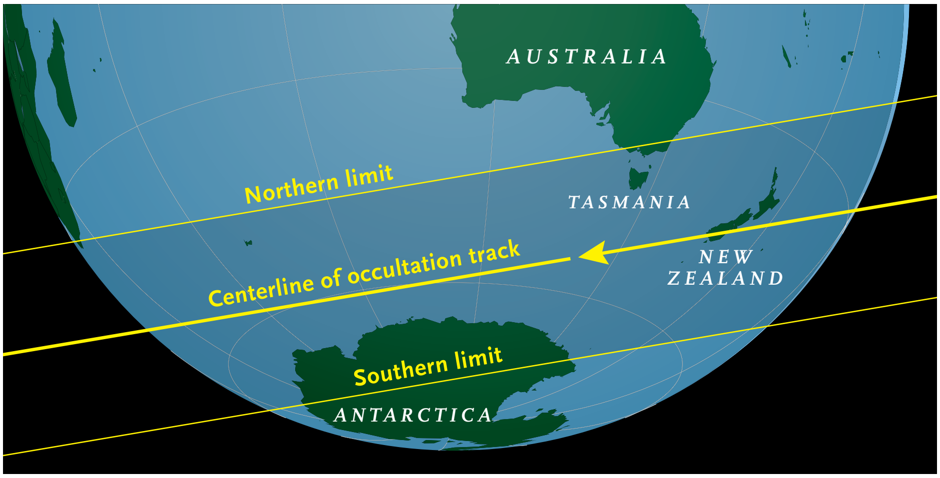


Ivan Gastaldo
Coconut Creek, Fl

Photo taken by:
Mark Sibole

PLUTO | Dwarf Planet Occults Star in Sagittarius, Teams Head South



S&T: GREGG DINDERMAN, SOURCE: CARLOS ZULUAGA / MIT

Observers in New Zealand and Tasmania had front-row seats when Pluto covered a 12th-magnitude star on June 29, 2015.

The stars and planets really were aligned on June 29th, when Pluto passed directly in front of an obscure 12th-magnitude star in north-central Sagittarius. The path of Pluto's "shadow" across Earth fell mostly over open water between Australia and Antarctica (see map above). But several teams of astronomers fanned out across New Zealand, Tasmania, and southeastern Australia to record this rare celestial opportunity.

A collaboration involving Williams College, MIT, and Lowell Observatory deployed observers at 12 telescopes in nine locations. One of those, Mount John Observatory on New Zealand's South Island, was positioned very near to the predicted centerline. During the event's midpoint its telescopes recorded a *central flash* — created when Pluto's tenuous atmosphere acted like a lens to refract a concentrated beam of light toward Earth.

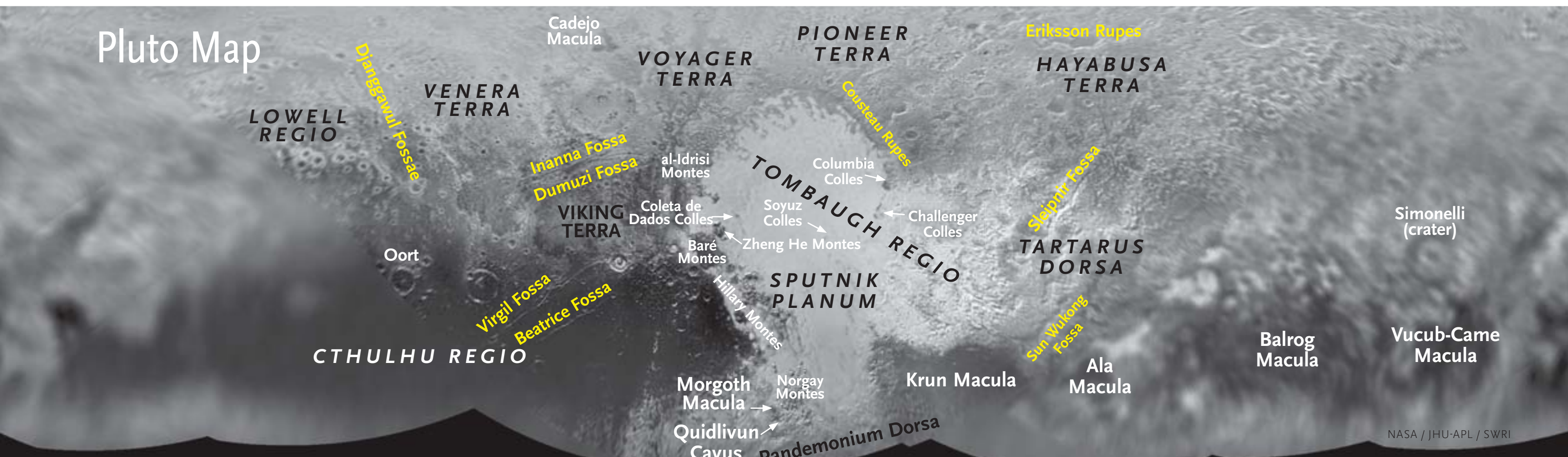
Eliot Young (Southwest Research Institute) dispatched seven teams, most of which paired a professional observer with an undergraduate student. Some used an existing telescope, but others lugged "portable" 14-inch telescopes to desirable locations. Veteran occultation observer Bruno Sicardy (Paris Observatory) also established observing stations at the just-opened Greenhill Observatory near Hobart, Tasmania, and at a robotic 0.6-m telescope at Lauder, New Zealand.

John Talbot provided coordination for the Royal Astronomical Society of New Zealand, and more than two dozen amateurs participated. Talbot reports that many succeeded despite interference from a nearly full Moon only 30° away.

Meanwhile, NASA had dispatched the Stratospheric Observatory for Infrared Astronomy (SOFIA) to Christchurch, New Zealand, to observe Southern objects for six weeks. Flying above South Island's coastline, its team of scientists, engineers, and reporters watched the event unfold from an altitude of 39,000 feet (11.9 km).

The occultation observations confirmed that Pluto's atmosphere has not entirely frozen onto its surface, as planetary scientists had speculated. New Horizons corroborated the result when it swept past Pluto two weeks later (see page 18). Read more about the adventures Down Under at **http://is.gd/plutoshadow**.

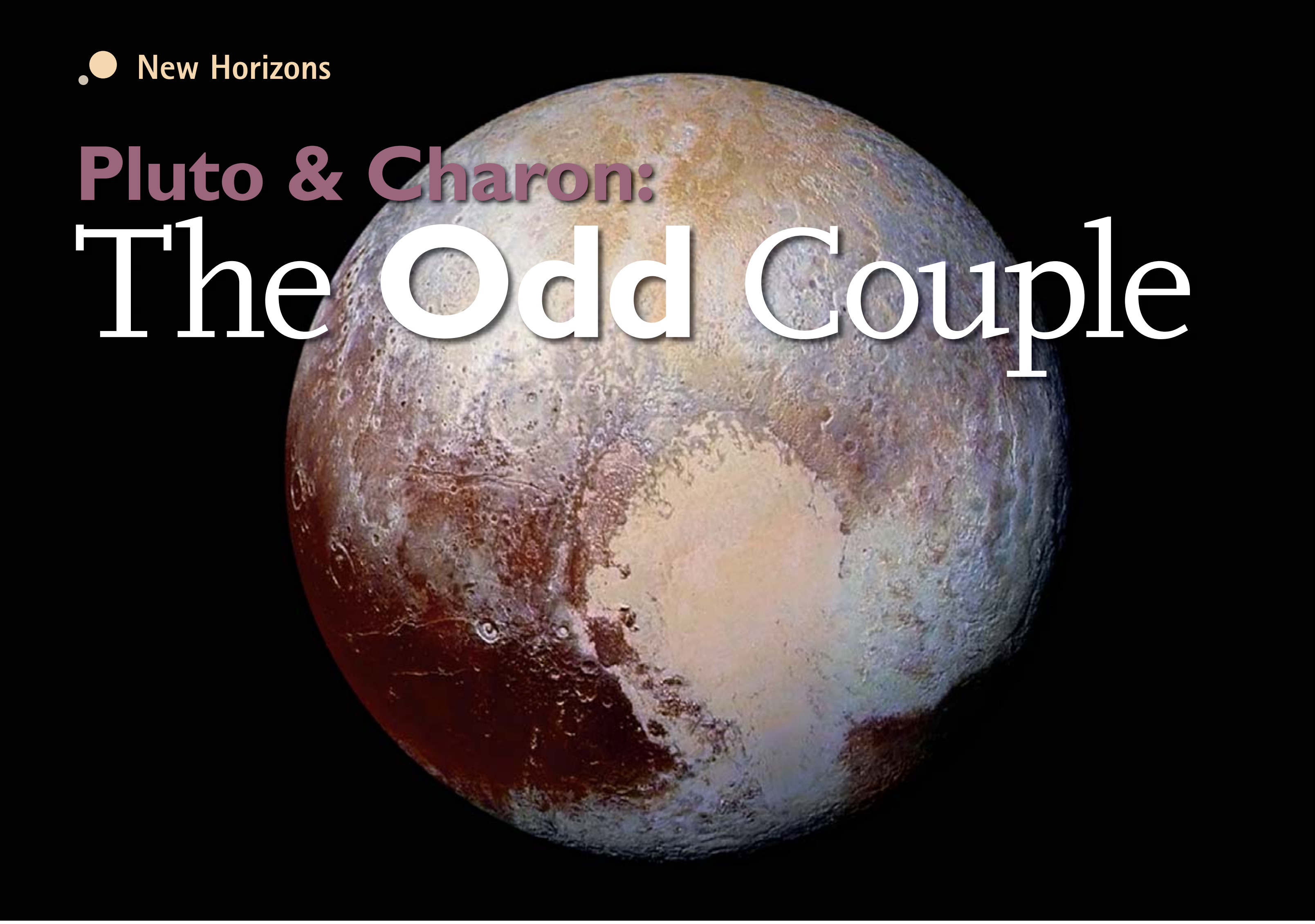
■ **J. KELLY BEATTY**



Now that we've seen Pluto's surface features in detail for the first time (see page 18), all those features need suitable names. The International Astronomical Union gets the final say, but before the flyby the New Horizons team ran a public campaign to solicit ideas and votes within a few broad categories: beings and locales associated with the underworld, scientists and engineers involved in the study of Pluto, historic explorers, and spacecraft. Charon will get monikers for fictional travelers, their vessels, and their destinations, along with authors, artists, and directors who have envisioned those explorations. See ourpluto.org for details. ✦

■ **J. KELLY BEATTY**

Pluto & Charon: The Odd Couple



NASA / JHU-APL / SWRI

After a 9½-year journey, NASA's New Horizons zipped past a pair of small worlds that couldn't be more different.

J. Kelly Beatty

In the annals of space exploration, July 14th will be remembered for two important milestones. The first was Mariner 4's flyby of Mars in 1965. Exactly 50 years later, on July 14, 2015, NASA's New Horizons spacecraft zipped past Pluto and its five moons at 13.8 km per second (30,900 miles per hour), passing 12,504 km (7,770 miles) from the celebrated dwarf planet.

As it sped past Pluto, the spacecraft used every available moment to scrutinize this icy world and its moons — in fact, it clicked and whirred for 22 hours without even stopping to transmit "A-OK" to its control center at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. Later that day, when New Horizons finally *did* report that its complicated flyby had been executed flawlessly, mission personnel celebrated and thunderous applause erupted from the standing-room-only crowd in a nearby auditorium.

A Geologic "Wonderland"

By design, getting the full story from New Horizons' historic encounter will take a very long time. In the weeks before and after the flyby, the spacecraft returned a limited sample of the 8 gigabytes of images, spectra, and other observations stored in its memory. The full data set is trickling home in highly compressed files through November, and then the spacecraft will transmit everything again in uncompressed form through most of next year (*S&T:* July 2015, p. 20).

But even those early, carefully chosen highlights revealed that Pluto and its largest moon, Charon, are

MOTTLED MOON *Above:* **Although it and Pluto orbit just 19,596 km (12,176 miles) apart, center to center, the sizable moon Charon has a very dissimilar surface from its dwarf planet. Shown here as seen by New Horizons on July 13th, the moon hosts an array of landforms — including a dark, red-tinged polar cap — that has stunned mission scientists.**

VARIEGATED PALETTE *Left:* **Mission scientists combined four images from New Horizons' Long Range Reconnaissance Imager (LORRI) with color data from the Ralph instrument to create this enhanced-color global view of Pluto. It reveals details as small as 2.2 km. The overall reddish hues are likely due to veneers of organic compounds.**

NASA / JHU-APL / SWRI

stunning — both in their geologic diversity and in their disparate appearance. Dynamicists strongly suspect that these two worlds have a shared history: Charon likely assembled from debris thrown out when Pluto suffered a titanic impact eons ago. Yet, despite this linked lineage, the two worlds couldn't be more different.

Let's start with Pluto. A patchwork of dark features girds much of its equator. Sandwiched between them is a bright, heart-shaped region that became evident many months before the spacecraft's arrival. In fact, planetary scientists had already mapped (thanks to decades of ground-based observations and Hubble Space Telescope images) the major bright and dark regions around its midsection. The terrain surrounding Pluto's north pole, tipped 51° toward the Sun right now, appears to be frosted with frozen molecular nitrogen (N_2) and methane (CH_4). This strong axial tilt also means that most of the southern hemisphere remained hidden in shadow throughout the encounter.

The heart-shaped expanse, provisionally named Tombaugh Regio to honor Pluto's discoverer, is about 1,600 km across. "We could see the heart from far away, 70 million miles, shining like a beacon as the brightest feature on the planet," explains principal investigator Alan Stern (Southwest Research Institute). "So that's why we want to call it Tombaugh Regio." (As of late August, the International Astronomical Union hadn't officially approved the provisional names used here.)

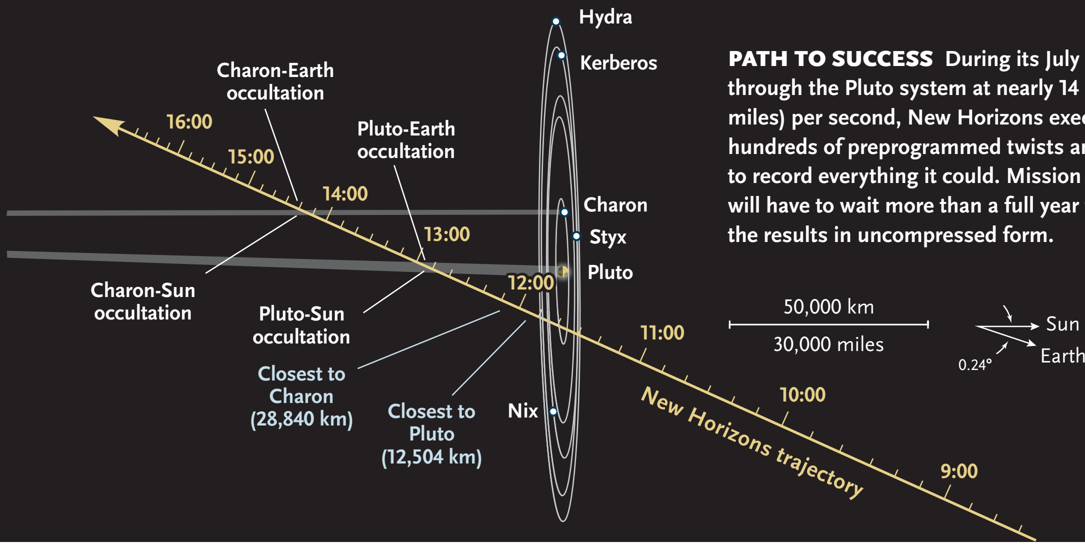
As the spacecraft closed in, its images showed that the heart's western half is very smooth and flat — hardly the ancient, cratered landscape that most everyone expected. The best views of this Texas-size region, dubbed Sputnik Planum, reveal meandering, interconnected depressions that subdivide the terrain into crude polygons roughly 30 to 60 km across. But what the team found most astonishing is the utter lack of impact craters there. According to Jeff Moore (Southwest Research Institute), this means the surface of Sputnik Planum can't be more than 100 million years old — and it's likely *much* younger. "It could be a week old, for all we know," he says.

Maybe there aren't any craters because the surface keeps moving around. One close-up shows that icy flows have migrated northward into a much older, eroded, heavily cratered, and generally beat-up-looking terrain. These flows mimic the motions of glaciers on Earth, but they can't be slabs of water ice. At Pluto's cryogenic surface temperature, roughly 38 kelvin (–390°F), water ice is about as mobile as the Rock of Gibraltar. Instead, the flows must consist of frozen nitrogen, methane, and carbon monoxide (CO), all of which remain pliable even in Pluto's extreme cold. In fact, one of New Horizons' spectrometers found that the CO ice is concentrated only within Sputnik Planum — curiously, it's nowhere else on Pluto.

Two clusters of rugged mountains, Hillary Montes and Norgay Montes (named for the first climbers to reach the summit of Mount Everest), frame the southern rim of Sputnik Planum and rise up to 3½ km (11,000 feet) in spots. That's far too tall, notes John Spencer (Southwest Research Institute), to be big piles of frozen nitrogen and methane. Instead, the underlying "rock" must be stiffer, sturdier water ice — something long

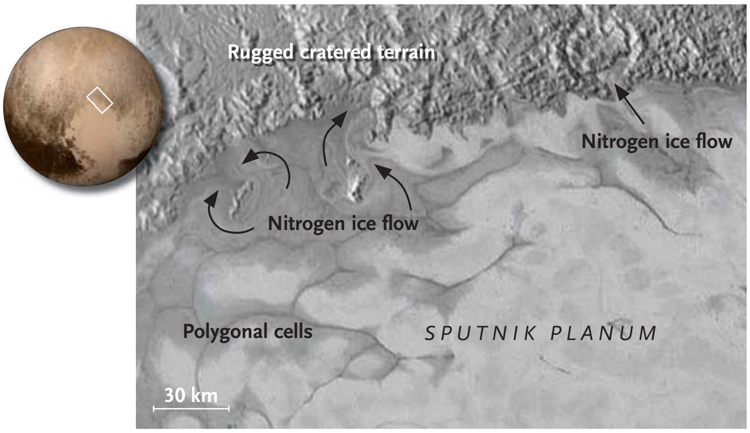
NASA / BILL INGALLS

TIME TO CELEBRATE **Guests and mission personnel count down to the moment when New Horizons passed closest to Pluto, at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland.**

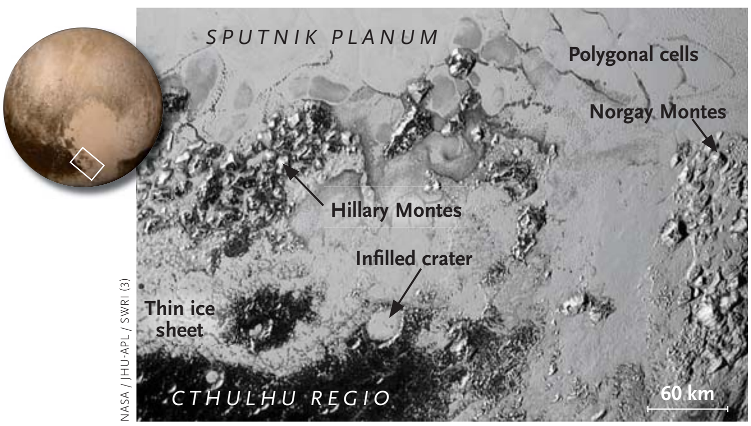


PATH TO SUCCESS During its July 14th pass through the Pluto system at nearly 14 km (8.6 miles) per second, New Horizons executed hundreds of preprogrammed twists and turns to record everything it could. Mission scientists will have to wait more than a full year to get all the results in uncompressed form.

S&T: GREGG DINDERMAN, SOURCE: NASA / JHU-APL / SWRI



ON THE MOVE Along the northern boundary of Pluto's Sputnik Planum, swirl-shaped patterns of light and dark suggest that frozen nitrogen and other exotic ices have flowed around obstacles and into depressions, much like glaciers on Earth.



NASA / JHU-APL / SWRI (3)

STARK CONTRASTS The southern region of Pluto's Sputnik Planum contains surprisingly tall mountain ranges, consisting mostly of water ice, that rise up to 3½ km (11,000 feet) above the surrounding terrain. They're called Hillary Montes and Norgay Montes to honor Sir Edmund Hillary and Tenzing Norgay, the first two humans to reach the summit of Mount Everest in 1953. A bright veneer of exotic ices covers much of the terrain.

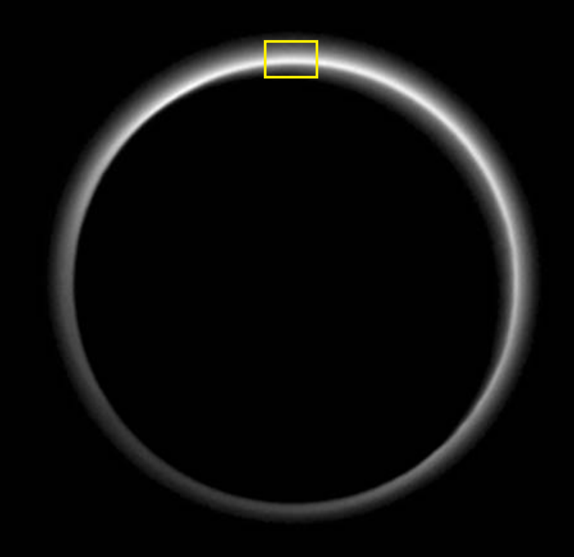
suspected by cosmochemists to exist on Pluto but undetected in spectra of its surface.

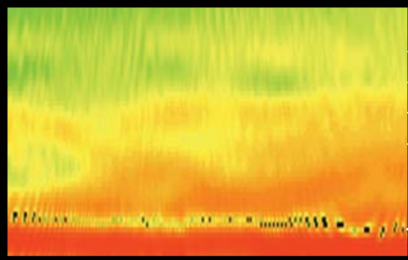
The spacecraft's color images and near-infrared spectra reveal that Pluto's surface has a coating of red-tinged material that's most likely a mixture of complex organic compounds. Scientists suspect that the darkest spots are coated with deposits of *tholins,* a catchall term coined in the 1970s for complex, carbon-rich organic compounds.

One basic characteristic that has eluded astronomers since Pluto's discovery 85 years ago is its precise diameter. Based on previous occultation work, researchers deduced that it was at least 2,302 km but couldn't pin down the true value. Now, thanks to the spacecraft's imagery, they realize that it's 2,370 km (1,475 miles).

This simple refinement means that Pluto is slightly larger than Eris (2,336 ± 12 km). The two had been in competition for "king of the Kuiper Belt" since the latter's discovery a decade ago. (Yet, despite being slightly smaller, Eris has a mass 28% greater than Pluto's.) It also means that Pluto's overall density must be lower than thought, somewhere around 1.90 g/cm^3. So the interior must be slightly more ice rich (35% or 40% by volume) and its rock fraction slightly lower (60% or 65%).

Floating above what Stern calls a "wonderland of diverse geological expression" is Pluto's extremely tenuous, nitrogen-dominated atmosphere. As depicted in the diagram above, the spacecraft briefly watched both the Sun and Earth duck behind the dwarf planet's limb, and these dual occultations provided unique probes of the atmosphere's cryogenic wisps. For example, the surface pressure was far lower than models predicted, no more than 10 microbars — what you'd experience at an altitude of 96 km above Earth. As recently as two years ago, ground-based occultations yielded pressures nearly twice as high. Pluto swung through the perihelion of its strongly elongated orbit in 1989. So some researchers have speculated that, in the 2½ decades since, everything has gotten colder and that the atmosphere is liter-





RING OF HAZE New Horizons was flying through Pluto's shadow on July 15th, roughly 2 million km (1¼ million miles) away, when it recorded the dwarf planet's thin, hazy atmosphere (backlit by sunlight) rimming its silhouette like a luminous halo. The boxed inset, enlarged above and color-coded to enhance subtle differences, reveals what appear to be layers or waves within the haze.

NASA / JHU-APL / SWRI

ally freezing and falling onto the surface as frost.

Yet, despite the low surface pressure, Pluto's atmosphere extends upward to about 1,600 km — much higher up than expected. Moreover, those thin wisps include a gauzy haze at least 160 km high that shows hints of at least two discrete layers or broad waves. The haze consists of acetylene (C_2H_2), ethylene (C_2H_4), and other organic compounds created after ultraviolet photons in the weak sunlight break down molecules of atmospheric methane.

There's growing evidence that Pluto is losing what little gas it has to interplanetary space at a rapid rate, roughly 500 tons per hour. "We know there's methane in the atmosphere," explains Fran Bagenal (University of Colorado, Boulder). "It absorbs sunlight, heats up, and gives the gas the energy it needs to escape." Once the escaping molecules are in space, ultraviolet sunlight ionizes them. Then they're swept up by the solar wind flowing past Pluto at hundreds of kilometers per second, creating a tail of charged particles that extends outward, away from the Sun.

Stern calculates that, over its history, Pluto must have lost enough nitrogen to form a global layer 0.3 to 3 km deep. So, for nitrogen to exist on the surface today, he feels that some process must be dredging it up from the interior. "We haven't found geysers or cryovolcanoes yet," Stern says, "but now we'll be looking for exactly the evidence of these phenomena."

Charon: Dark and Ancient

New Horizons didn't spend all of its flyby time trained on Pluto. It also scrutinized the sizable moon Charon. With a diameter of 1,208 km (751 miles), Charon is roughly half the size of Pluto and a little larger than the dwarf planet Ceres.

Unlike Pluto, Charon appears dark and more uniformly colored. Yet it too displays far more geologic diversity than anyone expected. "Originally, I thought Charon would show an ancient terrain covered in craters," admits deputy project scientist Cathy Olkin (Southwest Research Institute). But the spacecraft's most detailed images "blew our socks off."

The dark, red-tinged polar cap first seen from far away (and informally dubbed Mordor) bears some kind of structure — perhaps remnants of a large impact basin. Here and there are deep fractures, and a gash of interconnected canyons slashes across the southern hemisphere for some 1,000 km. Some regions look smooth and nearly crater-free, a telling sign that they're relatively young.

Has Charon been churning inside to cause all this geologic calamity? Perhaps, but the kind of tidal heating seen among the moons of Jupiter and Saturn can't be the reason. Pluto and Charon are solidly, permanently locked in a spin-orbit resonance that keeps one hemisphere of each constantly facing the other (imagine a pair of figure skaters holding hands while spinning around each other). This configuration doesn't generate tidal stress.

Meanwhile, New Horizons conducted extensive scans to spot undetected moonlets or faint rings but found nothing (yet another surprise). Nor did the spacecraft have especially good opportunities to view Pluto's four smaller moons. Nix turns out to be 42 by 36 km in size and Hydra 55 km long. Both are smaller and brighter than expected, so they're likely ice covered. Sizes for Styx and Kerberos will have to wait until the craft radios resolved images back to Earth.

In fact, Stern emphasizes that the slow playback will give waiting scientists a steady diet of new results to work with. "Expect many more images and spectra and, from those, many more discoveries in the months ahead," he says. "New Horizons is a gift that will keep on giving." ✦

*Senior Editor **Kelly Beatty** has covered planetary science for more than four decades. But his real claim to fame is that Clyde and Patsy Tombaugh once spent the night at his home.*

Superflares

Astronomers have discovered many Sun-like stars that unleash titanic flares. Could our Sun produce such a flare? Has it already?

Monica Bobra

The largest solar flare in modern history happened only 12 years ago. On November 4, 2003, a sunspot group on the western limb of the Sun hurtled a massive blast of particles in a direction away from Earth. A week before, the same sunspot group had cranked out eruptions that spawned auroras as far south as Florida. This flare was likely as big as the first one ever recorded, using ink and paper, in 1859.

But both these eruptions, monsters by our standards, are tiny compared with *superflares* — flares roughly tens to thousands of times more energetic than the largest solar flare ever observed. In fact, many yellow, middling-mass *G*-type stars like the Sun produce superflares. Astronomers wonder why this is. As such, they're beginning to ask: Could a superflare ever occur on the Sun?

That, it turns out, is a controversial question.

Flare Mechanics

The story of a solar flare begins deep inside the Sun. There, energy from the seething, boiling interior gets converted into magnetic energy, giving rise to the solar magnetic field. When strongly concentrated bits of field poke out of the solar surface (called the *photosphere*), they choke the motion of the photosphere's hot gas, making those locations appear dark. We call these dark features sunspots. In most cases, sunspots travel in pairs. Each pair acts like a tiny bar magnet worming its way across the solar disk, with one spot leading while the other follows.

Like long stalks of grass swaying in the breeze, the magnetic field is anchored firmly to sunspots but moves freely in the upper solar atmosphere, or *corona*. There, the field can twist, snap apart, and fuse back together, and when it does it releases energy. We call this burst of energy a flare.

To happen, solar flares need a magnetic field that's both freely moving and strong. That's why flares release most of their energy in the corona (where the field moves like billowing meadow grass), directly above sunspots (where the field is strongest).

During a flare, particles from the Sun head every which way. Some travel out into space. Under the right conditions, they flow seamlessly from the solar to terrestrial magnetic field, hit our ionosphere, and create auroras.

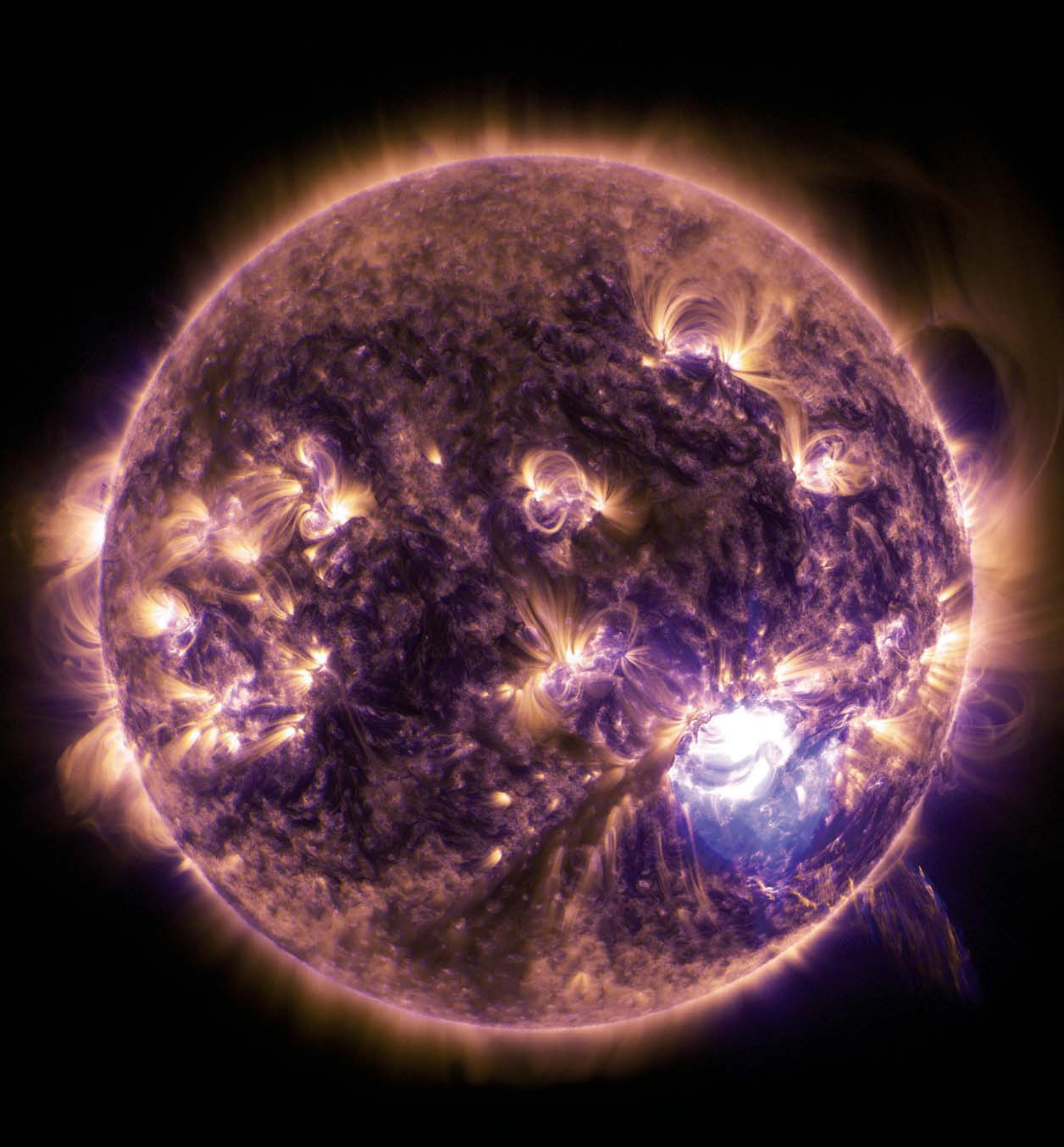
But our Sun's flares are nothing compared with superflares. In 2012, Hiroyuki Maehara (then at Kyoto University, Japan) and colleagues discovered 365 superflares on 148 solar-like stars, using data from NASA's Kepler space telescope in a landmark study of the largest sample of superflares compiled for these stars. The Kepler satellite, which observed more than 100,000 stars on a fixed patch of sky over a four-year period, was designed to detect exoplanets, but astronomers soon discovered that careful processing could uncover thousands of superflares. (The signal from an average-size solar flare is too faint for Kepler to detect.)

While Kepler cannot directly image these distant stars, it can detect how brightly a star shines over time. Astronomers compile this information in diagrams called light curves. By analyzing peaks in these light curves, Maehara's team and, soon after, many others discovered hundreds of superflares on solar-like stars.

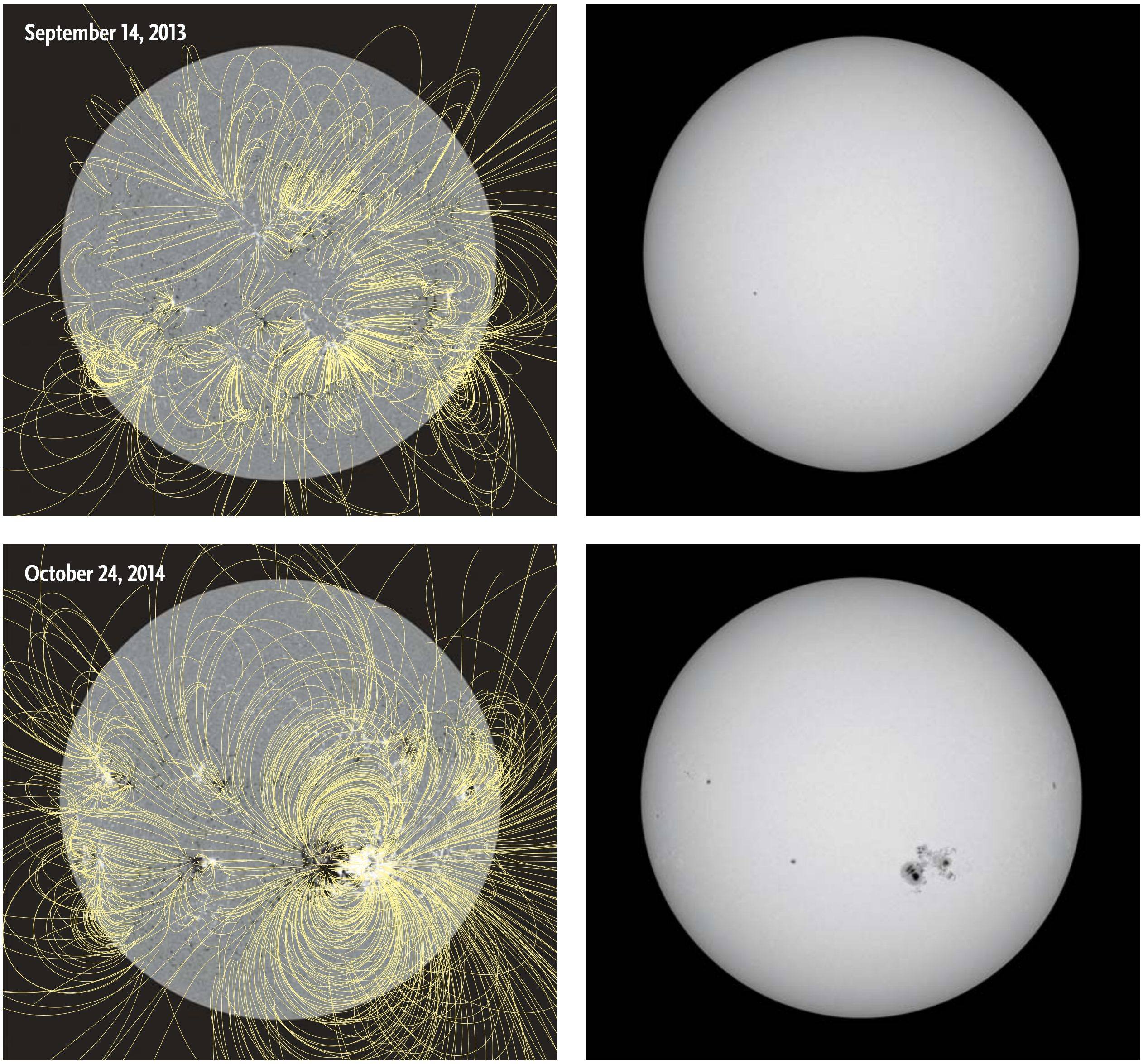
In addition, from dips in these same light curves, Maehara's team also inferred that these stars' surfaces are marred with massive starspots, the likes of which we've never seen on the Sun. These starspots cover huge swaths of the stellar surface and can survive for months on end.

This summer, Yuta Notsu (Kyoto University) and colleagues used the 8.2-meter Subaru Telescope atop the summit of Mauna Kea to track down some of the stars reported in Maehara's study. In particular, they looked at the stars' spectra in the ionized calcium (Ca II) and

NASA / SDO / GENNA DUBERSTEIN



X-CLASS FLARE On December 19, 2014, a powerful flare erupted on the Sun. This composite image from NASA's Solar Dynamics Observatory blends two wavelengths of extreme ultraviolet light, 17.1 nm (gold) and 13.1 nm (purple). Scientists rate flares according to their X-ray intensity; this flare (bright region, center right) they rated as X1.8, which puts it in the most intense category, X. The largest flare ever observed unleashed at least 15 times as much energy — fortunately, that one wasn't pointed at Earth.



C. SCHRIJVER / SDO / NASA (4)

SUN IN KNOTS Shown is the Sun on September 14, 2013, and October 24, 2014. In white light, we see only sunspots (or lack thereof). But solar physicists can use spectral-line observations to infer the photospheric magnetic field. From this map of the surface field, they can then model the coronal field *(left images)*. There's no strong concentration of field apparent on September 14th, when the Sun was nearly spotless. Conversely, on October 24th, almost all of the coronal magnetic field originates from the giant sunspot group AR 12193.

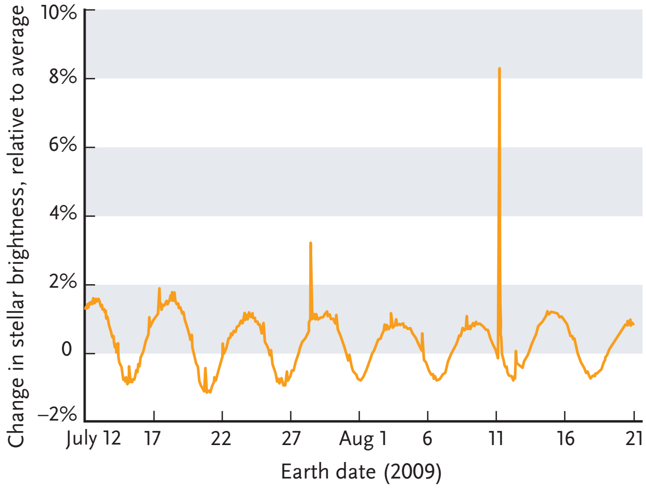
hydrogen-alpha wavelengths, which are better indicators of magnetic activity than Kepler's white-light observations. And they learned what makes these stars so special: superflaring stars have stronger Ca II and hydrogen-alpha signals than the Sun. In other words, these stars generate much stronger magnetic fields.

This makes sense. In general, the faster a star rotates, the stronger its dynamo, or mechanism for generating magnetic fields. Like a more powerful engine drives a more powerful car, a stronger stellar dynamo drives a stronger magnetic field. The stronger a star's magnetic field, the more spots it sports. And the greater the number of spots on a star, the more likely it is to unleash a superflare. In fact, superflaring solar-like stars could be plastered in spots. Maybe the periodic variations in a stellar light curve that we interpret as starspots (see page 25) are instead due to a singular bald patch — a small section of the photosphere that isn't covered by spots.

But while it's generally more likely for a massive spot to produce a massive flare, it's not necessary to have one to have the other. We see this on the Sun all the time. Sometimes large solar flares come from fairly innocuous-looking, decaying or small spots. And sometimes large sunspots don't produce massive flares.

In addition to differences in spot coverage among solar-like stars and the Sun, there are also differences in flare duration. On the Sun, the white-light emission from a flare usually lasts less than 10 minutes. On solar-like stars, the white-light emission from a superflare lasts for almost half a day. There is a plausible explanation for this discrepancy: perhaps the superflare is composed of many smaller — albeit still quite large — flares superimposed atop one another, creating a gargantuan signal.

This idea is not new. Observations from the Solar Dynamics Observatory and STEREO spacecraft clearly show that when the magnetic field rearranges itself during a solar flare, it can affect already-stressed magnetic fields elsewhere on the Sun. In some cases, this causes a domino effect, triggering flares that might not erupt otherwise. Recent numerical models, notably by Tibor Török (Predictive Science Incorporated) and colleagues, can reproduce such observations.



S&T: LEAH TISCIONE, SOURCE: H. MAEHARA ET AL. / *NATURE* 2012

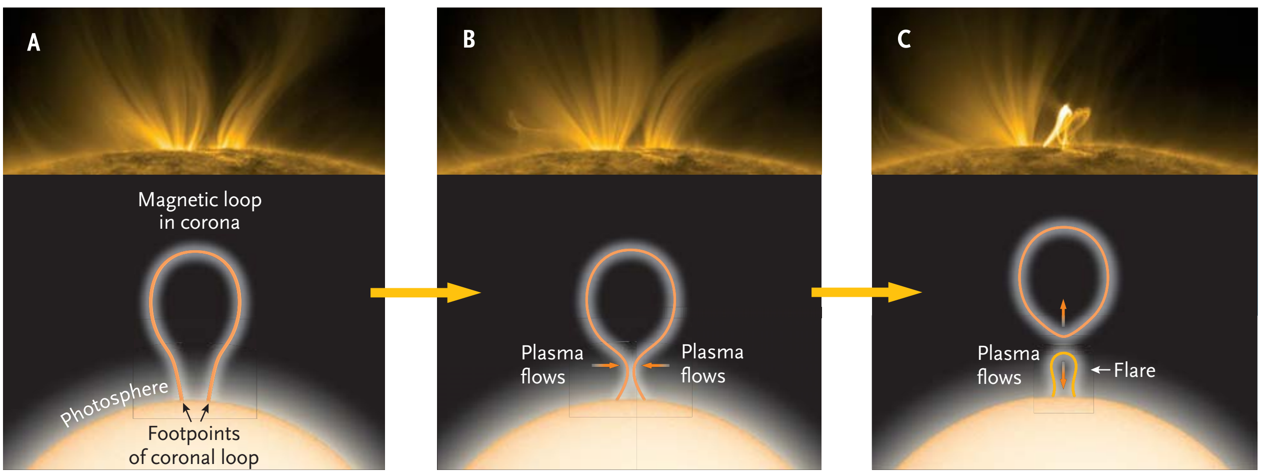
SUPERFLARE SPOTTED Hiroyuki Maehara's team used Kepler data to discover 365 superflares on Sun-like stars, including this flare on the star KIC 6034120. The superflare lasted 5½ hours and had a total estimated energy of 3 × 10^{35} ergs, or about a hundred times larger than the largest flare ever observed on the Sun. The team infers that the periodic variations in the light curve likely come from starspots rotating in and out of view as the star spins.

Signs of a Superflare?

While observations of other solar-like superflaring stars cannot provide all of the answers, there are other places to look. One place is right here, on planet Earth.

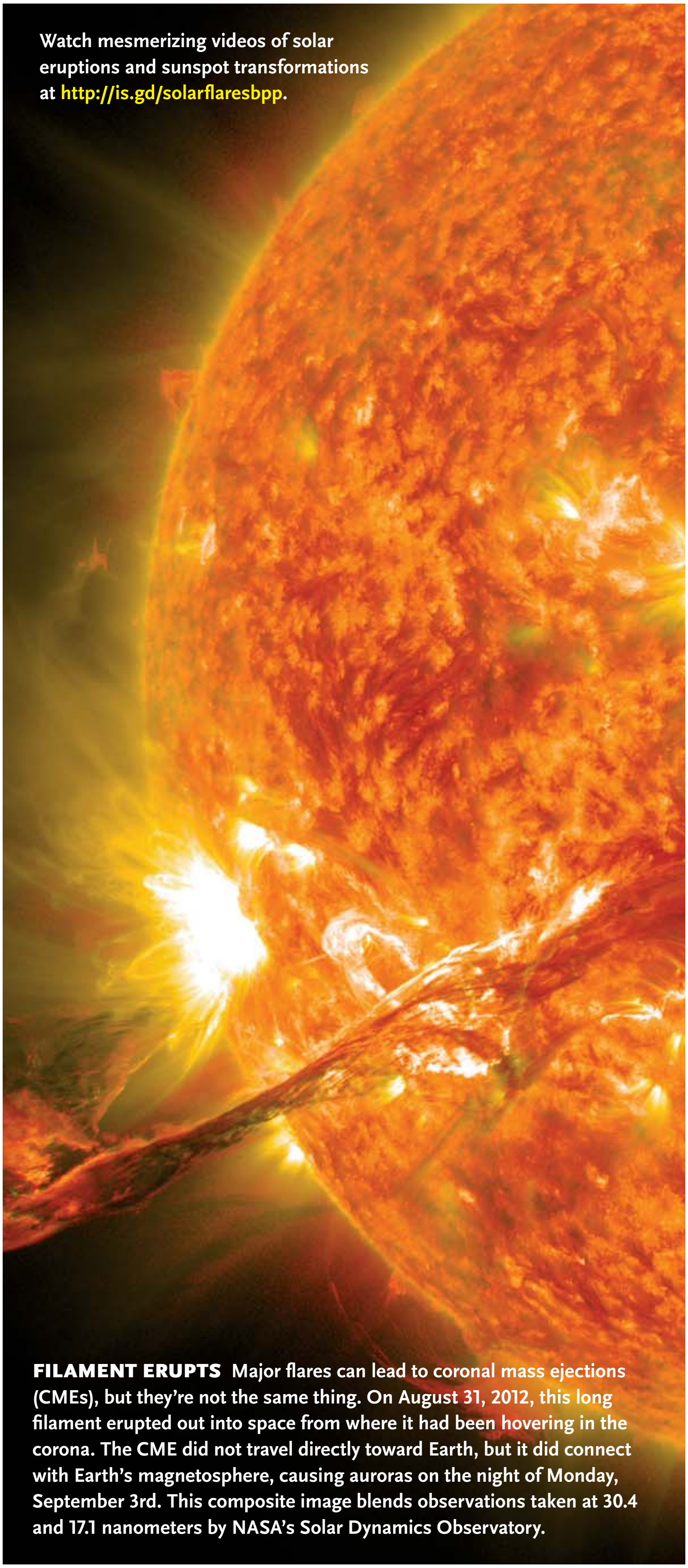
When high-energy particles impact Earth's atmosphere, they create a type of radioactive carbon called carbon-14, which is then incorporated into atmospheric carbon dioxide. During an extreme solar flare, these particles come from the Sun and bombard Earth, creating higher-than-normal levels of carbon-14. Trees ingest this carbon, preserving a historical record of the particle surge in their rings. But no such carbon-14 spikes were observed until 2012, when Fusa Miyake (Nagoya University, Japan) and colleagues unearthed a sharp increase in carbon-14 content in rings formed by Japanese cedar trees around AD 775. Since then, many groups have discovered similar increases from around the same year in bristlecone pines from the White Mountains of California, oaks from Germany, larches from northern Siberia, and, less than a year ago, kauri trees from New Zealand.

But trees aren't the only history books around. High-energy particles impacting Earth's atmosphere also



DIAGRAMS: S&T: GREGG DINDERMAN; FLARES: NASA / SDO AND THE AIA, EVE, AND HMI SCIENCE TEAMS

ONE WAY TO MAKE A FLARE Astronomers aren't quite sure of the mechanics behind solar flares, but one scenario is the pinching off of a magnetic field loop. In this scenario, the loop has its footpoints in the photosphere and extends into the corona (A). Plasma flows pinch the magnetic loop (B); these flows might be part of the natural movements in the solar atmosphere, or inherent to the plasmoid eruption's dynamics. The magnetic field lines then reconnect and the lower loop snaps back toward the photosphere (C). Plasma flows away from the reconnection point, and shock waves within the plasma heat it, creating the intense burst of emission we observe at multiple wavelengths. In simple 2D models like this one, the upper loop carries away ions and can evolve into a coronal mass ejection. But many flares don't show the pinch-off and plasma blob, leading researchers to suspect that, while magnetic knotting and reconnection are fundamental to flare creation, the loop pinch-off process is not.



Watch mesmerizing videos of solar eruptions and sunspot transformations at http://is.gd/solarflaresbpp.

FILAMENT ERUPTS Major flares can lead to coronal mass ejections (CMEs), but they're not the same thing. On August 31, 2012, this long filament erupted out into space from where it had been hovering in the corona. The CME did not travel directly toward Earth, but it did connect with Earth's magnetosphere, causing auroras on the night of Monday, September 3rd. This composite image blends observations taken at 30.4 and 17.1 nanometers by NASA's Solar Dynamics Observatory.

NASA / GSFC / SDO

create a shower of other secondary particles, notably the isotope beryllium-10. These particles fall to the ground. In cold environments, snow falls over these particles, covering them like a blanket. By drilling deep into the polar icecaps or glaciers, we can unearth yet another history. Motivated by all the tree-ring discoveries, Miyake and colleagues turned to Antarctica. There, they found 80% higher-than-average values of beryllium-10 deposits, corresponding once again to the year 775.

It's hard to know exactly what caused this massive increase in energetic particles. It's likely not a supernova, because it would have to have been a mere 52 light-years away to cause such a large carbon-14 spike, and a supernova that close should have been spotted by the naked eye at the time (and doubtless would show up in written records). It's also likely not a gamma-ray burst, which happens either when two compact objects like a neutron star or black hole merge (the short type of GRB) or when certain massive stars go supernova (the long type). Even long GRBs generally only last a few tens of seconds, and because the resulting jet is so narrow, the GRB would only have had enough time to irradiate one hemisphere of Earth. That would not explain why the increase appears in trees around the world.

And the spike isn't a solar flare of the kind we've seen before, because the 1859 flare isn't recorded in tree rings.

But it could be a superflare, some 10 to 50 times larger than the largest solar flare we've ever observed. There is no way to tell. Miyake's team has found hints of a second, smaller spike about 200 years later, but no others. The absence of other such spikes can set an upper limit on how frequently superflares might occur on the Sun.

Suggestive Sunspots

Another place to hunt for clues is, of course, our Sun. Since the advent of the telescope, we've been collecting solar data almost constantly. Though we don't have thousands of years of data as we do with tree rings, we do have the advantage of directly observing not only sunspots, but also the smaller-scale features that accompany them.

For example, we see that sunspots are made up of two distinct concentric parts — a dark umbra, which contains the strongest magnetic field, surrounded by a penumbra, made up of short-lived filaments. We observe how long spots live (most decay a few days after forming) and how many exist at any given time (the number of spots increases and decreases over a regular 11-year cycle). And from these data, we can predict whether the Sun could produce a superflare.

The largest sunspot group reported since the beginning of the 19th century, when sunspot observations became somewhat standardized, occurred in April 1947. It covered an area on the Sun about twice as large as Jupiter and was visible with the naked eye. Though it did not produce any flares that affected Earth, Guillaume

Aulanier (Paris Observatory) and colleagues recently used a numerical model to calculate the largest possible flare this sunspot could power under realistic solar conditions. The team discovered that even this largest-ever sunspot couldn't produce a flare more than a few times larger than the one in 2003.

Other groups have come up with similar results. Carolus Schrijver (Lockheed Martin Solar and Astrophysics Laboratory) and colleagues recently calculated that 10% of the Sun would have to be covered in spots to power a flare 10 times larger than the largest one observed. And we've never seen the Sun look like that. By statistically analyzing the size of solar flares — the vast majority of which are miniscule — Schrijver's team estimates that there's at most a 10% chance we'll see a superflare within the next 30 years.

Hugh Hudson (University of California, Berkeley) has made a similar calculation by analyzing *supergranules*, giant convective bubbles in the photosphere. Sunspot umbrae are not usually larger than the area of a supergranule, he observed. Thus, the average-size sunspot can contain only so much magnetic field. And the field can release its energy only so fast. After calculating these numbers, Hudson also concludes that the average sunspot can't produce flares much larger than the one in 2003.

All of these calculations, however, don't definitively exclude a solar superflare from ever happening. They simply point to the fact that the Sun, as it behaves right now, is unlikely to produce a superflare. But these data are only from recent historical records, and our middle-aged Sun has been around for 4.5 billion years. During that time, it has displayed some erratic, unpredictable behavior — such as the Maunder Minimum, between 1645 and 1715, when the Sun went nearly spotless — and such behavior might crop up again in the future.

Furthermore, solar superflares *are* theoretically possible. Calculations by Kazunari Shibata (Kyoto University) and colleagues show that in just one solar cycle, the Sun could theoretically build up enough magnetic field to power a solar flare 10 times larger than the 2003 flare. It would take 40 years to build up the magnetism needed to power a flare 100 times larger.

The Road Ahead

So, will the Sun ever superflare?

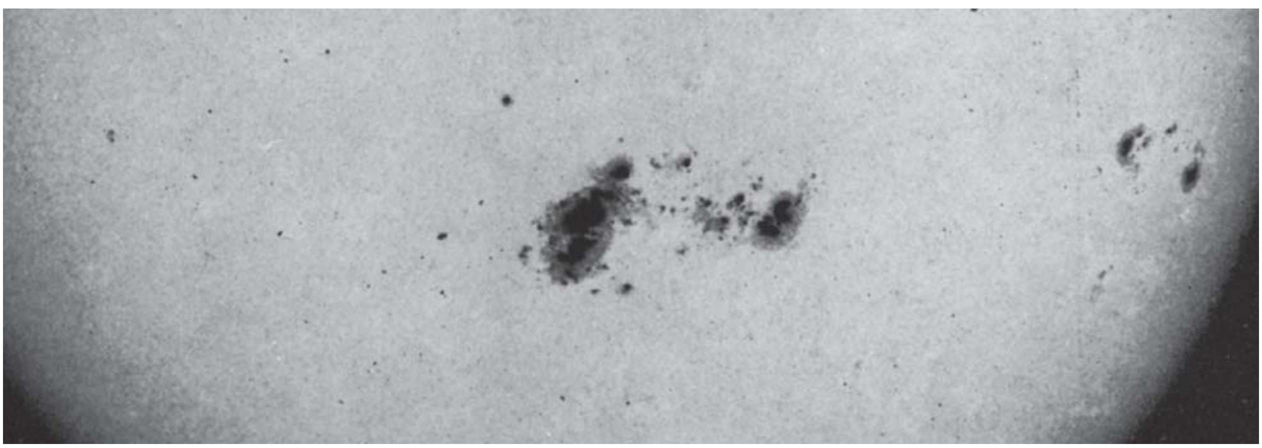
In truth, we aren't sure. We don't yet understand how closely the Sun's behavior mimics that of other stars like it. Although we detected gigantic stellar flares before the Kepler mission, until its advent we were unable to catalog hundreds of them at a time. The wealth of information in Kepler's data has raised more questions than it answered.

We see solar-like stars with a variety of rotation periods, temperatures, and diameters. We see flares 10 times larger than ones observed on the Sun, and we see flares 10,000 times that large, too. We infer that some solar-like stars have massive spots or are covered in spots, and some don't have any spots at all. Do all these stars have the same mechanism for generating magnetic fields? And how many superflares versus garden-variety flares do solar-like stars produce?

Thankfully, there are more data to comb through for answers. Promising information exists in recently digitized historical records from the Song Dynasty, as well as carbon-14 measurements from Chinese corals. The Solar Dynamics Observatory will continue taking almost-constant images of the Sun, ensuring we never miss another sunspot as it rolls across the solar disk. And observations by larger telescopes, better designed to study stellar flares, may allow us to answer some of these questions by observing fainter signals in more spectral lines. The last few years have been rife with discoveries, and the next few will likely be the same. ✦

***Monica Bobra** is a solar physicist at Stanford University.*

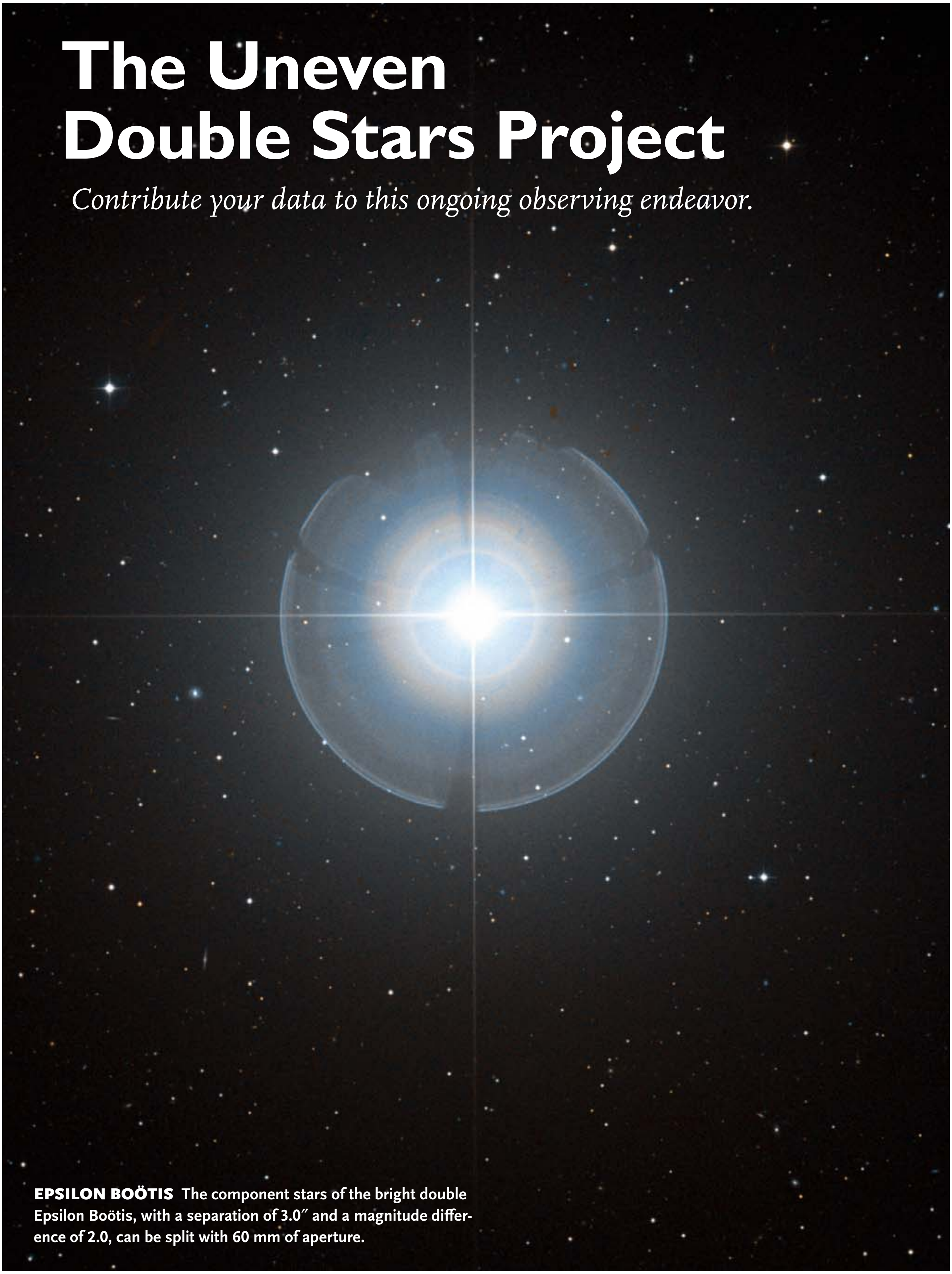
SOLAR BEAUTY MARK **In 1947 a gigantic sunspot group marred the solar surface for several months. At its largest, the group spanned an area roughly twice that of Jupiter. This photo shows the Sun as it appeared on April 6th of that year, right around the time the feature was at its maximum size.**



S&T ARCHIVE / MOUNT WILSON OBSERVATORY

The Uneven Double Stars Project

Contribute your data to this ongoing observing endeavor.



EPSILON BOÖTIS The component stars of the bright double Epsilon Boötis, with a separation of 3.0″ and a magnitude difference of 2.0, can be split with 60 mm of aperture.

POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

Sissy Haas

Want something new to do with your telescope? If I can interest you in joining our project, please know we'd love to add your help. And now with that much said, let me back up and start at the beginning.

You and I know the sky is filled with double stars. Almost every time we study star fields in our telescope, we'll see that one of the stars is actually two stars, barely separated with magnification. If you've seen showcase pairs like Albireo or Epsilon (ε) Boötis, you know they can have breathtaking colors. But we don't always know that we'll see a double star, even when the star is known to be one. If a pair is made of stars not fainter than 6th magnitude and not drastically unequal in brightness, you can use the Dawes limit as the guideline for your aperture: 116/aperture in mm = the smallest separation in arcseconds (″) possible to resolve. For example, the Dawes limit for my 60-mm telescope is 1.9″, since 116/60 = 1.9. Any pair at least this wide should look double in my 60-mm, so long as it's not faint or unequal. Of course, my 60-mm may not perform at the Dawes limit because of bad weather or other factors, but the rule holds true in ideal observing circumstances.

But what if the stars are very unequal in brightness? What's the limit of my telescope then? There have been many formulas published over the years devoted to answering this question. It was the subject about which I was most frequently asked when I had a regular column in this magazine, and Chris Lord of the United Kingdom spent 20 years of his life on it. He gathered personal observations for many years and used his background in mathematics to extrapolate a predictive formula between aperture and separation for unequal double stars; all it requires is a ruler and chart (see *S&T:* Jan. 2002, p. 120).

And now with all *this* said, I'll go back to the first sentence and talk about the Binary Star Observing Project and the Uneven Double Stars Project. Like Lord, we're looking to find the smallest realistic aperture for a specific separation and magnitude difference. But we're simply gathering observations: no predictive formula is intended from them. We've determined test pairs in increments of 0.5, starting at 1.0. All we ask you to do is look at them — as few or as many as you have time for — and see whether or not the pair splits in your aperture. That's it!

Even if our findings prove redundant to what Lord found or predicted, they'll reinforce his study and won't be wasted. What we'd like to have is so many observations, from so many different observers, that we can give a specific aperture for a specific separation/magnitude difference without fear of being wrong. We can already do that for a bright pair that is 3.0″ apart and unequal by 2.0 magnitudes, using **Epsilon Boötis** as the case example. We have 17 confirmations, from many different observers, that it can be split with 60-mm instruments, and 12 confirmations that it splits with still smaller apertures.

Test Pairs by Separation and Magnitude Difference

Separation	ΔM = 1.0	ΔM = 1.5	ΔM = 2.0	ΔM = 2.5	ΔM = 3.0	ΔM = 3.5	ΔM = 4.0
1.0″	Σ2054 (Dra)* 130-mm?	Hrg 47 (Car)* no data	Σ2403 (Dra)* no data	41 Oph no data	42 Ori 200-mm?	8 CMa no data	69 Her* no data
1.5″	Dun 39 (Car)* no data	Hu 544 (Per)* 80-mm?	θ Gru no data	Σ2303 (Ser) 150-mm?	β 67 (Cyg)* no data	90 Her* 150-mm?	no star —
2.0″	33 Ori 80-mm?	μ Cyg* 60-mm	49 Leo 100-mm	κ Lep 130-mm	3 Mon 200-mm	Σ1171 (Cnc) no data	Hu 1136 no data
2.5″	CapO 16 (Cir) no data	Σ389 Cam* 80-mm	38 Lyn 80-mm	no star —	H Vel no data	h3874 Pic no data	no star —
3.0″	17 Dra* 60-mm?	CapO 9 (Vel)* no data	ε Boo 60-mm	ψ Cyg* 80-mm?	23 Aql 100-mm	π Cap* 100-mm?	φ Ori 100-mm
3.5″	90 Leo 60-mm?	Σ2671 (Cyg)* 60-mm	Σ1881 (Vir) 100-mm	See 180 (Cen) no data	h4178 (Car) no data	h5188 (Sgr)* 100-mm?	no star —
4.0″	ρ Her* 60-mm	65 UMa 80-mm	Σ750 Ori 80-mm	Σ2958 (Peg)* 90-mm?	Σ1878 (Dra) 100-mm	5 Aur* 100-mm?	Σ3116 (UMa) 100-mm?

* visible now

POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

Thus, 60 mm is a confident aperture to give for splitting. We have similar overwhelming reports that 100 mm will split a separation of 2.0″ and inequality of 2.0 magnitudes (here, **49 Leonis** is our test pair).

The table on page 29 shows other test pairs of our project and what we can report at this time. The apertures with a question mark mean that we have several observations but not yet enough to give a confident aperture. The pairs marked with an asterisk (*) are visible in this season's night sky.

49 LEONIS **The component stars of double star 49 Leonis, with a separation of 2.0″ and 2.0 difference in magnitude, can be split with 100 mm of aperture.**

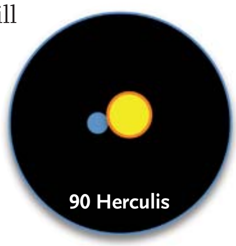
You can see where we still need help. We need it the most from Southern Hemisphere observers. You might also notice something else: the numbers on our chart don't always seem to make sense. Take **Mu (μ) Cygni**, for example, a pair that my notes call "bright yellow" and "pale plum" and split by the "tiniest sliver of space" with my 100-mm at 200×. It's 2.0″ apart and unequal by 1.5 magnitudes. Our reports show that it splits with just 60 mm of aperture, while equally separated but *less* unequal **33 Orionis** needs 80 mm. It may be that we need more observations, but it also could be that Mu Cygni, made of brighter stars, is easier to see in a little 60-mm scope.

Detailed Data for the Test Pairs

Star	Con	RA	Dec	Sep	PA	M1 – M2	ΔM	M1 Class
Hu 544	Per	03^h 15.8^m	+50° 57′	1.6″	102°	6.7 – 8.2	1.0	A0
Σ389	Cam	03^h 30.2^m	+59° 22′	2.7″	71°	6.4 – 7.9	1.5	A2
5 Aurigae	Aur	05^h 00.3^m	39° 24′	4.1″	284°	6.0 – 9.5	3.5	F5
h3874	Pic	06^h 32.0^m	–58° 45′	2.5″	230°	5.6 – 9.3	3.7	B9
Dun 39	Car	07^h 03.3^m	–59° 11′	1.4″	86°	5.8 – 6.8	1.0	B9
CapO 9	Vel	08^h 52.7^m	+52° 08′	2.9″	83°	6.6 – 8.2	1.5	A0
H Vel	Vel	08^h 56.3^m	–52° 43′	2.6″	333°	4.7 – 7.7	3.0	A2
h4178	Car	09^h 04.8^m	–57° 51′	3.4″	161°	6.5 – 9.6	3.1	A8
Hrg 47	Car	10^h 03.6^m	–61° 53′	1.1″	353°	6.3 – 7.9	1.6	B7
Σ2054	Dra	16^h 23.8^m	+61° 42′	1.0″	350°	6.1 – 7.1	1.0	G8
17 Dra	Dra	16^h 36.2^m	+32° 55′	3.2″	104°	5.4 – 6.4	1.0	B9
69 Her	Her	17^h 17.7^m	+37° 17′	0.9″	143°	4.6 – 8.5	3.9	A2
ρ Her	Her	17^h 23.7^m	+37° 09′	3.9″	322°	4.5 – 5.4	0.9	B9
90 Her	Her	17^h 53.3^m	+40° 00′	1.6″	110°	5.3 – 8.8	3.5	K1
Σ2403	Dra	18^h 44.3^m	+61° 03′	2.7″	71°	6.2 – 7.3	1.5	A2
ψ Cyg	Cyg	19^h 55.6^m	+52° 26′	1.1″	278°	5.0 – 7.5	2.1	G8
h1588	Sgr	20^h 20.5^m	–29° 12′	3.3″	42°	6.7 – 10.1	3.4	A2
π Cap	Cap	20^h 27.3^m	–18° 13′	3.3″	150°	5.1 – 8.5	3.4	B8
β 67	Cyg	20^h 50.6^m	+30° 55′	1.6″	306°	6.8 – 9.9	3.1	A8
μ Cyg	Cyg	21^h 44.1^m	+28° 45′	1.7″	319°	4.7 – 6.2	1.5	F6
Σ2958	Peg	22^h 56.9^m	+11° 51′	3.9″	15°	6.6 – 9.1	2.5	A3

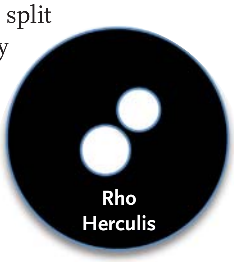
Right ascension and declination are for equinox 2000.0.

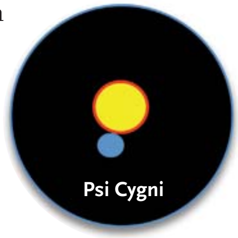
Another problem we've run into is the limiting magnitude. (This refers to the faintest magnitude a telescope can see.) That's because our test pairs that are 4.0″ wide and unequal by more than two magnitudes have 9th- to nearly 10th-magnitude companions. A star this faint is hard to observe with less than 100 mm, even when it stands alone, unless the sky is quite clear. That added complication shows up in our findings for **Σ2958** (Struve 2958) in Pegasus: it's wider than Psi (ψ) Cygni and no more unequal, but requires at least as much aperture. I need 100 mm to see its companion, and even with this much, all I see is a dim, nebulous globe beside a muddy white star. I can't even see the companion of **5 Aurigae** with that aperture, but Bill Boublitz of Hanover, Pennsylvania, an enormous contributor to our project, can, describing it as "a ghost of a thing . . . a faint, tiny, ice-blue point."



Still another problem we have found is the tiny 1.0″ or 1.5″ separations for pairs like **Σ2403** in Draco or **Beta (β) 67** in Cygnus. A pair this close should need at least 125 mm and a scope that gives razor-sharp images, even if it was made of equals; an unequal pair should need still more aperture, and scopes larger than 125 mm are greatly affected by the sky. We just don't have enough observers with large refractors or Maksutovs and excellent skies. Boublitz was able to split both these pairs, as well as equally hard **90 Herculis**, with his 178-mm Maksutov. He describes Σ2403 as "white [and] orange-gray, split was easy [at 150×]." He saw Beta 67 as a "white star" with a companion "that was quite dim without any vivid color . . . just sort of gray," but added that it "shows some orange-brown at times." 90 Herculis appeared as a "golden star with an orange fringe," with a "sparkling medium blue diamond" next to it, and he considered it a "very tough object," even for his 178-mm.

A much easier close pair that's also easy to find is **Σ2054** in Draco: it's in the same low-power field with **Eta (η) Draconis**. My logbook says I needed 350× with my 125-mm refractor to "just barely" split it. At the opposite end of the difficulty scale are **Rho (ρ) Herculis**, **17 Draconis**, and **Σ2671** in Cygnus. I'm sure these are pairs for the smallest telescope, but we need more confirmations of this for 17 Draconis. All are naked-eye stars easy to find and all split easily in my 60-mm refractor. Rho Herculis was among the first double stars I ever observed, many decades ago. I thought both stars looked white, but 19th-century observer Admiral Smyth considered the companion "pale emerald." What do you see? 17 Draconis will appear as a wide double star in your finder scope, comprising 16 and 17 Draconis. I see 17 as "yellow-tinted white and pale white," but the classic 19th-century observer T. W. Webb called the companion "pale lilac." My notes call Σ2671 a "bright white star with a gray smoke ball close beside it."





ALL SKETCHES BY THE AUTHOR

Psi Cygni is another fine naked-eye star that some of our observers have split with just 60 mm, but not me! My only notes are from my 125-mm, through which the pair appeared "brilliant yellow and ocean blue." Admiral Smyth described it as "bright white [and] lilac," however.

Hu 544 in Perseus is well placed for viewing, sharing a low-power field with Alpha Persei. Boublitz found it "challenging" to split with his 101-mm; he calls it "a tiny blue dot below a blue-white primary [star]." He found nearby **Σ389** in Camelopardalis a "striking and lovely pair . . . cream white and green" as viewed with his 178-mm, but saw "hints of orange" for the companion with his 101-mm.

For Northern Hemisphere observers, **Pi (π) Capricorni** and **h5188** in Sagittarius are about as well placed as they're going to get. I found Pi Cap radiant white and pure silver, but Boublitz saw the companion as "ruddy red or rust orange." He described h5188 as a group of stars, because he saw its very wide, faint companions along with the main AB pair that's our test object. Our other test pairs visible now are deep in the Southern Hemisphere. I can't tell you much about them from our reports, because we have so few southern observers.

We'd love to have you join us! To find out more about our project, visit **http://is.gd/HaasProject** and **http://is.gd/udstars**. You can send e-mail to **has103@comcast.net**, or write to me:

Sissy Haas
823 Reamer Ave. Ext.
Greensburg, PA 15601
U.S.A. ✦

***Sissy Haas** lives in a small city in western Pennsylvania at the end of an unlighted dead-end street, but whether her sky is dark depends on who rents the house next door.*

◄ **ULTRA-WIDES** Vixen Optics announces a new series of wide-field eyepieces. The SSW Ultra Wide Eyepiece series ($349 each) provides an expansive 83° apparent field of view with eye relief of 13 mm. These 1¼-inch oculars incorporate a 7-element design with high-transmission lanthanum glass and multi-coated surfaces to produce ghost-free images across the entire field. The series' hexagonal barrel design prevents rolling, and each model includes a retractable eye cup with rubber grip. Available in focal lengths of 3.5, 5, 7, 10, and 14 mm.

Vixen Optics
1050 Calle Amanecer, Suite C, San Clemente, CA 92673
949-429-6363; vixenoptics.com

▼ **BIG DOBS** Teeter's Telescopes unveils its latest custom Dobsonian telescope, the 16-inch f/4.5 TT/Stark (starting at $2,575 without optics). This Truss-Dobsonian is an "à la carte" telescope that you can customize yourself at time of order or later. Each unit is manufactured from Baltic birch plywood with Teeter's exclusive clear-gloss finish. Its mirror box weighs approximately 55 pounds (25 kg, including its optional primary mirror) and stands 69 inches when pointed at the zenith. Each TT/Stark Dobsonian can be ordered with a variety of options, from the primary optics to the focuser and finder, and is compatible with most popular upgrades and accessories.

Teeter's Telescopes
270 Route 46, Suite B, Rockaway, NJ 07866
732-991-1248; teeterstelescopes.com

▲ **COMPACT TRACKER** Fornax Mounts announces the LighTrack II, a portable camera tracking head for nightscape astrophotography. The LighTrack II attaches to your photographic tripod using a ⅜ thread (or a ¼-20" to ⅜" adapter) and can carry a DSLR or mirrorless camera and lens weighing up to 10 pounds (5 kg). The unit incorporates a friction motor drive that boasts a peak-to-peak unguided tracking error of around 2 arcseconds in exposures of up to 6 minutes. The LighTrack II weighs under 3 pounds (1.3 kg) and can track for about 2 hours before requiring a reset of the drive.

Fornax Mounts
Available in North America through BCS Astro
587-709-3976; bcsastro.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.

A Highly Evolved 10-inch

This planetary scope combines transportability and superb performance.

As Leonardo da Vinci once observed, "art is never finished, only abandoned." To some extent, this is also true of home-built telescopes. We often abandon a project when it's reached a stage of completion advanced enough to be functional. Usually we do so knowing we'll return to it again and again to make modifications or add features, as our needs and desires evolve with experience. As Novato, California, ATM Ken George says, "what you see here is an ongoing project with an accumulation of improvements to a telescope I began designing seven years ago."

KEN GEORGE

A 10-inch f/7 Dobsonian isn't a scope you see every day. One that can be transported easily is even rarer. Telescope maker Ken George built this instrument and optimized it for high-quality planetary viewing and quick-and-easy field setup when participating in public observing events.

Like many telescope makers, Ken started off with a specific goal in mind. "From the beginning, this was meant to be my ultimate planetary dream scope, with a focus on portability while preserving optimal performance," he says. The scope's high-performance foundation is its 10-inch, f/7 primary mirror crafted by the skilled hands of optician Carl Zambuto. And that was just the start. "A lot of reflectors are plagued with mediocre contrast, diffraction spikes, and thermal issues," he notes. "Over the years, I tackled each of these one by one." Among his many refinements, the scope features a curved-vane spider to eliminate diffraction spikes, a trio of variable-speed fans to control the primary mirror's thermal behavior, and felt flocking to tame stray light.

Form follows function, so the slightly unorthodox appearance of Ken's scope reflects his desire to make it easy to transport and quick to set up. "I've been active in the local astronomy community for many years and regularly set up my telescope for public viewing events at libraries, schools, museums, and parks," he says. "As you can imagine, efficient transport and quick assembly are important considerations."

Most portable Dobs are a pain to set up in the field. They usually require multiple trips back and forth from the car as each component is unloaded and assembled. The pain is compounded if you end up having to park a great distance from the observing area. Ken wanted to avoid that, so he built his telescope as an all-in-one unit that wheels in and out of his hatchback on a pair of 8-pound folding aluminum ramps. The unit incorporates everything he needs — from truss poles to eyepieces — with an integrated wheelbarrow setup that allows him to quickly and easily move the scope from his car to an observing spot in a single trip. Five minutes later, it's a sky-ready instrument.

How does this one-trip pony work? There are three key features. First is the previously mentioned built-in, double-folding "wheelbarrow" handles permanently attached to the rocker box. As Ken describes, "the primary fold is connected to the rocker box and utilizes a pair of 90°, self-locking shelf brackets, while the secondary fold has a standard gate hinge and is held straight by a heavy-duty three-axis locking latch."

KEN GEORGE

Everything he needs for a night of observing is integrated into the telescope — including foldaway "wheelbarrow" handles and wheels. The scope's truss poles and eyepiece box are attached to the rocker box during transport.

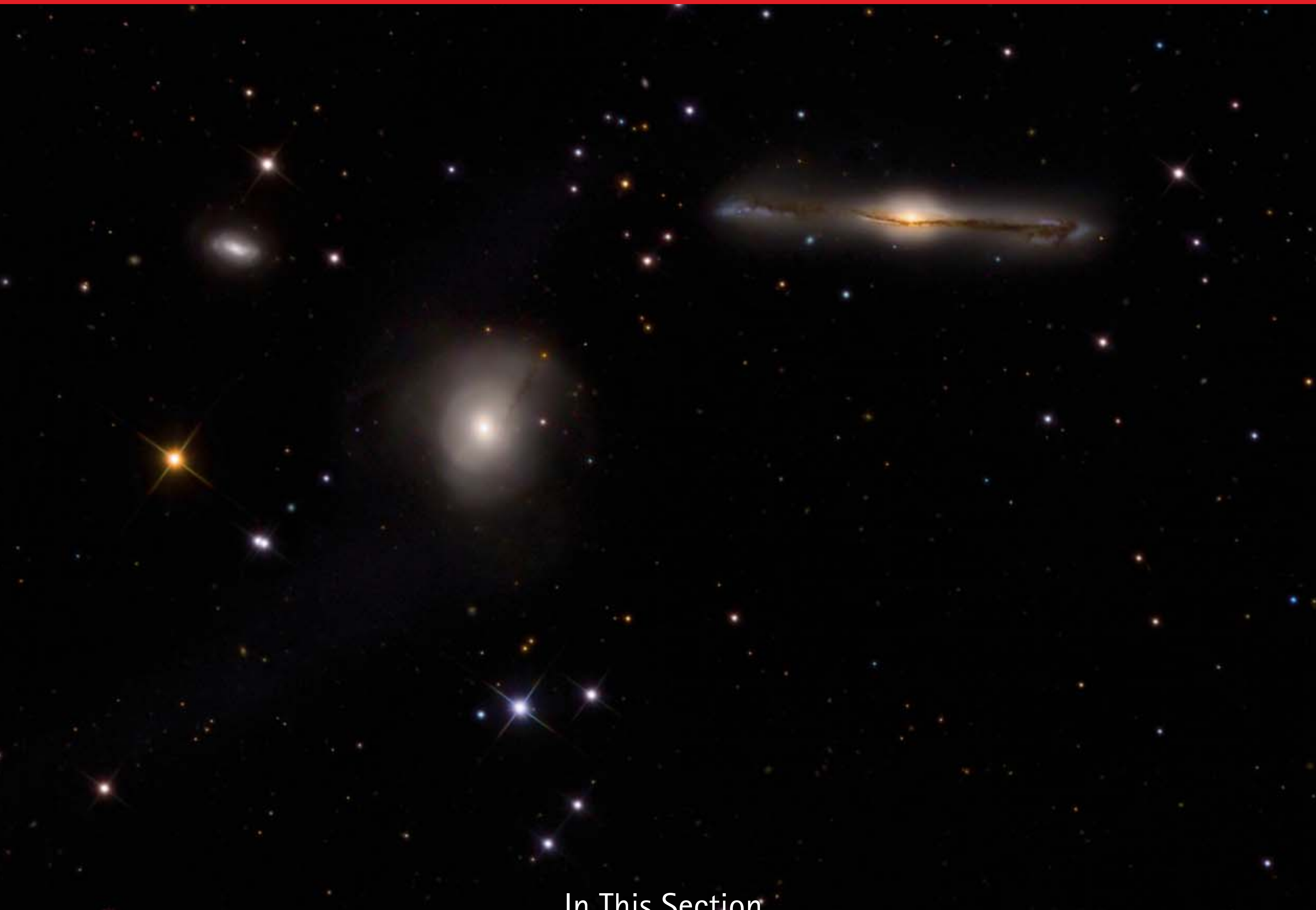
Second, and equally ingenious, are the two wheels mounted on the front of the rocker box. "Removable wheels are a hassle, and permanently fixed ones often get in the way during observing," he notes. "Each wheel on my Dob pivots on a very heavy-duty door hinge and locks into the open position using two metal, quick-release locking latches."

Lastly, Ken came up with a simple yet effective means of transporting the scope's four truss-pole pairs. He used twelve foldaway fish-pole clips affixed to the rocker box. On each side, four clips are attached directly to the rear of the rocker box, while two more are mounted on a pivoting arm that swings out from the front of the rocker box. Each individual clip folds flush against the scope to prevent clothing from snagging on them.

"This telescope performs and transports better than I ever expected," Ken says. "Designing and building it has taught me much about the finer details of optimizing portability and maximizing planetary observing performance."

Readers interested in learning more can e-mail Ken at **myinem@yahoo.com**. ✦

*Contributing editor **Gary Seronik** is an experienced telescope maker and observer who has made quite a few travel scopes over the years. Contact him via his website at **garyseronik.com**.*



In This Section

PHOTOGRAPH: ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA

Interacting galaxies NGC 678 and NGC 680 lie more than 20 million light-years away in Aries. NGC 678 appears almost edge-on, its nucleus visible just above a well-defined dust lane. The irregular shape of NGC 680 comes from the gravitational influence of its neighboring galaxy; see page 53.

Additional Observing Article:

NOVEMBER 2015

1 **DAYLIGHT-SAVING TIME ENDS** at 2 a.m. for most of the U.S. and Canada.

2 **DAWN:** Look for the close pairing of little red Mars and brilliant Venus. They're less than 1° apart this morning and for the next two mornings. Jupiter shines white gold about 6° to their upper right.

4 **NIGHT:** Algol is at minimum brightness for roughly two hours centered at 10:32 p.m. EST.

7 **DAWN:** The waning crescent Moon shines less than 2° from Venus, forming a triangle with nearby Mars. Jupiter stands about 11° above them.

NIGHT: Algol is at minimum brightness for roughly two hours centered at 7:21 p.m. EST.

17–18 **LATE NIGHT:** The typically weak Leonid meteor shower is likely to peak this night; it's best observed between midnight and morning twilight.

24 **NIGHT:** Algol is at minimum brightness for roughly two hours centered at 9:15 p.m. PST (12:15 a.m. November 25th EST).

25 **NIGHT:** The full Moon shines in the Hyades. For viewers in Canada and the northern U.S., the Moon occults Aldebaran in the early morning hours of November 26th; see page 45.

27 **NIGHT:** Algol is at minimum brightness for roughly two hours centered at 9:04 p.m. EST.

28 **DAWN:** First-magnitude Spica shines less than 5° from Venus for the next five days.

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

	◄SUNSET	MIDNIGHT	SUNRISE►
Mercury	Hidden in the Sun's glare all month		
Venus			E — SE
Mars			E — SE
Jupiter			E — SE
Saturn	SW	Visible through November 8	

Moon Phases

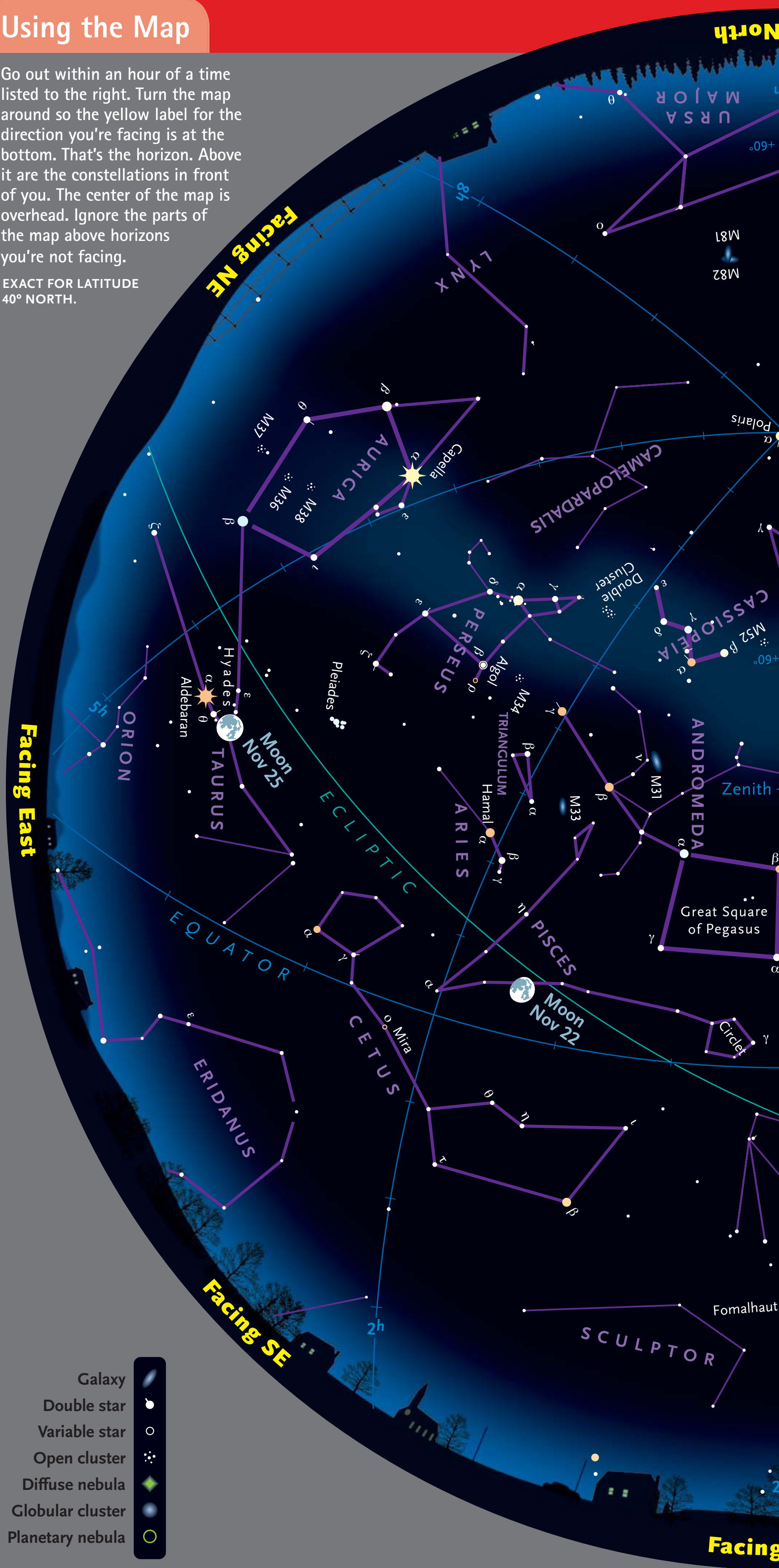
Last Qtr November 3 7:24 a.m. EST
New November 11 12:47 p.m. EST
First Qtr November 19 1:27 a.m. EST
Full November 25 5:44 p.m. EST

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

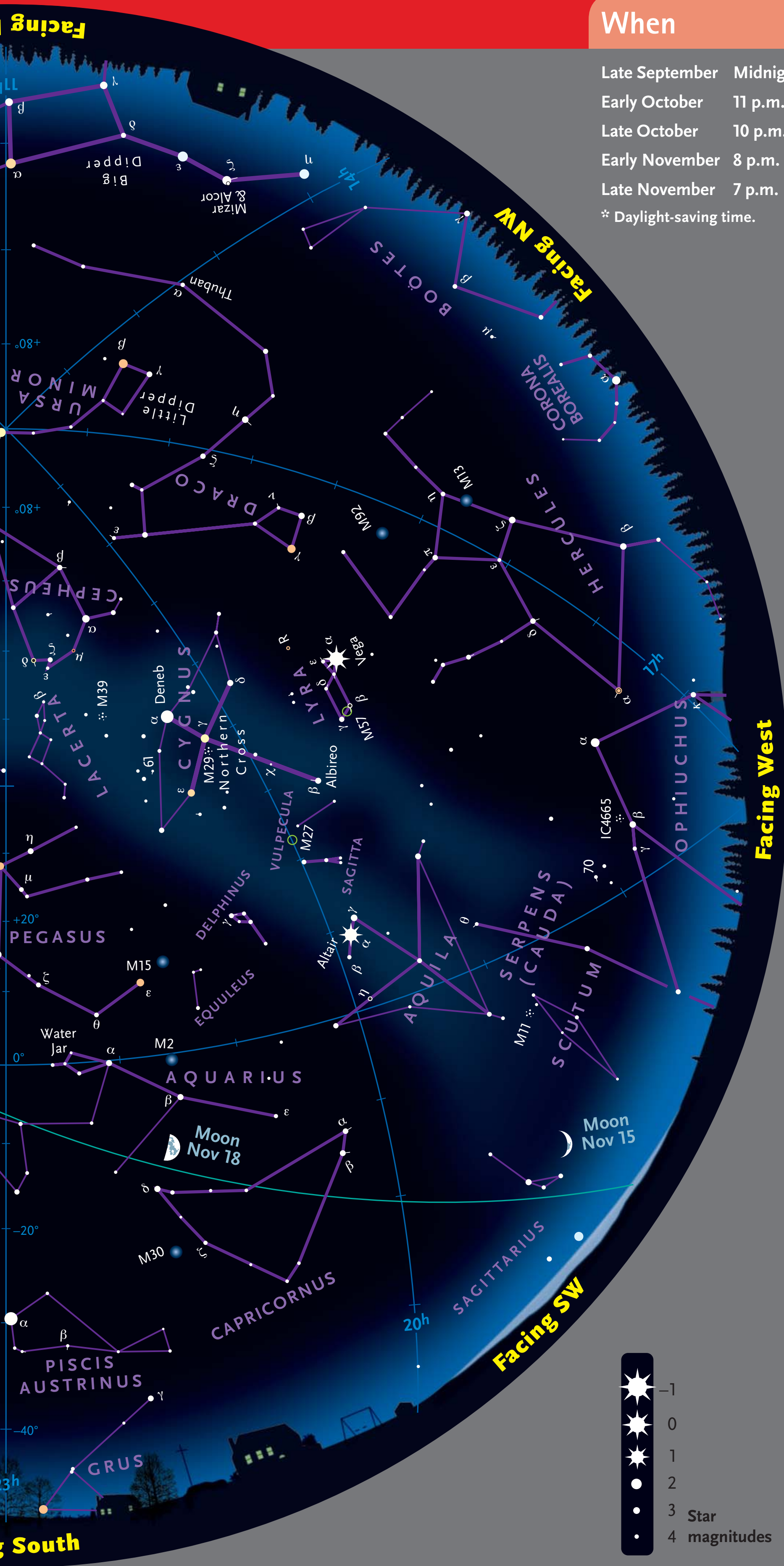
Using the Map

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.



Gary Seronik



When

Late September	Midnight
Early October	11 p.m.*
Late October	10 p.m.*
Early November	8 p.m.
Late November	7 p.m.

* Daylight-saving time.

Column #200

It's hard for me to believe, but this really is my 200th Binocular Highlight column. To mark the occasion, I'm going to finally answer a question I've been asked regularly since column #1: What's my favorite binocular highlight? It's tough to choose just one, so I'm going cheat a bit and list a current favorite from each major class of deep-sky object — that way I get six picks. And as it happens, most of my selections are visible in the November evening sky.

Galaxy: This is an easy one. For me, M31, the Andromeda Galaxy, is head and shoulders above all others. It's big, it's bright, and it has two bonus objects: M32 and M110 (see chart below).

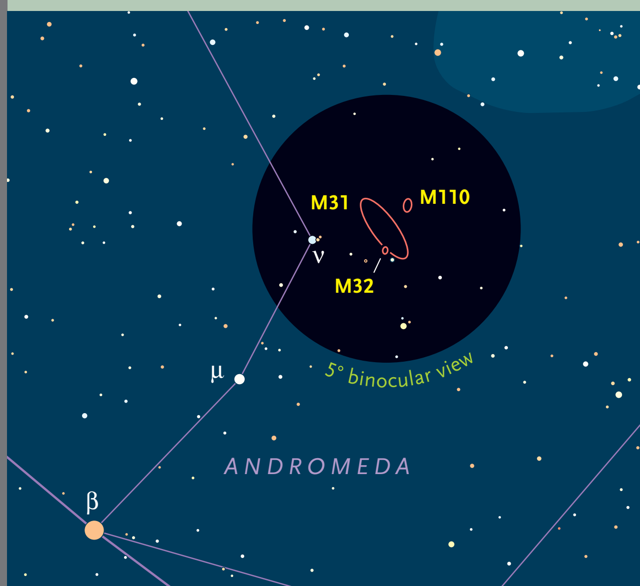
Open cluster: Another easy one. M45, the Pleiades, is not only the best in its class, it's arguably the finest binocular sight visible from mid-northern latitudes. I never tire of looking at it.

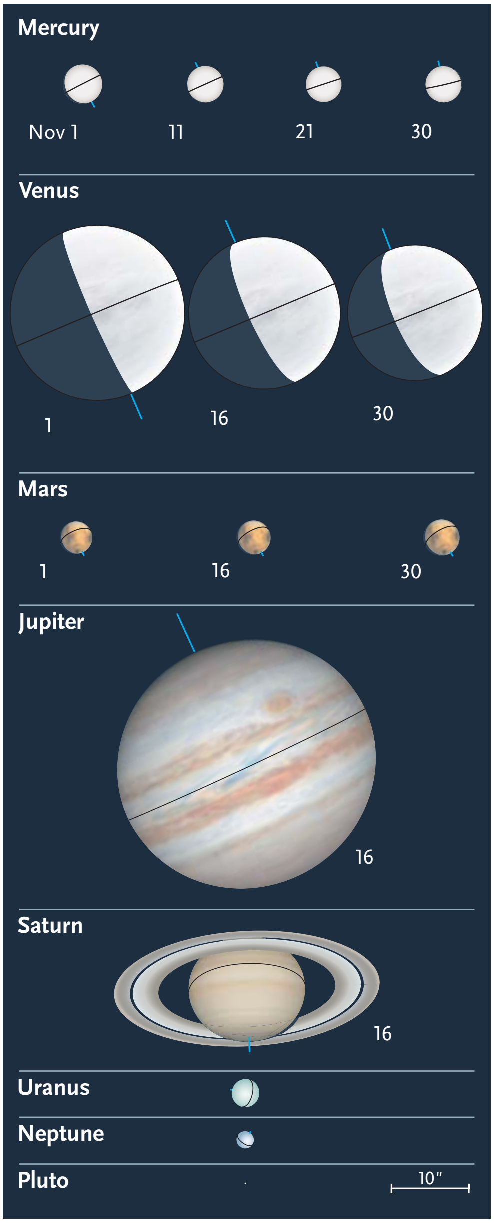
Globular cluster: The obvious choices are probably M13 in Hercules, or perhaps M22 in Sagittarius. Both are fine sights, but I'm picking M4 in Scorpius. It may not be the most spectacular, but I find it the most interesting.

Planetary nebula: I'm going with M27, the Dumbbell Nebula, in Vulpecula. With only a few exceptions, planetaries are tough binocular finds because they're so small. M27 is the best of the bunch. It's bright and (for a planetary) big.

Bright nebula: The Orion Nebula, M42. The nebula itself is a wonder, but if you include the neighboring deep-sky treasures that dot Orion's sword, you have one of the finest binocular fields in the entire sky.

Dark nebula: If there's one class of binocular deep-sky object that doesn't get enough attention, it's dark nebulae. Barnard's E in Aquila is my favorite. ✦



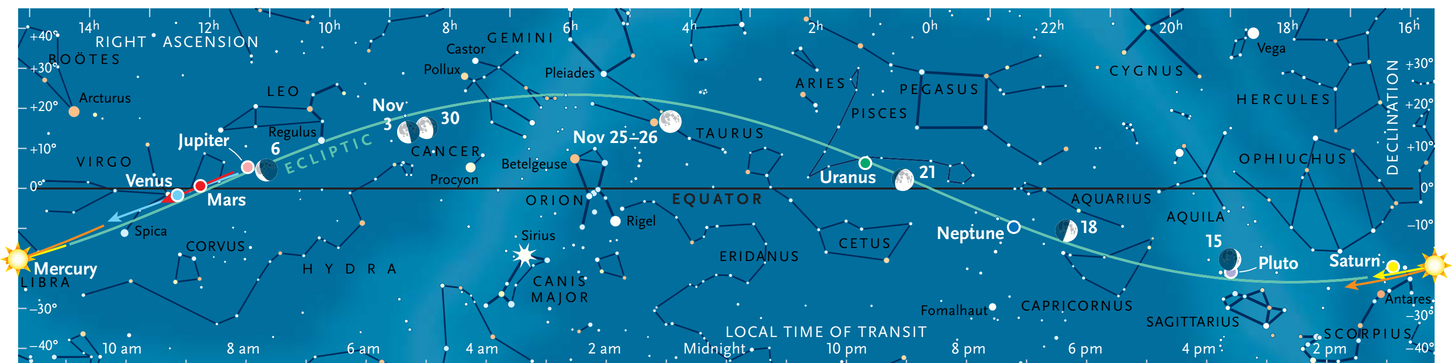


Sun and Planets, November 2015

	November	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$14^h\ 22.6^m$	–14° 11′	—	–26.8	32′ 13″	—	0.993
	30	$16^h\ 21.6^m$	–21° 31′	—	–26.8	32′ 26″	—	0.986
Mercury	1	$13^h\ 44.9^m$	–9° 12′	10° Mo	–1.0	5.1″	94%	1.319
	11	$14^h\ 47.1^m$	–15° 35′	4° Mo	–1.2	4.7″	99%	1.419
	21	$15^h\ 51.0^m$	–20° 46′	2° Ev	–1.3	4.6″	100%	1.450
	30	$16^h\ 50.4^m$	–23° 58′	7° Ev	–0.8	4.7″	98%	1.427
Venus	1	$11^h\ 30.3^m$	+3° 47′	46° Mo	–4.5	22.7″	54%	0.736
	11	$12^h\ 10.6^m$	+0° 15′	46° Mo	–4.4	20.6″	58%	0.811
	21	$12^h\ 52.3^m$	–3° 37′	45° Mo	–4.3	18.9″	63%	0.885
	30	$13^h\ 31.1^m$	–7° 14′	44° Mo	–4.2	17.6″	66%	0.950
Mars	1	$11^h\ 34.9^m$	+4° 13′	45° Mo	+1.7	4.2″	95%	2.202
	16	$12^h\ 08.3^m$	+0° 39′	51° Mo	+1.6	4.5″	94%	2.092
	30	$12^h\ 38.9^m$	–2° 36′	57° Mo	+1.5	4.7″	93%	1.978
Jupiter	1	$11^h\ 11.9^m$	+6° 15′	52° Mo	–1.8	33.1″	99%	5.965
	30	$11^h\ 27.5^m$	+4° 42′	77° Mo	–2.0	35.5″	99%	5.553
Saturn	1	$16^h\ 08.8^m$	–19° 17′	26° Ev	+0.5	15.3″	100%	10.886
	30	$16^h\ 22.8^m$	–19° 54′	2° Ev	+0.4	15.1″	100%	10.992
Uranus	16	$1^h\ 03.6^m$	+6° 04′	144° Ev	+5.7	3.7″	100%	19.172
Neptune	16	$22^h\ 35.3^m$	–9° 46′	104° Ev	+7.9	2.3″	100%	29.711
Pluto	16	$18^h\ 57.6^m$	–21° 06′	50° Ev	+14.2	0.1″	100%	33.607

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

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



The Sun and planets are positioned for mid-November; 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

In Praise of Pisces

A dim zodiac constellation offers some surprising attractions.

©BIGSTOCKPHOTO.COM / BILLYPHOTO2008

A vast section of the November evening sky is filled with dim water-related constellations. The faintest of them all is Pisces the Fish.

Even so, I write in praise of Pisces. I'm going to explain why even its dimness can be part of the pleasure we find in observing it. But there's much else of mental interest to ponder, and visual interest to observe, in this constellation of the (two) Fish.

Reclaiming the heritage of naked-eye Pisces. How easy is it to see anything in Pisces with the naked eye if you have a heavily light-polluted sky? Not very. The only two stars brighter than magnitude 4.0 in the constellation are Eta (η) and Gamma (γ) Piscium (magnitude 3.6 and 3.7, respectively).

Fortunately, that's not all there is to the story of observing Pisces. For instance, there are about 10 stars (one is a variable) between magnitude 4.0 and 4.5 in the constellation — and, of course, many more of 5th and 6th magnitude. This number begins to suggest how beautiful it is to experience with the naked eye a constellation like Pisces in a truly dark sky — the environment in which it was originally seen and created.

When you see Pisces in a dark sky you can start to reconnect with earlier skygazers and all of the wealth of observation, legend, and cultural tradition they found in the faint fish. This is not only one of the constellations of the zodiac, it's the one which today contains the vernal equinox point in the heavens. Think of the history and tradition we can regain in Pisces when we travel to a dark sky or succeed in reducing light pollution somewhere. Binoculars can help show the stars of Pisces if your sky is too bright, of course. But there's no replacement for the wide and natural naked-eye view.

Tracing the two fish and cord. First, trace out the Circlet asterism of stars that forms the head of the western fish of Pisces, right under the much brighter Great Square of Pegasus. Then scan east until you find a southeast-curving line of seven stars that begins just before the 1^h line of RA and ends just after the 2^h line. Less than 2° south of the second star in the line, Epsilon (ε) Piscium, is a special treasure this month: the magnitude-5.7 planet Uranus. The seventh star along the curve is magnitude-4.3 Alpha (α) Piscium. It's most often called Alrescha or Risha, which means "the rope," harkening back to an old legend in which the Great Square of Pegasus was a bucket attached to a rope. The star has also been called Okda, "the knot" in the cord connecting the two fish of Pisces.

You'll need quite dark skies to follow the line of the northern fish from Alrescha up to Andromeda. The triangular head of the northern fish is not far from the great but sometimes elusive M33, the Triangulum Galaxy. In the body of the northern fish shines Eta Piscium, which can be found by running a line from magnitude-2.0 Alpha Arietis (Hamal) through magnitude-2.6 Beta (β) Arietis (Sheratan) and extending the short line several times its length. Why would you want to find Eta Piscium? For one thing, it's a guide to Pisces' only Messier object: M74, just 1½° north-northeast of the star. M74, a lovely but low-surface-brightness spiral galaxy, is the first object everyone must find in March Messier marathons.

Mystery-hued doubles of the double fish. We can't pretend that Pisces is rich with bright galaxies, clusters, or nebulae. It very definitely isn't. But an overlooked type of deep-sky wonder in the underappreciated fish is its marvelous double stars. If you don't use too much aperture, you may be able to detect their tints. Do you see a hint of green in the brighter component of tight Alrescha (magnitudes 4.2, 5.1)? Wide lovely duos in Pisces include Psi^1 (ψ^1) Piscium and Zeta (ζ) Piscium. Fairly close pairs are 55 and 65 Piscium. And if you're looking for color, don't forget the very red 5th-magnitude variable star TX Piscium, on the edge of the Circlet. ✦

The Morning Show

Early risers will enjoy the best views of November's solar system happenings.

Saturn sinks out of view into the Sun's afterglow during November, leaving the entire evening devoid of bright planets. Before and during dawn, however, there is one last close, spectacular conjunction of 2015 — between Venus and Mars — and then a majestic, steadily lengthening line of Regulus, Jupiter, Mars, Venus, and Spica, visited by the waning Moon early in the month.

DUSK

Saturn starts November setting less than 1½ hours after the Sun; look for it extremely low in the southwest in twilight. Don't confuse Saturn with twinkling Antares about 9° to its left; binoculars will help your view.

Telescopes won't show a sharp image of a planet so close to the horizon, but under good conditions they should reveal the wide double star Beta (β) Scorpii (magnitudes 2.6 and 4.9) about a degree from Saturn (magnitude 0.5). More challenging to glimpse in a bright sky is the very wide double Nu (ν) Scorpii (magnitudes 4.0 and 6.3), which is only about 2′ south of Saturn on the American evening of November 7th.

Saturn will be lost from view in mid-November. It goes through conjunction with the Sun on November 30th.

EVENING

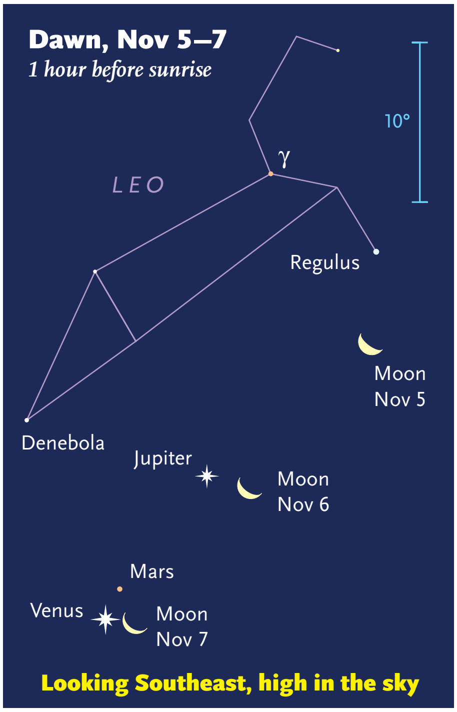
Even right after dusk, **Pluto** is too low now to be worth hunting. But we can note with mental interest that the dim, distant world passes remarkably close to — less than 1′ north of — Xi² (ξ^2) Sagittarii, the 3.5-magnitude tip of the Sagittarius Teaspoon, on November 14th.

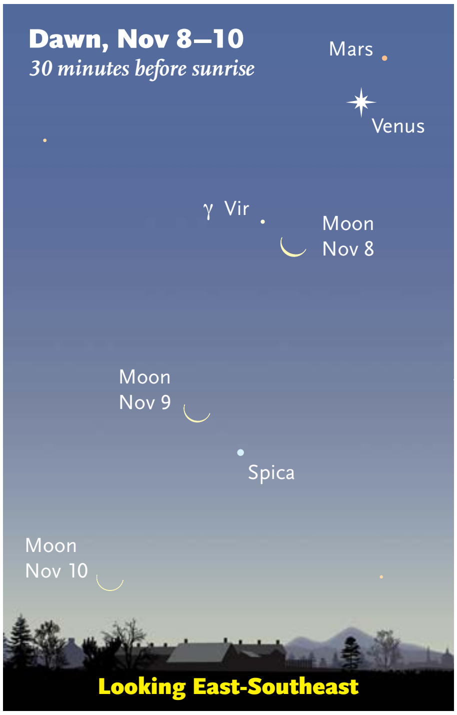
Neptune, in Aquarius, is highest in the south soon after evening twilight ends; **Uranus**, in Pisces, a few hours before midnight. Finder charts for them are in the September issue, page 48, and at **skypub.com/urnep**.

MIDNIGHT TO DAWN

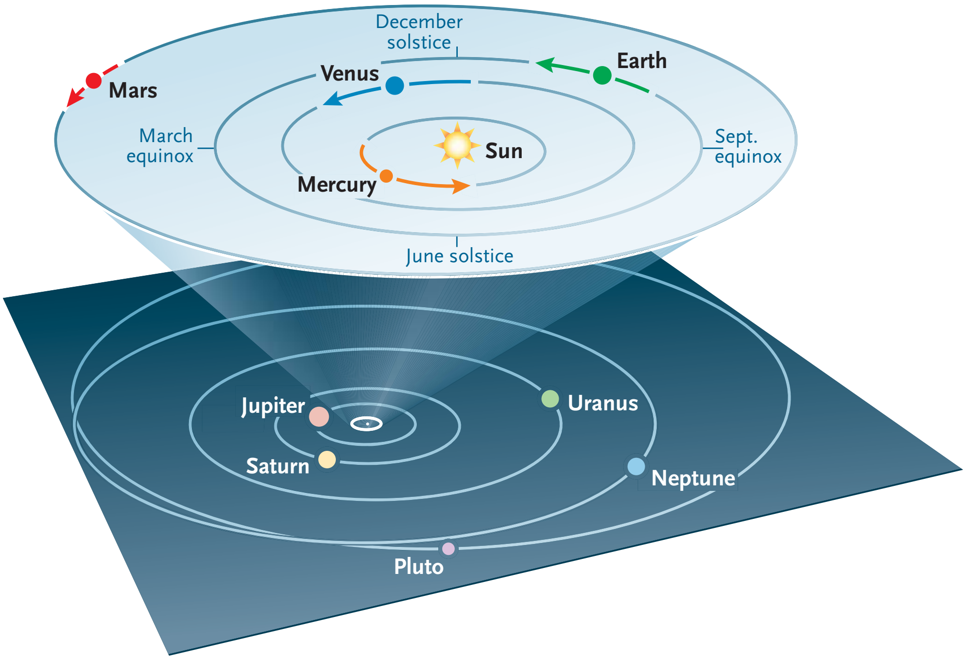
Jupiter rises in the east just after 3 a.m., followed by bright **Venus** and little **Mars** about a half hour later as the month begins. The three planets glowed together at the end of October, but Venus and Mars are moving away from Jupiter now and engaging in a quite close conjunction with each other. From November 2nd through 5th, they shine within 1° of each other, Venus blazing at magnitude –4.5 and Mars gleaming at only magnitude 1.7. The two come closest together on the morning of November 3rd, when Venus is just 0.7° south-southwest (lower left) of Mars. On these close mornings, a medium-power telescopic field of view can contain both Venus, about 22″ wide and 55% lit, and Mars, only 4.3″ wide and 95% lit.

During November the line connecting Jupiter, Mars, and Venus lengthens from about 6° long to more than 30°. By month's end, Mars is about 20° lower left of Jupiter and Venus about 14° lower left of Mars. Venus and Mars have their early-November conjunction at the border of Leo and Virgo and during the rest of the month move deeper into the latter constellation, decreasing the gap between themselves and Spica. Venus passes about 0.4° from 3.6-magnitude Beta Virginis on November 6th and blazes less than 0.2° from Eta (η) Virginis on the morning of November 13th. Mars makes its own close approach to Eta Virginis on the 21st,





Scenes are drawn for 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. For clarity, the Moon is shown three times its actual apparent size.



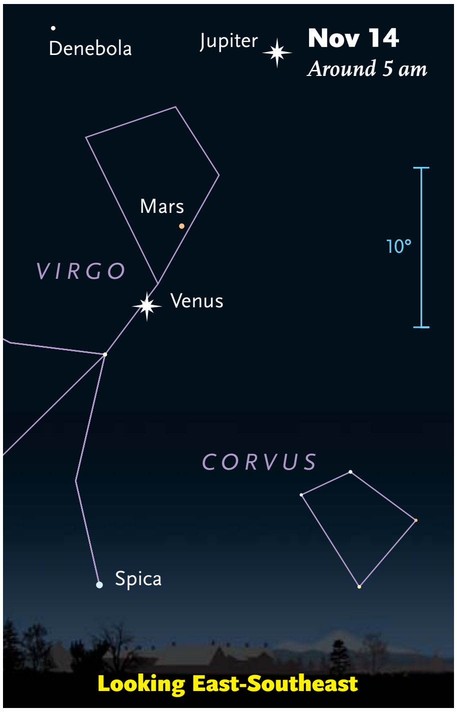
ORBITS OF THE PLANETS
The curved arrows show each planet's movement during November. The outer planets don't change position enough in a month to notice at this scale.

when you may see them as little as 0.1° apart, depending on your location.

Venus passes well to the upper left of Spica near month's end, shining within 5° of it from November 28th to December 2nd. Mars brightens a bit (from magnitude 1.7 to 1.5) this month while Venus dims (from –4.5 to –4.2). Jupiter also brightens from magnitude –1.8 to –2.0 during November, moving farther southeast in Leo — much farther to the lower left of Regulus. At mid-month, Jupiter, with an apparent diameter of 34″, passes less than 1° south of 4th-magnitude Sigma (σ) Leonis, Leo's hind foot. By month's end, Jupiter rises soon after midnight near the Leo–Virgo border.

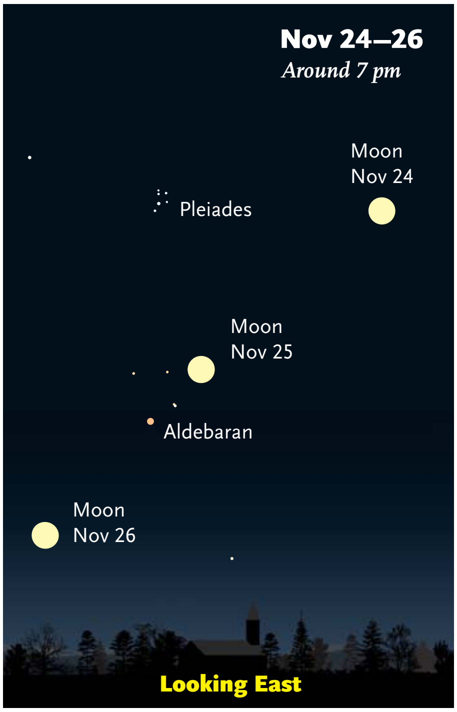
DAWN

Mercury reaches superior conjunction with the Sun on November 17th and is too low in the dusk to see for most of the month. It may be visible through binoculars about 20 minutes before sunrise for just the first few days of November.



MOON PASSAGES

The **Moon**'s pairings with planets and stars on the mornings of November 5th through 9th of this month are not to be missed. The Moon is a waning crescent as it descends, one dawn after another, down a lovely ladder of bright stars and planets. The thick lunar crescent is well to the upper left of Regulus on November 4th and a similar distance below it on the 5th. The thinner Moon appears less than 3° right or lower right of Jupiter for a striking pairing on the American morning of November 6th. The most spectacular of these lunar encounters comes on the morning of November 7th, when the Moon is less than 2° from Venus, with Mars and the fainter star Beta Virginis above them.



On November 8th, use binoculars to see Gamma (γ) Virginis (the tight double star Porrima) close to the left or upper left of the slim crescent Moon. The next morning, look a bit lower in the eastern sky to see a slender sliver of the waning Moon hanging just a few degrees to the upper left of Spica.

Back in the evening sky, the Moon swells to full on the American afternoon or early evening of November 25th. Then, toward dawn on November 26th, the Moon occults the orange giant star Aldebaran in Taurus for observers in the northern United States and Canada (see page 45 for details). ✦

Taurid Fireball Alert

If you see a really bright autumn meteor, note its direction of flight.

ROBERT MIKAELYAN

At dusk on October 13, 2009, a dazzling fireball grabbed attention across the Netherlands and northern Germany. Some called it as bright as the full Moon. Sonic booms followed. Was it a Taurid? The date and evening appearance were about right.

The Taurid meteors of October and November are like no other shower. They continue for many weeks, with two parallel components: the Southern Taurids running roughly through October and early November, and the Northern Taurids from late October through mid-November. Both streams originate from the periodic comet 2P/Encke. Like the comet, the Taurids follow unusually short-period orbits (about 3.3 years) near the plane of the ecliptic. Taurids catch up to the orbiting Earth somewhat from behind, so they travel unusually slowly across the sky. This configuration also makes the shower unusual for being as strong in the evening hours as in the morning.

And this year the Taurids promise something more: an especially good chance for occasional really brilliant fireballs, the kind that make the public call the police.

Comet Encke's debris trail is especially rich in large particles. Meteor-stream modeler David Asher finds that this year, we should pass through a relatively rich band of them. The likeliest dates, he says, run from shortly before Halloween to about November 10th.

Prospects are also good for lesser, more normal meteors. "Four of the last five Northern-autumn Taurid returns have each produced unusual, if variable, activity," notes the International Meteor Organization. "So there seems a good prospect that something may again happen this time."

The strongest recent Taurid return happened in 2005, when bright meteors made news around the world. The name "the Halloween fireballs" for Encke's spawn seems to date from that return.

One was even apparently seen hitting the nightside of the waxing Moon that November 7th. A 7th-magnitude flash was recorded on video; meteor scientists calculated that it would have been made by a 12-cm (5-inch) impactor if it arrived at the Taurids' speed of 27 kilometers per second (60,000 mph). It probably made a crater 3 meters (10 feet) wide and 0.4 meter deep.

All expectations for 2015 come with the usual caveat: meteor showers have a way of fooling everyone.

Between October 10th and November 25th, the shower's radiant moves all the way from north of the head of Cetus to north of Aldebaran. Keep looking up, and if you see a slow meteor during October or November, check whether its path leads back toward that direction.

A Taurid fireball lit up central Texas on the evening of November 8, 2014. This image, aired on Austin TV later that night, was enlarged from a driver's dashcam video.

ARMANDO BUSTAMANTE / KHON-TV

Alan MacRobert

T Cas & Its Partner

A beautiful example of contrasting star colors reappears every 15 months when T Cassiopeiae, especially red even for a Mira-type variable, rises to its maximum brightness. At these times it roughly matches an 8.1-magnitude bluish-white star 89 arcseconds to its northeast.

Now is such a time. The current maximum of T Cas should last from about mid-October through November, if the star behaves as it has during most of its recent cycles.

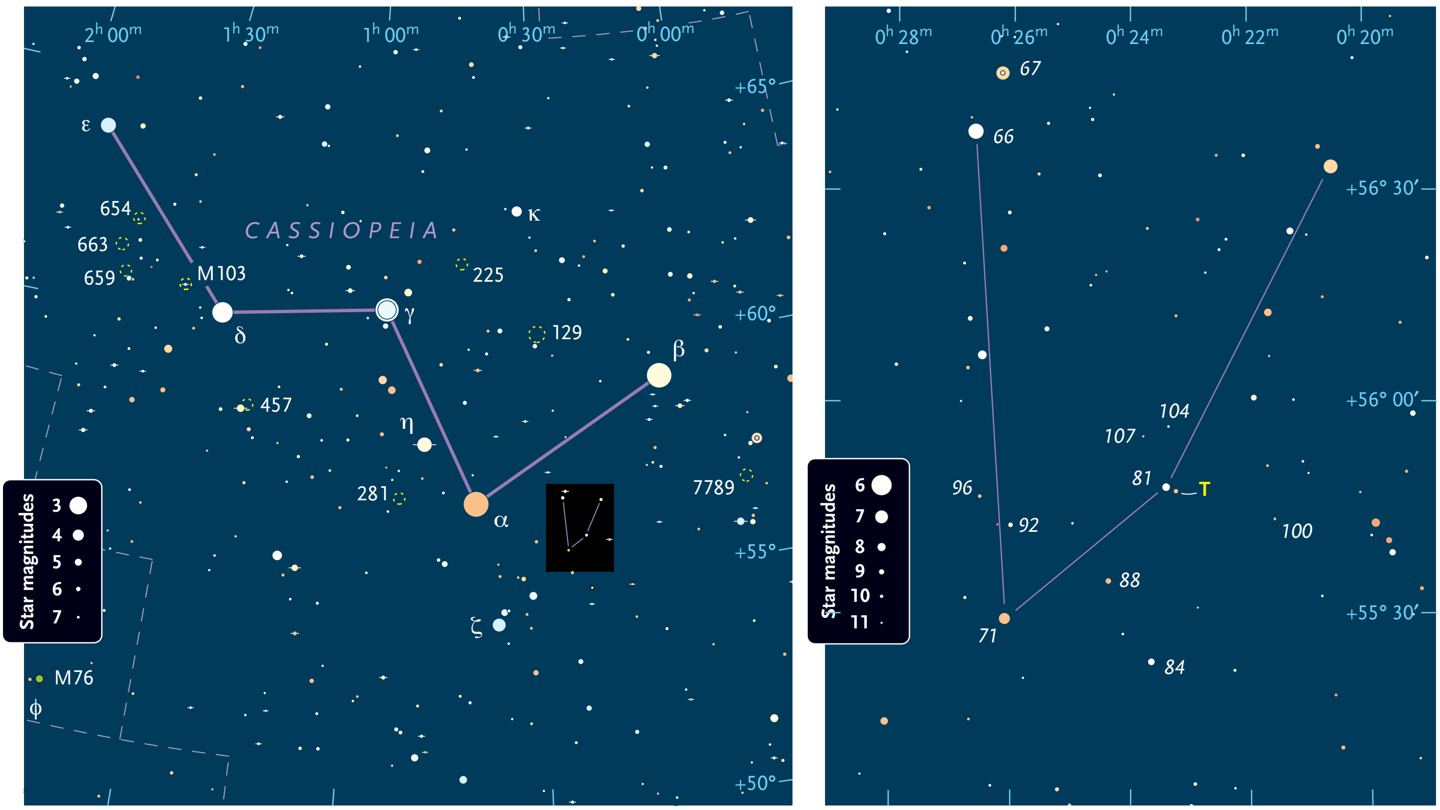
T Cas typically varies from visual magnitude 8.5 to 11.5 and back every 445 days, though it has been reported as bright as 6.9 and as faint as 13. Its maximum is unusually long lasting and nearly flat topped. In most years, anyway. Sometimes the star quickly rises to a peak and drops right back.

And the star's average behavior is changing. For many decades in the mid- and late 20th century, its cycles displayed sharp peaks but with the rise halting partway up and remaining nearly at a standstill around 9th magnitude before continuing the rest of the way. Apparently the star is pulsing in a double mode with two different, similar periods that gradually drift in and out of phase. Such behavior is not uncommon among Miras.

The neighbor star, HD 1873, is spectral type *A0*. Its very slight trace of a blue tinge appears exaggerated by the contrast with its ruddy companion. The two stars are unrelated; both lie thousands of light-years from us.

While you're here, check out the open clusters plotted around Cassiopeia below. My favorites are NGC 457 and 7789.

Just off Cassiopeia's bright side lie red T Cassiopeiae and its blue-white neighbor. On the wide-field chart below, the black box shows the area of the closeup at right. There, AAVSO comparison-star magnitudes are given to the nearest tenth with the decimal point omitted.



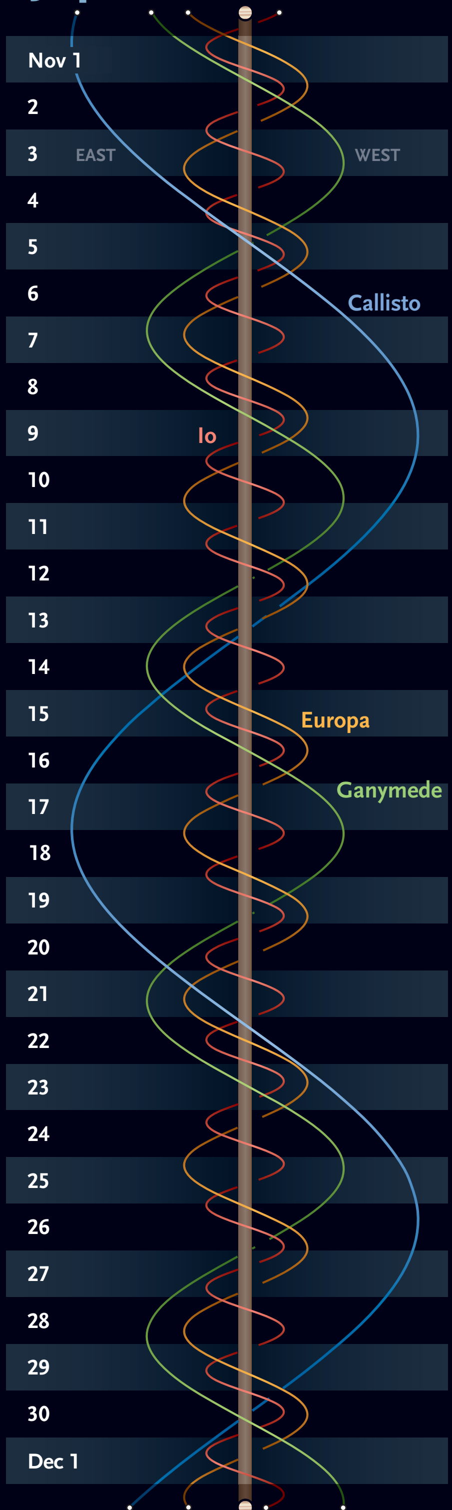
Full Moon Occults Aldebaran

At exactly its most annoying phase, plus or minus just a couple of hours, the full Moon will occult orange Aldebaran for Canada and the northern half of the United States on the morning of November 26th.

Most full-Moon occultations are unobservable. Nevertheless, at magnitude +0.9 Aldebaran is the brightest star that the Moon can ever pass across. Use high power, and you may be able to watch it disappear from view like a tiny orange fire burning on the Moon's limb, suddenly quenched.

Here are some predicted times (all a.m.): **Boston,** *disappearance* 5:50 EST, *reappearance* 6:25 EST. **Washington, DC,** *d.* 5:52, *r.* 6:32 EST. **Toronto,** *d.* 5:41, *r.* 6:31 EST. **Chicago,** *d.* 4:44, *r.* 5:28 CST. **Winnipeg,** *d.* 4:22, *r.* 5:19 CST. **Kansas City,** *d.* 4:54, *r.* 5:18 CST. **Edmonton,** *d.* 3:01, *r.* 4:05 MST. **Vancouver,** *d.* 1:56, *r.* 2:54 PST. Interpolate times between the two or three cities nearest you.

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

Jupiter in November is still an early-morning object and relatively small (33 to 35 arcseconds wide), but by the time dawn begins it's high in the southeast, nicely placed for telescopic observing above tiny Mars and brilliant Venus.

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually show two or three. Identify them using the diagram at left.

All the interactions in October between Jupiter and its satellites and their shadows are tabulated on the facing page.

Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Daylight Time is UT minus 4 hours; Eastern Standard Time is UT minus 5.)

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

November 1, 8:30, 18:25; **2,** 4:21, 14:17; **3,** 0:13, 10:08, 20:04; **4,** 6:00, 15:56; **5,** 1:51, 11:47, 21:43; **6,** 7:39, 17:34; **7,** 3:30, 13:26, 23:22; **8,** 9:17, 19:13; **9,** 5:09, 15:05; **10,** 1:00, 10:56, 20:52; **11,** 6:48, 16:43; **12,** 2:39, 12:35, 22:30; **13,** 8:26, 18:22; **14,** 4:18, 14:13; **15,** 0:09, 10:05, 20:01; **16,** 5:56, 15:52; **17,** 1:48, 11:43, 21:39; **18,** 7:35, 17:31; **19,** 3:26, 13:22, 23:18; **20,** 9:14, 19:09; **21,** 5:05, 15:01; **22,** 0:56, 10:52, 20:48; **23,** 6:44, 16:39; **24,** 2:35, 12:31, 22:26; **25,** 8:22, 18:18; **26,** 4:14, 14:09; **27,** 0:05, 10:01, 19:56; **28,** 5:52, 15:48; **29,** 1:43, 11:39, 21:35; **30,** 7:31, 17:26.

These times assume that the spot is centered at System II longitude 230°. Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting. A light blue or green filter slightly increases contrast and visibility of Jupiter's reddish and brownish markings.

The Coming Mars Apparition

Mars is still just a tiny dot in the pre-dawn sky, telescopically swelling from a pathetic 4″ to 5″ wide in October and November. But get ready for bigger things. That little spark, currently overwhelmed by Venus and Jupiter nearby, is beginning its best apparition since 2005. Mars will spend next May and June closer and larger than it has been since when you were 10 years younger, topping out at 18.6″. It will be at opposition on May 22nd and closest to Earth on May 30th. If you've never seen Mars well, this will be your chance.

Maybe. The downside is that Mars spends those months far down near the head of Scorpius at declination –21° or –22°. The farther north you are, the thicker the atmospheric seeing you'll be looking through — and the more important it will be to time your observing for late at night when Mars will be highest. Mark your calendar.

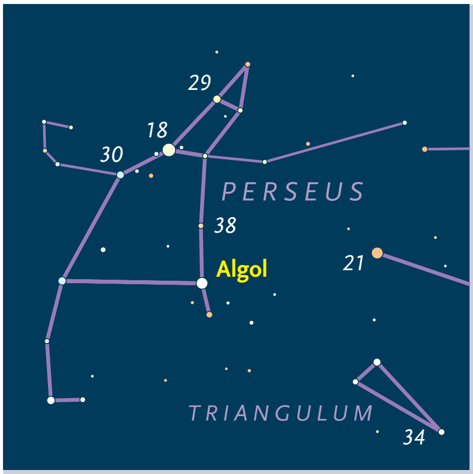
As a bonus Saturn will be shining in the same vicinity, to Mars's east.

Mars will come even closer in July and August 2018, when it will reach 24.3″. That's nearly as big as it can ever appear in its 15.8-year cycle of oppositions near and far. But it will then be in southern Capricornus, a couple degrees even farther south.

ASTEROID OCCULTATION

On the morning of November 14th, telescope users along a track from Virginia through Missouri, Kansas, and on to northern California can watch for a 9.6-magnitude star near Orion's Club to be occulted by the faint asteroid 213 Lilaea for up to 8 seconds. The track map, time predictions, and finder charts for the star are at **asteroidoccultation.com/IndexAll.htm**.

For how to time such events by video, see **asteroidoccultation.com/observations**. For advice and help, join **groups.yahoo.com/neo/groups/IOTAoccultations**. ✦



Comparison stars for Algol (decimal points omitted). At right, these geocentric predictions are from the heliocentric elements Min. = JD 2456181.840 + 2.86736*E*, where *E* is any integer. Courtesy Gerry Samolyk (AAVSO).

Minima of Algol

Oct.	UT	Nov.	UT
1	17:46	2	6:43
4	14:35	5	3:32
7	11:23	8	0:21
10	8:12	10	21:10
13	5:01	13	17:59
16	1:50	16	14:48
18	22:39	19	11:37
21	19:27	22	8:26
24	16:16	25	5:15
27	13:05	28	2:04
30	9:54	30	22:53

Phenomena of Jupiter's Moons, November 2015

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

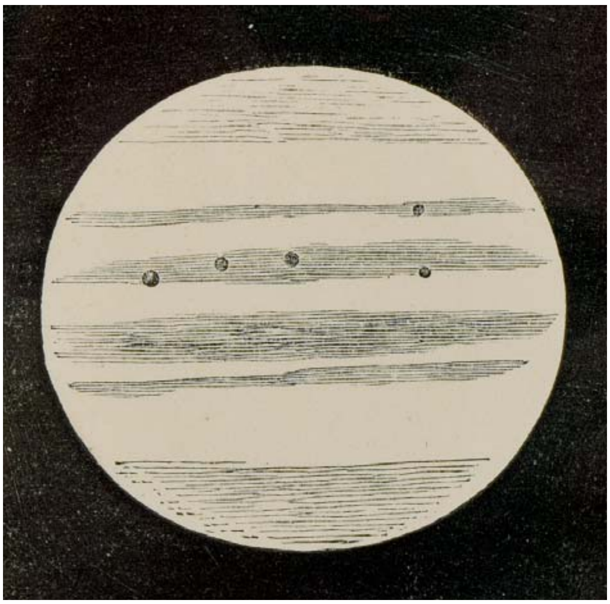
Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 4 hours ahead of Eastern Daylight Time, 5 ahead of Eastern Standard Time). Next is the satellite involved: **I** for 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. Courtesy IMCCE.

William Dawes' Jupiter

A celebrated 19th-century astronomer made remarkable observations of Jupiter and its moons.

Rising in morning twilight is the giant planet Jupiter. It's never too early to start observing this fascinating object. Armed with just an off-the-shelf planetary camera and a medium-size backyard telescope, you can take stunning, high-quality images that once were only possible with interplanetary spacecraft. But recording details on our Sun's largest planet in the days before photography was a slow, arduous task involving hours of sketching at the eyepiece by dedicated observers.

The serious study of Jupiter's dynamic, swirling atmosphere did not start until the mid-19th century. Before then, it was a completely mysterious world — we didn't fully know even its most basic properties (mass, size, density). One of the first observers to start systematic observations of Jupiter was Rev. William Rutter Dawes (1799–1868). Today he is best remembered as a prolific double-star observer and for determining the "Dawes' limit" of angular resolution for telescopes. However, by the mid-19th century, "Eagle-Eyed" Dawes was also considered one of the world's foremost planetary observers. Not only did he codiscover the Crepe (C) ring of Saturn in 1850, but his observations and drawings of Mars and especially Jupiter were also among the finest of the time.



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William Dawes twice witnessed occurrences when none of Jupiter's four large satellites appeared alongside the planet. This is the view he saw on the evening of August 21, 1867. Callisto is above Io on the disk (right of center), and Ganymede sits between Callisto's shadow (center) and its own; Europa is hidden behind Jupiter. South is up.

One of his earliest recorded observations was on September 28, 1843, when Jupiter appeared "without satellites." On that particular night, Io and its shadow, Ganymede, and Callisto were in transit across the disk, while Europa was occulted by the planet. Dawes started watching the event with George Bishop's 7-inch Dollond refractor but soon returned to his own residence after trees threatened to obscure the view. Using a 2.7-inch, f/16 Dollond refractor at 113×, he recorded the times of each satellite's motion across the disk. He noted, "For about 35 minutes, Jupiter was visible without any satellite."

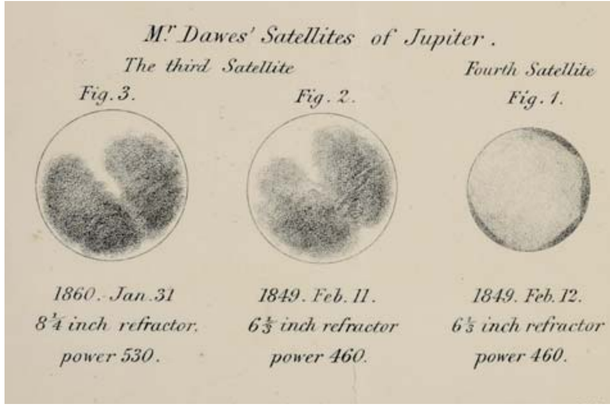
However, the relocation to his residence might have cost him the chance to record a partial eclipse of Io by Callisto (23:25 to 23:48 Universal Time) as both moved across Jupiter's disk. Dawes *did* observe this event, but his 2.7-inch aperture — unlike Bishop's 7-inch refractor — lacked sufficient resolution to separate their disks. Many years later (1862), George Airy, the Astronomer Royal, asked Dawes to submit these observations to the Royal Astronomical Society (RAS), as not a single notice of this rare event had been received by the society.

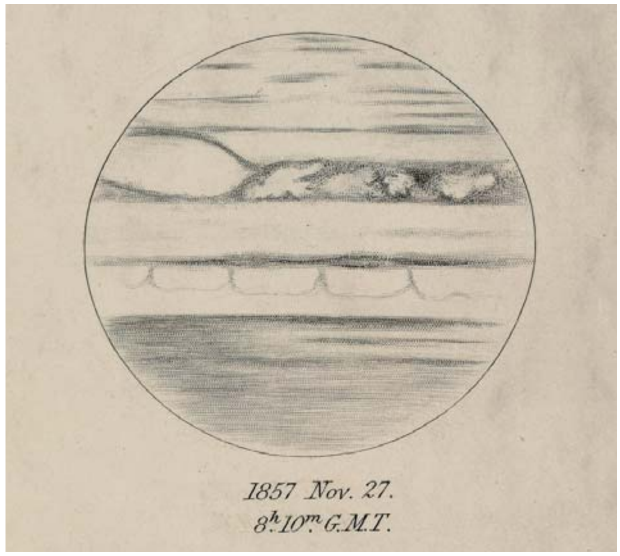
Dawes soon moved on to a superior 6.3-inch Merz refractor and used its excellent optics to great advantage. During 1849 and 1850, both he and William Lassell noted a rare outbreak of "bright round spots" in the planet's South Temperate Belt and South Temperate Zone. In the spring of 1850 Lassell submitted his observations and sketches to the RAS. However, the white-spot activity quickly subsided, with no further observations of them recorded until the latter part of 1857.

By then, William Dawes had become one of the most respected observers in the world, having won the Gold Medal of the RAS two years earlier. In September 1857, using an 8-inch Clark refractor, Dawes reported a new outbreak of white spots. He wrote, "They were five in number, two being nearly equal in size and almost

***Richard Jakiel** observes the solar system and deep space from his home, "Mars House," in the wilds of suburban Atlanta, Georgia.*

Richard Jakiel





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***Right:* Dawes' engravings from 1849 and 1860 show bright and dark details on Jupiter's "third satellite" (Ganymede) and a relatively featureless "fourth satellite" (Callisto). *Lower right:* On November 27, 1857, Dawes apparently became the first observer to record the Great Red Spot Hollow (though not the spot itself) as a large oval area at upper left on the disk. He made this observation at 8:10 Greenwich Mean Time, which in that era corresponded to 8:10 p.m. in England. South is up in both panels.**

as large as the third satellite [Ganymede] appears." He added that they traveled in close proximity to one another, with four of the five in a co-latitudinal line. The three smaller spots were the size of Europa (about 1 arcsecond across). More spots appeared over the next 3 months, until 11 of them were spread around the planet. Dawes was the first to note changes in the relative velocity of the spots, as those lower in latitude traveled faster around the planet.

Perhaps his most significant Jovian discovery was made on November 27, 1857. His drawings from that night record a series of disturbances and spots in the southern hemisphere. One sketch includes a large oval region that was about to rotate behind the planet. This represents one of the earliest observations of the structure now known as the Great Red Spot Hollow. (Not until 1878 would American astronomer Carr Walter Pritchett make the first well-documented appearance of the Great Red Spot itself.)

Dawes was never a robust man, and his health took a decided downturn in the 1860s. Still, along with numerous double-star measurements, he completed a series of remarkable drawings of Mars during its 1864 opposition and made detailed observations of the Leonid meteor storm on the night of November 13–14, 1866. In recognition of his many accomplishments, he was made a Fellow of the RAS in 1865. With his health failing, he still managed to observe a second occurrence of "Jupiter without satellites" on August 21, 1867. Unlike the 1843 event, this one was widely seen by observers across the European continent.

With his trusty 8-inch Clark at 412×, that evening Dawes observed the transits of Io, Ganymede, and Callisto plus their shadows, while Europa remained hidden behind Jupiter. He found Ganymede particularly interesting, and the sketch he submitted to the RAS shows darker terrain covering almost half of its surface. These and other details proved to be a good follow-up to the Galilean satellite observations he made in 1849–50.

On February 15, 1868, less than six months after witnessing his second moonless event, William Rutter Dawes passed away. But "Eagle-Eyed Dawes" left a rich legacy of careful observations that qualify him as one of the pioneers of planetary science. ✦

The Moon • November 2015

Distances

Apogee 252,103 miles	**November 7, 22h UT** diam. 29′ 16″
Perigee 225,444 miles	**November 23, 20h UT** diam. 32′ 55″

Librations

Poncelet (crater)	**November 23**
Byrd (crater)	**November 25**
Petermann (crater)	**November 27**

Phases

LAST QUARTER
November 3, 12:24 UT

NEW MOON
November 11, 17:47 UT

FIRST QUARTER
November 19, 6:27 UT

FULL MOON
November 25, 22:44 UT

NASA / LRO

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

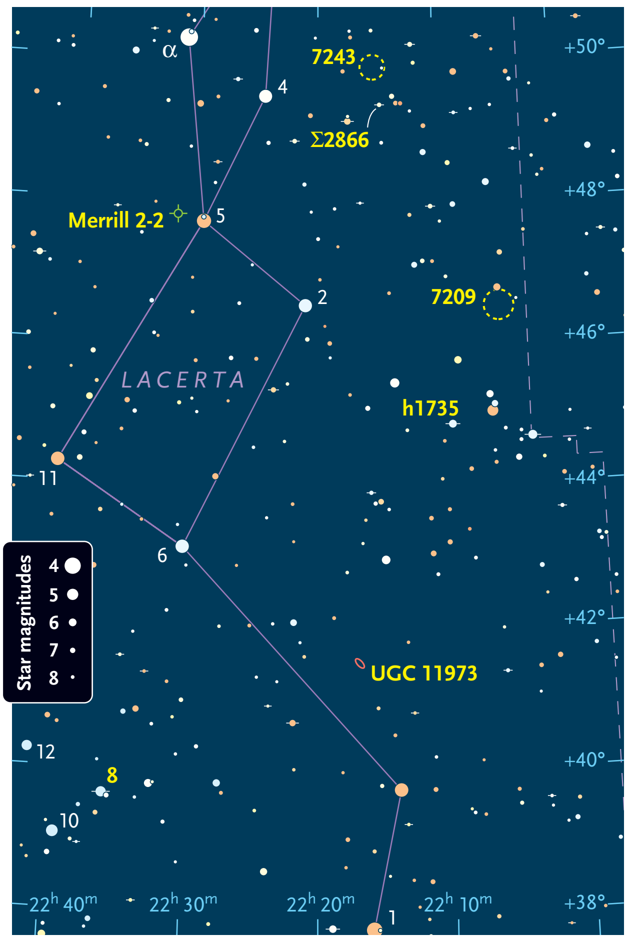
Love of Night

Lacerta, the Lizard, leads us to a surprising stellar bounty.

I love to rove amidst the starry height,
To leave the little scenes of Earth behind,
And let Imagination wing her flight
On eagle pinions swifter than the wind.
— Thomas Rodd, *Contemplation of the Heavens*, 1814

Every swath of the sky offers something to charm us, even those that don't announce their presence with the light of dazzling stars. Little Lacerta, the Lizard, fills one of those modest corners of the night, and it's surprisingly rich in telescopic treasures.

Through the eyepiece, there are few deep-sky wonders as beautiful as star clusters. These sparkly gatherings of gem-like stars almost seem designed to delight.



So, let's take advantage and start our tour of Lacerta with the bright open cluster **NGC 7243**.

Through my 18×50 image-stabilized binoculars, NGC 7243 shares the field of view with the star 4 Lacertae. The large, coarse cluster reveals 20 glittering stars disposed in four curving arms. The group fills out when seen through my 130-mm refractor at 37×, boasting 55 moderately bright to faint stars in a haphazard bunch tumbled across 24′ of sky. Nestled in the cluster's heart, double star Struve 2890 (Σ2890 or STF 2890) displays a nearly matched pair of 9th-magnitude suns, two of the cluster's brightest. The slightly dimmer companion floats 9.4″ north of its primary. **Struve 2886** also decorates the field, 33′ south of the cluster's center. The yellow-white primary shines at magnitude 7.6, and its 10.1-magnitude companion, perhaps a bit yellower, is widely separated 21″ to the east-southeast.

NGC 7243 has been variously described as a broken heart, a crab, a pair of seagulls in flight, or the whip of Indiana Jones. What does your imagination conjure?

Next we'll visit the petite planetary nebula **Merrill 2-2**, located 23′ east-northeast of orange 5 Lacertae. With my 130-mm refractor, I needed a magnification of 120× to star-hop through the abundant field stars, but when I reached the correct area, I saw one little point of light that didn't look as sharp as the stars. It makes a nearly straight, 1.8′-long line with two 12th-magnitude stars, the closer one to its west-northwest. Boosting the magnification to 164× stole away the nebula's starlike mask, although it remained very tiny. If the seeing doesn't allow you to distinguish Me 2-2 from the stars, try using a nebula filter. A narrowband filter dims the stars and makes the planetary stand out very well, but I prefer an O III filter when using a larger scope.

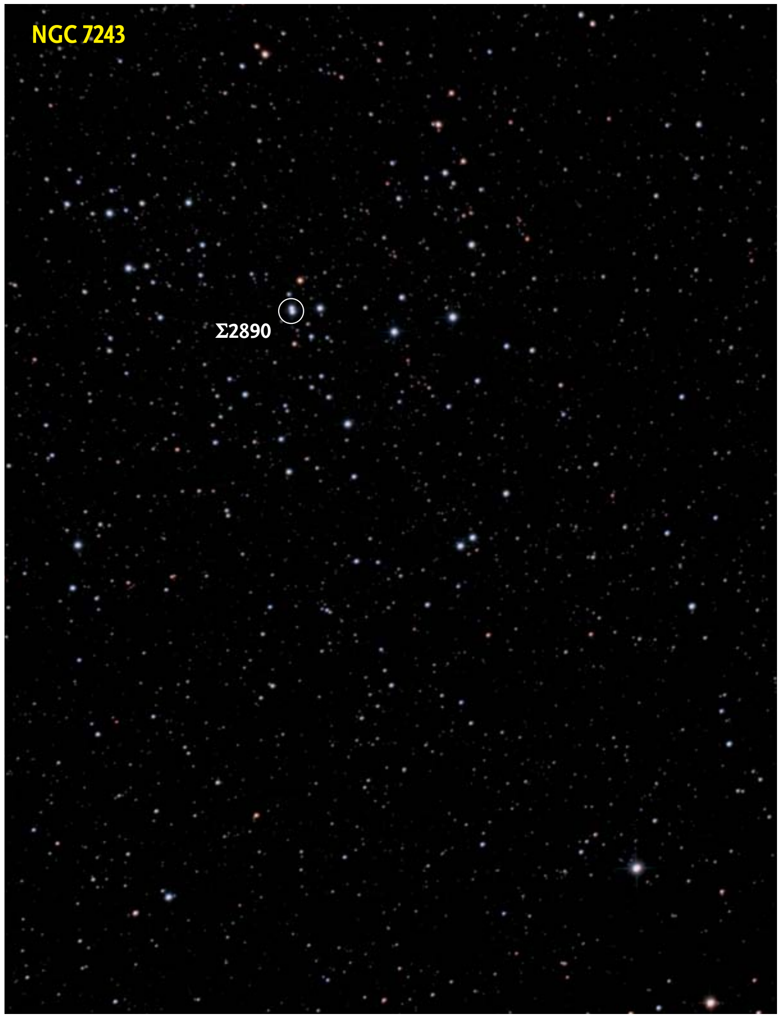
Planetary nebula distances are generally difficult to pin down, but according to a 2010 catalog by Letizia Stanghellini and Misha Haywood, Merrill 2-2 is probably between 32,000 and 48,000 light-years away from

us. That would place it beyond the outer reaches of our galaxy's disk.

Another open cluster, much different than our first, sits 2.7° west of 2 Lacertae. Through my 18×50 binoculars, **NGC 7209** is an obvious hazy patch generously flecked with pinpoint stars. The cluster sits within an irregular pentagon of brighter stars. The brightest one, north of the cluster, is an ember of smoldering orange. My 130-mm refractor at 23× draws out 30 stars, 9th magnitude and fainter, spanning about ¼°. Two reddish-orange, 9th-magnitude stars play sentinel to the group, one just beyond the cluster's eastern border and a more distant one off its south-southeastern side. Increasing the power to 37× sharpens the stars and doubles their number. Two of the brightest, north and east of center, have a golden sheen.

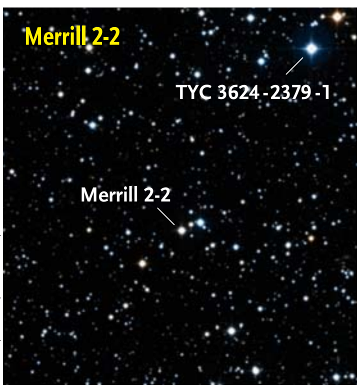
A physical member of NGC 7209 and the brightest star in its southwestern quadrant, SS Lac is a binary whose mutual eclipses ceased shortly before the middle of the 20th century. The solution to this enigmatic behavior was found in the tug of a third system member, which shifts the plane of the inner binary's orbit relative to our line of sight. According to a study by Guillermo Torres, published in the *Astronomical Journal* in 2001, the system undergoes a roughly 600-year cycle with two eclipse seasons lasting 100 years each. Eclipses aren't expected to start anew until early in the 23rd century.

Perched 1.8° south-southeast of NGC 7209, John Herschel's multiple star **h1735** (HJ 1735) is an interesting low-power triple. Observed through my 105-mm refractor at 17×, the trio forms a straight line. Its nicely matched bright components (magnitudes 6.7 and 6.8) are white with a hint of blue and very widely spaced. The third member (magnitude 9.7) is at the east-southeastern end of the line, very close to the primary star. If you have



MARK PHILLIPS

The relatively young open cluster NGC 7243 shines bright with blue and white stars; at its center rests Struve 2890, a double consisting of a 9.4-magnitude primary and 9.7-magnitude companion.



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

Planetary nebula Merrill 2-2 appears almost stellar through the eyepiece; blinking an O III filter will help you distinguish it from its neighbors.

Looking into Lacerta

Object	Type	Mag(v)	Size/Sep	RA	Dec.
NGC 7243	Open cluster	6.4	30′	22^h 15.2^m	+49° 54′
Σ2886	Double star	7.6, 10.1	20.6″	22^h 14.7^m	+49° 21′
Merrill 2-2	Planetary nebula	11.9	3.0″ × 1.4″	22^h 31.7^m	+47° 48′
NGC 7209	Open cluster	7.7	15′	22^h 05.1^m	+46° 29′
h1735	Triple Star	6.7, 6.8, 9.7	1.8′ × 27.3′	22^h 09.3^m	+44° 51′
UGC 11973	Spiral galaxy	12.7	3.2′ × 0.9′	22^h 16.8^m	+41° 30′

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.

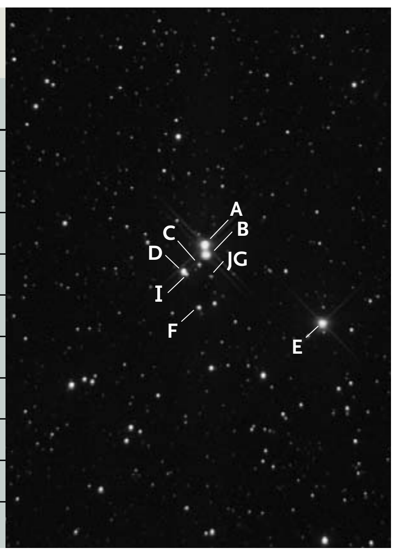
ANTHONY AYIOMAMITIS

First cataloged by William Herschel in 1788, the loose open cluster NGC 7209 is notable for the bright blues and oranges of its member stars.

trouble spotting it, just raise the magnification a bit. The trio's primary star is the eclipsing binary V402 Lac. The gravitational dance of the stars has a period of 3.78 days, winking with unequal brightness dips as each star eclipses the other. Even during the deeper minimum, the binary dims only a few tenths of a magnitude.

8 Lacertae

Comp.	Mag(v)
A	5.7
B	6.3
C	10.4
D	9.1
E	7.3
F	11.0
G	14.1?
H	14.6
I	~11
J	13.0?



MARTIN GERMANO

One night while armed with my 10-inch scope, I was seeking galaxies with the magnitude filter on my software atlas set fairly bright. I was surprised to see that the galaxy **UGC 11973** made the cut. At 88× this highly elongated galaxy leans northeast with a moderately faint star near each tip. The interior is about ¾′ long and visible with direct vision, while averted vision reveals fainter extensions that roughly double the galaxy's length. If you'd like to reach beyond galaxies with NGC designations, this is a good choice for a moderate-size telescope.

One of my favorite sights in the Lizard is the multiple star **8 Lacertae**. It has 11 components listed in the continually updated online Washington Double Star Catalog (WDS) maintained by the United States Naval Observatory (**http://is.gd/usnowds**). Although some of the components aren't physically related to one another, I had a lot of fun hunting them down.

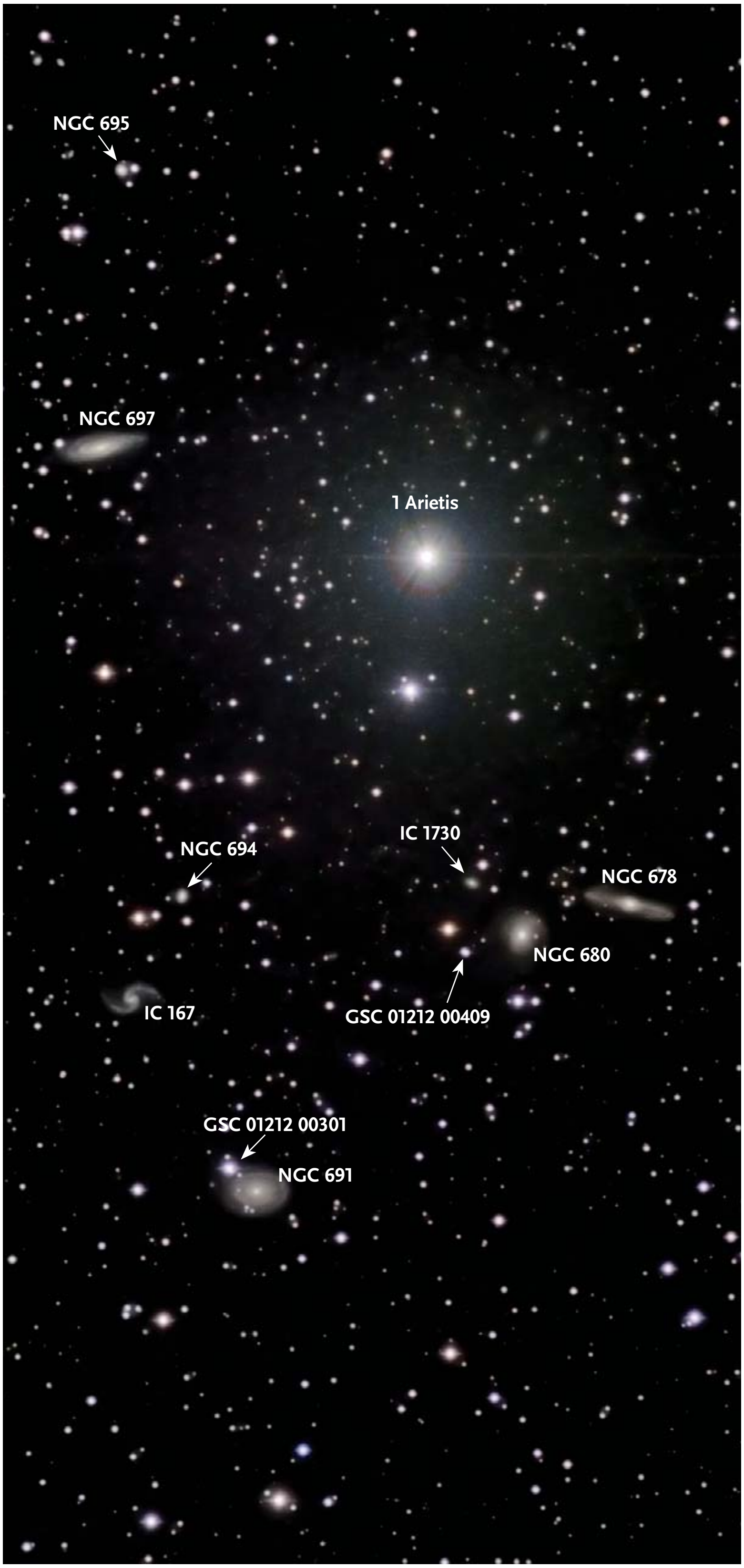
I started with my 130-mm refractor at 23× and saw a very cute arc of four stars spanning 1.4′. Component **A** sits at the northern end of the curve, which then sweeps southeast through **B**, **C**, and **D**. As you can see in the table of magnitudes, the components aren't lettered strictly by decreasing brightness, and star C is fainter than D. Two distant companions are also visible. **F** sits a fair piece (1.6′) south-southwest of D, and **E** is way off (4.9′) to the west of F. At 117× I saw a faint star making a neat rectangle with C, D, and F, but it's not given as part of the system. Try as I might, I couldn't spot any more components, even when I upped the magnification to 273×.

Undaunted, I tried my luck with my 10-inch reflector on the following night. At 299× I saw one star of the close **JG** pair. Now and then I thought I glimpsed component **I** close southwest of D, but I couldn't be sure. Two nights later, I rolled out my 15-inch scope. At 345× I could readily see star I, which is separated from D by 10″. Stars J and G were obvious as well, the brighter one situated 10″ west-southwest of its neighbor. There was one component I couldn't see, star **H**, which is a snug 1.4″ west-southwest of C and four magnitudes fainter.

The JG pair presents something of a puzzle. The WDS places the brighter star east-northeast of its neighbor, which is clearly not the case (G lines up west-southwest of dimmer J) and indicates that the listed magnitudes of those stars are inaccurate. Adding more interest to the scene, star A is a tight binary indivisible through the eyepiece, but it has been detected with speckle interferometry. In this imaging process, many millisecond exposures are statistically analyzed and combined by computer to overcome the blurring effects of atmospheric turbulence.

Both challenging and pretty, 8 Lacertae can give any observer yet another reason to love the night. ✦

Alan Whitman



ALSON WONG

Fresh Eyes

A visit to the 1 Arietis region after eye surgery gives a new look to old objects.

When working through the Herschel 2500 list of deep-sky objects discovered by William Herschel between 1783 and 1802, the observer occasionally experiences a pleasant surprise, such as an extreme edge-on galaxy or a tight clump of galaxies. The H2500 is a project that has kept me employed for years and always provides an answer to the perennial question: "What new object can I see tonight?" The question took on new meaning after my recent cataract surgery.

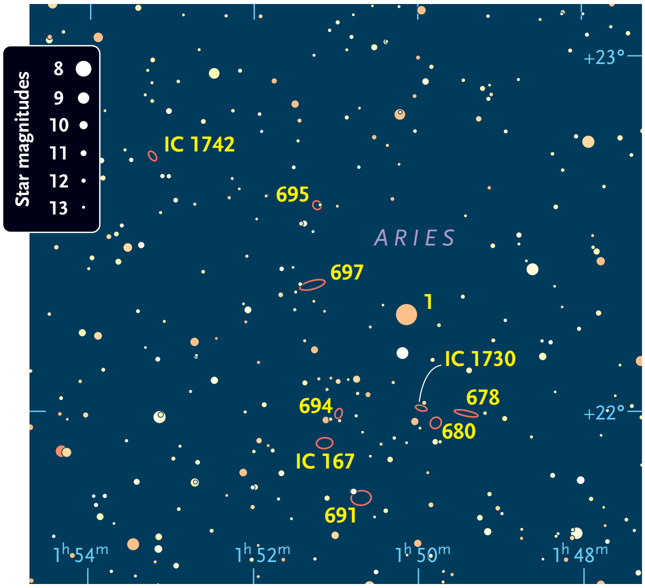
Once or twice a year I come upon a pleasing field of galaxies that I want to share with other observers. In the 50′ field surrounding 1 Arietis there are five fairly easy NGC galaxies, most or all of them associated members of the NGC 697 group. Together with four fainter galaxies and the three double stars in that field, the group provides a pleasant evening of observing, or in my case, re-observing with fresh eyes.

Our starting point is the colorful double star **1 Arietis** (Struve 174), an attractive 2.8″ pair with magnitudes of 6.2 and 7.2. The component stars are typically described as orange (*K*1III type) and light blue (*A*6V type), but after cataract surgery my color perception changed and I now see the duo as deep yellow and green instead.

I observed the galaxies of the NGC 697 group with my backyard observatory's 16-inch equatorially mounted f/4.5 Newtonian at 203×. This is my most commonly used power for viewing galaxies with this telescope — it yields an exit pupil of 2 mm.

Magnitude-12.8 **NGC 697** is the largest and third-brightest galaxy in the group. Located 17′ east-northeast of 1 Arietis, the barred spiral is elongated 5:1. Its core is also elongated and very, very gradually brightens to the center. A quarter degree farther north, the disturbed face-on spiral **NGC 695** appears very small and round;

Astronomers class NGC 697 and six additional galaxies — NGC 678, NGC 680, NGC 691, NGC 694, IC 167, and IC 163 (not shown) — as a group based on their relative proximity, radial velocities, and separation from other galaxies in space.



a very faint nucleus can occasionally be glimpsed. A magnitude-13 star is half an arcminute preceding.

The close and probably interacting pair of galaxies **NGC 678** and **NGC 680** is quite prominent in the 16-inch scope, 1/3° south of 1 Arietis. Magnitude-13.3 NGC 678 is elongated 3:1 and rises to a bright core holding a faint nucleus. Images show a very attractive edge-on that resembles NGC 4565, but unlike NGC 4565, NGC 678 sports twisted dust lanes. Neighboring galaxy NGC 680, a peculiar elliptical, is small, round, and bright. It rises to a glowing core with an obvious nucleus. The tough little spiral **IC 1730** makes this duo a trio. I could see the magnitude-15.3 galaxy only intermittently, but found it without knowing its exact position beforehand because my planetarium program mis-plotted its position as 3′ south of where it's shown in images. (I had failed to see this challenging object ten months earlier, before my cataract surgery.)

A line drawn from NGC 678 through NGC 680 and extended half the distance between the pair leads to **GSC 01212 00409**, a 6″ matched pair of 12.5-magnitude stars. The pair appears to be an independent discovery, since it's not in the Washington Double Star Catalog. I estimated the separation of 6″ in comparison with the 2.8″ of 1 Arietis in the next high-power field.

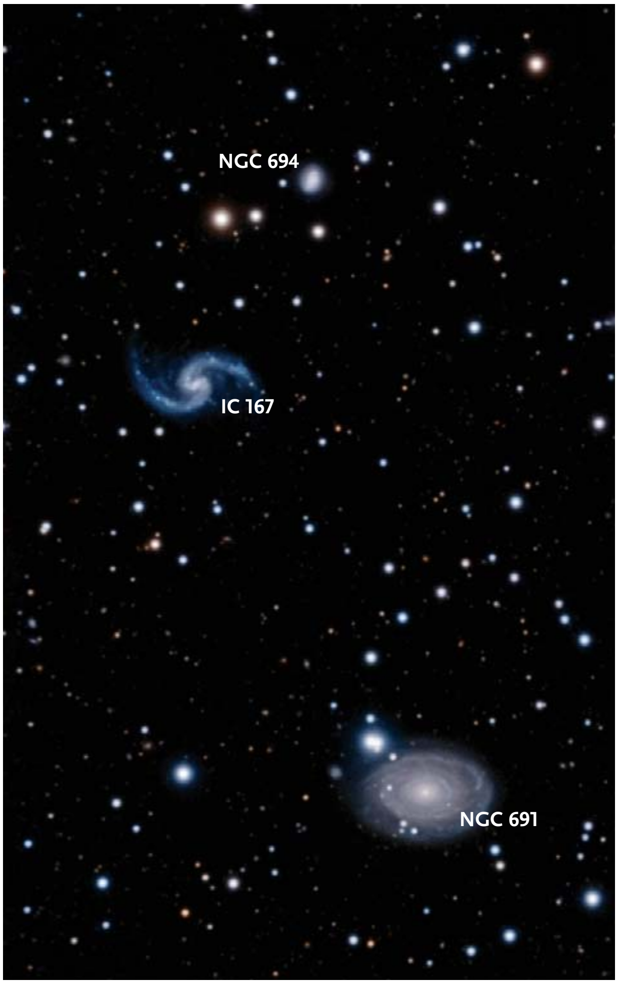
The second brightest and southernmost galaxy here is large and amorphous **NGC 691**. Its appearance immediately marks it as a face-on spiral; it only very gradually brightens in its middle. Another nearly matched double star, **GSC 01212 00301**, swam into my eyepiece immediately northeast of the galaxy. Also absent from the WDS, this pair shows a 7″ separation, judged by comparison with 7.5″ Gamma (γ) Ari, in position angle 70°. My mag-

In the Area of 1 Arietis

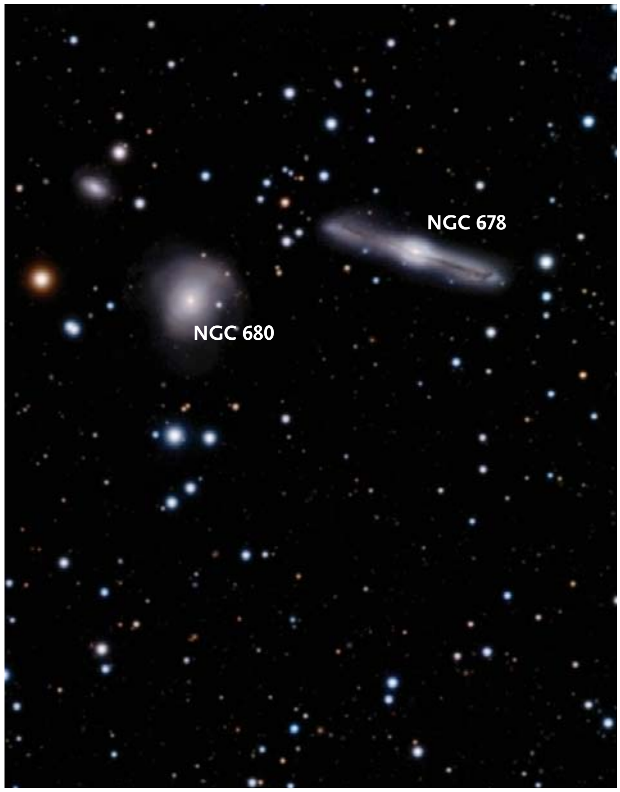
Object	Type	Surface Brightness	Mag(v)	Size/Sep	Position Angle	RA	Dec.
1 Arietis	Double star	—	6.2, 7.2	2.8″	165°	01^h 50.1^m	+22° 17′
NGC 697	Galaxy	13.9	12.8	4.5′ × 1.5′	105°	01^h 51.3^m	+22° 21′
NGC 695	Galaxy	12.2	12.9	0.8′ × 0.7′	40°	01^h 51.2^m	+22° 35′
NGC 678	Galaxy	13.7	13.3	4.5′ × 0.8′	78°	01^h 49.4^m	+22° 00′
NGC 680	Galaxy	13.1	11.9	1.9′ × 1.6′	—	01^h 49.8^m	+21° 58′
IC 1730	Galaxy	—	15.3	0.6′	—	01^h 50.0^m	+22° 01′
GSC 01212 00409	Double star	—	12.5, 12.5	6″	—	01^h 50.0^m	+21° 57′
NGC 691	Galaxy	14.6	12.2	3.5′ × 2.6′	95°	01^h 50.7^m	+21° 46′
GSC 01212 00301	Double star	—	10.3, 10.6	7″	70°	01^h 50.8^m	+21° 47′
NGC 694	Galaxy	14.6	14.2	0.5′ × 0.3′	160°	01^h 51.0^m	+22° 00′
IC 167	Galaxy	14.8	13.1	3.0′ × 1.9′	95°	01^h 51.1^m	+21° 55′
IC 1742	Galaxy	12.7	15.1	0.7′ × 0.5′	56°	01^h 53.2^m	+22° 43′

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.

*Author **Alan Whitman** is pleased that cataract surgery now allows him to see faint IC galaxies again.*



ALSON WONG (2)



Above: **The bright, extended galaxy NGC 678, seen almost edge-on from our vantage point, likely interacts with its close neighbor, the peculiar elliptical NGC 680. *Left:* The lenticular galaxy NGC 694 appears almost stellar in comparison with its neighbors, NGC 691, which sports an oval spiral structure, and IC 167, a weakly barred spiral galaxy.**

nitude estimates for the two stars are 10.3 and 10.6.

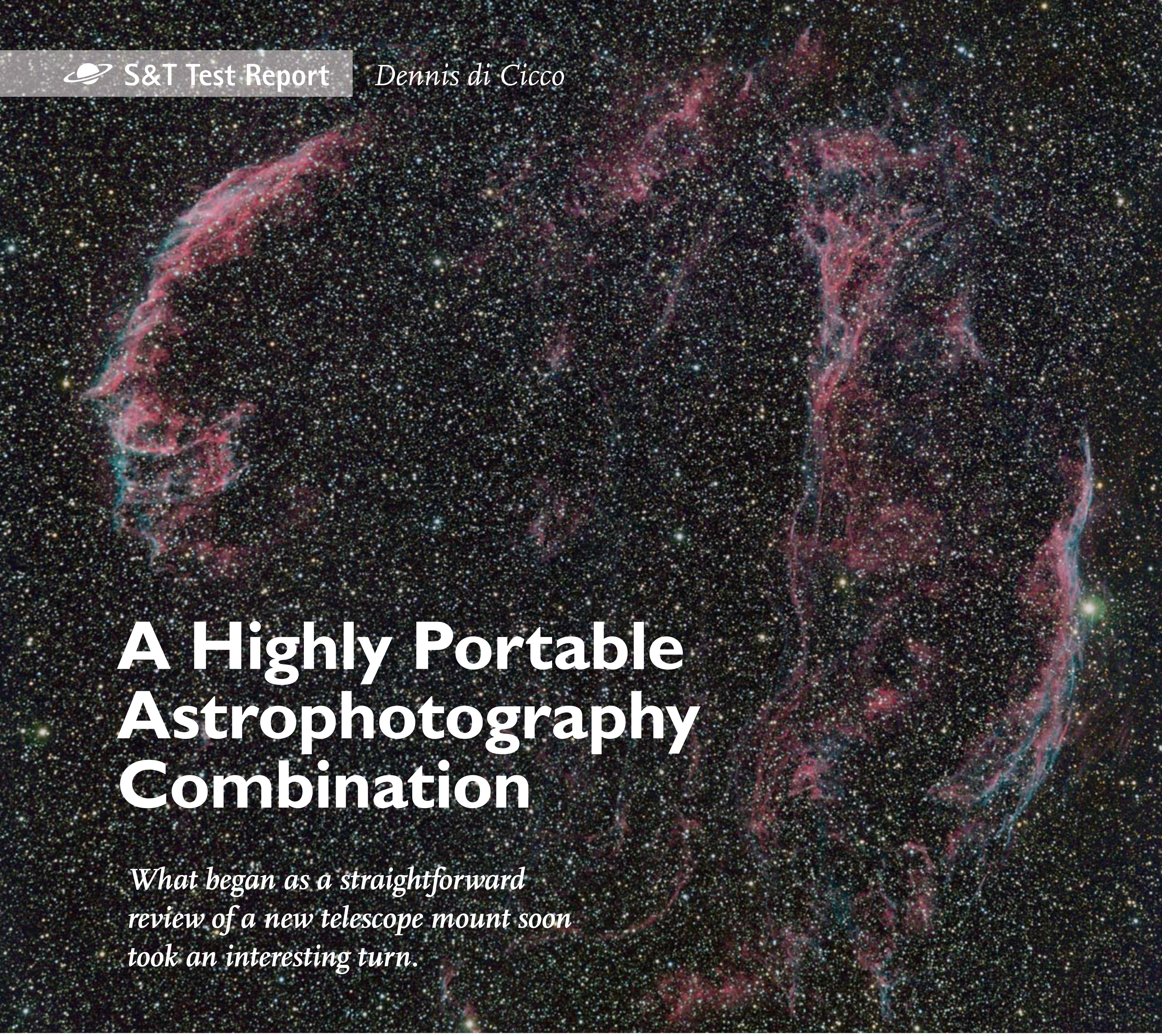
Don't be afraid to try for these galaxies with a smaller scope. My 8-inch f/6 Newtonian at 135× revealed the above five NGC galaxies — the same five that William Herschel discovered — in this field, though none of them showed any detail. NGC 695 was small and very difficult, with a magnitude-12.9 star immediately preceding. The 8-inch failed on NGC 691 at 135× but bagged the amorphous, very difficult, magnitude-12.2 galaxy at 244×, a much higher power than I normally use for galaxy viewing with that scope. These observations were made only a month before my cataract surgery — I would expect that scope to probe a little deeper today.

Herschel missed **NGC 694**, but my 16-inch revealed the lenticular galaxy — it's fairly small with a much brighter core. After cataract surgery, I wrote that it "was surprisingly easy for a magnitude-14.2 galaxy"; before I received my new lens I had logged NGC 694 as "small and difficult."

My new and more transparent eye lens also revealed two more IC galaxies. **IC 167** is amorphous and fairly large, the fourth-largest galaxy in the NGC 697 group. Images show that IC 167 is a gorgeous spiral galaxy with extremely open arms. Somewhat away from the main group, the magnitude-15.1 spiral **IC 1742** appears as an oval smudge in my eyepiece. The 11.5-magnitude star 8′ to the north-northwest hides this galaxy when I bring it into the field of view.

Cataracts reduce the amount of light reaching the retina, so surgery improved transmission; I can now see slightly fainter deep-sky objects. I chose lenses that correct my astigmatism and are optimized for infinity, so my naked-eye view of the sky is better than it ever was. I no longer wear light-reflecting and -absorbing glasses, and M5 and 5 Serpentis are split naked-eye for the first time in my life. So I can finally claim to see M5 naked-eye! On the downside, a bright bar of light extends from planets in the eyepiece, resulting in a subtle loss of contrast, and the dark brown and orange colors on Jupiter are muted, making my favorite planet appear bland. ✦

 Dennis di Cicco



A Highly Portable Astrophotography Combination

What began as a straightforward review of a new telescope mount soon took an interesting turn.

WHEN SOFTWARE BISQUE, makers of highly regarded telescope mounts found in countless amateur and professional observatories around the world, announced the Paramount MyT — its first-ever mount designed for portable use — there were immediate requests from readers for a review. So early this year we borrowed one from the company to test.

With a payload capacity of up to 50 pounds (23 kilograms), the MyT would be a good mount for a wide range of today's visual telescopes and astrophotography setups. Since imaging equipment places the greatest demands on a mount, we decided to test the MyT with an astrograph

The Paramount MyT with the NP127fli & ProLine 16803

U.S. prices: Paramount MyT: $6,000
NP127fli: $7,295
FLI imaging setup: approximately $16,000 as tested, but can cost more or less depending on options

As a package, the equipment discussed this month forms a powerful setup for wide-field, deep-sky astrophotography. This image of the famous Veil Nebula in Cygnus was captured in a single field of view and three hours of total exposure made through red, green, blue, and hydrogen-alpha filters.

ALL PHOTOS BY THE AUTHOR

created through a collaboration between Tele Vue Optics and Finger Lakes Instrumentation (FLI). Comprising a special model of Tele Vue's NP127 apo refractor coupled with FLI's Altas Focuser, Centerline Filter Wheel, and ProLine 16803 CCD camera (other models are also compatible), the setup tipped the scales at 38 pounds, including my ADM dovetail mounting bar and guidescope. A hefty load for a 5-inch imaging system, but one that on paper should be a good fit for the MyT.

Proof came after only a few nights of testing. This setup works superbly as a system, and people at Software Bisque, FLI, and Tele Vue have also recognized this. They are informally discussing the possibility of marketing the setup as a package deal. Someone even floated the idea of including a small, dedicated computer with all the necessary software preloaded and configured — a truly novel concept for a high-end, deep-sky astrophotography setup. Time will tell if this happens, but regardless, it put an interesting perspective on what began as a review of just the mount.

This gear is premium equipment, which is priced accordingly. As I've mentioned in the past, the bar is set very high when it comes to my expectations for this kind of equipment, and in this case I wasn't disappointed. After months of testing and hundreds of exposures made with the system used both as a portable setup and on a fixed pier in my backyard observatory, I am extremely impressed with how everything performed. I can comfortably endorse all of this equipment as a package as well as individual pieces. So, end of review? No. At least not if I want to walk away with a clear conscience. But I'll save my reservations for later in this story. For now, let's take a closer look at the equipment.

The Imaging System

The Tele Vue NP127fli is a dedicated imaging version of the company's 5-inch apo refractor reviewed in this magazine's July 2007 issue. It has no provision for visual use with eyepieces. The original telescope's focuser has been replaced with a rigid adapter that provides a strong, flexure-free connection to the FLI imaging train and permanently maintains the system's optical alignment. The scope also includes Tele Vue's Large Field Corrector lens properly positioned at the rear of the adapter to deliver optimal star images across the field of FLI's large-format CCD cameras. This lens slightly increases the scope's nominal 660-mm focal length to 680 mm, yielding an f/5.35 focal ratio and a field of view a bit more than 3° across with the ProLine 16803 camera I tested.

The Truesense KAF-16803 CCD in this camera has a square imaging area measuring 36.8 mm on a side. The scope provides 100% illumination across a field slightly more than 20 mm in diameter, beyond which the light falls off smoothly to 88% at the edges of the chip. The illumination 25 mm from the optical axis, which

WHAT WE LIKE:

Excellent combination for deep-sky imaging

All first-class equipment that worked flawlessly

Equally well suited for portable use or for unattended remote-observatory operation

WHAT WE DON'T LIKE:

While especially attractive as a "plug & play" imaging system, it can have an extremely steep learning curve for people new to CCD imaging or those lacking firsthand experience with similar equipment.

Above: **The 34-pound MyT equatorial head (sans counterweight shaft) and its custom 19-pound tripod (a $1,350 option) can easily be carried short distances in a single trip.**

Right: **Because of power requirements mentioned in the text, as well as those for his laptop computer and autoguider, the author did his "portable" testing at the end of an extension cord in his suburban-Boston driveway.**

corresponds to the corners of the CCD, is still greater than 70%, making the overall system vignetting easily corrected with standard flat-field calibration performed during image processing.

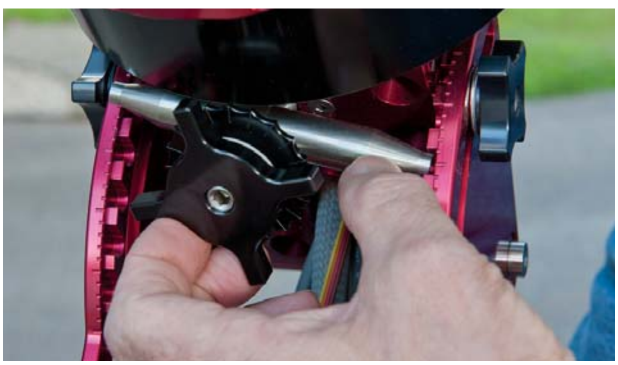
As the astrophotography with this review attests, the NP127fli delivered excellent star images across the full frame of the KAF-16803 chip. Furthermore, all the images here were taken on nights when the telescope was focused only once at the beginning of the imaging session and left unchanged regardless of the filter or filters used during the night. For general astrophotography, I can't ask for better performance from a 5-inch f/5.35 system than I got with the NP127fli.

While all the images here were made with the FLI ProLine 16803 camera we borrowed for this review, my strongest endorsement for the camera comes from having used the same model in my backyard observatory since late 2010. It has been hands-down the most trouble-free, high-end camera I've tested. I can't recall a single image that was lost because of a problem with the camera. Even on those occasional nights when extreme dewing conditions caused condensation to form on the CCD-chamber windows of some of my other cameras, the ProLine soldiered on without missing a beat. As such, you can consider my thumbs-up recommendation of the ProLine 16803 camera to be based on years of use rather than months.

This was, however, my first experience with FLI's Centerline Filter Wheel and Atlas Focuser. While both worked flawlessly, depending on the software you use to control this setup, you may have to upgrade to the latest version to access all 10 filter positions. I only used the wheel's first six slots, and had no problems accessing them with Diffraction Limited's *MaxIm DL* version 5.23 or Software Bisque's *TheSkyX Professional* supplied with the MyT.

Initially I controlled the Atlas Focuser manually from my laptop computer, finding it very accurate and consistently able to return the camera to pre-determined positions. But after a bit of trial-and-error tinkering with

Thanks to internal wiring and a variety of connectors built into the MyT's base (*top*) and saddle plate (*above*), it's relatively easy to run power and computer cables to telescopes and cameras on the mount. Two of the autoguiders used by the author were powered by their USB connections, but the cooled autoguiding camera seen in the accompanying photographs requires 12 volts DC. Because it draws more current than is available from the MyT's 12-volt outlet on the saddle, the author used a separate power cable that he threaded through the MyT's internal passageways.



Left: **Elevation of the MyT's polar axis can be set to its approximate position with this quick-release mechanism, but to prevent it from becoming wedged in place, both ends of the stainless-steel bar seen here should be fully seated in their respective slots before any weight is placed on the mount. Fine elevation adjustments are made with the large hand knob.** ***Right:*** **Little details such as arrows next to the tripod levels indicating which leg to adjust when leveling the mount are indications of the care that went into designing the MyT and its accessories.**

As with the picture of the Veil Nebula on page 56, this shot of the large emission-nebula complex IC 1396 in Cepheus was captured in a single field of view. It was assembled from four hours of total exposure. Both color images were processed by Sean Walker.

software settings in *MaxIm*'s focusing algorithm, I was able to focus automatically. It was very impressive to make a few mouse clicks and after about a minute have the telescope's focus automatically set to an accuracy easily as good as anything I could achieve manually. I wish I had this capability on all of my imaging setups.

The electrical cabling for the camera, filter wheel, and focuser are noteworthy for their simplicity. USB 2.0 computer connections and power for all three flow over just two wires that run from the camera. One goes to the camera's power supply and the other to your computer. Small jumper wires connect the camera with the filter wheel and focuser.

The Paramount MyT

While the MyT is promoted as a portable Paramount, at its heart is the same control system and feature set found in its larger siblings. Indeed, when controlling the MyT from a computer there's nothing that distinguishes it from the other Paramounts. This, in my opinion, is the MyT's greatest strength. I've covered these features in detail in reviews of the Paramount MX and ME II (July 2012 and September 2014 issues, respectively). Rather than repeat that material here, you can read both reviews on the *Sky & Telescope* website at **skypub.com/Paramount**. Each review covers different aspects, features, and ways of operating the mounts, and virtually everything said in those reviews is also applicable to the MyT, including my comments on the outstanding accuracy and precision of the mounts' pointing and tracking systems. It's one of the big reasons I was impressed with the MyT.

Weighing only 34 pounds without the counterweight shaft attached, the MyT certainly qualifies as a portable mount, but there's more to the story than just weight. Power requirements and polar-alignment methods need to be considered, since they set the MyT apart from many other portable mounts.

Top: **Mainly because of his experience with other Paramounts, the author obtained "keeper" images on his first clear night. This one is a 30-minute exposure of the North America Nebula made through a hydrogen-alpha filter.** ***Above:*** **It may be billed as a portable mount, but the MyT is every bit at home in an observatory, where it can be run remotely over the internet from any place in the world. Many of the author's tests were done with the setup in his backyard observatory and controlled from his house a few hundred feet away.**

The MyT, like the other Paramounts, requires 48 volts DC and it comes with an AC adapter for those who have conventional AC power available at their observing sites. But there are also a variety of ways to power the mount when AC isn't available. Software Bisque offers an optional adapter ($99) that delivers 48 volts DC using EGO 56-volt lithium-ion batteries sold by Home Depot (**homedepot.com**). These rechargeable batteries are available with 2 and 4 amp-hour capacities and charging options that can take as little as 30 minutes. Software Bisque says that the larger battery will power the MyT for more than 10 hours of typical use. There are also a variety of commercial 12- to 48-volt DC converters that will power the MyT from a 12-volt DC source such as a car battery.

Unlike many portable equatorial mounts, the MyT has no provision for a polar-alignment scope. You must use other methods to align the mount's polar axis on the celestial pole. Because the MyT has nicely engineered azimuth and altitude adjustments on its polar axis housing, it's easy to use traditional methods such as drift alignment to set up the mount.

But I particularly like a method that is unique to the current Paramount line. With the base of the mount carefully leveled, and the polar axis roughly positioned using a compass and the elevation scale engraved on the mount, you fire up the electronics and slew the mount to its "home" position. This position is carefully set during the mount's construction and corresponds to a precisely known position on the sky if the mount were accurately polar aligned. Since the mount probably isn't aligned at this point, you simply command the mount to slew to any celestial object currently visible in the sky, and using only the altitude and azimuth adjustments on the polar axis housing, you move the mount until the object is centered in the field of view of whatever instrument is on the mount. Done carefully, the method can result in polar alignment that is sufficiently accurate for most astrophotography.

This alignment method does involve caveats. One is that the process is easiest to do when there's a telescope with an eyepiece on the mount — something I didn't have with my imaging setup. Because my guidescope was carefully aligned with the main telescope, my solution was to temporarily replace the small CCD guiding camera with an eyepiece. The guidescope's 50-mm aperture was more than enough to show bright stars even before the Sun set.

TheSkyX software supplied with the MyT includes sophisticated methods for achieving precision polar alignment. I've used them, and they work extremely well, but they can be time consuming, especially if you don't take into account a small amount of inertia that's inherent in the mechanism on the mount's calibrated azimuth adjustment. Nevertheless, polar alignment requirements for various types of astrophotography are outside the scope of this review, but suffice it to say that the simple method outlined above will work for many applications, and more precise methods are available if you need them.

Final Thoughts

Because I've had mostly positive comments about the equipment covered here, as well as in the previous reviews of the Paramount MX and ME II, some may wonder why I hesitated making an unconditional recommendation at the beginning of this review. The reason is the *very* steep learning curve that goes with running this system. Let me explain.

The Tele Vue NP127fli is a straightforward instrument with little that will mystify even those new to imaging telescopes. And anyone who has experience working with astronomical CCD cameras will quickly master the FLI equipment. It is the Paramount MyT that presents the biggest learning curve, even for those familiar with German equatorial mounts in general. At its most basic level, the MyT can be set up and operated as simply as any motorized German equatorial mount, but learning the features that make it an incredibly powerful astrophotography platform take time, especially if you are not already familiar with *TheSkyX* planetarium software.

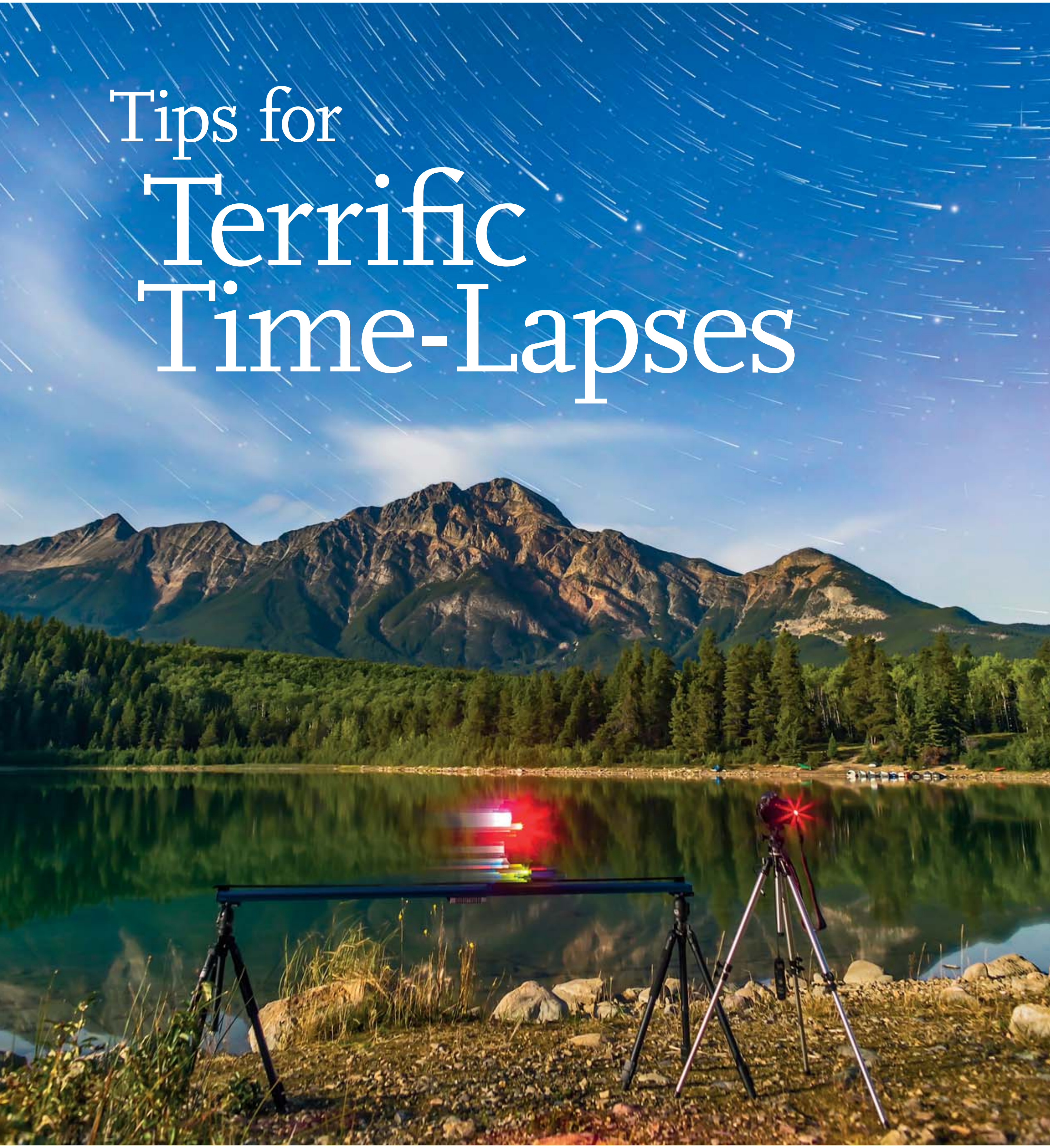
On the other hand, people experienced with previous Paramounts should find the MyT a breeze to use. Like me, they can probably spend a few hours unpacking, assembling, and balancing the equipment described here, followed by another hour or two connecting cables and setting up the software. That's all it took before I was ready to begin shooting "keeper" images on the first night. My shot of the North America nebula on the facing page is proof of that.

But a combination of products so nicely matched as the ones described here will likely appeal to people looking for a turnkey entry into the world of advanced deep-sky imaging. While this equipment does indeed make it easy to turn the key, it will still take time to learn how to drive the car. ✦

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

Wide-field imaging systems, especially when combined with image-stitching software, are ideal for exploring vast fields of nebulosity that are typically overlooked by astrophotographers shooting with narrow-field equipment. This two-panel mosaic created with *ICE* (Microsoft's stitching freeware) covers a 5°-tall area around Gamma Cygni, the central star in the Northern Cross asterism. It is only the tip of the iceberg when it comes to the overall nebulosity permeating this stretch of the Milky Way.

Tips for Terrific Time-Lapses



Alan Dyer

Use these techniques to create stunning movies of the sky turning above scenic landscapes.

In the days of film, only a handful of cinematographers attempted time-lapse photography of the night sky. To do it, they had to use extremely expensive, custom-made movie cameras. Today, the digital single-lens reflex (DSLR) camera has democratized time-lapse shooting, making it possible for anyone to create movies with up to IMAX-grade resolution. Success, though, comes from knowing some useful techniques.

If you followed my article in the October issue, chances are you're already well on your way to creating your own nightscape movie. Here are some tips to help you plan your time-lapse movie and bring it all together.

Focus and Compose

The hours you can spend shooting a time-lapse sequence will be for naught if all your images are out of focus. Use Live View (or Live Focus) to focus manually on a bright star or distant light. Then take test shots to get the framing right. Good composition is just as important at night as it is during the day. Time-lapse sequences also require that you compose not only for how the sky looks now, but how it will look an hour or more later when the sequence ends. Use planetarium software to illustrate how photogenic sky subjects such as Orion or the Milky Way will move during your shoot.

Exposures and Intervals

Just as with shooting nightscapes, the best exposure in a time-lapse sequence is whatever produces a well-exposed image for each frame. Underexpose and you'll introduce noise and ugly artifacts in the shadows.

However, time-lapses are made of hundreds of frames. To keep the time it takes to acquire all those frames to a reasonable length, you often need to restrict exposure to no longer than 30 seconds. That, in turn, might require shooting at a higher ISO speed (3200 to 6400) or wider aperture (f/2) than you might choose for a single-shot nightscape.

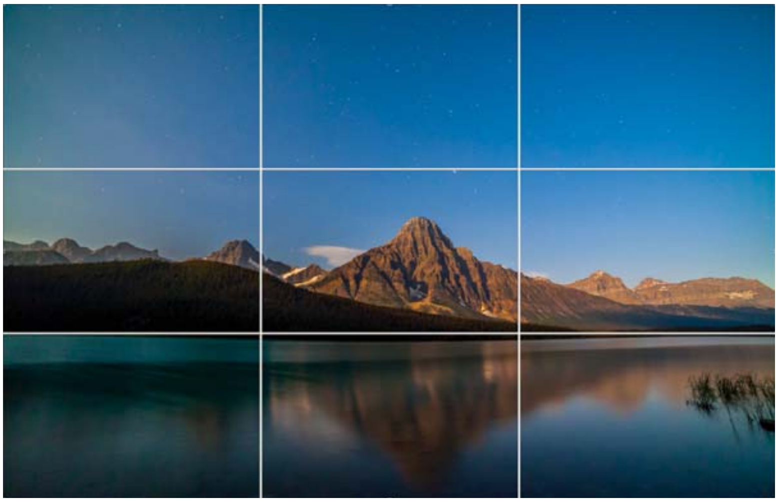
But what should the interval be? That depends on what your equipment's definition of interval is. Setting the interval can be confusing, as some intervalometers (notably Canon's TC-80N3) define "interval" to mean the time from when the shutter closes to when it opens again. In that case, set INT to no more than 1 to 5 seconds, assuming you are also using the intervalometer to set the exposure, with the camera itself on Bulb. Make the interval longer than a few seconds and the stars will jump across the sky.

However, many control devices define interval to mean the time from when the shutter opens to when it opens again for the next shot. In that case, set what the device calls interval to a value 1 to 5 seconds longer than whatever exposure time you are using. If you change your exposure time, you'll need to change the interval as well. Forget to do that and the device might try to fire the shutter while the camera is still taking an exposure, resulting in missed frames and gaps in the sequence, an error called "frame collision."

How many frames should you take? As another rule of thumb, plan to play back the final movie at 30 frames per second. This produces the smoothest motion. So for a clip that lasts 10 seconds on screen you will need to shoot 30 × 10 = 300 frames. You can shoot fewer frames, but the clip won't last as long.

MOTION PICTURES ***Facing page:*** **While time-lapse photography can involve the use of specialized motion-control gear, such as the Dynamic Perception dolly unit in use at left here, effective sequences are possible with no more than a camera on a fixed tripod, at right. All images are courtesy of the author.**

TIME-LAPSE GEAR ***Right:*** **Besides a tripod, a fast wide-angle lens and a reliable intervalometer are the most important time-lapse accessories. While camera batteries can last for 2 to 4 hours of continuous shooting, have an extra battery on hand to swap in mid-shoot if needed.**



COMPOSING Composition is important! Take care to level the camera and compose the scene, following classic rules of composition. For example, the "rule of thirds" suggests horizons and centers of interest should lie along and at the intersections of lines that divide the scene into thirds.

ADDING CAMERA MOTION

Time-lapse videos on the web often contain sequences in which the camera gradually moves across or through a scene. These cinematic moves are created with specialized "motion-control" devices. Each rotates a camera around an axis, along a dolly rail, or both, shifting its position in increments between each exposure.

An excellent choice for astronomers is Sky-Watcher's AllView Mount, a very sturdy Go To telescope mount. As a bonus, it offers a time-lapse mode, providing two-axis (pan and tilt) motion control, all while firing the camera shutter in sync with its incremental motion steps.

Get more serious about time-lapse imaging and you can choose from a host of dedicated motion-control units. I use models from Dynamic Perception, eMotimo, Radian, and Rhino and can attest to their effectiveness.

PANNING MOTION **Dedicated motion-control units are all "shoot-move-shoot" devices, controlling the shutter to synchronize exposures and movement. The device moves the camera only when the shutter is closed, during the few seconds between exposures. From left to right in the image above, these are the Dynamic Perception Stage Zero dolly, the Sky-Watcher AllView mount, and the eMotimo TB3 pan/tilt device.**

Batch-Processing RAW files

While it's tempting to shoot just JPG images for time-lapses, the card space you save doesn't make up for the loss of image quality. Shoot in RAW format. A 16- to 32-gig card will hold enough RAW files for two to four sequences, depending on your camera's sensor size. If you really need to save space, shoot in one of the "sRaw" (RAW size small) formats that produce smaller images, if the option is available in your camera.

When processing time-lapse sequences, *Adobe Lightroom* works well. Or, as an alternative, you can use *Adobe Bridge* and its *Adobe Camera Raw* utility, which is identical to the Develop module in *Lightroom*.

Pick a representative frame from the sequence and process it to look as good as possible.

Once one image is processed, it's a simple matter to right-click the processed image, select copy settings, then select all your other frames and paste the saved settings into all the other images in the sequence.

Assemble Your Movie

Now you need to assemble those frames into a movie. Each RAW frame from your DSLR is likely 5,000 or more pixels-wide. Unless you're producing a movie for the 4K video standard, those frame sizes are far too large to be practical. To create a playable movie, you first need to export the processed RAW frames into a folder of downsized "intermediates" — usually a set of JPGs, to satisfy the needs of most movie-assembly programs. For HD-format videos, reduce the intermediate images to a width of 1,920 pixels.

You then have a few choices for turning the intermediate JPGs into a movie file. Any recent version of *Adobe Photoshop* can do the job. First, switch to its Motion Workspace (using the pull-down menu at top-right of the screen) to reveal a movie timeline. Now select Open and navigate to your folder of intermediate JPGs. Select the first frame, and in the Open dialog box check "Open Image Sequence." *Photoshop* then strings the frames into a movie. You can then export the final movie using the pull-down menu File > Export > Render Video.

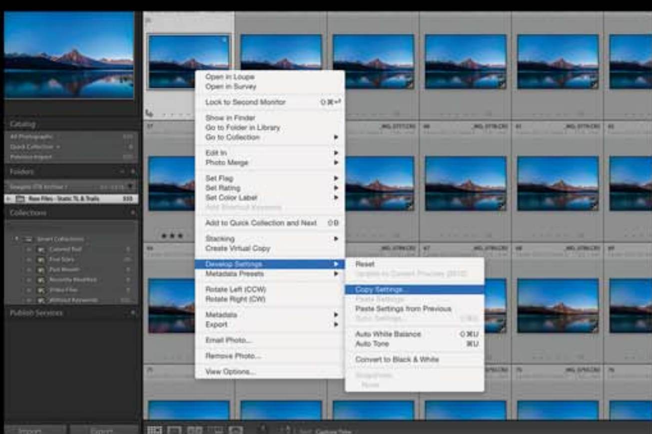
An alternative is to use a third-party assembly program. I like the MacOS program *Sequence*. But for Macs there is also *Time Lapse Assembler*, Microprojects' *Time-Lapse*, and *QuickTime 7 Pro*. Microsoft Windows users can also assemble their frames into a movie using use *Quicktime Pro*, *StarTrails.de*, *Time-Lapse Tool*, or *Virtual Dub*.

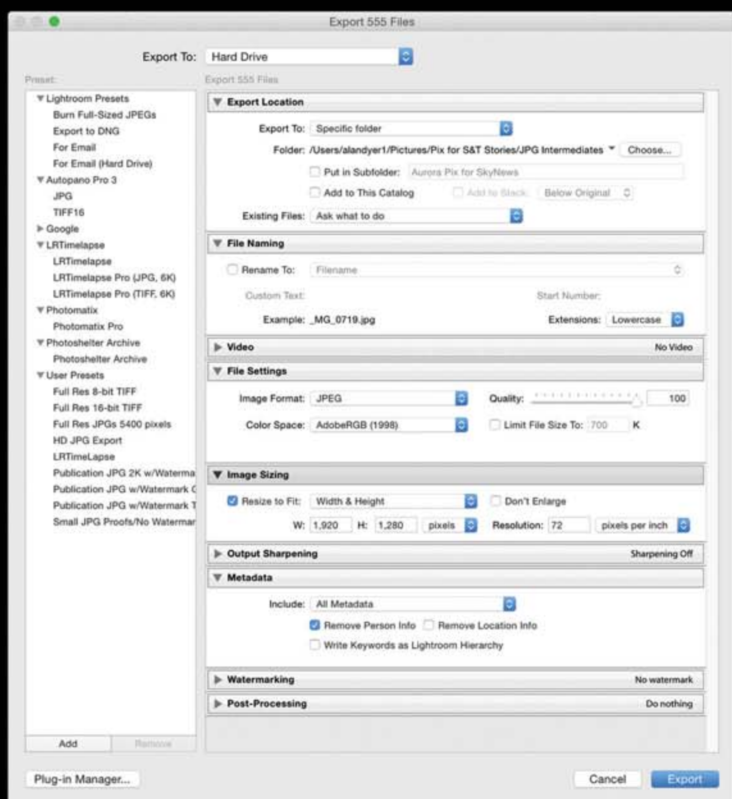
Pursuing the "Holy Grail"

Time-lapses are easiest when you start them after dark. The exposure time for the first frame will likely work fine for the rest of the night. Later, in processing, one setting will work when applied to all the frames.

But if the Moon sets or rises during the shoot, the scene brightness will change. Even more tricky is shoot-

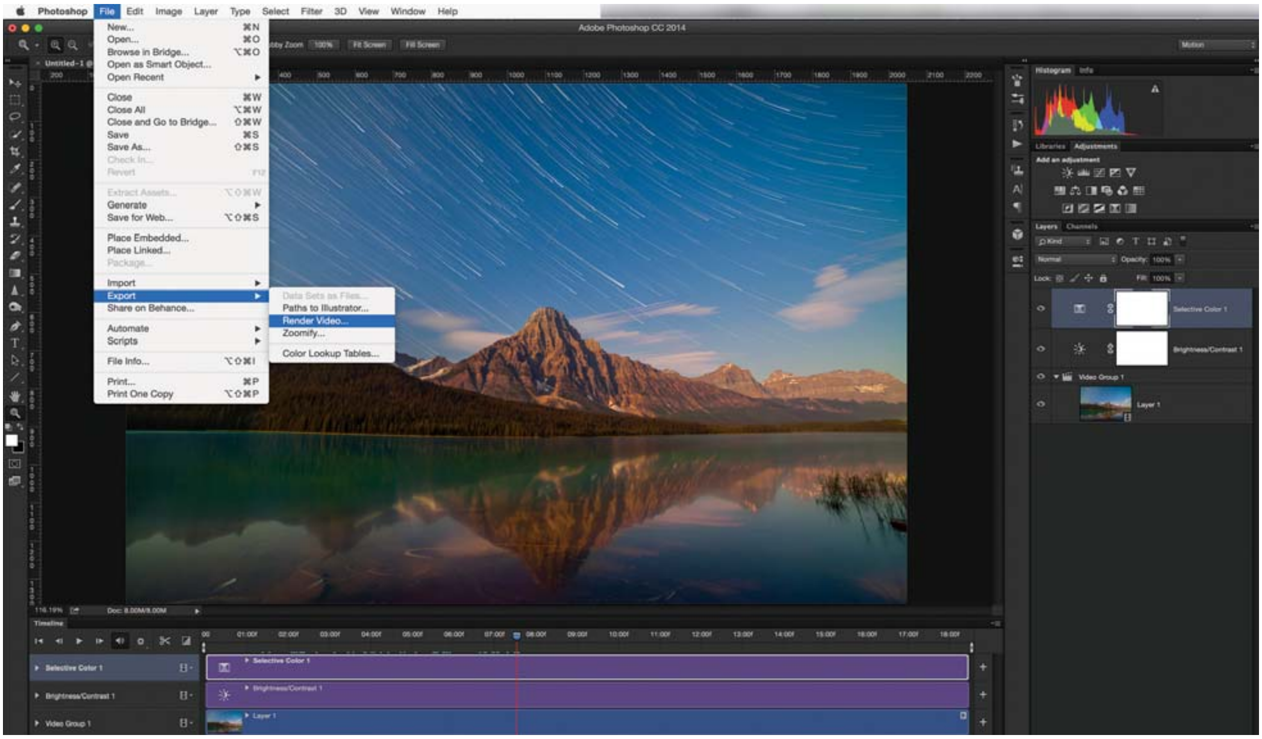
DEVELOPING DIGITALLY Use the Develop module in *Adobe Lightroom* to apply lens correction, noise reduction, highlight and shadow recovery, clarity and contrast boost, and color correction to make one frame look great.





Above: Once one image is processed, right-click on the image in either *Adobe Lightroom* (shown here) or *Adobe Bridge* to select Develop Settings > Copy Settings. Select all the other images in the folder (Command/Control + A), then select Paste Settings. In moments you've processed hundreds of frames from a shoot.

Right: In *Lightroom*, use the Export module to turn a folder of processed RAW files into JPGs. If you work in *Adobe Bridge*, choose Tools > Photoshop > Image Processor. Both methods can create a folder of downsized JPG images from the full-size RAW masters, a necessary step in assembling movies.



MOVIE ASSEMBLY With whatever assembly program you use (*Photoshop* is shown above), choose a frame rate of 24 to 30 frames per second. While you can render a clip at just 10 or 15 frames per second to make it last longer, the movie can look jerky.

ing what's known to time-lapse photographers as "holy grail" sequences. These are time-lapses that transition from full daylight or bright twilight through to dark of night, perhaps with the Milky Way prominent. The range of exposures can be as much as 18 to 22 f/stops or "exposure values" (EV). That's more than can be accommodated by adjusting shutter speed or aperture alone.

There are several options for shooting a holy grail sequence. One is to set your camera to Auto Exposure Program and Auto ISO modes, then hope for the best while the camera shoots away. A second method is to meticulously monitor the shoot, adjusting the camera by hand to increase the shutter speed, aperture, or the ISO speed every few minutes.

A third method is to employ a more advanced intervalometer (either a hardware unit such as the TimeLapse+ or software such as *GBTimeLapse*) that can "bulb ramp." These typically control the camera through its USB port to automatically shift all three exposure factors — shutter speed, aperture, and ISO — in small, smooth steps over a sequence.

Processing Holy Grails

Whatever method you use, processing final holy grail frames requires special work, and software. One processing setting won't work for all frames. Depending on how you shot the sequence, it might also exhibit unsightly flickering or jumps in brightness that need to be smoothed out. The solution is a program called *LRTimelapse* (**lrtimelapse.com**), which can work with either *Adobe Lightroom* or *Adobe Bridge*.

Watch an exclusive video on time-lapse photography on our website at http://is.gd/UK5qcd.

To use it, you first process several key frames at points in a sequence where the brightness, color balance — indeed any setting you can apply — need to change. *LRTimelapse* then interpolates those settings over the sequence, applying tiny changes to all the images' settings, creating a smooth transition from day to night.

Edit Your Masterpiece

As hard-won as they might be, individual time-lapse clips usually aren't much good on their own. You need to edit them into an inspiring movie, usually with dramatic music, titles, and an overall theme or scenic subject. Use "royalty-free" music clips to be sure you have the rights to publish the music on the web.

Shooting enough footage, then editing it all together, is no small amount of work, to be sure. However, the payoff is a montage that can captivate an audience emotionally as no still image can. It is truly moving. ✦

Contributing editor ***Alan Dyer*** *is author of the eBook* How to Photograph & Process Nightscapes and Time-Lapses *(**amazingsky.com/nightscapesbook.html**).*

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CALIFORNIA CRUISIN'

Kfir Simon

This colorful composite of the California Nebula (NGC 1499) shows the nebula's rich details, illuminated and excited in part by light from the hot, bluish star Xi Persei at upper right.

Details: *William Optics Gran Turismo 81 APO refractor and SBIG ST-8300M CCD camera used with Baader Hα, O III, and S II filters. Total exposure: 16 hours.*

▲ **WOLF MOON ASCENDING**

Giuseppe Pappa

A full Moon rises on January 4, 2015, over the Isles of Cyclops along the eastern shore of Sicily. The subtle pink horizontal band behind the lunar disk is a projection of sunset's reddened rays into the atmosphere and is commonly called the Belt of Venus.

Details: *Canon EOS 1100D DSLR camera set to ISO 200, with 300-mm lens. Exposure: 1⁄125 second.*

► **AURIGA'S FLAME**

Chris Grimmer

Strong light from the star AE Aurigae (near center) illuminates delicately shaped gas clouds in the Flaming Star Nebula (IC 405).

Details: *William Optics Gran Turismo 81 APO refractor and Starlight Xpress SXVR-H694 CCD camera with Baader narrowband filters. Total exposure: 9¼ hours.* ✦

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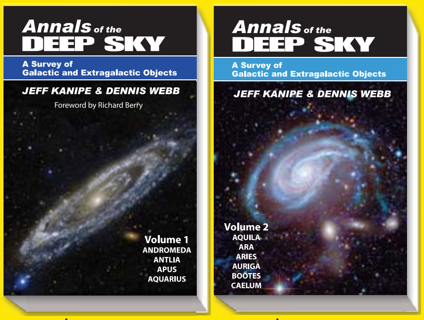

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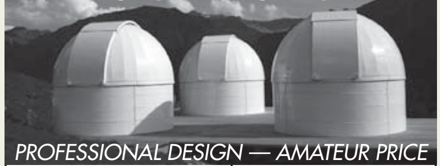

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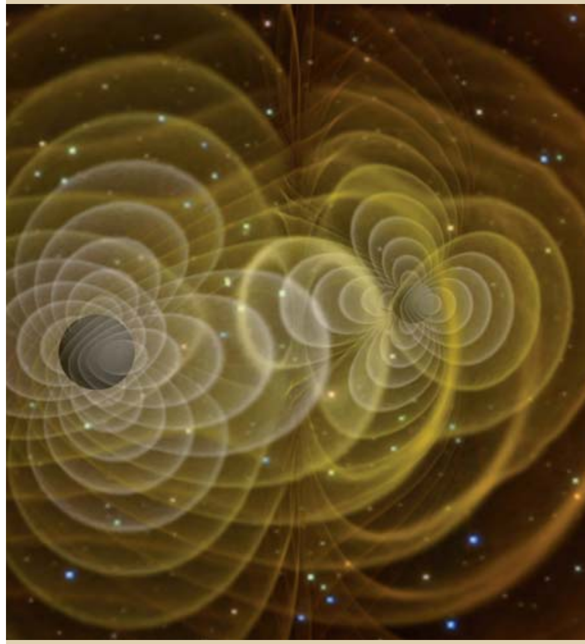

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The Last Visual Comet Hunters

The era that Charles Messier began 250 years ago comes to an end.

CASEY REED

My involvement in amateur astronomy ran hot and cold until 1985, when Halley's Comet returned. I loved the comet's unpredictability as I followed it each clear night for months before and after its perihelion in February 1986. Halley set my future direction in amateur astronomy, inspiring me to become a comet hunter in 1988. I had no idea at the time that I'd be in the last generation of visual comet hunters.

Charles Messier invented the discipline of comet hunting after witnessing Halley's first predicted return in 1758. The successful forecast made Halley the first comet internationally recognized as someone's *property*: it was Edmond Halley's comet. Comet naming became a tradition, and it motivates most Messier-like hunters today.

By 1992 I'd attached my name to four comets. But that same year, Spacewatch at Kitt Peak attached its name to the first automated comet discovery. That was a milestone: a robotic telescope collected the data, and software flagged the discovery images. Also in 1992 came the Spaceguard Survey Report, a U.S. Congressional study that mandated a NASA program to find 90% of all Near-Earth Objects (NEOs) larger than one kilometer across. Spaceguard funding gushed after the dramatic impact of Comet Shoemaker-Levy 9 into Jupiter in 1994, as we Earthlings sought to protect our own planet from a similar event.

With NASA funds, LONEOS and NEAT, two more automated surveys, began patrolling the night sky by 1995. The SOHO satellite launched that year as well. All these professional surveys, including Spacewatch, started making discoveries, but I had not found a comet in three years. Obviously, visual hunters were headed for extinction. In an article that year in *CCD Astronomy*, I prophesied an end to visual discoveries in perhaps a decade.

Happily for me, 1996 brought my fifth and final comet. But LINEAR, yet another automated survey, appeared that year, and four years later the Catalina Sky Survey began operations. Employing robotic scopes in both hemispheres, CSS led NEO discoveries by 2005. Next, in 2009, came the launch of the Wide-field Infrared Survey Explorer (WISE) spacecraft, followed by its NEOWISE component. And in 2010, Pan-STARRS in Hawaii started full-time science observations with its 1.4-gigapixel imaging camera.

Sky coverage widened still further with the launch of the Canadian NEOSsat in 2013, and the ATLAS Project received funding that year as well. Using small patrol scopes in Hawaii, ATLAS will be able to scan the entire visible sky several times each night by the end of 2015.

And whatever comets the satellites and large professional surveys miss, amateur-operated CCD patrols quickly detect.

Suffice to say my 1995 prediction has come true. With our planet in possible danger from NEOs, the automated patrols certainly offer the best protection. But for me and other visual hunters, it's a bittersweet moment. Robotic surveys have left little meat on the bone for visual hunters. In fact, it's been five years since the last visual discovery, that of Comet Ikeya-Murakami in 2010. Ikeya-Murakami may very well be the final Messier-like find ever.

I for one am pleased to have lived during this very special time in astronomical history, when an amateur could manually sweep the night sky with a telescope and discover an unknown comet. I'm proud I helped finish what Messier started. ✦

***Howard Brewington** and his wife, Maya, live in southern New Mexico. He recently retired from New Mexico State University as a telescope operator for the Sloan Digital Sky Survey.*

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