**Sky Spectacle: APRIL'S TOTAL LUNAR ECLIPSE** p. 60

**Comet ISON: PHOTO CONTEST WINNERS** p. 24

**70-inch Amateur Scope: WORLD'S LARGEST** p. 68

THE ESSENTIAL GUIDE TO ASTRONOMY

# SKY & TELESCOPE

Why Is Our Galaxy Blowing Bubbles? p. 26

# Cosmos Reborn p. 32

## Neil Tyson remakes Sagan's TV classic

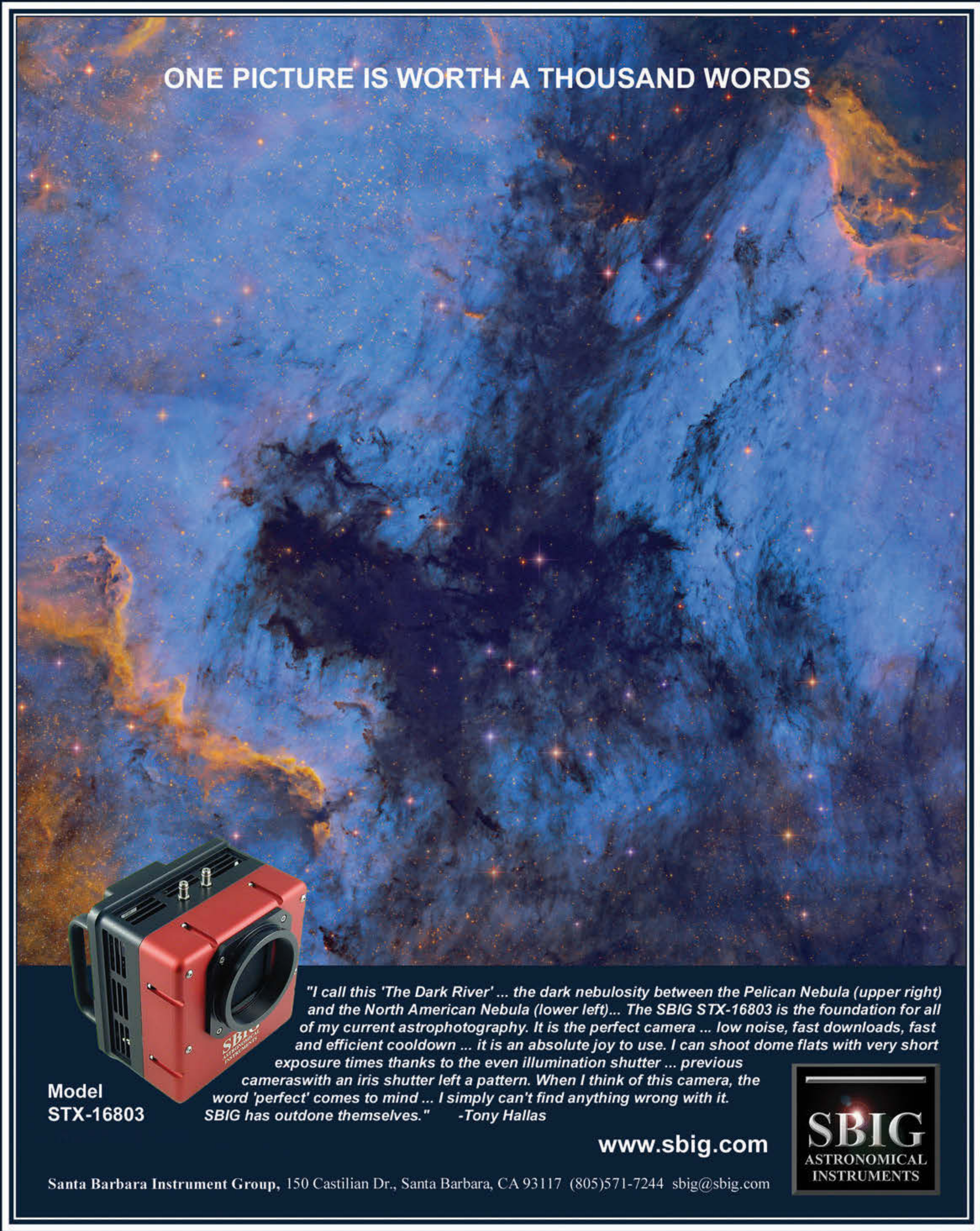
Celestron's New Planetary Cameras p. 62


Enhancing Your Nebula Images p. 72

Less Is More: Happiness with a Simple Scope p. 38

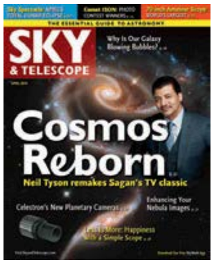
Visit SkyandTelescope.com

Download Our Free SkyWeek App


ONE PICTURE IS WORTH A THOUSAND WORDS
"I call this 'The Dark River' ... the dark nebulosity between the Pelican Nebula (upper right) and the North American Nebula (lower left)... The SBIG STX-16803 is the foundation for all of my current astrophotography. It is the perfect camera ... low noise, fast downloads, fast and efficient cooldown ... it is an absolute joy to use. I can shoot dome flats with very short exposure times thanks to the even illumination shutter ... previous cameraswith an iris shutter left a pattern. When I think of this camera, the word 'perfect' comes to mind ... I simply can't find anything wrong with it. SBIG has outdone themselves." -Tony Hallas
Model
STX-16803
www.sbig.com
SBIG
ASTRONOMICAL
INSTRUMENTS
Santa Barbara Instrument Group, 150 Castilian Dr., Santa Barbara, CA 93117 (805)571-7244 sbig@sbig.com

SKY & TELESCOPE

# April 2014 VOL. 127, NO. 4




**On the cover:** A new version of the iconic TV series returns, aiming to inspire the next generation as its predecessor did.

SPIRAL GALAXY: NASA / ESA / THE HUBBLE HERITAGE TEAM (STSCI / AURA); NEIL TYSON: PATRICK ECCLESINE / FOX

## FEATURES



## OBSERVING APRIL



## S&T TEST REPORT



## ALSO IN THIS ISSUE



There's more to find online @
SkyandTelescope.com

**SKY AT A GLANCE**
Our popular column highlights celestial delights for the upcoming week. Also available as an app — with sky charts included!
SkyandTelescope.com/ataglance


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

**SKYWEEK**
Watch our weekly PBS segment to learn about what's currently up in the sky.
skyweek.com

**ONLINE MARKETPLACE**
Browse and sell your personal used equipment for free.
SkyandTelescope.com/marketplace

**TIPS FOR BEGINNERS**
New to astronomy? Here's everything you need to jump into the fun.
SkyandTelescope.com/letsgo

**Find us on Facebook & Twitter**

*SKY & TELESCOPE* (ISSN 0037-6604) is published monthly by Sky & Telescope Media, LLC, 90 Sherman St., Cambridge, MA 02140-3264, USA. Phone: 800-253-0245 (customer service/subscriptions), 888-253-0230 (product orders), 617-864-7360 (all other calls). Fax: 617-864-6117. Website: SkyandTelescope.com.  Periodicals postage paid at Boston, Massachusetts, and at additional mailing offices. Canada Post Publications Mail sales agreement #40029823. Canadian return address: 2744 Edna St., Windsor, ON, Canada N8Y 1V2. Canadian GST Reg. #R128921855. POSTMASTER: Send address changes to *Sky & Telescope*, PO Box 420235, Palm Coast, FL 32142-0235. Printed in the USA.

# THE SMART SYSTEM

## LX850 f/8 ACF with StarLock

### Integrated, Built-in, Advanced Full-Time Auto Guiding System

LX850

Drawing on 40 years of experience and innovation, Meade Instruments introduces the latest in a long line of advanced astronomical products: the LX850. Using revolutionary new technology, every aspect of this amazing telescope system has been designed to deliver the new standard in astrophotographic and visual performance.

Shown with 12" ACF OTA


**FASTER, SHARPER OPTICAL SYSTEM**

The LX850 employs a fast f/8 ACF™ optical system with high-contrast baffling that assures crisp, pinpoint imaging to the very edge of the field. The all-new OTA features an internal Crayford-style, zero image-shift focusing system with a two-speed, 7:1 control that eliminates the need for a mirror lock.

**PRECISION MACHINED, SOLID GERMAN EQUATORIAL MOUNT**

Constructed of machined stainless steel and aircraft grade aluminum, the LX850 mount presents a rock-solid platform with precision roller bearings on both axes and a 1.75" stainless steel R.A. shaft. Its .68" diameter brass worms and 5.8" diameter, 225-tooth aluminum gears deliver smooth, precise movement with up to a 90 pound instrument load. A fully-computerized GoTo mount with GPS, the LX850 comes with a database of over 144,000 objects. All this sets atop a new super-stable tripod.

**STARLOCK — FULL-TIME AUTOMATIC GUIDING**

StarLock is the revolutionary new technology that makes target acquisition on your imaging sensor and accurate guiding during exposures completely automatic. StarLock uses an 80mm f/5 optic and a super wide-angle lens in a two camera system that automatically finds your target in high-precision, immediately captures a field star as dim as 11th magnitude and then guides to an accuracy of one arcsecond. There's no need for a separate guider or computer and the StarLock requires no user focusing or guide star selection. StarLock automatically programs periodic error correction and then corrects for any other errors down to virtually zero.

**With the combination of the finest optics, robust mount and revolutionary new StarLock, the LX850 from Meade Instruments is the most complete astro-imaging solution available.**

For more information on the LX850, or any of Meade's advanced astronomy products, just **visit meade.com** or contact an authorized dealer.

| | | |
|---|---|---|
| Optics Planet<br>800.504.5897 | OPT Telescopes<br>800.483.6287 | B & H Photo<br>800.482.8143 |
| Telescopes.com<br>800.303.5873 | Woodland Hills<br>888.427.8766 | Adorama<br>800.223.2500 |

Canada • Khan Scopes
800.580.7160

MEADE INSTRUMENTS
*Innovative products for curious minds* | *since 1972*

# Astronomy on TV

When I think back to the autumn of 1980, when I was a high school senior, I can't summon any memories of watching Carl Sagan's *Cosmos* series when it originally aired on public television. I watched the series years later, but by then I was already an astronomy buff. So unlike a lot of folks my age, *Cosmos* had minimal impact in raising my astronomical consciousness.

I don't remember exactly when I watched *Cosmos*. I recall enjoying the series enough that I eagerly anticipated every episode, and I loved the book. But I was only partially captivated by Sagan's persona, and I thought the series vastly oversold the prevalence of extraterrestrial civilizations given the paucity of evidence for their existence. I still feel that way today.

As a young adult I would try to watch any show on TV that was about astronomy, particularly because programs on science topics other than nature were as rare as TV shows about drying paint. But now that science programming has become more common, I rarely watch. I've reached a level where I almost never learn anything new about astronomy, physics, or planetary science from TV. A lot of televised science is mediocre at best, and is littered with unbridled speculation and sensationalism. It's almost impossible for me to watch a TV show on astronomy without cringing from egregious factual errors, misleading graphics, and oversimplifications.

A notable exception is public television's *Nova* series. I never miss an episode about astronomy because the producers actually try to get it right. For example, *Nova* aired an episode about the Chelyabinsk fireball just weeks after the event, and I was deeply impressed with the show's sophisticated content and commitment to accuracy. The producers even tagged along with American impact expert Mark Boslough as he traveled in Russia. I concur with planetary scientist Dan Durda, author of our May 2013 feature article about Chelyabinsk: Why can't all televised science be this good?

Although I would normally have some trepidation about the upcoming *Cosmos* series, I can't wait to watch it. I have met Neil deGrasse Tyson several times, and have always found him gracious. I greatly admire his work on popularizing astronomy, and have read many of his books and articles. So I'm optimistic the series will be very good and am curious to find out how much it follows Sagan's original *Cosmos*, and how much it veers off on its own path. To learn more about this series, check out Kelly Beatty's cover story on page 32.

Finally, on January 17th, shortly before this issue went to press, F+W Media acquired New Track Media, *S&T*'s parent company. This is only the second time in *S&T*'s 73-year history that its ownership has changed hands, the first being New Track's purchase of Sky Publishing Corporation in early 2006. My colleagues and I will miss our friends at New Track, but we are very excited about working with our new partners. I'll say a lot more about this next month. For more information, visit **skypub.com/fwmedia**. ✦

Robert Naeye
*Editor in Chief*



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



**Editorial Correspondence:** *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, USA. Phone: 617-864-7360. Fax: 617-864-6117. E-mail: editors@SkyandTelescope.com. Website: SkyandTelescope.com. Unsolicited proposals, manuscripts, photographs, and electronic images are welcome, but a stamped, self-addressed envelope must be provided to guarantee their return; see our guidelines for contributors at SkyandTelescope.com.

**Advertising Information:** Peter D. Hardy, Jr., 617-864-7360, ext. 2133. Fax: 617-864-6117. E-mail: peterh@SkyandTelescope.com
Web: SkyandTelescope.com/advertising

**Customer Service:** Magazine customer service and change-of-address notices: skyandtelescope@emailcustomerservice.com
Phone toll free U.S. and Canada: 800-253-0245.
Outside the U.S. and Canada: 386-597-4387.
Product customer service: skyprodservice@SkyandTelescope.com
Phone toll free: 888-253-0230.

**Subscription Rates:** U.S. and possessions: $42.95 per year (12 issues); Canada: $49.95 (including GST); all other countries: $61.95, by expedited delivery. All prices are in U.S. dollars.

**Newsstand and Retail Distribution:** Curtis Circulation Co., 730 River Rd., New Milford, NJ 07646-3048, USA. Phone: 201-634-7400.


ONE HALF OF THIS IMAGE WAS TAKEN WITH A $2,499 ESPRIT
THE OTHER WAS TAKEN WITH A SCOPE THAT COST TWICE AS MUCH
Imager: Jerry Keith of Fort Worth, Texas (Three Rivers Foundation Volunteer)
Scopes: Sky-Watcher Esprit 100mm EDT f/5.5 World-class 4-inch astrograph
Mount: Takahashi EM200 Temma2M
Guiding: Orion SSAG Magnificent Mini AutoGuider
Camera: Canon 60Da @ 800 ISO
Exposure: 20 light frames and 20 dark frames @ 300 seconds. No flats, dark flats or bias frames were used. 30 light frames and 15 dark frames @ 30 seconds were used for toning down the core of M31. The same processing was used for both scopes.
Actually, the other telescope cost more than twice as much as the Esprit, but that's not really the point. The point is, do you see twice as much performance on one side of the page than the other? Take a close look. Are the stars twice as pinpoint? Is the color doubly corrected?
We don't think so.
If you don't think so either, perhaps you should consider purchasing a Sky-Watcher Esprit triplet. At Sky-Watcher USA we pride ourselves on offering products with world-class performance at affordable prices. Because we know there are other things you could be spending that money on. Like a mount. Or a camera. Or even a really, really sweet monster flat-screen television, just for fun.
The Sky-Watcher line of Esprit ED Apo triplets. All of the performance, half the price.
©2014 Sky-Watcher USA. Specifications subject to change without notice. 20-14002.
If you really want to spend twice as much for the same performance, we're not going to stop you. We will be very disappointed with you, though.
Sky-Watcher PROFESSIONAL
Starting at only $ 1,649, the Esprit line is offered in 80, 100, 120 and 150mm apertures and comes complete with a 9 x 50 right angle finderscope, 2-inch Star diagonal, 2-element field flattener, camera adapter, mounting rings, dovetail plate and foam-lined hard case.
Sky-Watcher® USA
Be amazed.
For information on all of our products and services, or to find an authorized Sky-Watcher USA dealer near you, just visit www.skywatcherusa.com.
Don't forget to follow us on Facebook and Twitter!

## The Success of Comet ISON

Despite the disappointment to amateurs, Comet ISON's appearance was in no way a "dud," a "failure, or "the let-down of the century," as some have asserted in online forums and other venues. I think it was quite the opposite: astronomers gained far more from this comet's appearance than we have acknowledged.

ISON's refusal to perform visually in its final days was certainly frustrating. But it was a spectacular little comet in scopes and binos when it was higher in the sky. Its appearance with Lovejoy, Encke, and an outbursting LINEAR made for superb observing from late October to mid-November.

The final drama of searching SOHO's images for signs of ISON was a highlight of the year. I cannot remember days so full of anticipation, excitement, dismay — even panic — as those at the end of November, when thousands of the world's astronomers pored over LASCO and SDO images, ranted in online forums, haunted the NASA/ESA live feeds, and got up in the early hours (often in freezing weather) to try desperately to spot something for themselves.

And then the worldwide heartache when our hero disintegrated in front of our eyes! People were actually grieving for the little monster!

Amateur astronomy is often a laid-back affair, only really sociable on club nights or at star parties. ISON brought us together in a global star party. Not bad for a puny iceball with a creaky nucleus.

***Mick Forsyth-Caffrey***
*Sandown, Isle of Wight, United Kingdom*

## CubeSats Up and Away

I really enjoyed reading the article about current and future CubeSat activities (November issue, page 64). It is amazing how the number of CubeSat missions is growing, providing opportunities to test new technologies in a very efficient, low-cost way. In the past few years I was also involved in a CubeSat mission: the satellite we built was the first satellite of Hungary, called Masat-1. It was launched on February 13, 2012 with six other 1U CubeSats on the maiden flight of Vega. We managed to take more than 50 amazing pictures of Earth, and we also compiled a mosaic image of part of Africa and a 3-D image of clouds as well. You can find some of these pictures on our satellite team's website: **skypub.com/masat1**.

The first Hungarian satellite, Masat-1, took this picture of Earth using its 640 × 480-pixel CubeSat camera.

MASAT-1 TEAM

I encourage everyone to participate in CubeSat missions. It will give you the experience of a lifetime.

***Gábor Marosy***
*Budapest, Hungary*

***Editor's Note:*** *Our list of launch providers (page 67) wrongly implied that it was an all-inclusive one. Our apologies for appearing to ignore ESA's Vega and other providers.*

Tim DeBenedictis's article "Amateur Space Exploration" did an admirable job describing CubeSats and their current uses. Amateur satellites have been around for more than 50 years: the first, OSCAR 1 (Orbital Satellite Carrying Amateur Radio), launched in 1961. It and OSCAR 2, which launched six months later, were designed and built entirely by amateur radio operators and launched as piggybacked payloads from Vandenberg Air Force Base. Granted, neither did much — OSCAR 1 only transmitted "Hi" in Morse code (I actually heard it) — and each lasted in orbit for only about three weeks. But those projects were pioneers. Amateurs from roughly two dozen countries have now followed the OSCAR builders' example.

Although CubeSats, their vendors, and the people who design and build them are very welcome additions to this growing enterprise, the amateur radio operators should get the credit they deserve for their trailblazing efforts.

***K. A. Boriskin***
*Bellingham, Massachusetts*

## More on Seeing the Sky Better

Concerning Aldo Cugnini's letter in the December issue (page 8): Cogan's dystrophy, or map-dot-fingerprint dystrophy, can be treated with a laser procedure called phototherapeutic keratectomy (PTK). Similar to the Lasik laser surgery commonly used to correct vision, PTK resurfaces the outer cornea by removing the islands of vision-distorting tissue. My wife had it done about five years ago, and the results were outstanding.

***Roger Kern***
*Richmond, Virginia*

## Equipment in the Field

Thank you for your test report on the Meade LX850 Astro-Imaging System (December issue, page 60). I have a 14-inch LX200 ACF and am considering switching to an LX850 for the portability factor, because the 14-inch LX200 doesn't break down into pieces that can be moved by just one person. Even loading or unloading it into a car is a two-person job.

My biggest worry was whether or not the LX850 would be solid enough for guided imaging, so I was especially interested in your commentary on its consistent performance in that area.

Incidentally, I shared your opinion on the inadequate Autostar II keypad cord. Then I realized the cord is really just an ordinary, coiled telephone-handset cord (the type used for a desk or wall-mounted phone). Fortunately, these coiled cables are widely available in a 25-foot length. I replaced my keypad cord during the first week of ownership and have been much happier with it since.

***Tim Campbell***
*Dearborn, Michigan*

I have a suggestion for those using the iOptron SkyTracker (*S&T*: May 2013, page 64). As part of the polar alignment process you must locate Polaris by looking through the polar sight hole. This can be difficult to do. Instead, I use Howie Glatter's SkyPointer and shine the laser beam through the hole and make adjustments to get the alignment close. Then I finalize it by viewing through the polar scope.

*Jim Radford*
*Templeton, California*

## Delightful Galaxy Article

I tremendously enjoyed Ted Forte's "Exploring the Triangulum Galaxy" (December issue, page 34). It mixed just the right amount of informative science with the observational possibilities available to the amateur astronomer. I just had to go out and take a look! I was also so impressed with the *Pocket Sky Atlas* chart for finding M33, I had to order that, too.

*Eric Nelson*
*Via e-mail*

## When is a Dwarf not a Dwarf?

In her December Deep-Sky Wonders column (page 56), Sue French writes, "Despite its diminutive size, M32 is not a dwarf galaxy." But my understanding is that M32 is a "compact elliptical," which is a type of dwarf galaxy. Do not compact ellipticals have masses on the order of $10^9$ solar masses, making them dwarfs? Giant ellipticals have $10^{11}$ to $10^{13}$ solar masses.

For many years I have followed French's columns, and they are great — especially the poetical introductions.

*Pedro Augusto*
*Lisbon, Portugal*

***Author's Note:*** *M32 is a strange case. The NASA/IPAC Extragalactic Database (NED) lists M32 as a "compact E2," and some sources claim the galaxy is a dwarf elliptical (although NED's detailed classifications don't). M32's stellar population, nucleus size, and compactness make it look like a much larger elliptical galaxy. It also has an effective surface brightness about four times brighter than dwarfs of comparable absolute magnitude. If we define dwarfs based on surface brightness (which I'm partial to, as an observer), I would argue M32 isn't a dwarf. However, M32 is only 3 billion solar masses. Like other compact ellipticals, it was probably tidally stripped to a fraction of its original mass. That might explain why these objects have big-galaxy properties but dwarf masses.*

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

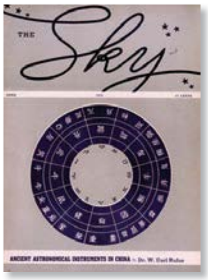
## For the Record

✷ *Only PlaneWave's 12.5-inch CKD telescope is f/8 (January issue, page 68). The 14-inch is f/7.2, and the 17-inch is f/6.8.*

✷ *The planet sizes in the Kepler results graph (February issue, page 14) are wrongly doubled, as were those in the April 2013 issue. Ergo, "Earth-size" should be "<1.25 Earth diam." and so forth.*

# 75, 50 & 25 Years Ago

*Roger W. Sinnott*




**April 1939**

**Kudos** "The January issue of the Astrophysical Journal [contains] photographs obtained by Mr. H. A. Lower of San Diego, California, with a Schmidt camera of his own construction. I thought you would perhaps like to mention in The SKY that the Astrophysical Journal has given this unusual recognition to the work of an amateur astronomer.

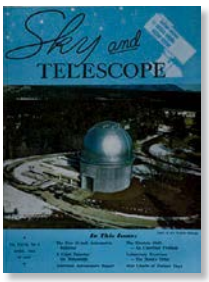
"The value of the photographs is, of course, not only pictorial. A careful study of the plates reveals the existence of many nebulae which had not formerly been known and which appear to shine in the light of the red line of hydrogen."

*Coming from Yerkes astronomer Otto Struve, this letter was high praise. The father-and-son team Charles and Harold Lower were among the first amateurs to make and use a Schmidt camera.*

**April 1964**

**Bent Starlight** "At present, total solar eclipses are the only occasions when stars near the sun become visible to us, permitting measurement of the Einstein shift [of starlight's path by the Sun's gravity. T]he amount of this deflection becomes observationally quite inappreciable at distances of more than, say, six radii from the sun's center. . . .

"In practice, these measurements are very difficult and uncertain, since eclipse observations are made under unusual circumstances. . . . The problem must be left to future eclipses or, perhaps, to observations from artificial satellites. . . . Owing to the observational difficulties, the Einstein shift will remain a moot problem for years to come."




*The author of this article, Felix Schmeidler (Munich University Observatory), had himself tried to measure the Einstein shift at several eclipses. Only with the ESA's Hipparcos satellite (1989–1993) did astronomers confirm Albert Einstein's predicted shift to within one part in 1,000. The European Space Agency's Gaia satellite, launched last December (this issue, page 10), should do even better than Hipparcos.*


**April 1989**

**Alien Eruptions** "When the Voyager 1 spacecraft glided past Jupiter and its satellites in 1979, no one expected to see images of volcanoes on the moon Io spewing sulfur-laden magma. The surprising discovery marked the first time active volcanism was seen on another body in the solar system. . . .

"Observations made during Jupiter's 1986 apparition have led researchers to conclude that Io's volcanoes erupt silicates as well as sulfur. [The] 1986 outburst was around 900° K, hotter than the boiling point of sulfur (715° K)[, which] rules out pure sulfur as the major constituent of the magma in this eruption."

*Nowhere in the solar system does volcanism currently dominate as it does on Io. Mercury, Venus, and Mars all have ancient volcanic plains, although there's no definitive evidence for ongoing activity on any of them. Astronomers have observed geysers on Jupiter's Europa, Saturn's Enceladus, and Neptune's Triton. They still debate whether Saturn's Titan exhibits cryovolcanism.*

# MISSIONS | Gaia Launches to Pinpoint a Billion Stars

This illustration depicts the Gaia spacecraft in deep space, hard at work mapping 3-D locations for many of the Milky Way's stars.

SPACECRAFT: ESA / ATG MEDIA LAB; BACKGROUND: ESO / SERGE BRUNIER

**ESA's long-awaited** Gaia mission launched December 19th on a Soyuz rocket from Europe's spaceport in Kourou, French Guiana. The spacecraft's instruments will map the size, shape, and dynamics of our galaxy to extraordinary precision by obtaining über-accurate star positions, motions, and distances.

Accurate star positions are the foundation of nearly everything we know about stars and, in turn, form the base for the cosmic distance scale. Gaia is the first great leap in the measurement of stellar positions, proper motions, and parallaxes — called *astrometry* — since ESA's Hipparcos mission of the early 1990s.

The plan is to map 1 billion stars down to 20th magnitude, nearly 1% of all the stars in our galaxy. Gaia will measure stars from 5th to 15th magnitude to an accuracy of at least 25 microarcseconds, and even better on the brighter end of this range. That's 40 times more precise than Hipparcos could do for stars down to magnitude 8 or 9. Gaia will measure its faintest stars (to magnitude 20) to 300 microarcseconds or better. It will also catalog star brightnesses from the near ultraviolet to the near infrared (*S&T:* March 2008, page 36).

To accomplish these feats, Gaia will observe each star about 70 times. Additionally, it will measure the stars' radial velocities, creating a full 3-D map of both their motions and locations. The accuracy of individual parallaxes will range from 20% for stars near the galactic center (26,000 light-years away) to a remarkable 0.001% for nearby dim stars.

Gaia will carry out its planned 5-year mission at the Sun-Earth $L_2$ Lagrangian point, 1.5 million kilometers (930,000 miles) away from our planet's nightside. The spacecraft's two identical telescopes point 106.5° apart, and as the craft rotates once every 6 hours, each will survey a narrow band of the celestial sphere. A gradual tilt of the spacecraft's axis will slowly result in full-sky coverage. The telescopes have folded focal lengths of 35 meters (115 feet) and focus onto imaging chips totaling more than 900 megapixels. Gaia is expected to produce more imaging data in 5 years than NASA's Hubble Space Telescope did in its first 21 years.

Ultimately, Gaia should produce top-quality 3-D coordinates for 10 million stars, compared with Hipparcos's 118,000 measured stellar parallaxes. The first catalogs should come in mid-2016 and the final one around 2023. Gaia's mission planners also hope to gather indirect data on hundreds of exoplanets and possibly identify thousands of new brown dwarfs.
■ **EMILY POORE & ALAN M. MACROBERT**

# STELLAR | New Cutoff for Star Sizes

**Astronomers have found** a long-sought gap between "real" and "failed" stars.

Observers have had trouble detecting the boundary that separates stars — which spend most of their lives fusing hydrogen in their cores, during the *main sequence* — and brown dwarfs, which can't sustain hydrogen fusion. But new results in the *Astronomical Journal* point to a clear demarcation between the two.

Sergio Dieterich (Georgia State University) and colleagues assembled data on 63 nearby low-mass stars and brown dwarfs. The team meticulously measured objects' distances and colors in multiple optical and infrared wavelengths. They next combined these parameters to estimate each object's temperature, radius, and luminosity by comparing it with expectations from cutting-edge models. The astronomers verified their method by comparing their computed sizes with a handful of directly measured radii.

A star's (or a brown dwarf's) radius is related to its brightness and surface temperature. The team examined the radius-luminosity and radius-temperature distributions, searching for a gap in sizes that would mark a break between the smallest stars and the largest brown dwarfs. Astronomers expected this gap to exist because although stars and brown dwarfs' radii are related to their brightness and temperatures, they're related in opposite ways: if you increased the mass of a star, it would respond by growing in size; a brown dwarf would shrink.

The search turned up a gap. "We can now point to a temperature (2100 K), radius (8.7% that of our Sun), and luminosity (1/8,000th of the Sun) and say, 'The main sequence ends there,'" says coauthor Todd Henry (Georgia State University).
■ **JOHN BOCHANSKI**

# EXOPLANETS | Weather on Alien Worlds . . .

**The age of** "astrometeorology" is upon us. From high-altitude clouds discovered on a super-Earth to massive, hurricane-force storms on a nearby brown dwarf, results presented at the winter 2014 American Astronomical Society meeting show that we've moved beyond merely counting alien worlds to giving weather forecasts.

Two teams of astronomers reported what look like high-altitude clouds on two transiting exoplanets, GJ 1214b (a super-Earth 42 light-years away) and GJ 436b (a Neptune-size planet 33 light-years away). The clouds turned up as a *lack* of certain features in the spectra of starlight passing through the planets' atmospheres as the worlds transited their host stars' faces.

Laura Kreidberg (University of Chicago) and colleagues watched GJ 1214b transit 15 times, observing in a wavelength band (between 1 and 2 microns) that ought to have shown hints of water vapor, gaseous carbon dioxide or carbon monoxide, or methane molecules. Instead, the spectrum showed no features at all.

Heather Knutson (California Institute of Technology) found similar, though less conclusive, "flatline" results for GJ 436b. These null results show that hazes must block our view of the worlds' atmospheres, in keeping with hot-Jupiter observations (March issue, page 14).

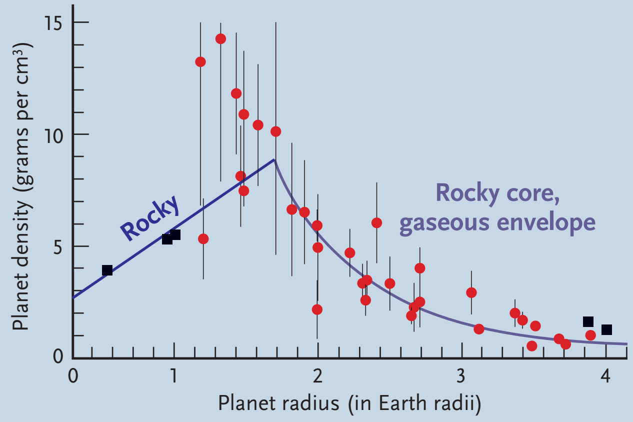
These clouds are potentially exotic compounds, such as droplets of potassium chloride (a form of potash that's pink in liquid form) or zinc sulfide. Both studies also appear in the January 2nd *Nature*.

Brown dwarfs have "bad" weather, too. Observations from an international monitoring campaign spanning four continents showed that 15–25% of the dwarf WISE J1049B's visible surface is covered in a massive, hurricane-force storm, Adam Burgasser (University of California, San Diego) reported. (The Great Red Spot covers only 1% of Jupiter.) Previous near-infrared observations from Spitzer have shown the dwarf's thick cloud decks are likely made of silicate and iron.

Surveys are capturing many more brown dwarfs with weather. Aren Heinze (Stony Brook University) announced the results of a monitoring campaign of 44 brown dwarfs, about half of which changed in brightness over the 21 hours of observation. Two varied regularly, suggesting stable Great Red Spot–like features rotating in and out of view. But the others, as on WISE J1049B, varied more erratically, suggesting that massive cloud formations can form and fade within hours.

■ **MONICA YOUNG**

# . . . and is "Super-Earth" a Misnomer?




SOURCE: GEOFF MARCY AND LAUREN WEISS

A study of small exoplanets (dots) confirms that small planets get denser as they grow in size. But at roughly twice Earth's diameter, planets instead grow fluffier with increasing radius. A second study found a similar trend. Black squares are Mars, Venus, Earth, Uranus, and Neptune.

**Two studies of** dozens of alien worlds confirm that planets more than twice Earth's size can't be rocky, astronomers announced at the winter AAS meeting. But gas planets don't seem to have a corresponding lower limit.

Of the Kepler spacecraft's 3,500-plus exoplanet candidates (February issue, page 14), roughly three-quarters of them have diameters between those of Earth and Neptune, which is four times Earth's size. But astronomers also need the mass before they can calculate a planet's density and deduce whether it's gaseous or rocky.

Geoff Marcy (University of California, Berkeley) reported on four years of Keck observations, which followed up on 22 stars with 42 exoplanets. His team measured the planets' gravitational tugs on their host stars to calculate masses for 16 planets and either rough estimates or upper limits for the rest.

Working independently, Yoram Lithwick and Sam Hadden (both at Northwestern University) instead measured wobbles in a *planet's* position due to another planet's tug. The team measured the masses of 58 super-Earths. Most of these are relatively firm estimates, with about 10 "rough guesses."

Both teams found the same thing: up to between 1.5 and 2 Earth radii, the bigger the planet, the denser it becomes — as expected for rocky planets. But planets larger than this size grow fluffier, not denser. These bigger-but-less-dense planets probably are larger thanks to an extended atmosphere around a rocky core.

These results match previous observations and theoretical work, the latter of which suggests rocky planets should never be bigger than about twice Earth's size. That's because at a certain point, adding more mass just compresses a body instead of making it larger.

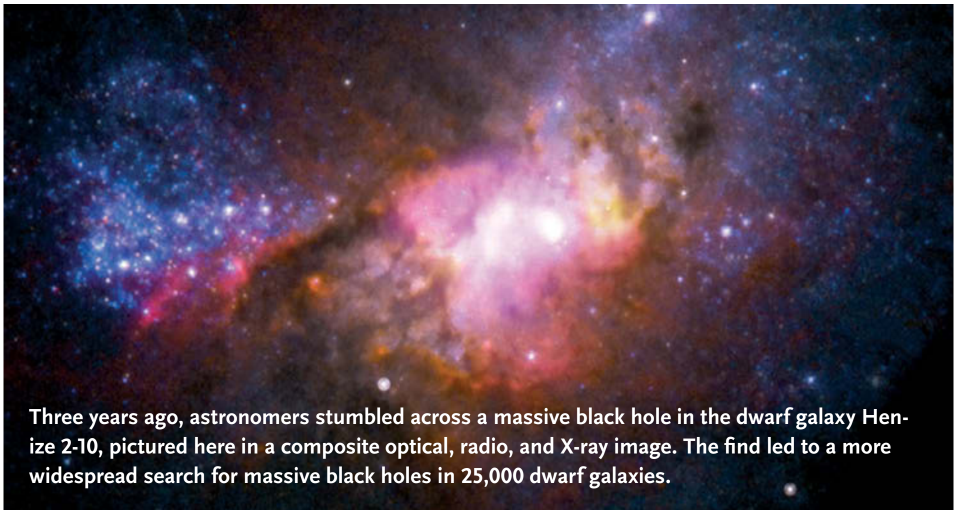
But apparently the dividing line doesn't work both ways. David Kipping (Harvard-Smithsonian Center for Astrophysics) also announced the discovery of KOI-314c, an Earth-mass candidate that is 60% wider than Earth. In classic mini-Neptune style, it likely has a rocky core surrounded by gas.

"If you told an astronomer yesterday that they'd found an Earth-mass planet, they'd think it would surely be rocky," Kipping says. "[This planet] suggests we can't just draw a line in the sand."

■ **MONICA YOUNG**


ORION®
Since 1975
EVERYTHING FOR THE AMATEUR ASTRONOMER
Orion® StarBlast™ AutoTracker Altazimuth Mount
#8975 $199.99
NEW PRODUCT 2013
(camera not included
Orion® Thin Off-Axis Guider for Astrophotography
#5531 $149.99
NEW PRODUCT 2013
Orion® StarShoot™ Solar System Color Camera IV
#52175 $99.99
Deluxe upgrade of our popular XT8 Classic
Orion® SkyQuest™ XT8 PLUS Dobsonian
#8974
$499.99
NEW PRODUCT 2013
Orion® Dual Finder Scope Mounting Bracket
#10145 $49.99
NEW PRODUCT 2013
Orion® ShoreView™ Pro 10x42 Waterproof Binoculars
#8449 $79.99
NEW PRODUCT 2013
Orion® StarShoot™ 5 MP Solar System Color Camera
#52097 $199.99
NEW PRODUCT 2013
Orion® StarBlast™ 114mm AutoTracker Reflector
#10140 $279.99
NEW PRODUCT 2013
Orion® EON™ 110mm ED f/6.0 Apochromatic Refractor Telescope
#10031 $1,299.99
NEW PRODUCT 2013
Elegant solutions to transport, protect, and wirelessly control your XX16g!
Orion® SkyQuest™ XX16g GoTo Truss Tube Dobsonian
#8968
$3,649.99
NEW PRODUCT 2014
Orion® Wheel Kit for SkyQuest™ XX16g
#5780 $279.99
Orion® StarSeek™ Wi-Fi Control Module, Serial/USB
#5969 $159.99
Orion® SteadyPix™ Universal Smartphone Adapter
#5693 $69.99
Orion® 1.25" SkyGlow™ Broadband Filter
#5660 $79.99
Set of Orion® SkyQuest™ XX16g Padded Cases
#15102 $379.99
Orion® Light Shroud for SkyQuest XX16
#15101 $139.99
Orion® 8" f/3.9 Newtonian Astrograph Reflector
#8297 $519.99
Orders: (800) 447-1001
Customer Service: (800) 676-1343
Suggested retail prices subject to change.
OrionTelescopes.com
Shop Orion On-the-Go.
Easy Access right on your Smartphone.
Check us out on Facebook
www.facebook.com/oriontelescopes

# BLACK HOLES | Galactic Runts Host Beasts



X-RAY: NASA / CXC / VIRGINIA / AMY REINES ET AL; RADIO: NRAO / AUI / NSF; OPTICAL: NASA / STSCI

Three years ago, astronomers stumbled across a massive black hole in the dwarf galaxy Henize 2-10, pictured here in a composite optical, radio, and X-ray image. The find led to a more widespread search for massive black holes in 25,000 dwarf galaxies.

**Astronomers are edging** closer to discovering how the universe's most massive black holes form — by studying the smallest galaxies.

It's easy to make a black hole a few times the mass of the Sun: a massive star loses its battle against gravity and collapses under its own weight. But no star contains millions or even billions of Suns, which is where the most massive black holes weigh in.

There are two main ideas on how to grow these monsters. One camp holds that supermassive black holes could be the remnants of the first generation of stars. Unpolluted by heavier elements, these stars could have grown to tremendous sizes, with masses up to hundreds of times that of the Sun. These stars then would have collapsed into "seed" black holes that then grew to supermassive sizes by sucking in more material.

Even better, says another camp, would be to collapse a black hole directly out of a gas cloud. That's tricky to do, but with the right conditions it might be possible to make black holes thousands of times the mass of the Sun. Observers have detected black holes a billion times the mass of the Sun just 1 billion years after the Big Bang, so this theory is a tempting one.

To find the answer, astronomers are looking at dwarf galaxies. Dwarfs haven't changed much since the beginning of the universe, so they should retain the memory of black holes' seeding scenario, says Amy Reines (NRAO). If supermassive black holes formed from the first stars, then every dwarf should have one. On the other hand, because the direct-collapse process is more difficult, it would probably leave most dwarf galaxies without a supermassive black hole to call their own.

Until recently, astronomers had only found a few cosmic heavyweights in dwarf galaxies, such as the one in NGC 4395, which is a few hundred thousand times the mass of the Sun.

Reines and her colleagues have expanded that sample. Presenting at the winter AAS meeting, Reines's team pulled 25,000 dwarf galaxies from the Sloan Digital Sky Survey and searched their visible-light spectra for telltale signs of a massive, feeding black hole. They found those signals in 151 dwarf galaxies — not even 1% of the full sample.

Reines cautions that this result is only a first step, because the team could only detect feeding black holes. Dormant ones — and most of these objects would be dormant most of the time — would go undetected. Furthermore, a dwarf galaxy with lots of star formation would drown out the signal from its black hole.

The team next plans to observe with the Very Large Array and NASA's Chandra X-ray Observatory. Black holes emit in radio and X-rays even when not chowing down, so the expanded survey should reveal quieter beasts that are invisible to SDSS.

■ **MONICA YOUNG**

## IN BRIEF

**Supernova in M82.** Astronomers spotted the Type Ia supernova SN 2014J on January 21st at magnitude 11.7. See skypub.com/M82.

**New Way to Weigh Worlds.** Julien de Wit and Sara Seager (both at MIT) have devised a method to estimate a transiting exoplanet's mass using its atmosphere. Astronomers can detect the outer atmosphere's extent and composition during transit, then calculate the mass needed to hold onto it, the duo reports in the December 20th *Science*. The team successfully confirmed the mass of the well-studied hot Jupiter HD 189733b. Current technology limits the technique's usefulness to hot Jupiters for now.
■ **MONICA YOUNG**

**Mini Robots Go Observing.** Astronomers have developed tiny robots called Starbugs to help them conduct sky surveys. Big surveys, such as the Sloan Digital Sky Survey, use fiber optics to collect spectra of thousands of objects. Light from galaxies travels along the fiber and into a spectrograph, which splits the light into a spectrum. But plugging each fiber into place takes time, so researchers at the Australian Astronomical Observatory are designing Starbugs to scurry across observing plates and place the fibers for them. Each Starbug is made of two ceramic cylinders nested one inside the other, which each move slightly when a voltage is applied, allowing the robot to "walk." A vacuum in the space between the cylinders keeps the whole device pinned to the plate. Read more about them and watch videos of Starbugs in action at skypub.com/starbugs.
■ **MONICA YOUNG**

**Rosetta Spacecraft Wakes Up.** After sleeping for 957 days, the comet chaser awoke on schedule on January 20th. Rosetta and its lander, Philae, have traveled about 10 years and 800 million miles to catch up to Comet 67P/Churyumov-Gerasimenko. The spacecraft should reach the comet's vicinity in May; in August, it will begin searching the nucleus for a landing location for Philae, to be deployed in November. If successful, the mission will be the first soft landing on a cometary nucleus, providing an incredible close-up view as the comet approaches its August 2015 perihelion.
■ **EMILY POORE**

# GALAXIES | New Views of Cosmic Infancy

**Galaxy research** presented at the AAS meeting in January fleshes out our picture of early cosmic history, spurring astronomers to peer more carefully at what we can see of the ancient universe.

Galaxies started forming in the first couple hundred million years after the Big Bang. These galaxies were small, blobby irregulars, like the Magellanic Cloud dwarf galaxies. From about 400 million years to 3 billion years (or from a redshift of 12 to 2, in astrospeak), star formation ramped up in the universe. Then it tapered off. Today it's maybe one-tenth what it was in the universe's heyday.

Astronomers base this picture on observations of galaxies at various cosmic epochs. They have identified about 1,000 galaxies that lived between 1 and 1.5 billion years after the Big Bang, about 700 at 950 million years, and another 700 between 650 and 800 million years after the universe's birth. But they only have about two dozen from earlier times.

Among those rare gems are four bright galaxies that Garth Illingworth (University of California, Santa Cruz) and colleagues studied using NASA's Hubble and Spitzer space telescopes. The light from these four galaxies was emitted 500 million years after the Big Bang, but they're 10 to 20 times brighter than other galaxies detected in this era. Although theory predicts such objects should exist, the researchers were so surprised by the detections that they thought they were doing something wrong.

By estimating the galaxies' masses from their light output, the team determined that these objects have on the order of a billion solar masses' worth of stars, on par with a recently discovered star-forming galaxy that existed about 200 million years later (February issue, page 10).

Most galaxies at early times were fainter than these, and they're challenging to spot. To see them, astronomers look for examples that are magnified by a foreground object's gravity, an effect called *gravitational lensing*.

Anahita Alavi (University of California, Riverside) and colleagues were able to use the lensing power of galaxy cluster Abell 1689 to reveal 58 faint galaxies that shone between 2.8 and 3.7 billion years after the Big Bang. These galaxies are about 100 times fainter than those previously studied in this era, which is roughly when star-formation rates peaked. Even when magnified, the galaxies appear to be at most tens of thousands of light-years across, roughly a tenth the Milky Way's size. Yet Alavi says it's these galaxies that account for more than 70% of the universe's star formation at the time.

Observations show that the universe's galactic makeup didn't change much between about 700 million years after the Big Bang and the era Alavi's team studied. This same type of faint, small galaxy probably predominated all the way back to the cosmos's earliest days, Illingworth says.

Buoyed by these results, Hubble scientists are setting out to study lensed galaxies in long-exposure images in a 3-year project called Frontier Fields. They've found almost 3,000 distant galaxies after scrutinizing their first lensing object, the galaxy cluster Abell 2744, Jennifer Lotz (Space Telescope Science Institute) reported. These galaxies would have been invisible without Abell 2744, which magnified them 10 to 20 times.

■ **CAMILLE M. CARLISLE**

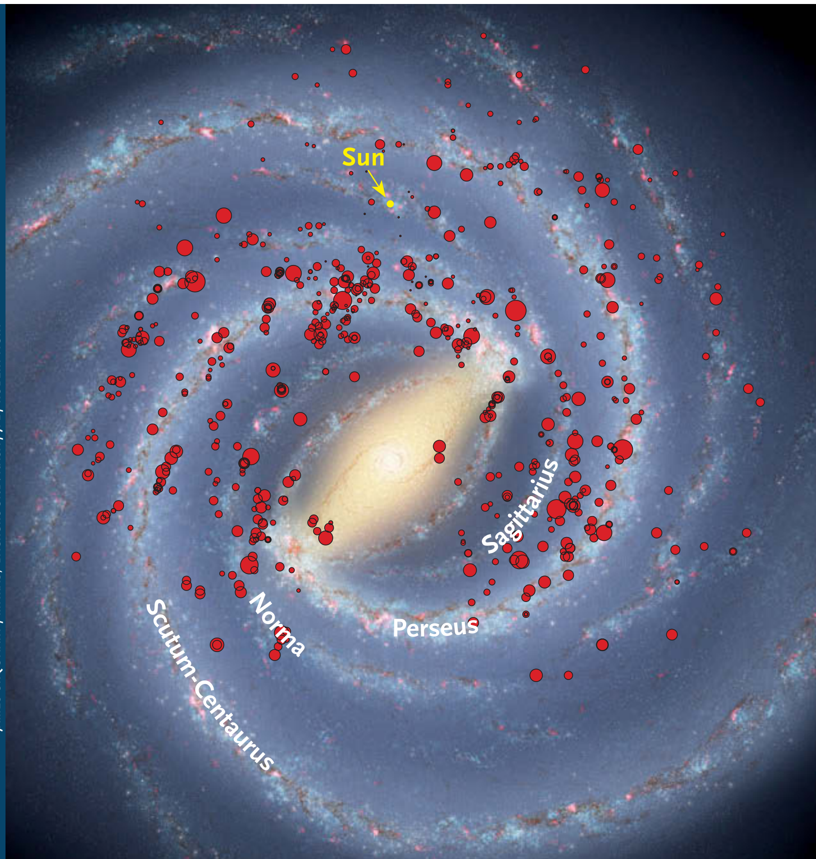
## Milky Way Hugs Self with Four Arms

**Using a 12-year radio survey of newborn, massive stars, James Urquhart (Max Planck Institute for Radio Astronomy, Germany) and colleagues have confirmed that our spiral galaxy has four major arms, not two. It's difficult to deduce the Milky Way's shape from within the disk, and though astronomers agree it has both a fat central bar and the Perseus and Scutum-Centaurus Arms (*S&T*: July 2013, foldout), they've disagreed on additional features. Far-infrared maps of interstellar gas show four large arms, whereas stars seen in infrared with NASA's Spitzer Space Telescope strongly outline only two.**

**The new work focuses on stars that live about 10 million years, and as the team reports in January 11th's *Monthly Notices of the Royal Astronomical Society*, a map of 1,650 of these stars clearly delineates all four spiral arms — confirming that the Sagittarius and Norma Arms exist. That doesn't mean Spitzer's results are wrong: the spacecraft only saw cooler, low-mass stars like the Sun, which live longer and spread out across the galaxy with time. The young stars the team targeted (red dots) don't have time to move from their birthplaces in the spiral arms, making them better tracers. ✦**

■ **J. KELLY BEATTY**

JAMES URQUHART / MNRAS; BACKGROUND: NASA / JPL / ROBERT HURT



# ISON's Day in the Sun

**"It can't do that!" I cried aloud.**

The date was November 28, 2013, and I had just received new observations of Comet ISON's brightness as it rounded the Sun.

"What is this [mild expletive] comet doing?"

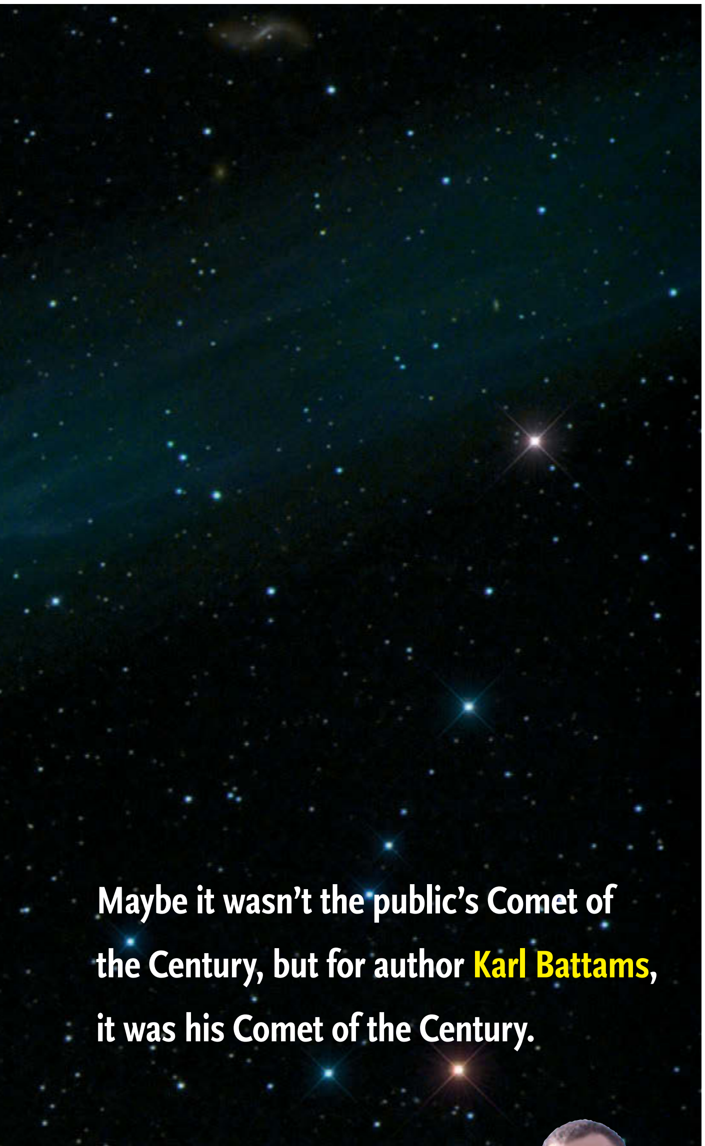
The frustration, amazement, and disbelief I experienced that day sum up quite nicely the emotional roller coaster that was the past year or so of my life. Without a doubt it's been one of the most stressful and intense periods of my career. It has also been the most extraordinary and thrilling.

So allow me to walk you through 2013 for a glimpse into how Comet ISON, C/2012 S1, had me alternating between elation and despair at almost every available opportunity.

## In the Beginning

In late 2012, the astronomy community was quick to jump on Comet ISON and the potential it held. Three things made this comet stand out. First, it was a surprisingly bright object for being one of the most distant discovered comets on record. Second, it came from the Oort Cloud, an icy reservoir surrounding our solar system and partway to the next nearest star. Third, and the final ingredient in our big bowl of hype-soup, it was following a path that would take it extremely close to the Sun. We were observing a dynamically new comet on a sungrazing trajectory that was still more than 16 months from perihelion and already a relatively bright object. This combination wasn't simply rare; it was unprecedented.

Exciting indeed, but here's where things went somewhat awry early. The astronomy community understandably began speculating on the comet's prospects, catching the ears of sensationalist media. By November 2012, with ISON still a year from perihelion, a phrase that would come to haunt me — Comet of the Century — began being plastered all over the



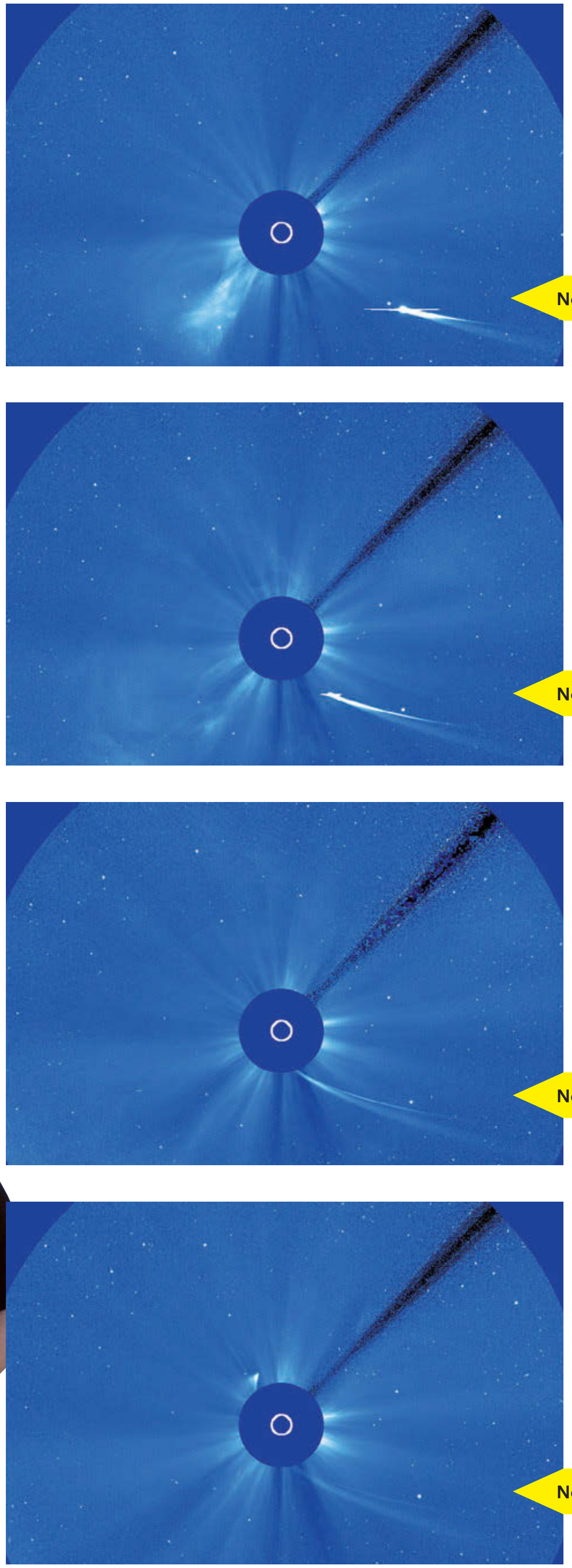
**Maybe it wasn't the public's Comet of the Century, but for author Karl Battams, it was his Comet of the Century.**

DAMIAN PEACH

internet. At this time my professional interest in ISON was already strong, but as yet I had no official involvement in studies of the comet. As an astrophysicist at the U.S. Naval Research Laboratory, I work with the NASA and ESA solar spacecraft: SOHO, STEREO, and SDO.

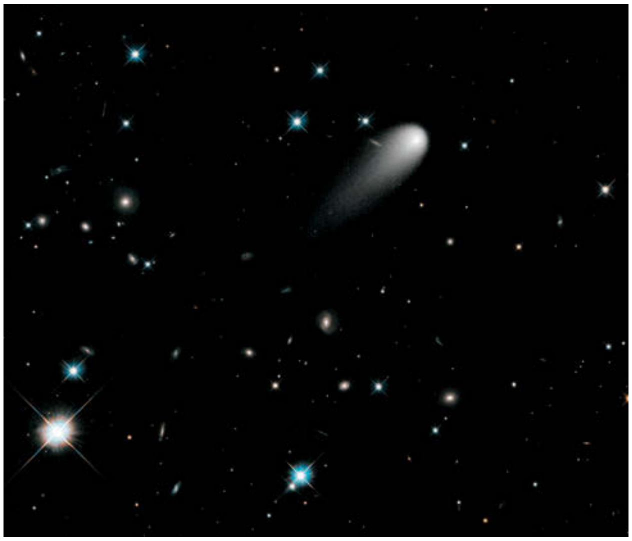
In January 2013 I was invited to join the NASA-backed Comet

***Above*: Comet ISON was a decent photographic object as evident from this November 15, 2013 view. *Right:* Author Karl Battams helped keep the world informed about ISON's latest developments.**




**The LASCO C3 camera aboard the orbiting Solar and Heliospheric Observatoy (SOHO) kept a dutiful eye on the comet as it rounded the Sun last November 28th.**

NASA / ESA / SOHO (4)



NASA / ESA / HUBBLE HERITAGE TEAM (STSCI/AURA) (2)

***Above:*** **Spacecraft as diverse as the Mars Reconnaissance Orbiter and the Hubble Space Telescope captured images of Comet ISON. Hubble's views include one of the inbound comet (*left*) amid a field of galaxies near the Gemini-Auriga border on April 30, 2013. Hubble's final view (*right*) was on October 9th when ISON was 175 million miles (280 million km) from Earth.**

***Below:*** **Austrian photographer Gerald Rhemann captured some of the best Earth-based images of the comet, including this one on the morning of November 21st, just a week before perihelion.**

ISON Observing Campaign (CIOC). Our mission was to encourage and facilitate a global and celestial observing campaign. The CIOC was high-profile and ambitious, promising extraordinary results, but also hinging on our judgment call that the comet would survive long enough for us to study it.

I had never been involved in such an endeavor, but I was assured that it would be fun and not too much work. Despite this being an unfunded effort, I agreed to volunteer my time. After all, it was just a comet. How much time could it possibly take? (Did I not mention my notoriously poor judgment?)

## Trouble, Trouble, and More Trouble

By March 2013 the campaign was under way, and already there was a problem to deal with — that awful phrase. Even before a dedicated group of professional comet scientists had been set loose on ISON, the media hype machine was already way out of control with talk of the comet being "daytime visible" and "brighter than the full Moon." The internet was full of conflicting articles and forum discussion that would either promote grossly exaggerated ideas of the comet's performance, or proclaim how we'd set ourselves up to face a Kohoutek-like public-relations disaster.

Although ISON held extraordinary scientific potential, it was never likely to be a Comet of the Century. As scientists, we were left in a position where we had to simultaneously tell everyone to not get excited about ISON for the reasons they had heard, but instead get excited for a whole different set of reasons. It was just one of many early and time-consuming challenges that the comet gave us. Well before ISON was encroaching on the inner solar system, it was encroaching on my free time.

Hype aside, the professional-astronomy community's response was overwhelmingly positive. Support for CIOC flooded in from major ground- and space-based observatory teams, as well as amateur astronomers equipped with an extraordinary array of advanced instrumentation. Things were shaping up nicely. We just lacked one key element — a cooperative comet.

Between April and October 2013, ISON appeared to almost willfully misbehave. In late spring and through the summer it should have steadily increased in brightness, but instead it remained almost stagnant. There was a small uptick during the fall, but given the lofty goals set for ISON, there were definitely hints of an underperformance issue. Compounding the problems were numerous unsubstantiated reports of how the comet was fizzling (it wasn't), and how its nucleus had already fallen apart (it hadn't). Meanwhile, a vocal minority of conspiracy theorists on the internet were claiming we were withholding information (we weren't). These were trying times.

I was starting to feel a mixture of frustration and panic. I'd just spent the best part of a year telling the world how we were about to get a spectacular amount of data from ISON, but the comet was sputtering along at only a few magnitudes brighter than it was 12 months earlier. But relief, of sorts, was to come.

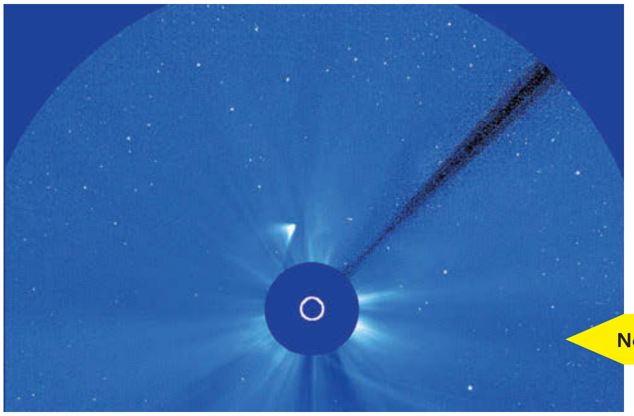
## The Brightening

Through late October and early November, ISON dramatically increased in both brightness and the rates at which it was releasing dust and gas. It wasn't yet behaving like a sungrazing comet, but it was at least behaving like a near-Sun comet. It was a start.

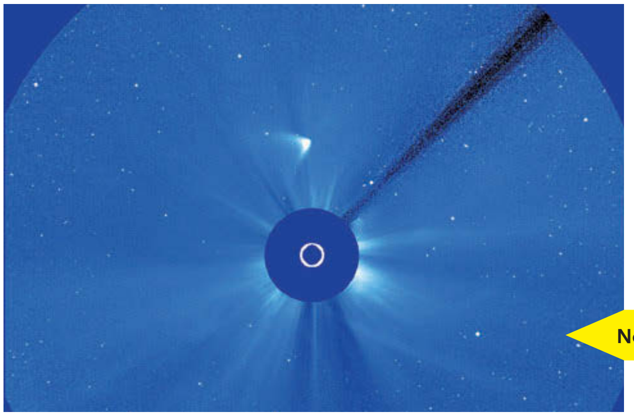
On November 21st, a healthy-looking Comet ISON entered the Heliospheric Imager-1 (HI-1) field of view on NASA's STEREO-A satellite. This was my domain, and I actually felt happy and relieved for the first time in months. But that feeling persisted for all of 48 hours. ISON's roller coaster finale was under way, and I awoke on November 25th to bad news — ISON's dust production rates had gone sky-high while gas emission had fallen through the floor. This is bad news for a comet, because it implies a massive outburst in which volatiles are exhausted and all trapped dust has been released. An exploding comet would look a lot like this. Its brightness in the STEREO spacecraft images now held the vital clues to its fate, and for this information I turned to my colleague and fellow sungrazer aficionado Matthew Knight.

He and I were shoulder to shoulder at Arizona's Kitt Peak Observatory for perihelion week, and it was there that he gave me more bad news — ISON's brightness had leveled off and was now falling. I believe his quote was, "I think we've lost it." The evidence was almost overwhelming that ISON had fallen apart and was going to fade fast. The mood of the day was somber.

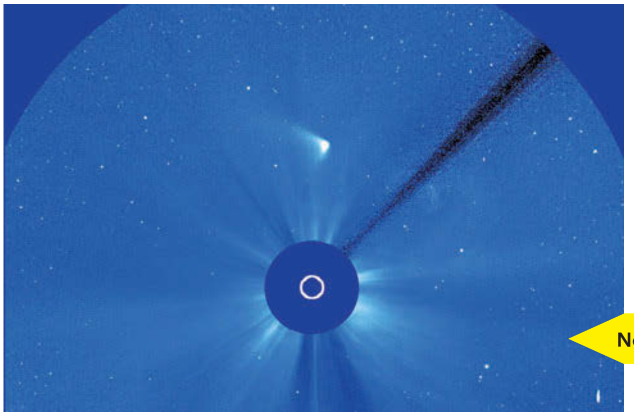
The following three days were a perfect illustration of why part of me never wants to see another comet again, while the rest of me simply can't wait for the next one. ISON had entered the LASCO C3 field of view on the SOHO satellite, and not only had it decided to stop fading,



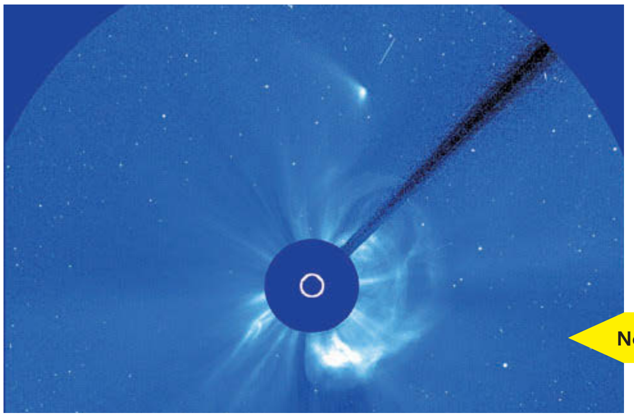
Nov. 29 - 02:35 UT



Nov. 29 - 07:07 UT

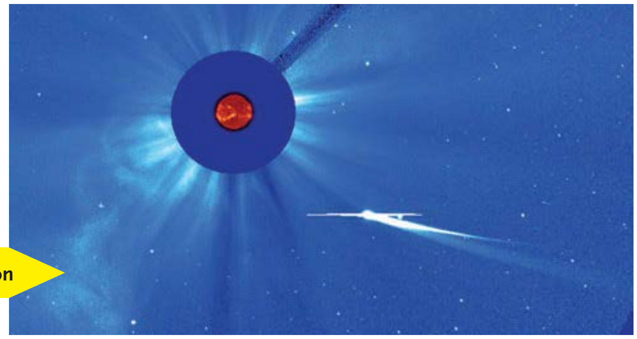


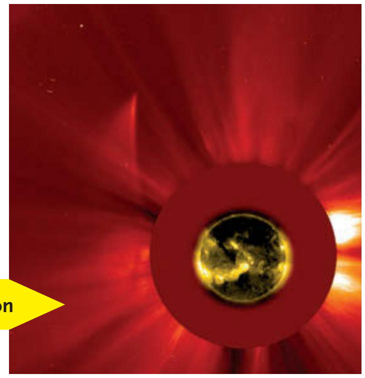
Nov. 29 - 12:30 UT



Nov. 29 - 23:32 UT

NASA / ESA / SOHO (4)




NASA / ESA / SOHO (2)

The digital eyes of Sun-gazing satellites sent most comet watchers on a roller-coaster ride of emotions as ISON swept around the Sun. Although the comet's pre-perihelion surge in brightness lifted spirits, the mood soon turned somber as it became obvious the comet's nucleus did not survive perihelion.

it was brightening, and brightening fast. The future was suddenly looking bright.

ISON, it seemed, had finally become a sungrazer. Typical comet rules no longer apply here. The surface of the nucleus was not just losing water ice to the vaporizing power of sunlight — it was losing everything! Ice and rocks on its surface were being vaporized, and the comet was lighting up accordingly. These were a wonderfully exciting few hours, but there were still surprises to come.

## Perihelion: ISON's Last Stand

November 28, 2013. Perihelion day. Bleary-eyed at 4:30 a.m., I trudged through the thin, cold air and total darkness atop Kitt Peak. My first task was to find coffee, and then to find an internet connection that would be my lifeline to both the comet and the outside world throughout what would prove to be the busiest and most amazing day of my career.

The first order of business was to look at the LASCO data. By now, the comet was just hours from perihelion and experiencing the most hostile conditions that our solar system could offer a loosely packed snowball. And the latest satellite images painted a grim picture. In this cosmic battle of "Fire v's ISON" (NASA's rather amusingly titled Google+ hangout I was to attend later that day), it seemed that fire had taken a definite upper hand. Comet ISON was now fading fast.

In the hours until perihelion, ISON was truly behaving like the sungrazing comet it was destined to be. At first, this might sound like a good thing because some sungrazers get extremely bright. But there's something else they also do rather well — fall apart and vaporize.

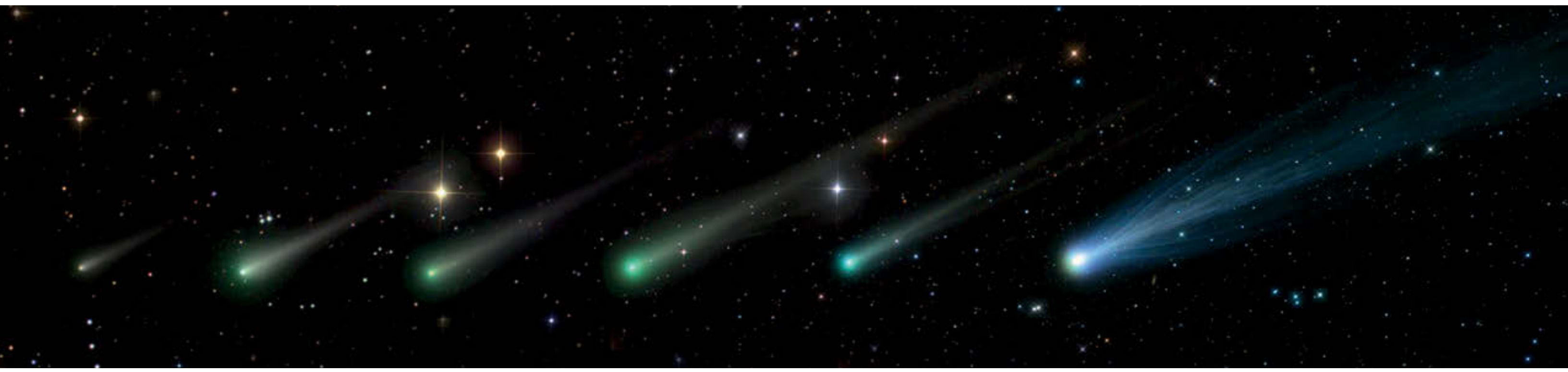
By the time ISON disappeared behind the Sun-blocking disk of the SOHO/LASCO C2 camera, we knew what we had just witnessed. We've seen it dozens of times before. A long, thin, and dense tail, tapering to a fine needle-like point, told us that Comet ISON was no longer a comet, or at least not in the traditional sense. The intense radiation and shearing gravitational forces of the Sun had obviously proven too much for it.

## Phoenix

When the comet failed to make any kind of appearance in images from NASA's Solar Dynamics Observatory, I knew it was over. In 2011, we saw two sungrazing comets in this satellite's field of view, including the spectacular C/2011 W3 (Lovejoy), so I thought our chances of seeing something this time were good. Even in the scenario of a fully fragmented comet, I thought the debris trail would light up in the Sun's million-degree atmosphere, leaving a glowing trace across magnetic field lines. But yet again this comet defied my expectations, and the massive cloud of dust and debris passed invisibly through the field of view.

Anyone who has watched Hollywood thrillers knows

This montage sequence by British astrophotographer Damian Peach follows the development of Comet ISON on (left to right) September 24th, October 11th and 27th, and November 6th, 10th, and 15th. The first four views were captured with a 17-inch reflector, while the last two were with a 4.2-inch refractor.



that you can't just kill the bad guy once and relax. You might think the drama is over, but they never stay down the first time. Although Comet ISON was certainly no bad guy, I admit to making the foolish mistake of assuming the show was over.

My heart skipped a beat when "Something has emerged!" (or words to that effect) appeared on my Twitter feed. I could scarcely believe it, but our icy phoenix was emerging from the solar corona. For one more time — albeit truly the final time — Comet ISON made me question every assumption and prediction I had made.

Why was it brightening? Maybe there is something still there. I see lots of dust, so surely it must still be producing? A nucleus — there must still be a nucleus!

Over the next few hours, as this dusty feature began to brighten, hope clouded my judgment and had me thinking once more that maybe, just maybe, we would get our December comet.

Of course, it was not to be. In hindsight I should have stuck to my initial reaction about the faint and dusty surviving feature. It was clearly not an active object. But I had fallen victim to my own hype, perhaps scarred by trying to guess and double-guess the behavior of this extraordinary and dynamic object. Subsequent computer models of the dust tail now provide compelling evidence there was no nucleus and no activity by this time. All that emerged was simply a rubble pile from the object formerly known as Comet ISON, which likely fell apart in the hours and days preceding its brush with the Sun.

In the following days these dusty remains faded fast and Comet ISON's show was truly over. There would be no December sky show, and not even the powerful eyes of the Hubble Space Telescope would give us a parting shot of the comet that had gripped our imagination and attention for well over a year.

## Postmortem

For many, ISON's death scene was anticlimactic, leaving only memories and dreams of what could have been. I understand that sentiment, but for me it's rather different. Beautiful as it is, the focus of my interest is not comets we see in the night sky. Quite the opposite. For me, the interest lies with comets near the Sun, when they are invisible from Earth but shining vividly in spacecraft images. This is a domain rich with science about not only comets but also the Sun and near-Sun conditions. And Comet ISON delivered several days of spectacular images for us to digest and analyze.

That analysis is ongoing, and during the coming months and years, numerous scientific papers and results will be announced, detailing the discoveries and insights drawn from this truly amazing event. Although there is so much more I could write here, I think this is the point on which I would like to end.

We did not get the Comet of the Century. Comet ISON

**This image by Austrian photographer Michael Jäger is one of the last Earth-based views of ISON. It was recorded in the morning twilight of November 22nd with an 80-mm (3.1-inch) refractor.**

was never brighter than the full Moon. It did not even survive its encounter with the Sun. But we never promised any of that.

What we did promise was an all-inclusive observing campaign that would result in one of the broadest, largest, and most detailed data sets of any comet in history. Without question, we got this. Within this data lies a wealth of scientific insight that will allow us to carefully piece together the story of Comet ISON, from its formation through to its demise. And this will ultimately allow us to put one more puzzle piece into the big picture of how our solar system and all its amazing contents came to be.

Everyone comes away from an event like this with his or her own perspective and opinion, and that's okay. There's no right or wrong answer. But for me, both professionally and in many ways personally, this was absolutely my Comet of the Century. Now I'm almost ready for the next one! ✦

---

*Through his Twitter feed and blog posts on NASA's Comet ISON Observing Campaign website, astrophysicist **Karl Battams** kept the world appraised of the comet's apparition.*

# Photo Contest *Winners*

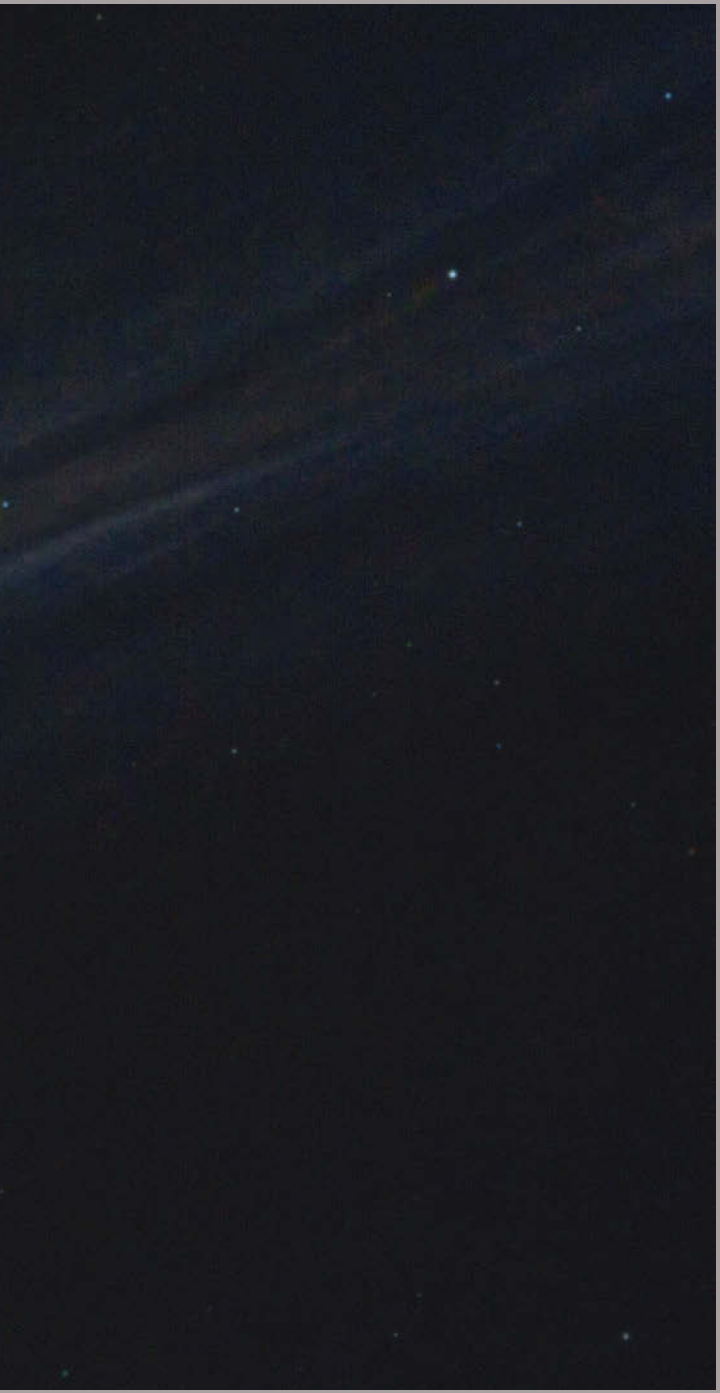
SKY & TELESCOPE

## FIRST PLACE

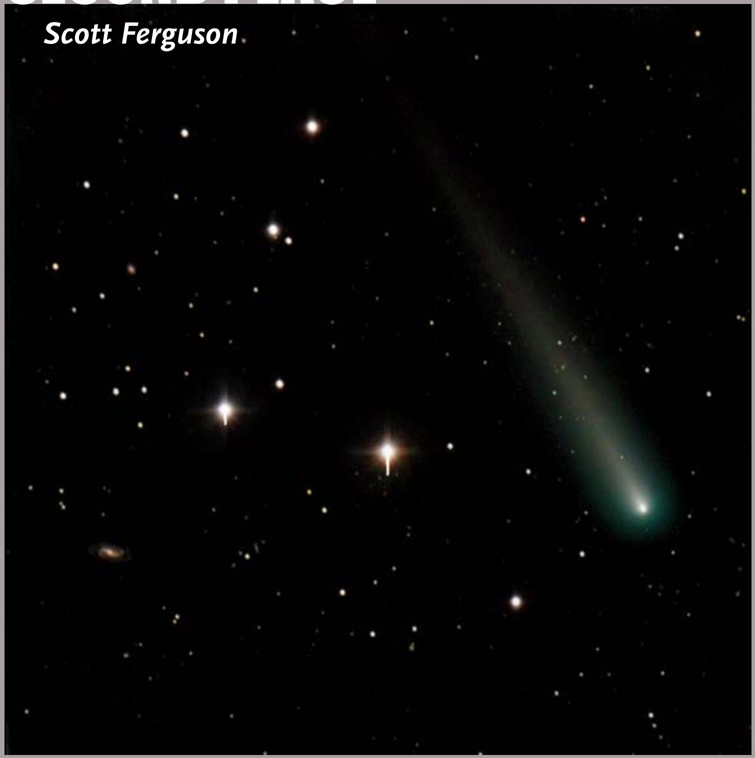
*Jerry Lodriguss*

*When we announced the Comet ISON Photo Contest we welcomed entries of every sort — from wide-field nightscapes to high-power telescopic close-ups. Though the comet's visual performance fell short of expectations, our photographically inclined readers did not disappoint.*

*The editorial and art staffs selected 12 finalists from many fine submissions, then we turned over the final vote to our readers online. The winners you selected will each receive a prize from Celestron. We extend special thanks to Celestron for its sponsorship and support.*



## SECOND PLACE



Scott Ferguson

## THIRD PLACE

Bob Sandbank

◆ *First place went to Jerry Lodriguss's extraordinary close-up — he "froze" the comet's motion in the sky by tracking on the comet and the stars in separate exposures.*

◆ *Scott Ferguson's photo puts the comet in cosmic perspective, as it passed near galaxy NGC 3429 early in its apparition.*

◆ *Bob Sandbank tracked on the background stars and captured the tail's fine wisps.*

We also announce the prizewinners (and their prizes) at skypub.com/winners.

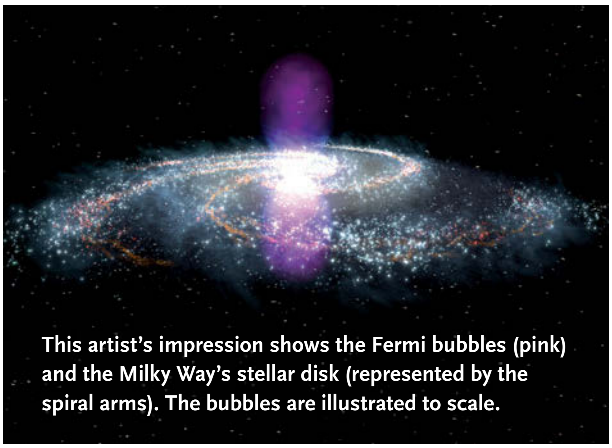
# Mystery in the Milky Way

Two gigantic bubbles ejected from our galaxy's center launched astronomers on a decade-long odyssey.

**Camille M. Carlisle**

***A villain lurks*** in our galaxy's core. Behind the glitter of the Milky Way's dusty, star-studded plane hides the culprit of one or more ancient upheavals. We don't know whether it's the central supermassive black hole or a cascade of stellar explosions. But in the last few million years, something in the galactic center spewed two gargantuan bubbles of high-speed particles into interstellar space, creating a diffuse dumbbell that spans 50,000 light-years end-to-end.

Astronomers have debated the existence of these so-called Fermi bubbles since 2003, when Doug Finkbeiner (now at the Harvard-Smithsonian Center for Astrophysics) discovered a fog of energetic particles in data from NASA's Wilkinson Microwave Anisotropy Probe (WMAP). But although they're now accepted as reality, the bubbles still perplex astronomers.



This artist's impression shows the Fermi bubbles (pink) and the Milky Way's stellar disk (represented by the spiral arms). The bubbles are illustrated to scale.

NASA GSFC

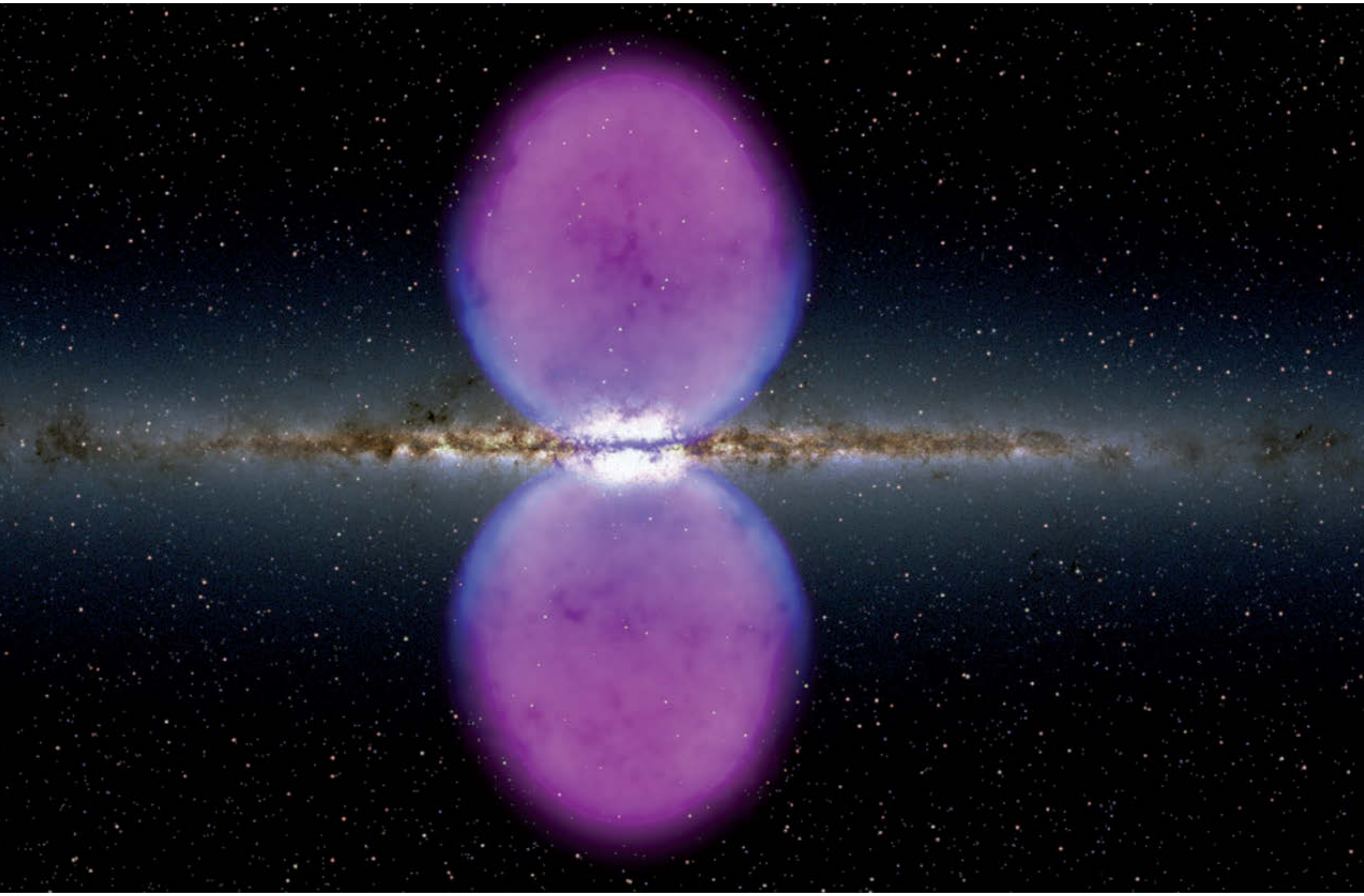
## A Curious Mist

WMAP might seem an unlikely instrument for a Milky Way discovery. WMAP's mission was to map the cosmic microwave background (CMB), the leftover radiation from the Big Bang. The spacecraft studied the CMB for nine years in five microwave frequency bands, and its results helped refine modern cosmology (*S&T*: May 2003, page 16).

But mapping the microwave background takes more than staring into deep space. The solar system is embedded in the Milky Way's disk, which means that our galaxy's glimmering plane stretches across our view of the universe. To look at the CMB, cosmologists first have to identify all the nearby emission sources littering their microwave picture — the bugs on the windshield — and then create maps of the smears so that they can subtract them from the background radiation.

While peeling apart layers of WMAP data to look at these bugs for their own sake, Finkbeiner discovered a faint haze in the galaxy's diffuse microwave emission. The feature extended several thousand light-years above and below the galactic plane before fading into the background, almost as though something were bleeding out from the core. Most of it was a long-sought signal from spinning dust grains, but there was a residue the dust couldn't explain.

Even as his spinning dust paper was appearing in the *Astrophysical Journal*, Finkbeiner warily posted another paper on the open-access research site arXiv.org, proposing that the fog might come from dark matter. The haze was synchrotron radiation, emission from relativistic electrons corkscrewing in magnetic fields. These electrons



NASA GSFC

From end to end, the Fermi bubbles (pink, illustrated using data from NASA's Fermi Gamma-ray Space Telescope) span about 50,000 light-years. The purple edges are from X-ray observations by the German-led ROSAT from the 1990s. The full bubbles do not appear in X-rays, although hints of what might be their edges do.

might be byproducts of dark matter particles annihilating one another, he suggested.

That idea didn't win over many converts. In a 2012 blog reflecting on the bubble saga, Finkbeiner wrote, "I was a young postdoc, claiming the haze might be a sign of dark matter annihilation, when many colleagues did not accept the haze was even there at all. This sounded like crackpot territory."

But despite taking the hint that "it would be good to work on something else for a while," Finkbeiner eventually came back to the haze. In 2007 he partnered with Dan Hooper (Fermilab) and Gregory Dobler (then also at the CfA) to report that the WMAP haze was consistent with what would be produced by theoretical particles called WIMPs (*S&T*: January 2013, page 26).

Dark matter or not, Finkbeiner's haze split the community. Some astronomers found it in their data; others — including the WMAP team — did not. The problem lay in the peeling process. Astronomers need a map of foreground sources in order to remove those sources from the data. But in many cases, observers create the smear map they use from the very same observations they're analyzing. They sort signals based on certain assumptions, and these assumptions influence what the final layers look like. They could even create a layer that isn't really there.

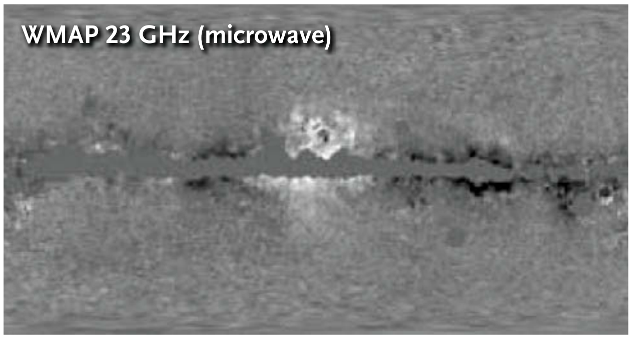
**Watch an animation of the Fermi bubbles: skypub.com/grbubbles.**

## Gamma-ray Giants

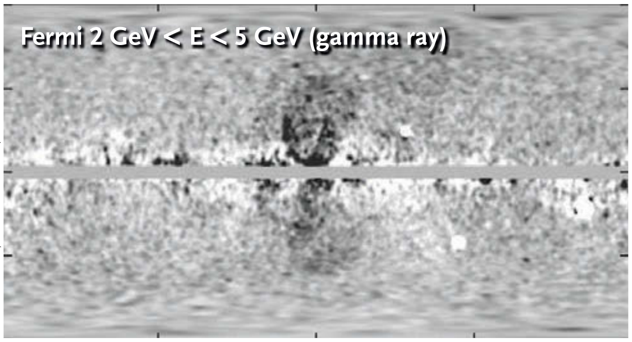
In 2010, on their quest to prove the WMAP haze existed, Dobler, Finkbeiner, and their colleagues turned to another space observatory, NASA's Fermi Gamma-ray Space Telescope. Fermi observes at energies up to a million billion times higher than those WMAP detects, but the team expected to see signals with both spacecraft because electrons moving fast enough to emit synchro-

ERIN CRAM

Astronomer Doug Finkbeiner stumbled across a faint haze of particles around the Milky Way's center that proved to be one of the largest structures in the galaxy. He and his colleagues spent years trying to confirm the puzzling discovery.




DOUG FINKBEINER / ASTROPHYSICAL JOURNAL 2004




MENG SU ET AL / ASTROPHYSICAL JOURNAL 2010

***Center map:*** **Shown here at a frequency of 23 gigahertz, the WMAP haze only appeared after its discoverer removed signals from other sources.** ***Bottom map:*** **Meng Su, Tracy Slatyer, and Doug Finkbeiner found that the haze was actually two gigantic bubbles. The trio won this year's prestigious Rossi Prize in high-energy astrophysics for their discovery of the surprising Fermi bubbles.**

tron radiation should also joust with nearby photons, kicking the photons up to gamma-ray energies.

"It was a very dramatic thing when the data first came out," Dobler recalls. And as soon as they made the maps, the astronomers found what they were looking for: a huge gamma-ray structure appeared right in the center of the galaxy, *right on top of* the microwave haze. This haze stretched even farther than the microwave signal, reaching 50° above and below the disk and spanning half the sky. "If your eyes were sensitive to gamma rays, you would be blown away every time you looked outside," he says.

Assuming the gamma-ray radiation indeed comes from electrons (and not everyone agrees that it does), both it and the synchrotron emission come from electrons ramped up to at least a few gigaelectron volts, corresponding to velocities 99.99999999995% the speed of light. In contrast, a typical electron in interstellar space moves at less than 1% the speed of light.

But the gamma-ray signal had a weird shape. More careful analysis revealed that it had hard edges: the "fog" was in fact two humongous lobes, regions filled by tangled magnetic fields and plasma containing $10^{23}$ times more energy than the Sun radiates each second. Inside, the gas is about one-tenth as dense as the material outside the bubbles, but a lot of high-speed particles zoom around in there, too. Although the lobes' bases hide in the galaxy's plane, they appear to anchor in the Milky Way's core. A magnetic sheath encases each bubble along its edge.

The edges undermined the dark matter hypothesis: edges imply an event, such as an explosion, but dark matter annihilation would continuously generate particles and therefore create a hazier distribution.

"It's somewhat unusual to discover something in a subfield that you have nothing to do with, just because you tripped over it while looking for something else," says Finkbeiner. "I'm in the uncomfortable position of not really being an expert at all in this kind of thing, even though my colleagues and I found it."

Further study only made the edges more problematic. The Fermi bubbles appear uniformly bright across their surfaces and at their boundaries — no limb darkening as we see on the Sun, but no edge brightening, either. That means the particles responsible for the emission are whizzing around like giddy bees not only near the bubbles' bases but also higher up toward the top and even at the edges. Electrons would have only a few million years to make it from the galactic center to the bubbles' tops before losing their high energies (and normally they shouldn't make it so far). That is a very short amount of time to blow bubbles 25,000 light-years long.

## Planck Steps In

Contrary to the discoverers' hopes, the Fermi bubbles failed to sway all naysayers of the microwave haze. Although the gamma-ray features were clearly real, WMAP mission scientists continued to find no concrete evidence for the haze.

That left the haze debate at the mercy of ESA's Planck satellite. Planck launched in 2009 to follow up on WMAP's CMB study, covering a much broader range of frequencies. Planck also improved on WMAP's angular resolution by roughly a factor of two. Coupled with the satellite's superb sensitivity, the heightened angular resolution gave Planck an unprecedented view of the microwave universe, refining key cosmic parameters (*S&T*: June 2013, page 10).

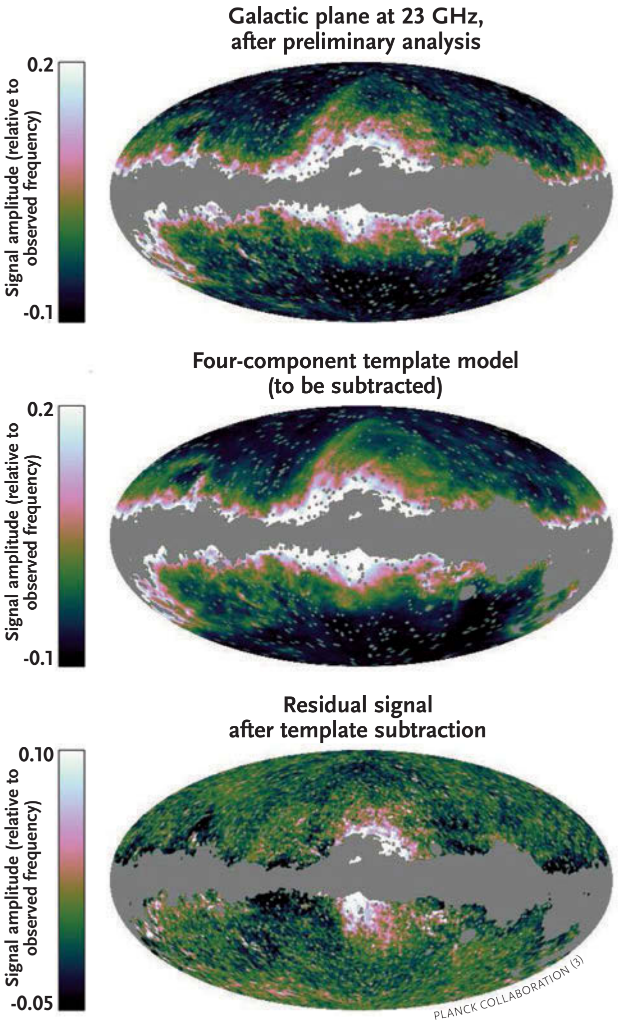
Planck's scientists decided to use the foreground detritus in their CMB observations to vet the mysterious microwave haze. First, they looked for it using the simple approach of peeling apart layers of data, as Finkbeiner and others had done. But then they tried a more complex, comprehensive approach. Instead of starting with pre-fab maps, they carefully took apart all the satellite's data at the same time, sorting each piece into different categories — such as "dust" or "cosmic microwave background" — as they went. Then they built new maps with these sorted pieces and compared them with the regular maps in order to confirm their results.

"We started this trying to actually take down the claim of WMAP conclusions from Finkbeiner and others, hoping that their analysis was, frankly, circular," admits Krzysztof Górski (JPL and Warsaw University Observatory, Poland). But the Planck results, reported in 2012, didn't work out that way. "What we ended up with was essentially confirming [the bubbles' existence]," he says.

## Villain on the Loose

The last decade's worth of accumulated evidence has still left a major mystery unsolved: what created the bubbles in the first place? There's a long list of contenders, but the answers basically fall into two categories: either supernovae did it, or the galaxy's central black hole did.

Planted in star-forming clusters around the galactic center, bursts of supernovae could blast out the particles that make up the bubbles, their explosions feeding the lobes' bases like helium tanks inflating balloons. Two facts favor this hypothesis. First, the galactic center is one of the most active star-forming regions in the Milky Way, so it's constantly producing the massive stars that go supernova. Second, astronomers know that supernova outflows create lobes, some of which can erupt out of a galaxy's disk. A few hundred thousand stellar bombs might be able to inflate the Fermi bubbles — although it would take at least 100 million years, meaning the emission Fermi detects




**ESA's Planck mission picked up an assortment of microwave signals in the Milky Way (*top*). The Planck team created a template of known types of microwave emission (*center*), which the researchers "peeled" away from the original observations. In doing so, they detected the two Fermi bubbles (*bottom*).**

NASA / CXC / CFA / ROBERT KRAFT ET AL

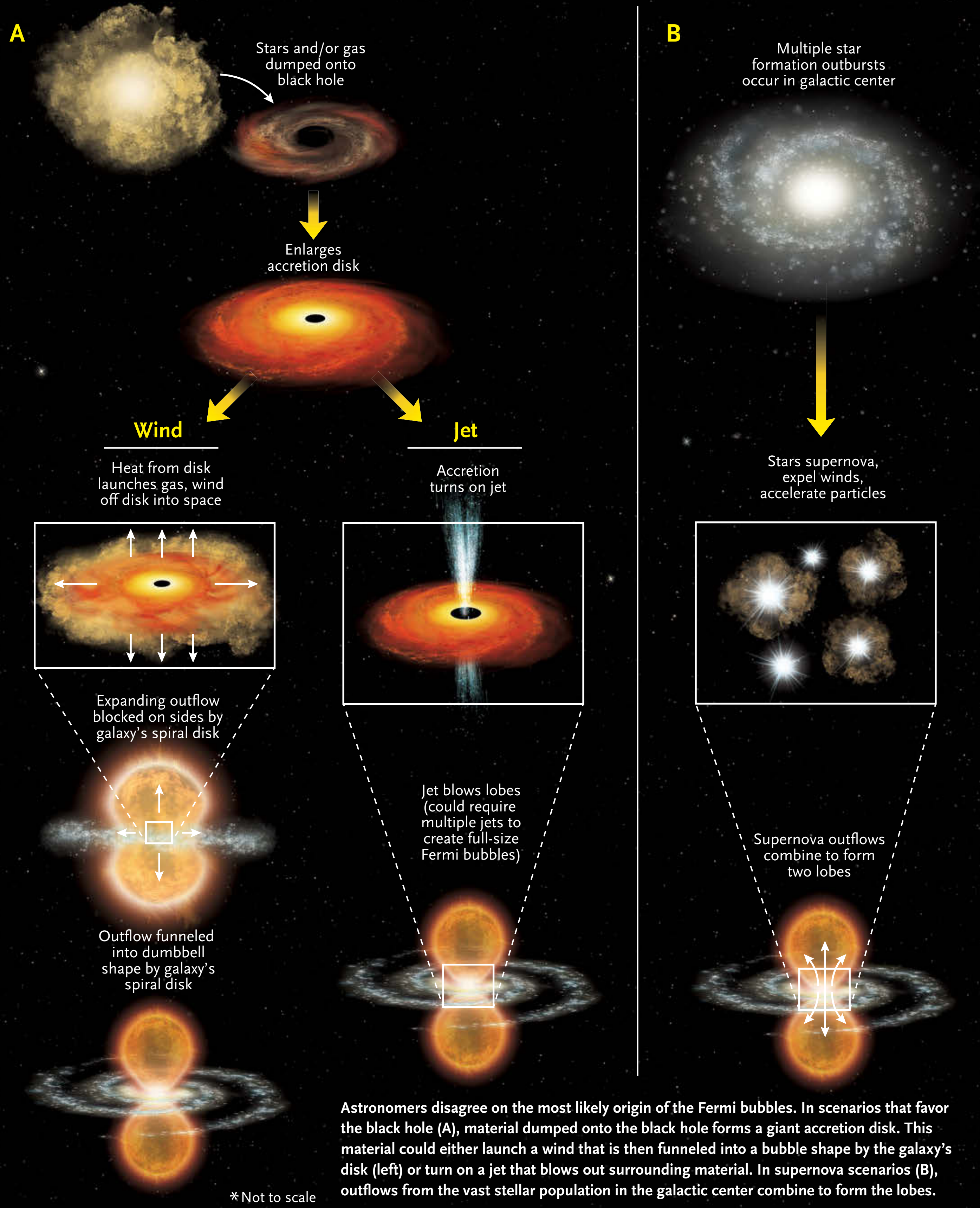
**The Milky Way** isn't the only galaxy with a belching problem: dozens of galaxies have extended structures shooting from their centers. Those from Centaurus A, for example, may stretch 10 times longer than the Fermi bubbles, with strong evidence for shock waves and photons being kicked up to high energies by speedy particles.

Not all these outflows have the same origin. Astronomers blame some on voracious supermassive black holes, which can create galaxy-scale balloons as they gobble gas. Others likely come from bursts of star birth and death in the galaxies' cores. The two scenarios might not even be exclusive: NGC 3079, for example, has fingerprints from both black hole jet and starburst activity.

Although bubbles are common in galaxies with lively black holes, many of these active galaxies also have ramped-up star formation in their centers. But there may be a time delay between these two processes, potentially as much as a couple hundred million years. If astronomers can pin down the timing of these bubble structures, they might gain a better understanding of their causes.

This image from NASA's Chandra X-ray Observatory shows the jets and bubbles emanating from the core of the galaxy Centaurus A. The jet on the left side extends 13,000 light-years.

# Potential Origins for the Milky Way's Fermi Bubbles




**Astronomers disagree on the most likely origin of the Fermi bubbles. In scenarios that favor the black hole (A), material dumped onto the black hole forms a giant accretion disk. This material could either launch a wind that is then funneled into a bubble shape by the galaxy's disk (left) or turn on a jet that blows out surrounding material. In supernova scenarios (B), outflows from the vast stellar population in the galactic center combine to form the lobes.**

S&T: LEAH TISCIONE

would only be from the latest pulse of star formation.

Among the evidence offered for supernovae are recent radio observations by Ettore Carretti (CSIRO Astronomy and Space Science, Australia) and colleagues that reveal what look like ridges of polarized emission in the bubbles. Polarization arises in the presence of orderly magnetic fields, which astronomers would expect from structures formed by supernovae. Observers had previously failed to find a strong polarization signal, suggesting that the fields inside the bubbles were turbulent. If the ridges Carretti's team detected are indeed related to the bubbles, they might reveal a lot about the bubbles' origin. But there are oddities in the observations that make several researchers doubt the result.

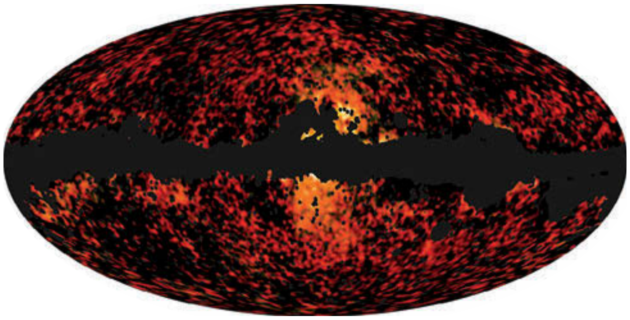
Some astronomers think the gamma-ray signal is being produced by high-speed protons instead of electrons. The supernova explanation is particularly attractive to this group, because active regions of stellar birth and death accelerate vast quantities of protons as cosmic rays. Protons might sidestep some problems with explaining the high particle velocities and the bubbles' young age.

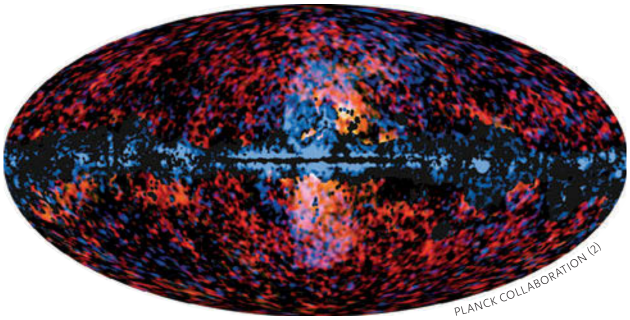
But a black hole outburst could pump out protons, too. The second possible culprit behind the Fermi bubbles is the Milky Way's own supermassive black hole, a behemoth "weighing" 4 million Suns that's nestled in the galaxy's heart. The black hole offers multiple solutions to the bubble enigma. A jet could blow out the gas and dust sitting around the galactic center, similar to how you would blow an air bubble in a glass of water with a drinking straw. Mounting evidence suggests that the Milky Way's black hole has thrown its share of tantrums in the past, from X-ray echoes and jetlike features to tantalizing hints of an ultraviolet flash bathing the Magellanic Stream a few million years ago.

But these jetlike features don't align with the galaxy's spin axis the way the bubbles do. Plus, it would take either a precessing jet or several jets to make the lobes as wide as they are — more than 15,000 light-years at their widest.

That calls for a source that's a little wider, perhaps an accretion disk. A feast of infalling gas would form a giant disk around the black hole. As material in the inner disk fell toward the black hole, it would heat up, radiating so strongly that it could launch a powerful wind of gas off itself. The disk's intense radiation would continue to push on this diffuse gas, shoving it out at relativistic speeds. The gas would pick up more material as it propagated outward, eventually clearing out the bubbles.

This disk-wind scenario avoids the shape problem. The outflow would naturally expand spherically in all directions, but in the galactic center it would be pinched in on its sides by the thicker gas and dust in the galactic plane. The outflow would consequently funnel out in the directions of least resistance (along the galaxy's rotation axis) and thereby produce the observed dumbbell shape. The scenario might also explain two rings of young stars near





PLANCK COLLABORATION (2)

**After careful analysis, the haze Finkbeiner discovered shows up clearly in Planck data at 30 and 44 GHz (*top*). The haze lines up with the Fermi bubbles as seen from 10 to 100 GeV (*bottom*, blue).**

the black hole, which could have formed from the outer sections of the giant accretion disk.

An accretion-driven outflow, whether from jets or a disk wind, prevailed as the prime suspect at an April 2013 Fermi bubble workshop organized by Finkbeiner and others. But the larger community is still divided.

Planck's polarization data, part of which is set to be released later this year, might bring some answers. The strength of the polarization signal could reveal which processes accelerate the particles inside the bubbles and keep their energies high: stronger polarization means more shocks, with the particles bouncing between the waves like a tennis ball ricocheting off two converging rackets; weaker polarization means more turbulence, with the particles energized by billowing magnetic fields.

Astronomers are also working on the complex calculations needed to follow all the major players — including electrons, protons, and magnetic fields — that will allow them to carefully compare their theories with reality.

And so even after so much toil, the case is not closed on the Fermi double-bubble. "It was completely hidden from view up until 2003, and then all of a sudden, in the span of a decade, we went from detection of this hazy, fuzzy blob toward the galactic center to an incredibly detailed view," Dobler says. "And yet we still have no idea exactly what it is. It's one of the biggest structures in the galaxy, and we just don't know. Amazing." ✦

---

*Assistant editor **Camille M. Carlisle** loves writing about anything that has to do with supermassive black holes.*

# The Return of COSMOS

Will this high-profile, big-budget television series about the universe be a worthy successor to its groundbreaking predecessor?

**WAY BACK IN 1980,** Cornell astronomer Carl Sagan and public television's KCET in Los Angeles teamed up to produce 13 hours of prime-time programming about the universe and everything therein. *Cosmos: A Personal Voyage* was an audacious undertaking at a time when American audiences were still getting used to cable television. Sagan strove to be "engrossing and captivating to a broad, general audience, while simultaneously portraying science accurately and even conveying something of what makes it tick."

Filmed on 100 locations worldwide and infused with state-of-the-art special effects, *Cosmos* was a smash hit. It has been seen by an estimated 800 million viewers worldwide, making it the Public Broadcast System's most-watched series of all time. It made Sagan an iconic figure, more celebrity than scientist in the minds of many. And his captivating style and powerful narration helped propel astronomy to new levels of "cool."

Now consider what Sagan, together with cowriters Ann Druyan (whom he later married) and astronomer Steven Soter, *couldn't* show their viewers: Voyager 2 had yet to reach Uranus or Neptune. The Hubble Space Telescope was still 10 years from launch. The concept of dark energy was decades away. Not a single extrasolar planet had been discovered.

Sadly, Sagan died in 1996, at just 62, after a difficult, years-long battle with myelodysplasia. Druyan resolved to keep his drive for scientific literacy and enlightenment alive. About six years ago she and Soter got serious about rolling out a completely retooled "Cosmos 2.0," with astrophysicist Neil DeGrasse Tyson, the irrepressible director of New York's Hayden Planetarium, serving as host and cosmic tour guide.

But the usual cable and public television outlets weren't biting. Programs such as the History Channel's *The Universe* and BBC's *Wonders of the Universe*, to name just two, had already been providing TV viewers with a steady diet of prime-time astronomy.

**J. Kelly Beatty**

The Ship of the Imagination (SOTI) explores the murky realm inside one of Titan's many lakes. SOTI appears in all 13 episodes of *Cosmos: A SpaceTime Odyssey*.
SOTI illustration courtesy Fox.

Then one evening in 2011, after speaking at an event in Los Angeles, Tyson was approached by entertainment wunderkind Seth MacFarlane. He was eager to champion astronomical outreach — after all, MacFarlane gushed, Sagan and Druyan's work had been a huge influence as he grew up. Before long, MacFarlane and Druyan were pitching *Cosmos* to Peter Rice, head of Fox Broadcasting, and wowing him. It's been a race to the finish line ever since.

Beginning Sunday evening, March 9th, *Cosmos: A SpaceTime Odyssey* will be broadcast on the Fox television network. The next night it appears on the National Geographic Channel (with "all-new bonus footage and behind-the-scenes content"). All told, it will debut in 174 countries and 47 languages — arguably the most globalized rollout of any series in television history.

Fox executives wouldn't divulge the project's cost, but it must be astronomical. The series is being produced jointly by Druyan's Cosmos Studios and MacFarlane's Fuzzy Door Productions. They're joined by veteran television executive Mitchell Cannold and Emmy-nominee Brannon Braga as executive producers. Braga is also the series' director. Bill Pope (of *Matrix* fame) directed the photography, and Rainer Gombos (*Game of Thrones, The Perfect Storm*) leads the special-effects team. MacFarlane's production company supplied the animation sequences — more on that later — voiced by A-list actors such as Kirsten Dunst, Amanda Seyfried, and Patrick Stewart.

## Prime-Time Astronomy

With that kind of entertainment firepower, can the series deliver content that's captivating enough to hold viewers' interest for 13 weeks? "We're telling completely new, untold stories," Druyan responds. More importantly, it's not just an astronomical romp across the universe. "It's about geology, climate, biology, cosmology, chemistry, engineering, and mathematics."

"*Cosmos* is a series that very much covers the whole breadth of science," agrees Cannold, who got hooked on astronomy at a young age (and who is a longtime reader of *S&T*). "From first moment to last, viewers feel they're on an adventure from the get-go, and they'll want to come back every week."

The production has been cloaked in secrecy — for example, the shooting locations haven't been revealed. (One exception: windswept cliffs overlooking the Pacific in Carmel, California, are again used for the iconic opening and closing scenes.) But Fox provided preview clips of some episodes to offer a taste of what's to come.

Two key visual elements from the original series are back. One is the "Ship of the Imagination," which transports viewers from the very micro (an atom's nucleus) to the very macro (the edge of the observable universe). Whereas Sagan's SOTI was a stylized dandelion of light, its new iteration is a sleek, bubble-domed sliver of futuristic design.

The second returnee is the "Cosmic Calendar." Sagan used this clever visualization to compress the entire history of the universe (15 billion years back then, 13.8 billion now) into a single year. By this reckoning, our solar system formed in early September — and humans didn't make their appearance until the final hour of December 31st.

Whereas the original series used actors to re-create many historical scenes, this time MacFarlane wanted animations to tell those stories. But don't expect cameos from the likes of *Family Guy's* irreverent character Stewie. Instead, these are straightforward animated sequences with a "gothic-novel feel," Cannold explains, infusing "an entirely new vocabulary for telling science history to a global audience." You'll see portrayals of a book burning in ancient China, the friendship between Isaac Newton and Edmond Halley, and William Herschel telling bedtime stories to his son, John, among many others.

The special effects are impressive, as expected. In one sequence, Tyson's SOTI hovers over a seething Sun before racing outward on a tour of the solar system. We dive down with him to the hellish surface of Venus, buzz the Viking landers on Mars, peer into a very dramatic re-creation of Jupiter's Great Red Spot, and "surf" the

JPL

Carl Sagan, posing with a Viking lander model during shooting for the original *Cosmos* series, became known worldwide as an astronomy popularizer.

*Cosmos* principals *(from left)* director Brannon Braga, host Neil deGrasse Tyson, writer Ann Druyan, and executive produer Mitchell Cannold appear together at New York Comic Con in October 2013.

CRAIG BLANKENHORN / FOX

## A SpaceTime Odyssey

"It has been written," note the show's creators, "that most epic tales consist of many stories with one hero. *Cosmos* is one story with many heroes — the saga of how the generations of humanity discovered our coordinates in space and time and began to understand nature's laws." Below are synopses of the series' 13 hour-long episodes.

FOX

**Episode 1** • March 9/10

**"Standing Up in the Milky Way"**

Host Neil deGrasse Tyson uses his "Ship of the Imagination" (SOTI) to introduce us to the mad but cosmically insightful 16th-century priest Giordano Bruno (under tree at left). Then he offers a preview of the Cosmic Calendar, which compresses the universe's 13.8 billion years into a single 12-month span.

rings of Saturn. (One technical quibble is that the asteroid and Kuiper belts veritably teem with closely spaced objects, a misconception dating back to *Star Wars*.)

In another episode, Tyson visits the supermassive black hole at the Milky Way's core and, throwing caution and physics to the wind, dares to go in. The SOTI shakes violently amid blazing light as it draws near the black hole's event horizon, and just as it's about to cross over . . . well, you'll have to watch to see what happens.

## A New Host for a New Generation

It's inevitable that many of you will want to compare and contrast the original series with the new one. That's valid, but only to a point. "Words like 'reboot' and 'sequel' are misleading," cautions Cannold. The new offering is "utterly faithful to the iconic elements of the original series. But all of the material is new and fresh."

The host is likewise "new and fresh." Tyson is the obvious choice, at least for American audiences. He's an increasingly well-known popularizer of all things astronomical. Besides his day job in New York, he has hosted the PBS series *Nova Science Now,* authored 10 books, appears often on national television, has 1½ million followers on Twitter, and even has a weekly radio show about space called *Star Talk*.

**For more information about this TV series, visit skypub.com/cosmos.**

Tyson feels an obligation to carry on Sagan's legacy of educating the public about astronomy. Now 55, he first met Sagan in 1975 while considering where to go to college. Surprisingly, Sagan invited him to Cornell University (in upstate New York) and gave the wide-eyed teenager a personal tour of his lab. It didn't work — Harvard got the nod — and in the years thereafter the two crossed paths only a handful of times.

Sagan was a hip-looking 46 when *Cosmos* first aired. He had an easily recognizable but measured delivery. Tyson, by contrast, has a more flamboyant style and envious comedic timing, characteristics that make him much better known among Millennials than among Baby Boomers. Thanks to all his TV face time, Tyson is a polished presenter.

But can he convey the same sense of awe and wonderment that made Sagan a household name? Cannold, who is president of Cosmos Studios, puts it

**The Cosmic Calendar compresses 13.8 billion years into the span of a single year, starting with the Big Bang (on January 1st) and ending now (December 31st).**


FOX

**Episode 2** • March 16/17
**"The Rivers of Life"**
Evolution and natural selection have taken life on Earth from basic microbes to the stunning biodiversity we see around us today. But mass extinction events have truncated many branches in the Tree of Life.

**Episode 3** • March 23/24
**"When Knowledge Conquered Fear"**
Mathematical insights by Newton and Halley made sense of orbital motion and transformed comets from malevolent omens to Rosetta Stones of solar system history.

**Episode 4** • March 30/31
**"Hiding in the Light"**
We're transported back in time to witness the emergence of the scientific method and to explore the intertwined meanings of "light" and "enlighten-ment" during the past two millennia.

**Episode 5** • April 6/7
**"A Sky Full of Ghosts"**
Viewers discover how light, time, and gravity combine to distort our perceptions of the visible universe. A motorcycle ride through the Italian countryside is used to demonstrate rela-tivistic motion.

SARAH MOZAL / COSMOS STUDIOS

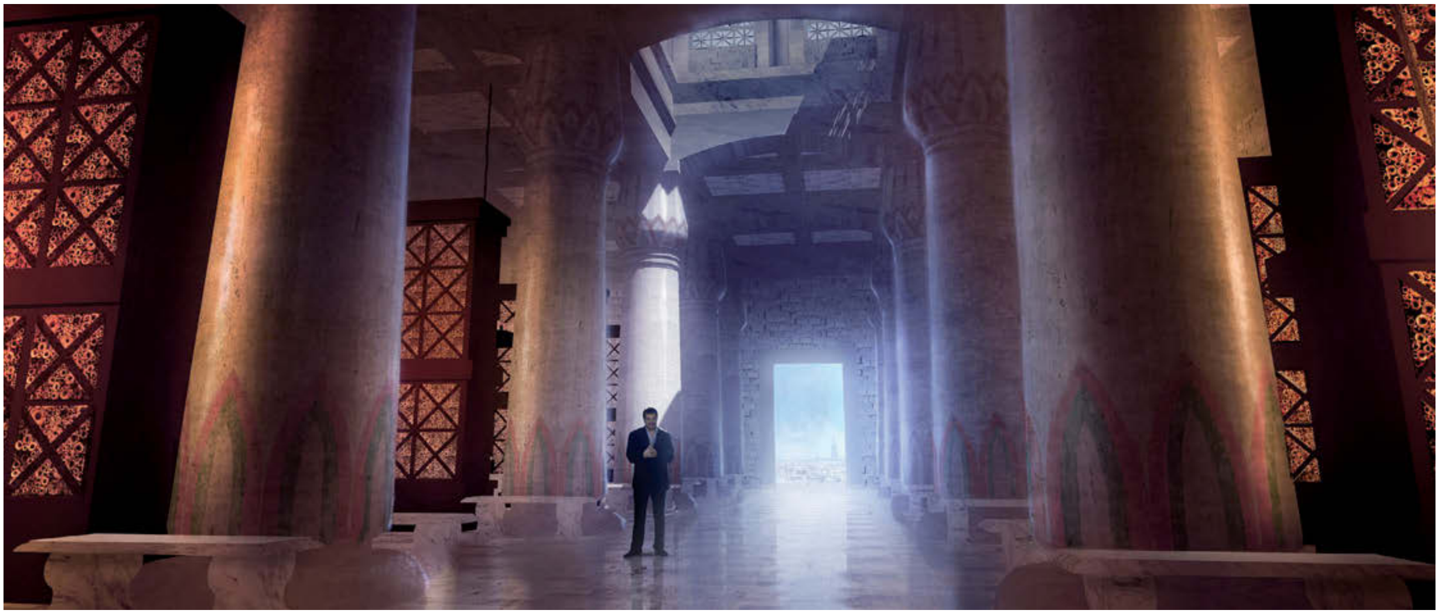
***Above***: **Writer Ann Druyan and director Brannon Braga are pictured on location in Carmel, California. *Below*: Host Neil Tyson walks through a re-creation of the corridors of the great Library of Alexandria in ancient Egypt, whose vast collection of written knowledge included an estimated 700,000 scrolls.**

this way: "Neil's enthusiasm and energy are appropriate for the times, just as Carl's were for those times. The audience will find that he's effected a style all his own — an aspect of a kid in a candy store. Neil is very good at conveying the awe, wonder, and magic."

Druyan and Soter have kept the writing sparse yet evocative, and Tyson demonstrates that he is indeed a worthy successor to his boyhood hero. "There are people who remember Carl who'd say I'm assuming his mantle," Tyson reflects. "The reality is those are big shoes to fill, so I don't try, because I can't. But I *can* be a really awesome version of myself."

Someone who watches all 13 of the 42-minute-long episodes will see the equivalent of five full-length movies — completely devoted to science. "At a minimum I want to reignite people's curiosity in the natural world," Tyson says. "Our collective goal is that the series empowers you to want to learn more."

Given today's cultural environment, the producers feel there's much at stake here besides Nielsen ratings. "When *Cosmos* was first broadcast, the attitude toward science was much friendlier," Druyan explains. She regrets that



FOX

**Episode 6** • April 13/14

**"Deeper, Deeper, Deeper Still"**

Tyson takes an inward turn, using SOTI to navigate a dewdrop at microscopic scales and to drill down even further, exploring the makeup of atoms and the process of fusion.

**Episode 7** • April 20/21

**"The Clean Room"**

Determining the true age of Earth has frustrated scientists for centuries. The answer emerges in the saga of a kid from Iowa who finds a foolproof way to determine it — but who attracts a nemesis along the way.

**Episode 8** • April 27/28

**"Sisters of the Sun"**

There's double meaning here: these "sisters" are not only the stars that fill the night sky above us but also the pivotal yet largely unsung female astronomers of the early 20th century.

**Episode 9** • May 4/5

**"The Electric Boy"**

Michael Faraday overcomes the abject poverty he endured as a child to become a scientific great whose insights into field theory permeate all the electronic wonders of our modern-day world.

so many people have become uninformed about and even openly hostile toward fact-based thinking, and specifically, climate research. But she senses that the “pendulum is swinging back our way. We’re ready to explore again.”

Druyan and her dream team promise to offer viewers a “vision of the cosmos on the grandest scale,” presenting scientific concepts with “stunning clarity, uniting skepticism and wonder, and weaving rigorous science with the emotional and spiritual into a transcendent experience.”

That’s a tall order in this whiz-bang age of seconds-long sound bites and fleeting attention spans. Let’s hope they succeed. ✦

---

*Senior contributing editor* ***Kelly Beatty*** *also previewed the original* Cosmos *series in the September 1980 issue. For summaries of those episodes, visit* ***www.tv.com/shows/cosmos/episodes***.

***Right***: **In this *Cosmos* scene, the SOTI hovers over the surface of Mars. *Below*: Astrophysicist Neil Tyson, director of New York City’s Hayden Planetarium, has become a well-known popularizer of astronomy. He has appeared on shows hosted by David Letterman, Jay Leno, Jon Stewart, Stephen Colbert, and others. He has an undergraduate degree from Harvard and a Ph.D. in astrophysics from Columbia University.**

PATRICK ECCLESINE / FOX

FOX

**Episode 10** • May 11/12
**“The Lost Worlds of Planet Earth”**
Viewers see their home planet up close and personal, probing its lands, oceans, and all living things — past, present, and future. Will alien worlds look anything like ours?

**Episode 11** • May 18/19
**“The Immortals”**
Do we have to die? Do civilizations have an expiration date? Tyson explores our modest attempts to communicate with other intelligent life and introduces us to a spaceship populated by our future descendants.

**Episode 12** • May 25/26
**“The World Set Free”**
Viewers are reminded that Earth’s resources are not boundless and that climate change is a growing threat. Can human resolve and technology combine to save our planet from the fate that befell Venus?

**Episode 13** • June 1/2
**“Unafraid of the Dark”**
Having traveled from the heart of an atom to the farthest reaches of the cosmos, Tyson confronts the realization that we know little about the cosmic ocean into which we’ve taken our first, tentative steps.

# Stargazing Simplified

*James Mullaney*

FRED ESPENAK

## A small scope at medium-low power has boundless potential.

A spotting scope is perfect for viewing the Moon near the horizon, where atmospheric distortion would disrupt the view in a larger telescope.

JAMES MULLANEY (2)

*Alas!* Today's hectic lifestyle, obsession with electronic gadgets, and the mantra that "bigger is better" have carried over into amateur astronomy. Witness the Messier Marathon, computer-controlled remote CCD-imaging telescopes, and observatory-sized, trailer-mounted Dobsonian reflectors. Casual, relaxing stargazing seems to be largely a thing of the past — something practiced by only a few purists. To me, stargazing should provide a relaxing interlude from the pressures and worries of everyday living rather than contributing to them.

I've been privileged to use some of the largest telescopes in the world, including a 30-inch Brashear refractor. While the views in giant scopes can certainly be awesome, my most enjoyable stargazing sessions have been with very small instruments. As an example, I'll share some of the exciting celestial sights I continually enjoy on clear nights using a basic 3-inch achromatic spotting scope intended for nature study such as bird watching. It has a fixed magnification of 30× — no fiddling with eyepieces in the dark or deciding which to use. Its field of view is 100′. That may seem modest in this age of fast apochromatic refractors and wide-field 2-inch eyepieces, but it's ample to frame many of the sky's best vistas.

With its simple tabletop alt-azimuth mount and a total weight less than five pounds, my spotting scope is always ready for instant use; no cool-down time needed! Being a refractor with an unobstructed light path, its images are razor sharp. And the views are virtually unaffected by poor atmospheric seeing due to the scope's small aperture and low magnification. For more prolonged sessions, I also use it on a vintage Unitron alt-azimuth mount with slow-motion controls and a tripod with wooden legs, which are far superior to metal legs at damping vibrations.

This little glass has yet another virtue over big ones: it has a relatively limited number of targets. You might not consider this an advantage — but it is! I'm not tempted to find large numbers of objects every time I go out, eliminating the malady I refer to as "saturated stargazing." Astronomy writer Michael Covington tells us that "All galaxies deserve to be stared at for a full 15 minutes." I would extend this advice to every celestial object. I prefer to view at most a dozen of the sky's wonders (including the Moon and planets) during the course of an evening in a relaxed and contemplative manner. To me, glancing at an object, then rushing on to another and another is like reading the CliffsNotes of the world's great novels.

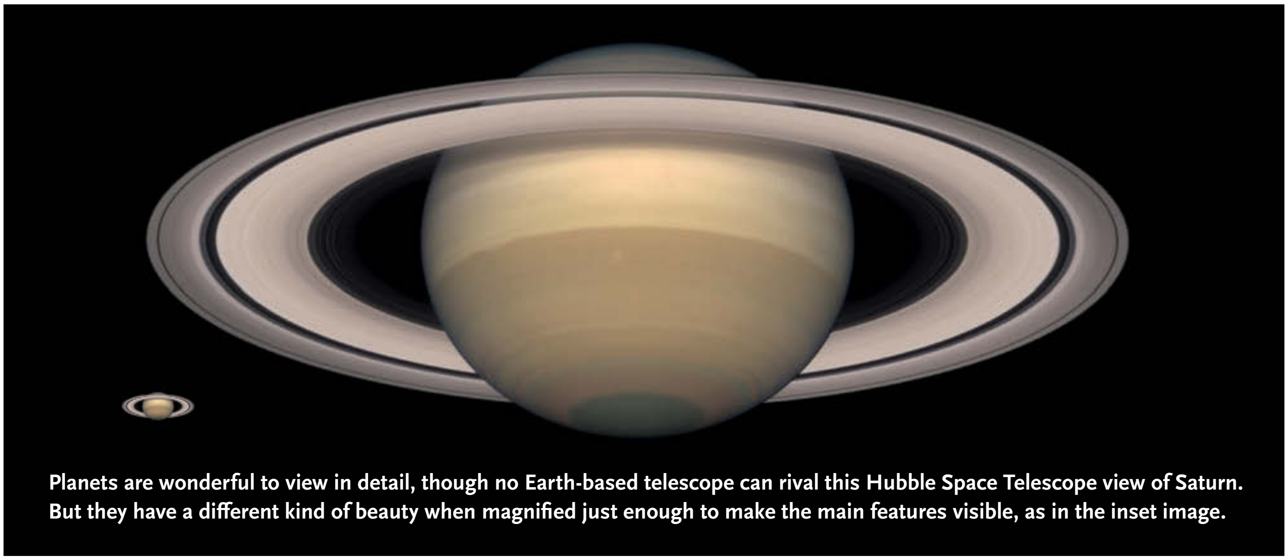
JOHANNES SCHEDLER

**Many widely spaced double stars appear more impressive in small telescopes at low magnifications than in big scopes. Colorful Albireo, shown here, is a prime example.**

Here are some of the celestial sights that I enjoy most through the small spotting scope.

**The Moon.** Those who have ever only looked at our lovely satellite close up with high magnifications are surprised and delighted at its crystalline appearance at 30×. Lunar eclipses are at their absolute best at such a magnification, which bridges the gap between typical telescopic and binocular views. So too is earthshine, the "new Moon in the old Moon's arms," which seems more intense in this little scope than in bigger or smaller instruments. And for the ultimate thrill, I watch lunar occultations of other sky targets, especially planets or large star clusters such as the Hyades (see page 50). The Moon appears suspended in three-dimensional space as it glides across a cluster, covering and then uncovering individual stars, making its slow eastward orbital motion a joy to watch.

**Planets.** Several of the planets look positively jewel-like magnified just 30 times! Venus when in its crescent phase a month or two before and after inferior conjunction is one example — a tiny, radiant silver sliver hanging in the sky. Jupiter has to be one of the grandest and most thrilling sights in the heavens. The endless dance of the Galilean moons about the planet, continually changing position and configuration, never loses its fascination.



**Planets are wonderful to view in detail, though no Earth-based telescope can rival this Hubble Space Telescope view of Saturn. But they have a different kind of beauty when magnified just enough to make the main features visible, as in the inset image.**

NASA / HUBBLE HERITAGE TEAM / STSCI / AURA

Watching the satellites disappearing in front of or behind the planet's disk, or passing in or out of its shadow, is like watching a celestial four-ring circus! And then there's Saturn, the supernal wonder of celestial wonders, the iconic image of astronomy, the most otherworldly object in the heavens. The spectacle of the rings hugging the planet, just barely resolved at 30×, looks too beautiful and ethereal to be real!

**Comets.** My little scope is ideal for viewing bright comets, its wide field typically taking in the entire object — nucleus, coma, and tail. It's also superb for including other objects in the same view, which sometimes makes it possible to see the comet's motion in a matter of minutes.

**Double stars.** My favorite deep-sky targets in the 3-inch glass are double and multiple stars. Literally thousands can be split even in such a small aperture. Many people's favorite is magnificent Albireo (Beta Cygni). Its topaz-orange and sapphire-blue hues are magnificent, with the components separated just right at 30×.

But this jewel is basically a summer and fall target. A great substitute in late winter is h3945 in Canis Major. And moving into spring, there's also Iota Cancri. I've christened them the Winter Albireo and Spring Albireo, respectively, and both of these clones are beautiful sights in the smallest of telescopes. Another favorite target is wide Mizar and Alcor at the bend of the Big Dipper's handle, with Mizar itself neatly resolved into blue-white gems at 30×.

Most readers have viewed the stunning quadruple Theta$^1$ Orionis — better known as the Trapezium — at the heart of the magnificent Orion Nebula. At 30×, the stars in this tight knot appear nearly in contact with one another!

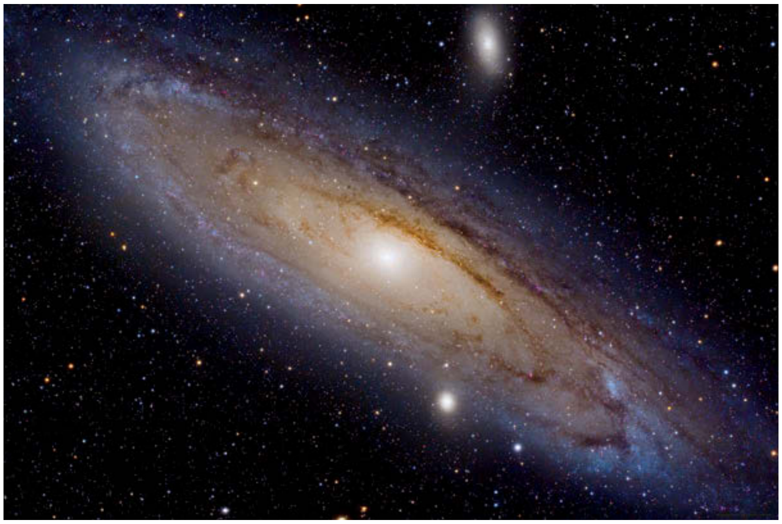
At the other extreme, the sky contains many widely separated pairs that look like unrelated stars in a large telescope and appear to best effect in a small glass. One example is Omicron$^1$ Cygni, the sky's widest beautiful triple system. It displays striking contrasting hues of orange, white, and blue at low power, but the effect disappears as magnification increases and the components become unduly separated.

**Star clusters, asterisms, and associations.** The magnificent Pleiades in Taurus and Beehive Cluster in Cancer are perfect matches for my little glass, filling its field of view. The grand Double Cluster in Perseus is a dual starburst against a rich Milky Way field.

Although globular clusters need larger scopes to appreciate their full magnificence, these fuzzy starballs look remote and mysterious at 30×. And some of the brighter ones, such as M13 in Hercules and M22 in Sagittarius, sparkle when viewed with averted vision.

AKIRA FUJII

*Left:* The open cluster Messier 44, in the center of this photo, tends to appear like a group of unrelated stars when viewed at high power. *Lower left:* M31, the Andromeda Galaxy, makes an incredible wide-field tableau with its satellites M110 (top) and M32 (bottom). *Below:* Cigar-shaped M82 and the huge spiral M81 form the brightest galaxy pair in the sky.



LORENZO COMOLLI

ADAM BLOCK / NOAO / AURA / NSF

AKIRA FUJII

Finally, there are truly expansive stellar groupings such as the Alpha Persei Association and big asterisms like the Coathanger (Collinder 399) in Vulpecula, both of which are amazing in a wide field at 30× or less.

**Nebulae.** Sure — everyone has seen the magnificent Orion Nebula before. But have you viewed the entire complex? In addition to M42 and M43, it includes the sparse open cluster NGC 1981 to the north and the two neighboring double stars Iota Orionis and Struve 747 just to the south — all of which can be seen in a single eyepiece view at 30× on the 3-inch. Again, most readers have seen the Lagoon Nebula (M8) and Trifid Nebula (M20) in Sagittarius — but have you seen them together in same eyepiece field, as I can in my spotting scope?

Diffuse nebulae aren't the only nebulous attractions — we also have planetaries. Everyone's favorite, the Ring Nebula (M57) in Lyra, looks like a tiny elliptical donut, with the central hole just visible using averted vision at 30×. Seeing it just barely resolved is quite thrilling! The Dumbbell Nebula (M27) in Vulpecula is much bigger and more obvious, looking like a little pillow floating among the rich Milky Way background. And a third type of nebulosity is represented by the Crab Nebula (M1) in Taurus. I can spy this supernova remnant easily in the 3-inch, and although it's small at 30×, its elliptical shape is obvious.

**Galaxies.** This entire article could easily be devoted to the galaxies visible in a 3-inch glass. At the top of the list is the magnificent Andromeda Galaxy (M31) and its two dim companions, M32 and M110. Not only do all three fit in the same eyepiece, but the main galaxy itself extends far beyond my scope's wide field of view in opposite directions. Sweeping back and forth across this wonder of the great beyond on a dark night is thrilling beyond words.

Other favorites with my little glass are the Triangulum Galaxy (M33), Bode's Galaxies (the M81/M82 pair) in Ursa Major, the Whirlpool (M51) in Canes Venatici, the Sombrero (M104) in Virgo, and the big Sculptor Galaxy (NGC 253). All of these island universes are alluring sights in the 3-inch and have a decidedly remote look to them at just 30× — unlike the close-up views at higher powers.

**The Milky Way.** Saving the best for last, the grandest object in the entire heavens is our own Milky Way Galaxy! Sweeping its massed star clouds at low power is an exhilarating experience — especially those of summer in Cygnus, Scutum, and Sagittarius. This is truly Downtown Milky Way! And while the winter Milky Way isn't as rich and obvious in those months, it's still a starry wonderland in constellations such as Cepheus, Cassiopeia, Perseus, Auriga, and Puppis.

Whatever part of this Great White Way of the heavens you choose to view, be alert to an amazing illusion — one that favors low-power, wide-field views, and is actually at its best in binoculars. As you stare into a particularly rich star cloud, note that the brighter stars appear closer to you than the fainter, more distant ones behind them. As the eye-brain combination makes this connection, a sensation of 3-dimensionality can occur, causing the Milky Way to jump right out of the sky at you!

It's always been a rule of thumb in stargazing that the smaller the telescope, the more often it will be used. Part of that relates to weight and portability. But as the above discussion clearly demonstrates, there's certainly more involved here than size alone! ✦

***James Mullaney****'s latest book is* Celebrating the Universe!: The Spirituality & Science of Stargazing.


"UNBELIEVABLE"
"INCREDIBLE"
"WOW"
THERE'S A LOT YOU CAN SAY ABOUT SOLARMAX II.
AND ABOUT THE VIEW IT DELIVERS.
From the compact 40mm PST (Personal Solar Telescope) to the research-grade SolarMaxII 90, there's a Coronado scope for you.
The Coronado SolarMax H-alpha solar telescopes have long been recognized as the premier solar instruments for the amateur and professional for years. With the introduction of the SolarMax II with patented RichView™ tuning, the best is even better. The RichView™ tuning method works by directly tuning the etalon, the heart of the Coronado Ha filter system, which gives you greater tuning range and detail than that found on other solar telescopes.
You can easily zero in on precise wavelengths of light for each area of interest for the highest contrast views of active regions, flares, filaments and other surface features or for spectacular images of prominences on the solar limb. With prices for Coronado starting lower than ever, these amazing solar telescopes are within the reach of even the casual observer.
For more information on the whole Coronado line of solar telescopes, visit meade.com/coronado.
SolarMaxII 90
from $3,599
SolarMaxII 60
from $1,299
PST (Personal Solar Telescope)
from $699
Optics Planet 800.504.5897
OPT Telescopes 800.483.6287
B & H Photo 800.482.8143
Telescopes.com 800.303.5873
Woodland Hills 888.427.8766
Adorama 800.223.25006
Canada • Khan Scopes 800.580.7160
MEADE INSTRUMENTS
Innovative products for curious minds
since 1972
©2013 Meade Instruments Corp. All rights reserved. 30-13046 Solar image shown taken through a Coronado SolarMax 90.

The Moon will pass through the Hyades star cluster (directly above) on April 3rd.

## In This Section



PHOTOGRAPH: AKIRA FUJII



**Additional Observing Articles:**

# Sky at a Glance

## APRIL 2014

**3** **EVENING:** North American binocular and telescope users can watch the waxing crescent Moon pass through the Hyades star cluster, occulting (hiding) several medium-bright stars; see page 50.

**6** **EVENING:** The half-lit Moon shines near Jupiter, as shown on page 48.

**8** **ALL NIGHT:** Mars is at opposition.

**10** **EVENING:** The Moon shines below Regulus.

**12** **DAWN:** Neptune shines 0.7° south of Venus, a difficult but interesting view through a telescope.

**13** **ALL NIGHT:** Vesta, the brightest asteroid, is at opposition. See the February issue, page 50, for a guide to Vesta and Ceres.

**14–15** **ALL NIGHT:** Mars is closest to Earth for 2014; see the March issue, page 50, for a viewing guide.

**LATE NIGHT:** The full Moon shines near Mars and very near Spica. A total lunar eclipse is visible in the Americas; see page 60 for details.

**17** **DAWN:** Saturn shines very near the Moon. The Moon occults Saturn in southernmost South America and the South Pacific.

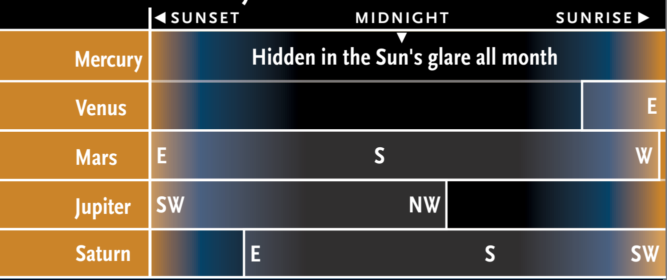
**22** **PREDAWN:** The weak Lyrid meteor shower peaks this morning; see page 52.

**25, 26** **DAWN:** The waning crescent Moon shines upper right of Venus on the 25th and lower left of Venus on the 26th.

**27** **A SOLAR ECLIPSE** is visible in Antarctica, Australia, and parts of Indonesia, as described on page 49.

## Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH




## Moon Phases

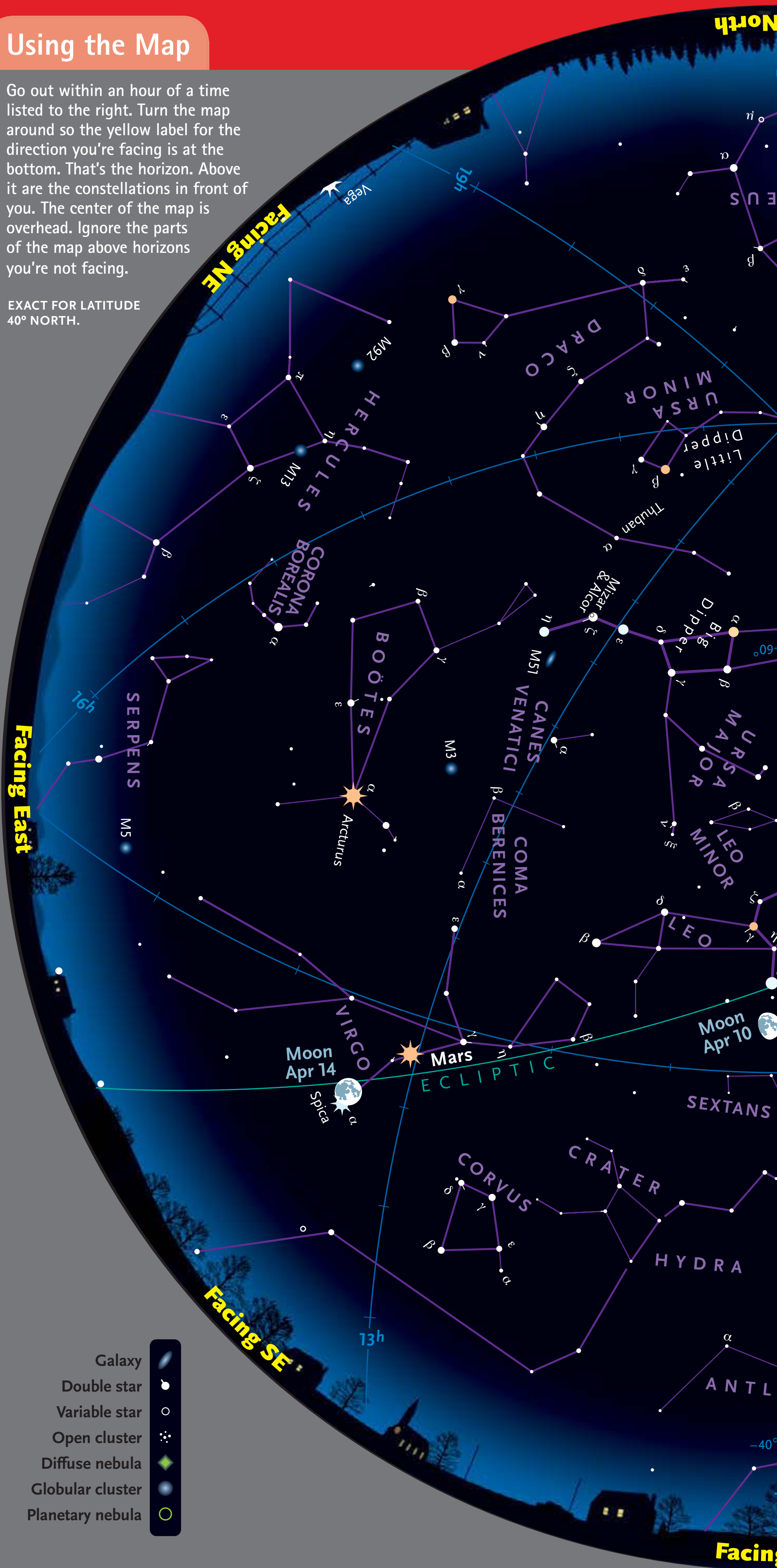
- First Qtr April 7 4:31 a.m. EDT
- Full April 15 3:42 a.m. EDT
- Last Qtr April 22 3:52 a.m. EDT
- New April 29 2:14 a.m. EDT

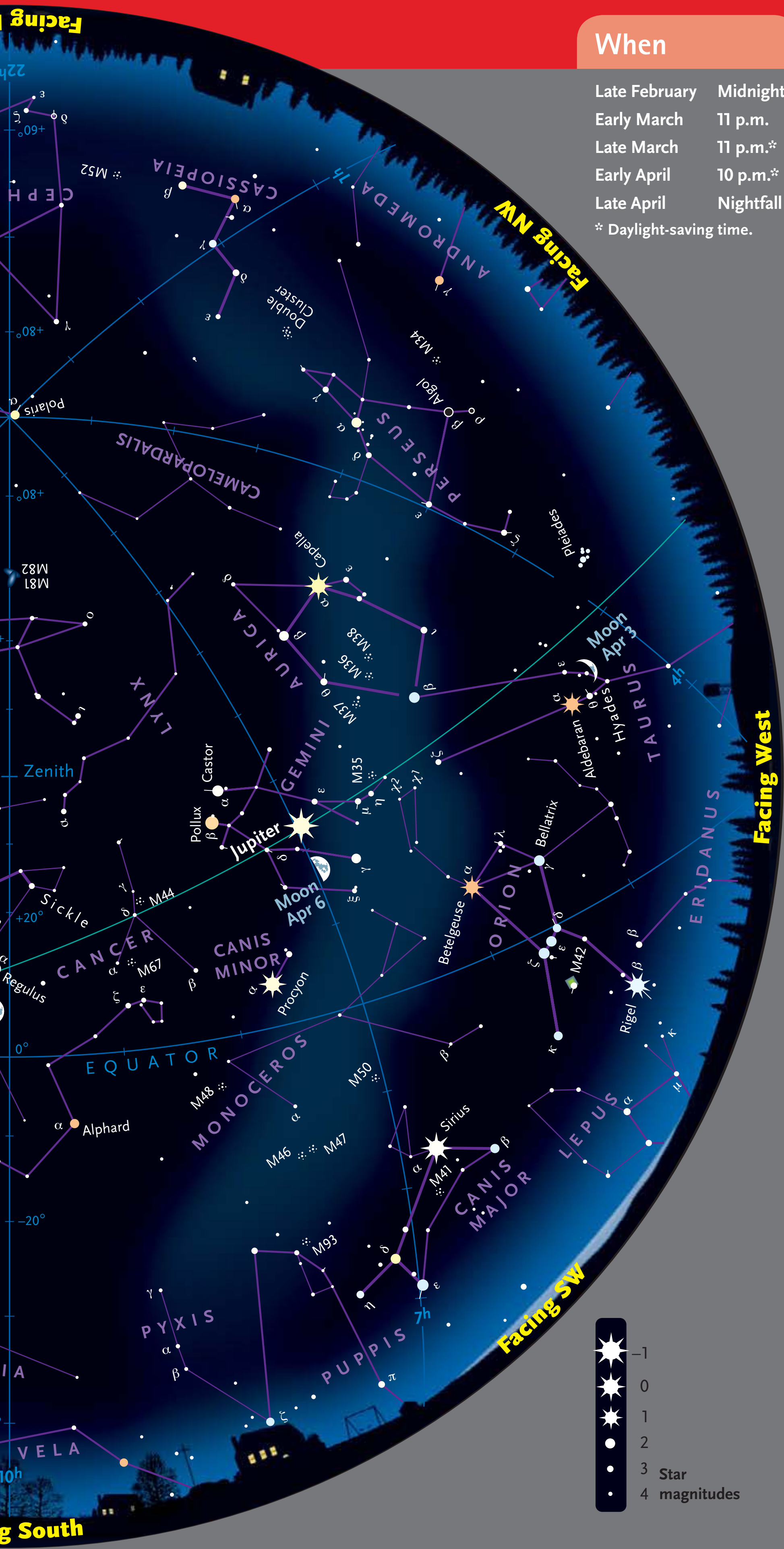
| SUN | MON | TUE | WED | THU | FRI | SAT |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | | | |

## Using the Map

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

EXACT FOR LATITUDE 40° NORTH.






## When

| | |
|---|---|
| Late February | Midnight |
| Early March | 11 p.m. |
| Late March | 11 p.m.* |
| Early April | 10 p.m.* |
| Late April | Nightfall |

* Daylight-saving time.

Gary Seronik

Binocular Highlight

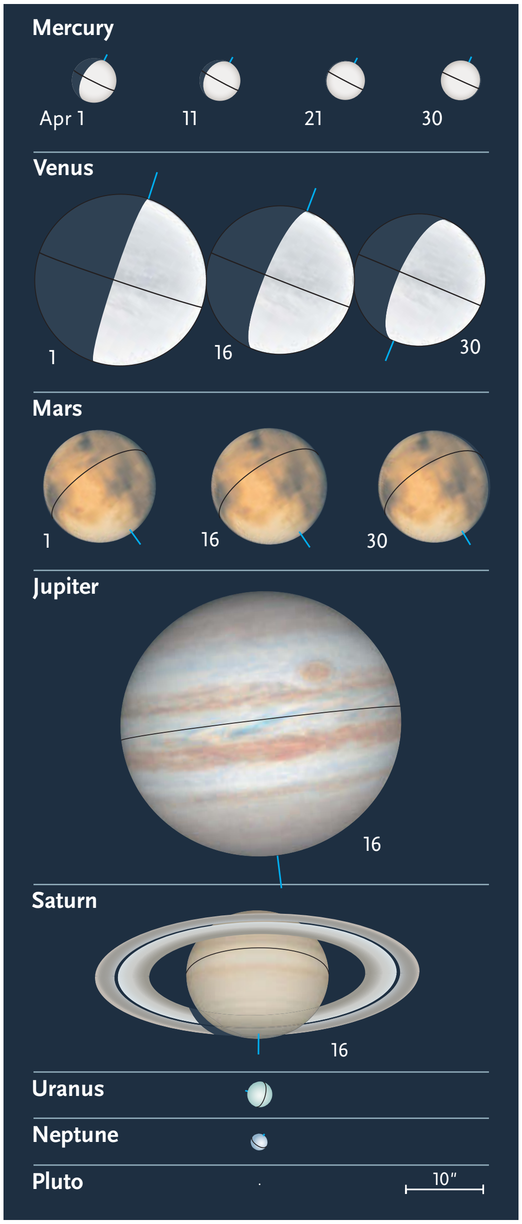
# The Binocular Full Moon

**Spring skies** are populated with faint, distant galaxies. But if you're a binocular observer living in a city or a brightly lit suburb, this can be a bit of a dry time. So why not give in and have a look at something that's both bright and nearby: the full Moon.

Right away (once you get used to the Moon's brightness), you'll notice three distinct lunar landforms. First, there are the dark lunar seas (*maria*) — vast expanses of solidified lava that mostly welled up to the surface 3.9 to 3 billion years ago. This material is some of the freshest on the Moon and covers roughly a third of its Earth-facing hemisphere. The maria are hemmed in by bright *highlands*. The southern half of the Moon is dominated by this heavily cratered, ancient terrain.

Especially rewarding for binocular users are the Moon's prominent *ray craters*. The most spectacular of these is Tycho, whose feathery rays extend thousands of kilometers across the lunar disk. Rays don't last forever, so only the youngest craters typically have them. For example, look at Copernicus, the second most conspicuous ray crater. It's very young compared to most lunar craters but older than Tycho (about 800 million years versus 109 million), so its rays aren't quite as dramatic.

Finally, one of my favorite full-Moon activities is to carefully inspect the lunar limb. If you do this regularly, you'll notice that the Moon is rarely "full" in the sense that no trace of the terminator can be seen. Usually you can discern a hint of it somewhere, especially if you're viewing a few hours either side of the exact time of full Moon. ✦

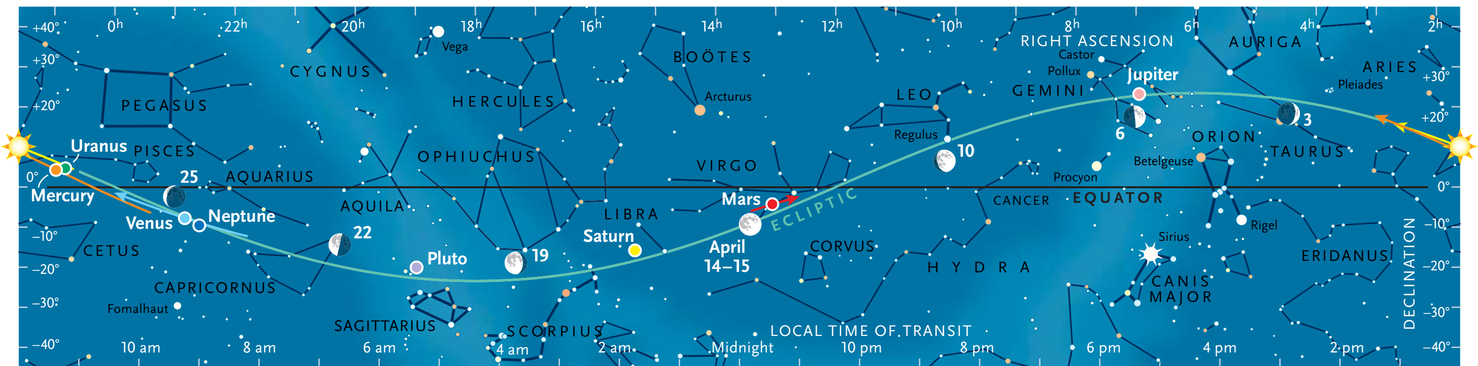



## Sun and Planets, April 2014

| | April | Right Ascension | Declination | Elongation | Magnitude | Diameter | Illumination | Distance |
|---|---|---|---|---|---|---|---|---|
| Sun | 1 | $0^h\ 40.4^m$ | +4° 21′ | — | –26.8 | 32′ 01″ | — | 0.999 |
| | 30 | $2^h\ 28.0^m$ | +14° 37′ | — | –26.8 | 31′ 46″ | — | 1.007 |
| Mercury | 1 | $23^h\ 23.2^m$ | –6° 34′ | 22° Mo | –0.2 | 5.8″ | 77% | 1.166 |
| | 11 | $0^h\ 24.3^m$ | +0° 14′ | 15° Mo | –0.6 | 5.3″ | 88% | 1.270 |
| | 21 | $1^h\ 33.9^m$ | +8° 32′ | 6° Mo | –1.6 | 5.1″ | 98% | 1.330 |
| | 30 | $2^h\ 45.4^m$ | +16° 18′ | 5° Ev | –1.9 | 5.2″ | 98% | 1.304 |
| Venus | 1 | $21^h\ 46.6^m$ | –12° 22′ | 46° Mo | –4.4 | 22.2″ | 54% | 0.750 |
| | 11 | $22^h\ 28.4^m$ | –9° 30′ | 46° Mo | –4.3 | 20.1″ | 59% | 0.828 |
| | 21 | $23^h\ 10.5^m$ | –6° 03′ | 44° Mo | –4.2 | 18.4″ | 63% | 0.906 |
| | 30 | $23^h\ 48.5^m$ | –2° 35′ | 43° Mo | –4.2 | 17.1″ | 66% | 0.974 |
| Mars | 1 | $13^h\ 24.1^m$ | –5° 58′ | 169° Mo | –1.3 | 14.7″ | 100% | 0.637 |
| | 16 | $13^h\ 02.5^m$ | –4° 15′ | 170° Ev | –1.4 | 15.2″ | 100% | 0.618 |
| | 30 | $12^h\ 44.7^m$ | –3° 01′ | 152° Ev | –1.2 | 14.6″ | 98% | 0.641 |
| Jupiter | 1 | $6^h\ 49.1^m$ | +23° 14′ | 90° Ev | –2.2 | 38.5″ | 99% | 5.124 |
| | 30 | $7^h\ 03.6^m$ | +22° 56′ | 65° Ev | –2.0 | 35.3″ | 99% | 5.577 |
| Saturn | 1 | $15^h\ 22.6^m$ | –16° 00′ | 139° Mo | +0.3 | 18.2″ | 100% | 9.130 |
| | 30 | $15^h\ 15.4^m$ | –15° 30′ | 169° Mo | +0.1 | 18.6″ | 100% | 8.917 |
| Uranus | 16 | $0^h\ 49.0^m$ | +4° 33′ | 13° Mo | +5.9 | 3.4″ | 100% | 21.004 |
| Neptune | 16 | $22^h\ 34.4^m$ | –9° 43′ | 49° Mo | +7.9 | 2.2″ | 100% | 30.623 |
| Pluto | 16 | $18^h\ 57.0^m$ | –20° 06′ | 102° Mo | +14.1 | 0.1″ | 100% | 32.405 |

**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-April; 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

# A Month of Rapid Change

## April brings new life on the ground and in the night sky.

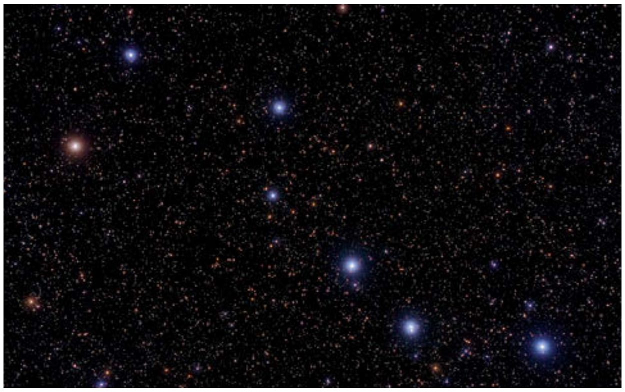
*The wind is full of memories*
*That murmur and sigh*
*Hills lie in the foaming grass of Clare*
*Below the cold moon's eye*
*But you should come and see them now*
*When they are on fire*
*And running with the shades of gloria.*
— Gerry O'Beirne, *Shades of Gloria*

**This song,** most beautifully sung by Maura O'Connell, is both a tribute to the late great tin-whistle player Micho Russell and a celebration of spring in Ireland's legendarily beautiful County Clare. Spring comes, and wherever you are, by day or by night, you should be able to feel it. For many readers of this magazine, April is the month when spring truly arrives.

Where I live on the edge of southern New Jersey's million-acre Pine Barrens, swallows usually return at the very start of April, and the grass suddenly shoots up and blazes with fresh green after one specific April rain. But there also comes a twilight toward the end of the month when the haunting song of the whip-poor-will returns as the stars of April evenings blossom into view.

**High beasts and rising humans.** As our all-sky map shows, at nightfall in April a vast avalanche of winter-constellation brightness is sliding down and out of the western sky. But our attention turns to the new constellations of spring.

The high north and south shoulders of the sky are occupied by the mighty beasts Ursa Major, the Great Bear, and Leo, the Lion. The Bear's hindquarters and (unnaturally long) tail are formed by the famous Big Dipper, which is upside down and at its highest above the North Star during April nightfalls.



AKIRA FUJII

**The Big Dipper floats upside down near the top of the sky on early spring evenings, as though pouring out the April showers that will bring May's flowers.**

Leo's most prominent feature is his front half: a backward question mark — often called the Sickle — composed of the Lion's head, mane, neck, and chest. The Lion's heart is marked by 1st-magnitude Regulus, whereas the mane contains the wonderful 2nd-magnitude double star Gamma Leonis, also known as Algieba. The Lion's hindquarters are formed from a right triangle of stars whose eastern end is 2nd-magnitude Denebola.

The ascending humans of April evenings are the herdsman Boötes, the maiden Virgo, and the strongman Hercules. Mighty ginger-ale-colored Arcturus, spring's brightest star at magnitude –0.05, dominates Boötes. Virgo's long, lovely, dim, reclining form features 1.0-magnitude Spica — this April joined by blazing Mars.

That's not all the bright lights ascending. Two other zero-magnitude lights are rising or about to rise: Vega in the northeast and, this year, Saturn in the southeast.

**Other starry creatures and adornments.** Despite its share of bright stars and planets, most of the spring constellations are relatively dim. There is real peace in contemplating the gentle radiance of the spring stars shining above and through the slowly opening leaves of trees.

*And the waves roll at the headland*
*When the tide is rising there*
*And here there is starlight falling*
*Down on the hills of Clare.*

Largely dim creatures low in the April sky include long, long Hydra, the Water Snake, and, just right of Spica, compact Corvus, the Crow. High up, between Leo, Boötes, and the Big Dipper are the dim but eye-catching constellations Corona Borealis, the Northern Crown, and Coma Berenices, Berenice's Hair.

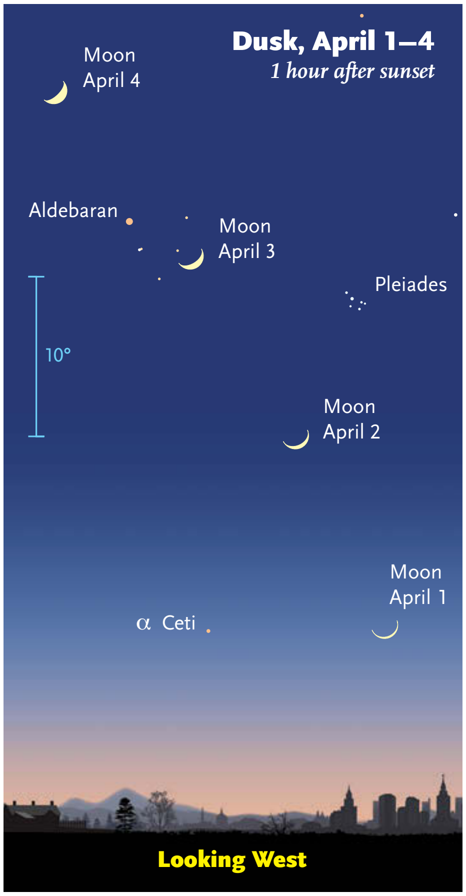
*I am going to the country*
*Going down that verdant lane*
*With nothing but a whistle in my hand*
*And a pocket full of rain.*
*Can you hear that distant sound*
*Coming down the West Clare railway*
*Running with the shades of gloria.* ✦

# April's Close Approaches

Mars, Vesta, and Ceres all come closest to Earth this month.

**The total lunar eclipse** on the night of April 14–15 should be a spectacular sight across the Americas; see page 60 for details. On April 29th Australia and parts of Indonesia experience a partial solar eclipse, and a few errant penguins may see an annular eclipse, as described below.

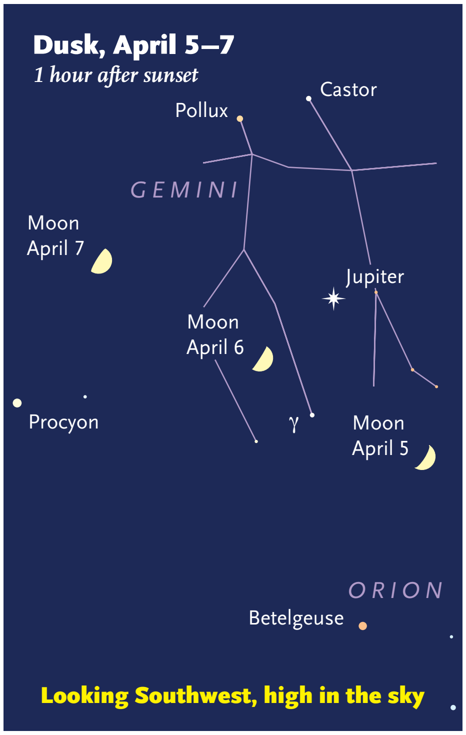
Mars appears brighter and bigger (when viewed through a telescope) than it has for the last six years. It becomes visible low in the east at dusk, while Jupiter shines even brighter high in the west-southwest. Saturn, also nearing its maximum brightness and size, rises in the evening. And Venus rises just before the first light of dawn.




## DUSK AND EVENING

**Jupiter** is not far past the sky's central meridian as it glimmers into view soon after sunset. It's in Gemini, near the ecliptic's northernmost point, so it's still very high at dusk for mid-northern observers despite being three months past opposition. Its magnitude dims from –2.2 to –2.0 in April — still significantly brighter than Mars — and its equatorial diameter shrinks from 38″ to 35″.

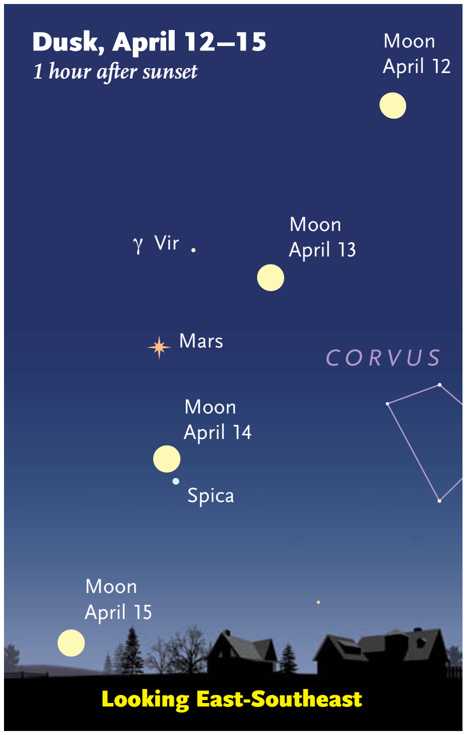
Jupiter is at eastern quadrature (90° east of the Sun) on April 1st, so the Galilean satellites appear far from their shadows as they pass in front of Jupiter. Likewise, when the satellites pass behind Jupiter, they reappear from the planet's shadow quite far east of the planet's disk. Jupiter is moving slowly eastward relative to the starry background. It marches away from Epsilon (ε) Geminorum, and ends April between Omega (ω) and Zeta (ζ) Geminorum.




## ALL NIGHT

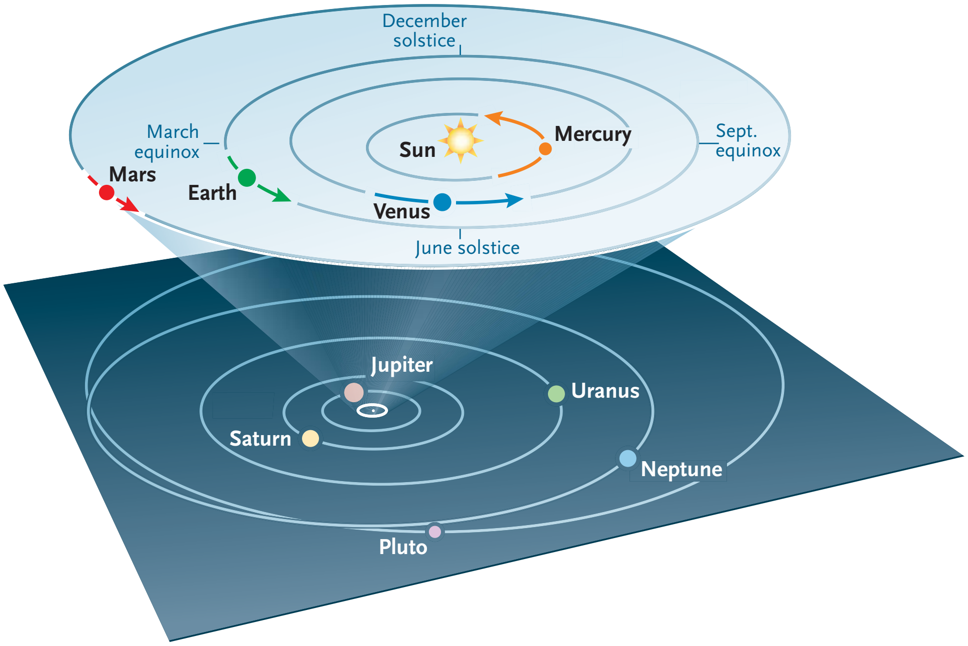
**Mars** reaches opposition on April 8th and is therefore visible from dusk to dawn this month. In the second week of April the campfire-colored planet reaches a maximum brightness of –1.5, matching Sirius, which is setting in the southwest in dusk. Mars culminates (is highest) around 2 a.m. daylight time as April opens but around 11 p.m. as April closes. It is retrograding in Virgo, nearing Gamma (γ) Virginis, also called Porrima, by the end of the month.

Due to the considerable ellipticity of the Martian orbit, Mars is actually closest to Earth on April 14th, nearly a week after opposition. Its apparent diameter then is 15.16″, and it remains bigger than 14.5″



**ORBITS OF THE PLANETS**

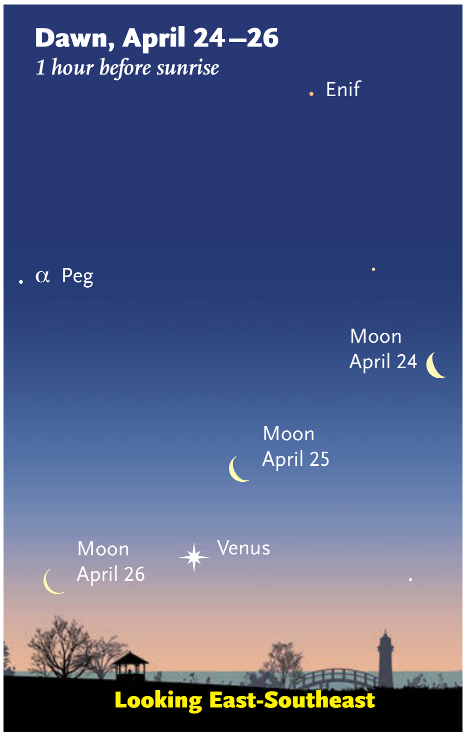
**The curved arrows show each planet's movement during April. The outer planets don't change position enough in a month to notice at this scale.**




throughout April. This is slightly larger (and brighter) than Mars has appeared at any time since its 2007 opposition. Yet viewing any but the most prominent surface features with a medium-size or larger telescope will still require good seeing (steadiness in Earth's atmosphere). That's particularly true at mid-northern latitudes, where Mars never shines very high during this apparition.

If you don't see much in a telescope, remember that Mars has a bland side and a more interesting side. Use our Mars Profiler (**skypub.com/marsprofiler**) to see which side is facing you at any time and date. For a full map and guide to viewing Mars, see page 50 of the March issue.

Asteroid **Vesta** is at opposition on April 13th at an unusually bright magnitude 5.8, and **Ceres** is at opposition on April 15th at magnitude 7.0. See the February issue, page 50, for details about observing the pairing of these two big asteroids this spring and summer.




## EVENING TO DAWN

**Saturn** will arrive at opposition on May 10th, and by late April it already shines at magnitude +0.1, its brightest for the year. Thus it greatly outshines Spica and rivals Arcturus — though Arcturus is much higher. Saturn is now retrograding very slowly in Libra, a rather southerly constellation, so it doesn't rise until about 10:30 p.m. daylight time as April starts and 8:30 p.m. (in bright twilight) as April ends.

An important reason for Saturn's brilliance is the orientation of its rings, which remain near 22° from edge-on. Saturn is highest (best for telescopic observations) a few hours after midnight this month.

## DAWN

**Venus** rises a little before the onset of morning twilight, and it's still less than 10° high an hour before sunup. Venus shines around magnitude –4.3, making it easy to spot even when it's low in bright dawn. But 7.9-magnitude **Neptune** may be challenging to glimpse through a telescope when it's 0.7° south of Venus on the American morning of April 12th.

It may be possible to locate **Mercury** with a telescope very low in bright dawn in early April, but Mercury can't be viewed when it passes through superior conjunction with the Sun on April 26th.

**Uranus**, in Pisces, is in conjunction with the Sun on April 2nd and probably impossible to view all month. **Pluto**, in Sagittarius, is findable before dawn but is still far from ideally placed.

## MOON AND SUN

The **Moon** is a waxing crescent near Aldebaran on April 3rd. North American observers can watch the Moon pass through the Hyades cluster that evening, occulting several medium-bright stars; see page 50 for details.

The half Moon is fairly near Jupiter on April 6th. The full Moon is near Mars and very near Spica on the night of April 14–15, and just as it reaches its fullest that night, it experiences the total eclipse described on page 60.

The waning gibbous Moon is very near Saturn at dawn on April 17th, and the waning crescent passes Venus in the dawns of April 25th and 26th.

The **Sun** undergoes an unusual eclipse on April 29th. The eclipse's centerline passes just south of Earth's globe, so only a tiny patch of Antarctica experiences a brief annular eclipse, with the Sun very low on the horizon. The partial phase is visible across Australia and parts of Indonesia; see **eclipse.gsfc.nasa.gov/OH/OH2014.html** for details. ✦

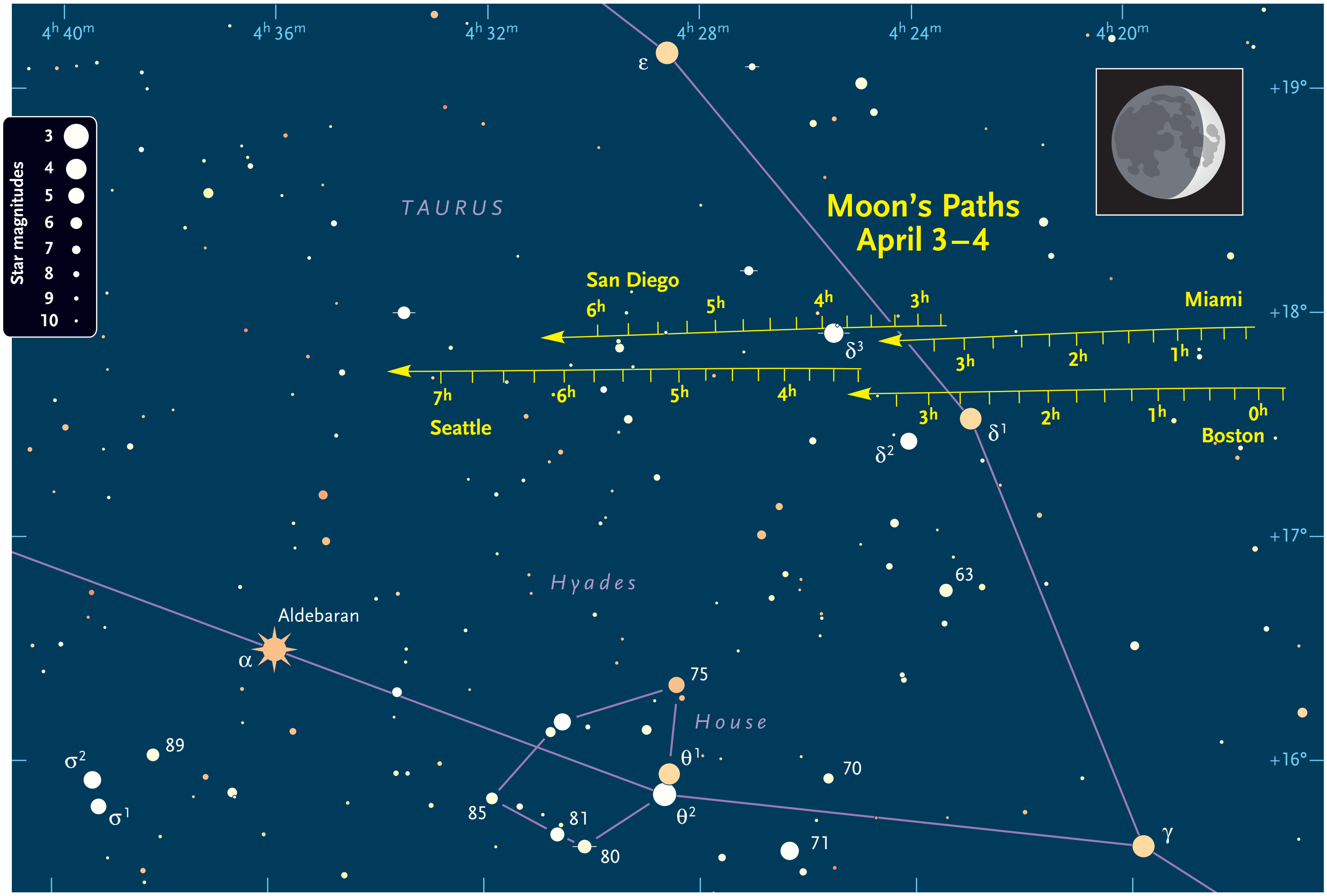
# Moon Occults Hyades Stars

On April 3rd, the earthlit crescent will put on an unusual show.

**Year after year** the April waxing crescent Moon poses with the Pleiades and Hyades in the west at nightfall, a reliable scene of early-spring beauty. But now, at this point in the 18.6-year cycle of the lunar nodes precessing around the ecliptic, the Moon's orbit is shifting so that the Moon crosses bright stars of the Hyades every month for the world's mid-northern latitudes. This last happened from 1995 to 2001. The current Hyades "occultation season" for our latitudes will continue until 2020.

This April's crossing is well timed for skywatchers in North America. The map below shows what will happen. In the top right corner is the waxing crescent with the correct size, phase (20% sunlit), and orientation for the map. (North is up on the map; north is upper right in your western sky.) The four arrows show the path of the Moon's center as seen from four corners of the United States. The Moon is so close that your location on Earth makes quite a difference in where you see it against the background stars.

The Moon will cross the northern branch of the Hyades on the evening of April 3rd. The Moon inset shows its correct size, phase, and orientation. Mentally slide its center along a yellow arrow to get an idea of what stars it will cover and uncover for that city, and when. The time ticks show Universal Time (April 4th). Each arrow begins a half hour after local sunset and ends at moonset. Interpolate between the lines for your own location.



If you're near one of the cities given, mentally slide the center of the Moon disk along the city's line (or cut out a photocopy and slide it) to see what stars will be occulted and when. If you're elsewhere, interpolate between the cities to draw a line for your location.

The time ticks on the arrows show Universal Time on April 4th (on the evening of the 3rd local time). Subtract 4 hours from UT to obtain Eastern Daylight Time; 7 hours to get Pacific Daylight Time.

Each arrow begins 30 minutes after local sunset and ends at local moonset. The farther east you are, the lower the Moon will be.

The three brightest stars to be occulted are Delta$^1$ ($\delta^1$), Delta$^2$, and Delta$^3$ Tauri, magnitudes 3.8, 4.8, and 4.3, respectively. The Moon's earthlit limb hits the first as seen from much of Canada and the eastern and central U.S. except the South. The second is occulted somewhat farther north, and the third from most of the central and western U.S. and Canada. See the maps and detailed local time predictions for each of the three at **lunar-occultations.com/iota/bstar/bstar.htm**. Can your telescope show fainter stars winking out too?

As usual when the Moon is waxing, stars disappear on the dark limb and reappear from behind the bright limb, where they're harder to observe.

## Little Moon, Big Cluster

People are always surprised by how small the Moon actually appears in the sky. With a diameter of ½° it easily fits behind your fingertip at arm's length and appears only about ⅙ as wide as M31, the Andromeda Galaxy, if you count the galaxy's dim outer arms that appear in deep images.

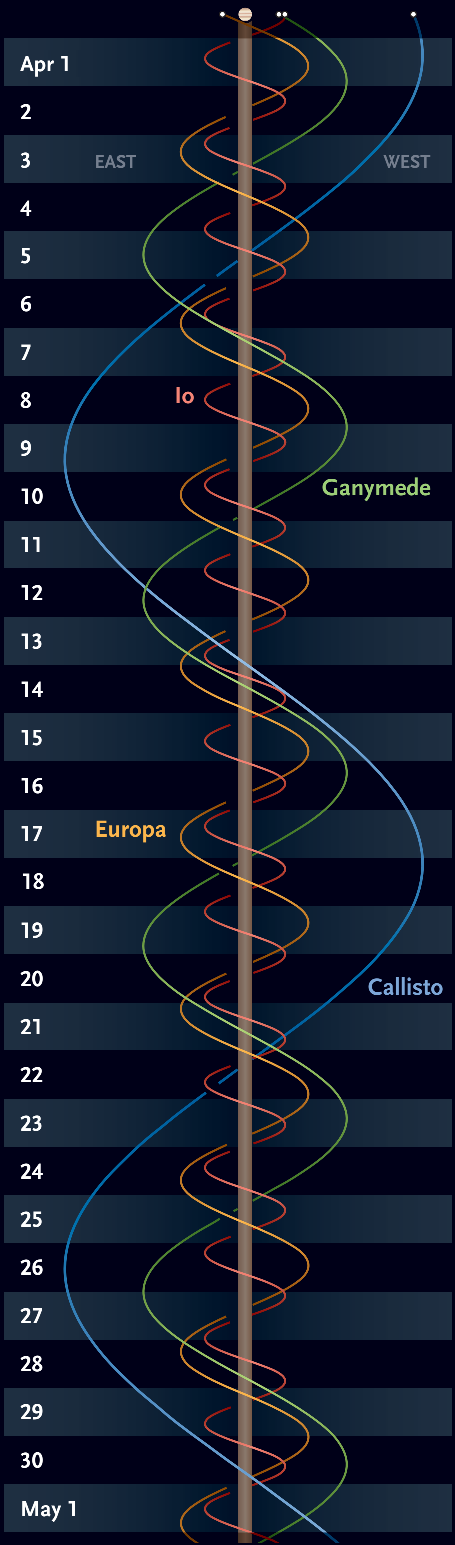
And it's *much* smaller than even the inner Hyades with their familiar V shape. One of the most attractive features of the Hyades, in binoculars or a finderscope, is the "House" asterism that includes the lovely pair Theta$^{1,2}$ ($\theta^{1,2}$) Tauri. The Thetas (which can just be separated with the naked eye) are one of three pairs forming an equilateral triangle at three corners of the House. The entire April 3rd Moon would just fit inside this triangle!

## Phenomena of Jupiter's Moons, April 2014

| | | |
|---|---|---|
| Apr. 1 | 1:48 | I.Ec.R |
| | 19:24 | I.Tr.I |
| | 20:41 | I.Sh.I |
| | 21:39 | I.Tr.E |
| | 22:56 | I.Sh.E |
| Apr. 2 | 9:31 | II.Oc.D |
| | 14:54 | II.Ec.R |
| | 16:43 | I.Oc.D |
| | 20:16 | I.Ec.R |
| Apr. 3 | 13:53 | I.Tr.I |
| | 14:53 | III.Oc.D |
| | 15:10 | I.Sh.I |
| | 16:08 | I.Tr.E |
| | 17:25 | I.Sh.E |
| | 18:07 | III.Oc.R |
| | 20:06 | III.Ec.D |
| | 23:27 | III.Ec.R |
| Apr. 4 | 4:38 | II.Tr.I |
| | 7:10 | II.Sh.I |
| | 7:18 | II.Tr.E |
| | 9:53 | II.Sh.E |
| | 11:12 | I.Oc.D |
| | 14:45 | I.Ec.R |
| Apr. 5 | 8:22 | I.Tr.I |
| | 9:39 | I.Sh.I |
| | 10:23 | IV.Oc.D |
| | 10:37 | I.Tr.E |
| | 11:54 | I.Sh.E |
| | 14:01 | IV.Oc.R |
| | 22:30 | IV.Ec.D |
| | 22:50 | II.Oc.D |
| Apr. 6 | 2:35 | IV.Ec.R |
| | 4:13 | II.Ec.R |
| | 5:41 | I.Oc.D |
| | 9:14 | I.Ec.R |
| Apr. 7 | 2:51 | I.Tr.I |
| | 4:07 | I.Sh.I |
| | 5:00 | III.Tr.I |
| | 5:06 | I.Tr.E |
| | 6:23 | I.Sh.E |
| | 8:11 | III.Tr.E |
| | 10:09 | III.Sh.I |
| | 13:28 | III.Sh.E |
| | 17:57 | II.Tr.I |
| | 20:28 | II.Sh.I |
| | 20:36 | II.Tr.E |
| | 23:10 | II.Sh.E |
| Apr. 8 | 0:10 | I.Oc.D |
| | 3:43 | I.Ec.R |
| | 21:20 | I.Tr.I |
| | 22:36 | I.Sh.I |
| | 23:35 | I.Tr.E |
| Apr. 9 | 0:52 | I.Sh.E |
| | 12:09 | II.Oc.D |
| | 17:32 | II.Ec.R |
| | 18:39 | I.Oc.D |
| | 22:12 | I.Ec.R |
| Apr. 10 | 15:49 | I.Tr.I |
| | 17:05 | I.Sh.I |
| | 18:04 | I.Tr.E |
| | 18:56 | III.Oc.D |
| | 19:21 | I.Sh.E |
| | 22:10 | III.Oc.R |
| Apr. 11 | 0:06 | III.Ec.D |
| | 3:28 | III.Ec.R |
| | 7:15 | II.Tr.I |
| | 9:46 | II.Sh.I |
| | 9:55 | II.Tr.E |
| | 12:28 | II.Sh.E |
| | 13:08 | I.Oc.D |
| | 16:40 | I.Ec.R |
| Apr. 12 | 10:18 | I.Tr.I |
| | 11:34 | I.Sh.I |
| | 12:33 | I.Tr.E |
| | 13:50 | I.Sh.E |
| Apr. 13 | 1:29 | II.Oc.D |
| | 6:51 | II.Ec.R |
| | 7:37 | I.Oc.D |
| | 11:09 | I.Ec.R |
| | 21:28 | IV.Tr.I |
| Apr. 14 | 1:06 | IV.Tr.E |
| | 4:47 | I.Tr.I |
| | 6:03 | I.Sh.I |
| | 7:02 | I.Tr.E |
| | 8:19 | I.Sh.E |
| | 9:04 | III.Tr.I |
| | 9:17 | IV.Sh.I |
| | 12:16 | III.Tr.E |
| | 13:20 | IV.Sh.E |
| | 14:08 | III.Sh.I |
| | 17:28 | III.Sh.E |
| | 20:35 | II.Tr.I |
| | 23:03 | II.Sh.I |
| | 23:15 | II.Tr.E |
| Apr. 15 | 1:46 | II.Sh.E |
| | 2:06 | I.Oc.D |
| | 5:38 | I.Ec.R |
| | 23:17 | I.Tr.I |
| Apr. 16 | 0:32 | I.Sh.I |
| | 1:32 | I.Tr.E |
| | 2:48 | I.Sh.E |
| | 14:50 | II.Oc.D |
| | 20:10 | II.Ec.R |
| | 20:35 | I.Oc.D |
| Apr. 17 | 0:07 | I.Ec.R |
| | 17:46 | I.Tr.I |
| | 19:01 | I.Sh.I |
| | 20:01 | I.Tr.E |
| | 21:17 | I.Sh.E |
| | 23:03 | III.Oc.D |
| Apr. 18 | 2:18 | III.Oc.R |
| | 4:06 | III.Ec.D |
| | 7:29 | III.Ec.R |
| | 9:54 | II.Tr.I |
| | 12:21 | II.Sh.I |
| | 12:34 | II.Tr.E |
| | 15:04 | II.Sh.E |
| | 15:04 | I.Oc.D |
| | 18:35 | I.Ec.R |
| Apr. 19 | 12:15 | I.Tr.I |
| | 13:30 | I.Sh.I |
| | 14:31 | I.Tr.E |
| | 15:45 | I.Sh.E |
| Apr. 20 | 4:10 | II.Oc.D |
| | 9:29 | II.Ec.R |
| | 9:34 | I.Oc.D |
| | 13:04 | I.Ec.R |
| Apr. 21 | 6:45 | I.Tr.I |
| | 7:58 | I.Sh.I |
| | 9:00 | I.Tr.E |
| | 10:14 | I.Sh.E |
| | 13:12 | III.Tr.I |
| | 16:25 | III.Tr.E |
| | 18:08 | III.Sh.I |
| | 21:28 | III.Sh.E |
| | 23:14 | II.Tr.I |
| Apr. 22 | 1:39 | II.Sh.I |
| | 1:54 | II.Tr.E |
| | 4:03 | I.Oc.D |
| | 4:22 | II.Sh.E |
| | 5:00 | IV.Oc.D |
| | 7:33 | I.Ec.R |
| | 8:45 | IV.Oc.R |
| | 16:33 | IV.Ec.D |
| | 20:45 | IV.Ec.R |
| Apr. 23 | 1:14 | I.Tr.I |
| | 2:27 | I.Sh.I |
| | 3:29 | I.Tr.E |
| | 4:43 | I.Sh.E |
| | 17:32 | II.Oc.D |
| | 22:32 | I.Oc.D |
| | 22:48 | II.Ec.R |
| Apr. 24 | 2:02 | I.Ec.R |
| | 19:44 | I.Tr.I |
| | 20:56 | I.Sh.I |
| | 21:59 | I.Tr.E |
| | 23:12 | I.Sh.E |
| Apr. 25 | 3:12 | III.Oc.D |
| | 6:29 | III.Oc.R |
| | 8:06 | III.Ec.D |
| | 11:30 | III.Ec.R |
| | 12:34 | II.Tr.I |
| | 14:56 | II.Sh.I |
| | 15:15 | II.Tr.E |
| | 17:02 | I.Oc.D |
| | 17:39 | II.Sh.E |
| | 20:30 | I.Ec.R |
| Apr. 26 | 14:13 | I.Tr.I |
| | 15:25 | I.Sh.I |
| | 16:29 | I.Tr.E |
| | 17:41 | I.Sh.E |
| Apr. 27 | 6:53 | II.Oc.D |
| | 11:31 | I.Oc.D |
| | 12:07 | II.Ec.R |
| | 14:59 | I.Ec.R |
| Apr. 28 | 8:43 | I.Tr.I |
| | 9:54 | I.Sh.I |
| | 10:58 | I.Tr.E |
| | 12:10 | I.Sh.E |
| | 17:23 | III.Tr.I |
| | 20:37 | III.Tr.E |
| | 22:08 | III.Sh.I |
| Apr. 29 | 1:29 | III.Sh.E |
| | 1:55 | II.Tr.I |
| | 4:14 | II.Sh.I |
| | 4:36 | II.Tr.E |
| | 6:01 | I.Oc.D |
| | 6:57 | II.Sh.E |
| | 9:28 | I.Ec.R |
| Apr. 30 | 3:12 | I.Tr.I |
| | 4:23 | I.Sh.I |
| | 5:28 | I.Tr.E |
| | 6:39 | I.Sh.E |
| | 16:25 | IV.Tr.I |
| | 20:11 | IV.Tr.E |
| | 20:16 | II.Oc.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). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

## Jupiter's Moons




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

# Action at Jupiter

In April Jupiter shines high in the west as twilight fades away. Your telescope has not been weakening; Jupiter in April shrinks from 38″ to 35″ wide, compared to its 47″ at opposition in early January.

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

The table on the previous page lists all the interactions in April between Jupiter, its shadow, and the moons and their shadows.

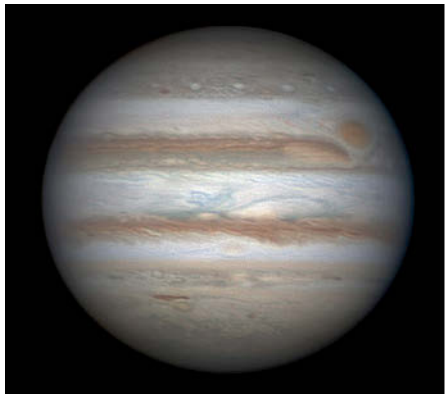
Here are the times, in Universal Time, when Jupiter's Great Red Spot, now a relatively strong shade of orange, should cross Jupiter's central meridian. The dates, also in UT, are in bold:

**March 1**, 2:09, 12:05, 22:00; **2**, 7:56, 17:52; **3**, 3:47, 13:43, 23:39; **4**, 9:35, 19:30; **5**, 5:26, 15:22; **6**, 1:18, 11:13, 21:09; **7**, 7:05, 17:00; **8**, 2:56, 12:52, 22:48; **9**, 8:43, 18:39; **10**, 4:35, 14:31; **11**, 0:26, 10:22, 20:18; **12**, 6:14, 16:09; **13**, 2:05, 12:01, 21:57; **14**, 7:52, 17:48; **15**, 3:44, 13:40, 23:35; **16**, 9:31, 19:27; **17**, 5:23, 15:18; **18**, 1:14, 11:10, 21:06; **19**, 7:01, 16:57; **20**, 2:53, 12:49, 22:44; **21**, 8:40, 18:36; **22**, 4:32, 14:27; **23**, 0:23, 10:19, 20:15; **24**, 6:11, 16:06; **25**, 2:02, 11:58, 21:54; **26**, 7:49, 17:45; **27**, 3:41, 13:37, 23:32; **28**, 9:28, 19:24; **29**, 5:20, 15:16; **30**, 1:11, 11:07, 21:03; **31**, 6:59, 16:55.

**April 1**, 2:52, 12:48, 22:44; **2**, 8:39, 18:35; **3**, 4:31, 14:27; **4**, 0:22, 10:18, 20:14; **5**, 6:10, 16:06; **6**, 2:01, 11:57, 21:53; **7**, 7:49, 17:45; **8**, 3:40, 13:36, 23:32; **9**, 9:28, 19:24; **10**, 5:19, 15:15; **11**, 1:11, 11:07, 21:03; **12**, 6:59, 16:54; **13**, 2:50, 12:46, 22:42; **14**, 8:38, 18:33; **15**, 4:29, 14:25; **16**, 0:21, 10:17, 20:12; **17**, 6:08, 16:04; **18**, 2:00, 11:56, 21:51; **19**, 7:47, 17:43; **20**, 3:39, 13:35, 23:31; **21**, 9:26, 19:22; **22**, 5:18, 15:14; **23**, 1:10, 11:05, 21:01; **24**, 6:57, 16:53; **25**, 2:49, 12:45, 22:40; **26**, 8:36, 18:32; **27**, 4:28, 14:24; **28**, 0:20, 10:15, 20:11; **29**, 6:07, 16:03; **30**, 1:59, 11:54, 21:50.

These times assume that the spot is at System II longitude 209°. If it's elsewhere, it will transit 1⅔ minutes early for every degree of longitude less, or 1⅔ minutes later for every degree more.

Features on Jupiter appears closer to the central meridian than to the limb for 50 minutes before and after transiting. Read lots more about observing Jupiter in the January issue.



These two faces of Jupiter show the regions following the Great Red Spot (*top*) and preceding it (*bottom*). South is up. Christopher Go in the Philippines shot these images on December 31st and January 4th.

# Lyrid Meteors

**The last-quarter Moon will impair the viewing for this year's Lyrid meteor shower, which is expected to peak on the morning of April 22nd local time. Even in years when the sky is dark, observers typically report fewer than 20 Lyrids visible per hour before dawn. However, the shower is known for occasional surprises.** ✦

# History of the Moon

## How do we know when things happened?

**Although the average** age of Earth's surface is only about 500 million years, the oldest rocks geologists have found on our planet formed 3.8 billion years ago. Earth had a rocky crust for 700 million years before then, but it is long gone. Erosion and plate tectonics have erased all of the landforms from the earliest periods of Earth's history. But you can see another world from your backyard where you can identify features dating from its infancy up to the most recent times.

JOCELYN SEROT

The contrast between heavily cratered highlands (bottom) and Mare Humorum demonstrates the rapid decline of impacts prior to about 3.5 billion years ago.

The Moon, like the Earth, Sun, and all other objects within our solar system, ultimately formed from materials that condensed out of the solar nebula roughly 4.5 billion years ago. Its surface was shaped by both external energy (impact cratering) and internal energy (volcanism and faulting). Both processes were vastly more active early in lunar history than they are today. Borrowing a phrase used to describe Earth in the earliest days of its history, the Moon was dominated by "tempestuous tectonics." Impacts, eruptions, and faulting were everywhere!

The immense energy from the countless impacts that brought the stuff together that formed the Moon caused it to completely melt, forming a global magma ocean. Low-density elements such as aluminum floated to the surface as a frothy scum, while denser materials such as iron sank deeper into the molten orb, in a process known as *planetary differentiation*.

The early Moon radiated away its heat rather quickly and began to solidify, though it continued to be punctured repeatedly by a torrent of projectiles — remnants from the solar system's formation. Over the first 600 to 700 million years, huge impactors collided with the Moon, producing giant basins that are hundreds to more than a thousand miles in diameter.

Over time, heating due to the radioactive decay of uranium and thorium melted parts of the lunar mantle. This fresh magma rose up through fractures under the young basins, erupting vast expanses of lava onto the surface. Tens of thousands of eruptions built up the thick, dark flows on basin floors that we see today in **Mare Imbrium, Mare Serenitatis**, and **Mare Crisium**. Sinuous rilles, such as **Hadley Rille**, mark locations where rapidly flowing lavas cut winding channels. This upflow of magma from the mantle to the lunar surface caused the basins to sink, producing fractures around their margins (such as the concentric rilles bordering Mare Serenitatis), and faults in their interiors as the cooled lavas were forced to fit within smaller volumes.

About 3.8 billion years ago, impact cratering rapidly declined in both frequency and the size of craters formed. In fact, comparison of the number of impact craters on the lunar highlands with maria ages show that by the time most mare lavas erupted (between 3.8 and 2.5 billion years ago), cratering was thousands of times less frequent as it was during the earlier epoch.

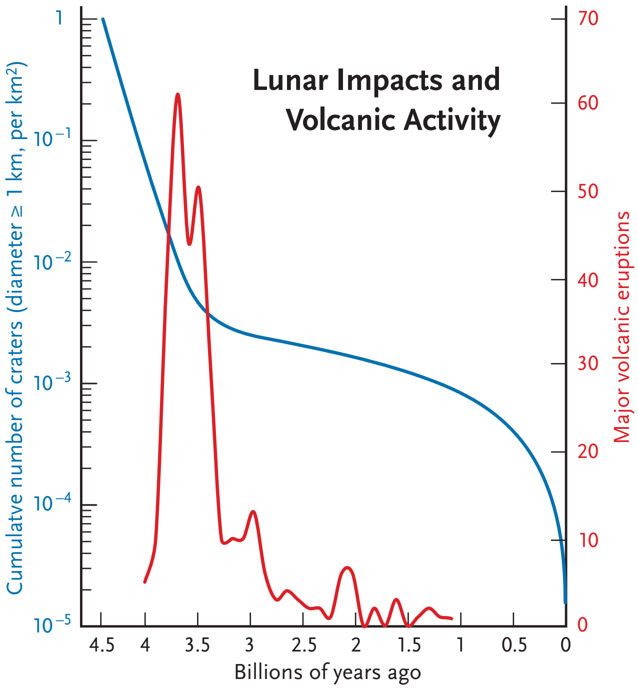
Lunar scientists deduced this sequence of events based on the stratigraphic relations of different areas: features that are on top of others are younger than the underlying strata. To anchor this sequence to a specific time frame, scientists used radiometric dating to measure the absolute ages of samples returned by the Apollo astronauts four decades ago. Unfortunately, these samples were collected from only the six Apollo landing sites. Three more from Soviet Luna sample-return missions don't make the collection much bigger.

Numerous gaps in our knowledge of lunar chronology are filled with estimates of surface ages based mostly on crater counting. In general, we know that the rate of crater formation in the Moon's first half-billion years was very high and that the rate quickly declined afterwards, with bumps or spikes over the last 3 to 4 billion years. The exact shape of this cratering curve is debated, so the crater count ages are called "model ages" and are based on combined evidence from the Apollo landing sites, impact rates on Earth, and observations of many asteroids of different sizes.

Recently refined crater counts come from high-resolution images returned by NASA's Lunar Reconnaissance Orbiter (LRO). In fact, you can help contribute to our lunar knowledge by joining the crowd-sourced classification of LRO images at **www.moonzoo.org**. This ongoing work is leading to a more expansive list of model ages of lava flows, craters, and, most difficult of all, the major impact basins.

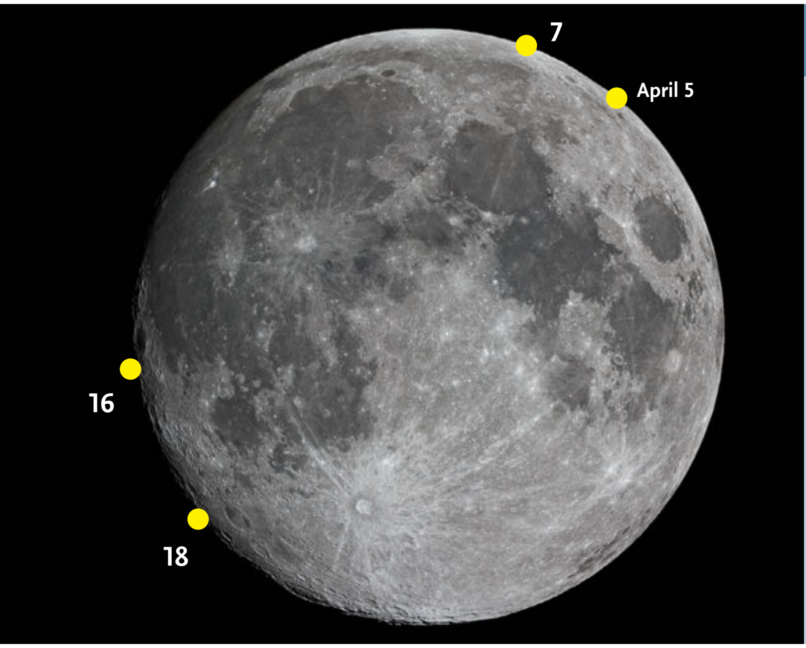
In truth, this scenario is all a house of cards, but it's a well-constructed house, and it's the best we can do until we bring many more samples from various parts of the Moon back to Earth and study them in laboratories. That is the next major goal of lunar science, but we must return to the Moon to accomplish it.

In my next column, we'll tour the visible clues of lunar history that you can see with your own telescope. ✦




**This graph compares the lunar impact rate (shown in blue) with the occurrences of lunar volcanism (red).**

SOURCE: H. HIESINGER ET AL / *JOURNAL OF GEOPHYSICAL RESEARCH* 2012




S&T: DENNIS DI CICCO

## The Moon • April 2014

### Phases

**FIRST QUARTER**
April 7, 8:31 UT

**FULL MOON**
April 15, 7:42 UT

**LAST QUARTER**
April 22, 7:52 UT

**NEW MOON**
April 29, 6:14 UT

### Distances

| | | |
|---|---|---|
| Perigee | December 10, 10h UT | |
| 251,344 miles | diam. 29′ 32″ | |
| Apogee | December 22, 11h UT | |
| 229,762 miles | diam. 32′ 19″ | |

### Librations

| | |
|---|---|
| Mare Humboldtianum | April 4 |
| Cusanus (crater) | April 7 |
| Lacus Veris | April 16 |
| Vallis Bouvard | April 18 |

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

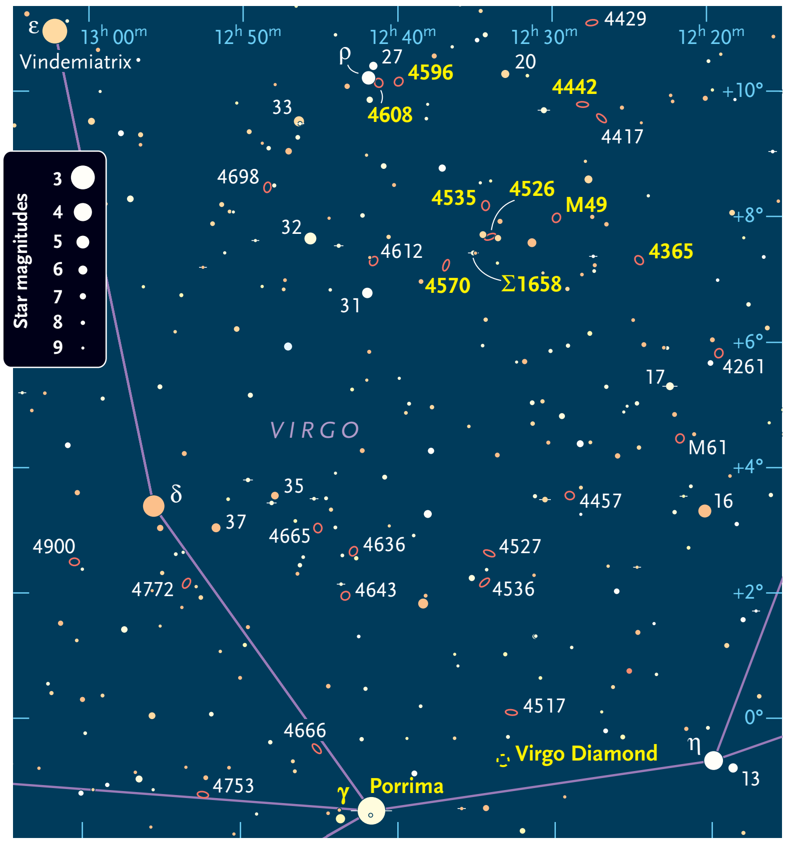
# The Last Messier

## Many fascinating galaxies swarm around giant M49.

**With my May 2012 column,** I thought that I'd finished covering all the objects from Charles Messier's famous 18th-century catalog. Not so! Ohio amateur Rod Cook astutely pointed out that the galaxy Messier 49 was still unaccounted for. Now it's time to remedy the situation.

To ferret out **Messier 49**, slip 1.9° southwest from Rho (ρ) Virginis to a 6.6-magnitude star, the brightest in the area. Extend your sweep for three-quarters that distance farther to arrive at the middle of a nearly straight, 48′-long line of three unevenly spaced stars. The westernmost star is brightest and orange in hue. M49 is 33′ northwest of that star, and it's visible through 50-mm binoculars in moderately dark skies.

In 15×50 binoculars, M49 appears relatively large, as galaxies go, and sports a small, bright center. It shows an oval profile through my 105-mm refractor at 127×, and a tiny, bright nucleus punctuates the galaxy's small, well-defined core. A faint star is superimposed on M49's halo, just east of the core. Viewed in my 10-inch reflector at 118×, M49 covers about 5′ × 4′.



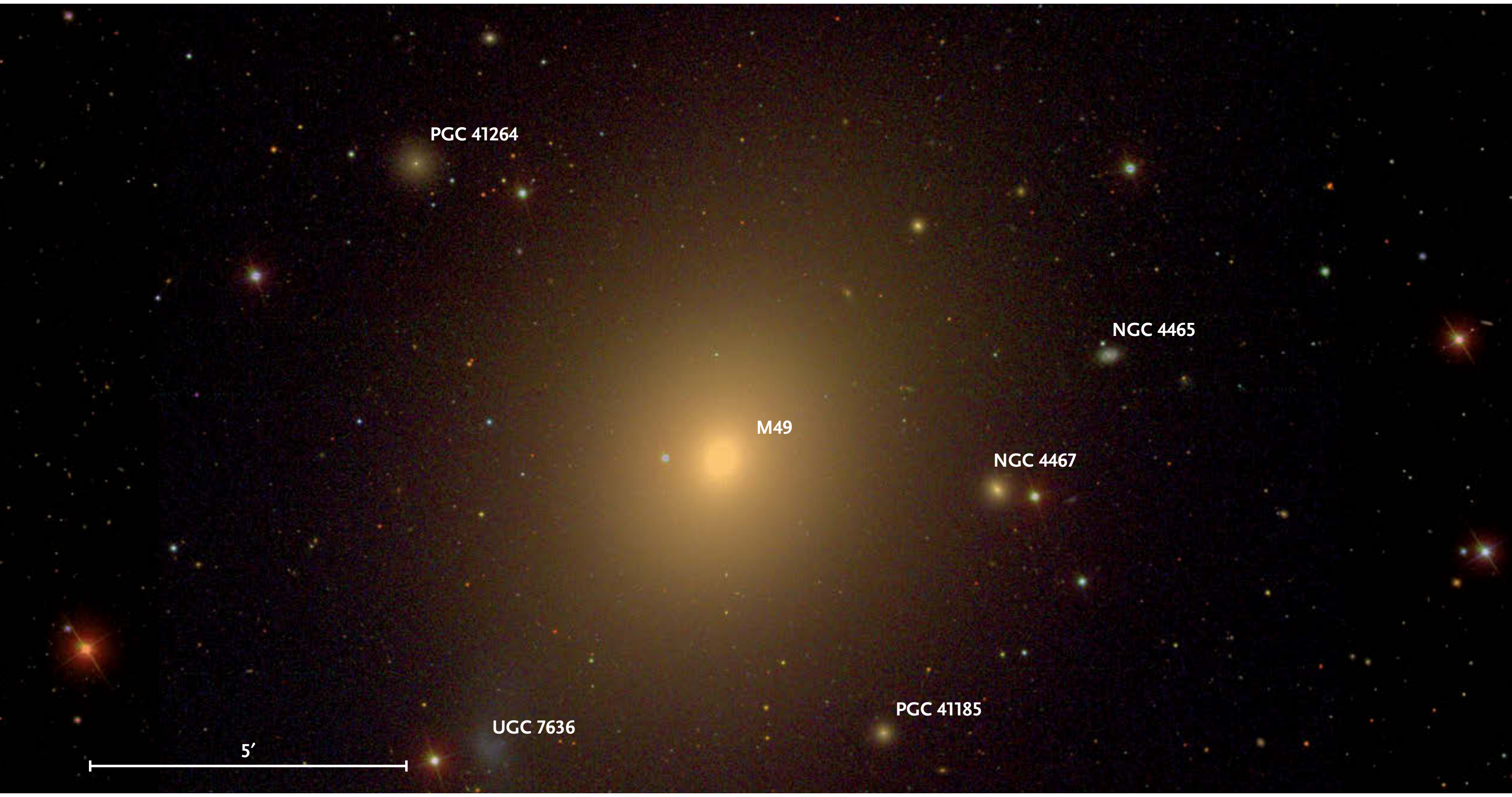

The dwarf galaxy UGC 7636 dwells a mere 50″ west-northwest of a 12th-magnitude star that guards M49's southeastern edge. According to a paper in *Astronomy & Astrophysics* (Arrigoni Battaia et al., 2012), the dwarf has suffered much wear and tear from at least two close encounters with M49. As UGC 7636 plowed through M49's hot, dense halo, the resulting pressure stripped the little galaxy of its own supply of gas, quashing star birth within the dwarf. M49's tidal pull abetted this process. It also gave UGC 7636 a tail of stars reaching out toward M49, as well as a counter-tail stretching southwest. The orphaned cloud of turbulent gas eventually developed its own star-forming regions.

UGC 7636 has been seen under very dark skies in scopes as small as 16 inches in aperture. Several other small galaxies flock around M49, as shown in the image on the facing page, but our sky tour will focus instead on some of the brightest galaxies in the region.

To find them, we'll return to the line of stars that helped us locate M49. **NGC 4526** lies between its easternmost and middle star, while **NGC 4535** hovers 28′ north of the former. These galaxies share the field of view through my 105-mm scope at 47×. NGC 4535 is a softly glowing, 6′ × 4′, north-south oval that brightens only slightly toward the center. NGC 4526 looks smaller but brighter than its neighbor. Its spindle shape is tipped east-southeast and bears a brighter, somewhat elongated core. At 87× a starlike nucleus appears.

Through my 10-inch scope at 149×, NGC 4535 harbors a small brighter core with short extensions northeast and southwest. This seems to give the galaxy a bar about 1½′ long, slanted northeast. In reality this feature is partly made up of the inner regions of two opposed spiral arms. Faint stars dot the galaxy 57″ north and 2.2′ south of its center. An extremely faint star is intermittently visible just west of the bar's southern extension. It makes a nearly isosceles triangle with the southern star and a brighter star near the galaxy's southwestern edge.

The triple star **Struve 1658** (Σ1658) sits 22′ southeast of NGC 4526. In my 105-mm refractor at 17×, the bright, yellow primary star has an orange companion spaciously removed to the west. Relative motion indicates that these stars don't form a true pair. Boosting the power to 87×




SLOAN DIGITAL SKY SURVEY

**The giant elliptical galaxy Messier 49 is surrounded by many fainter companions. The most prominent galaxies in M49's immediate vicinity are labeled here.**

unveils a dimmer companion close to and north-northeast of the primary. Its color is difficult to discern, but it seems to be a deeper shade of yellow than the primary. This pair is about 230 light-years away.

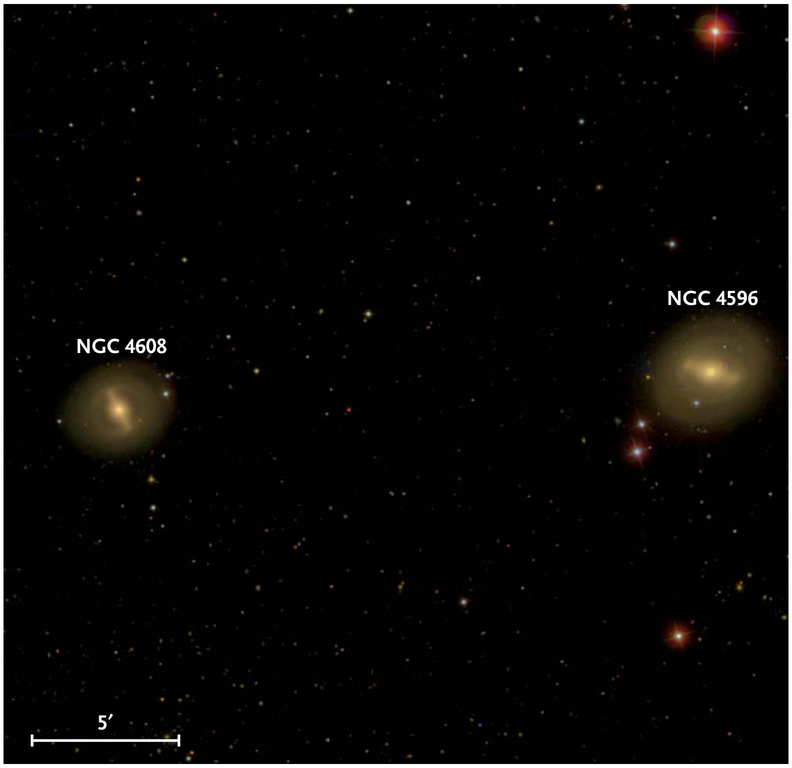
**NGC 4570** resides 29′ east-southeast of Struve 1658. They share the field with NGC 4526 through my 105-mm refractor when I use a wide-angle eyepiece at 47×. NGC 4570 is a very small but easily visible streak tilted north-northwest. At 87× the galaxy displays a relatively large, elongated core and a bright, starlike nucleus. With my 10-inch reflector at 171×, I estimate an apparent length of 2½′ and a central width of ½′.

Returning once again to our handy line of three stars, let's draw an imaginary line from the easternmost to the westernmost star, and then extend the line for twice that distance. This takes us to **NGC 4365**, which shares the field of view with M49 through my 105-mm refractor at 17×. This small, oval galaxy is adorned with a much brighter center, and it sits at the southwestern corner of a nearly square, roughly 16′ box that it makes with three 10th-magnitude stars to its north, northeast, and east. At 87× NGC 4365 is about 4½′ × 2¾′, elongated northeast-southwest, and it holds a large, bright, oval core enfolding

## Galaxies and Stars in South-Central Virgo

| Object | Type | Magnitude | Size/Sep. | RA | Dec. |
|---|---|---|---|---|---|
| Messier 49 | Galaxy | 8.4 | 9.4′ × 8.3′ | $12^h$ $29.8^m$ | +8° 00′ |
| NGC 4526 | Galaxy | 9.7 | 7.2′ × 2.4′ | $12^h$ $34.1^m$ | +7° 42′ |
| NGC 4535 | Galaxy | 10.0 | 7.1′ × 5.0′ | $12^h$ $34.3^m$ | +8° 12′ |
| Struve 1658 | Multiple star | 8.1, 9.1, 10.5 | 128″, 2.7″ | $12^h$ $35.1^m$ | +7° 27′ |
| NGC 4570 | Galaxy | 10.9 | 3.8′ × 1.1′ | $12^h$ $36.9^m$ | +7° 15′ |
| NGC 4365 | Galaxy | 9.6 | 6.9′ × 5.0′ | $12^h$ $24.5^m$ | +7° 19′ |
| NGC 4442 | Galaxy | 10.4 | 4.6′ × 1.8′ | $12^h$ $28.1^m$ | +9° 48′ |
| NGC 4596 | Galaxy | 10.4 | 4.0′ × 3.0′ | $12^h$ $39.9^m$ | +10° 11′ |
| NGC 4608 | Galaxy | 11.0 | 3.2′ × 2.7′ | $12^h$ $41.2^m$ | +10° 09′ |
| Porrima | Double star | 3.5, 3.5 | 2.2″ | $12^h$ $41.7^m$ | –1° 27′ |
| Virgo Diamond | Asterism | 10.4 | 0.8′ | $12^h$ $33.3^m$ | –0° 39′ |

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.




SLOAN DIGITAL SKY SURVEY

**The barred spiral galaxies NGC 4596 and 4608 are uncannily similar to each other.**

a small, brighter nucleus. The galaxy is flanked by a faint star near its northwestern side and a brighter but more distant star off the opposite side.

A yellow, 6th-magnitude star rests 48′ northwest of M49. It makes an isosceles triangle with 8th-magnitude stars 1.3° north-northeast and north-northwest. **NGC 4442** lies halfway between these two stars and a bit north of an imaginary line connecting them. My 105-mm scope at 28× shows an elongated galaxy with a much brighter core. At 87× I estimate dimensions of 3.4′ × 1′, with the galaxy tipped a smidgen north of east. The core appears slightly oval at 122×. Through my 10-inch scope at 187×, the halo is shaped much like a double-convex lens. Faint stars pin its rim south-southwest of the galaxy's nucleus and on the north side of its eastern end.

Two adorable galaxies inhabit the sky near Rho Virginis: **NGC 4596** and **NGC 4608**. Through my 105-mm refractor at 17×, the galaxies are just tiny spots of mist. NGC 4608 is 11′ west-southwest of Rho, and NGC 4596 is 19′ west of its companion in a north-south zigzag of eight stars, magnitude 9 and fainter. At 87×, the galaxies look like phantom Saturns — each a ball with faint extensions. NGC 4596's "rings" tilt east-northeast, while those of NGC 4608 are harder to see and lean north-northeast. NGC 4608 is accompanied by a faint star 1.6′ west-northwest. NGC 4596's "Saturn" is embedded in a dim halo tipped northwest and has a faint star off its "south pole."

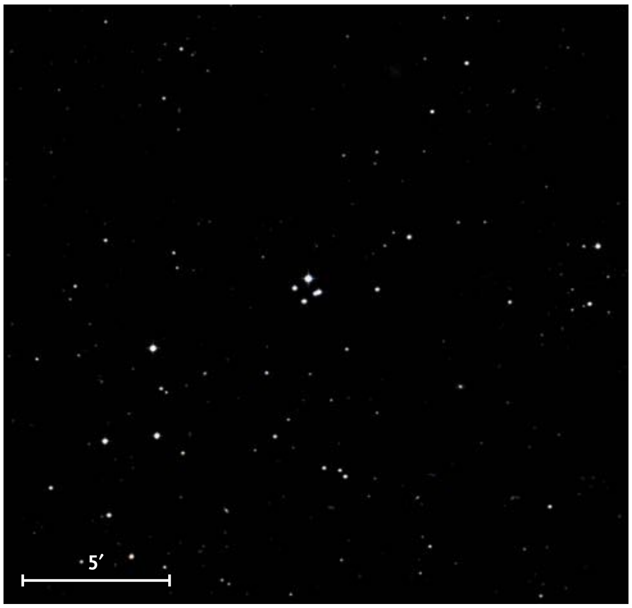
My 10-inch reflector at 187× shows that NGC 4608 has a ghostly, oval halo perpendicular to the plane of "Saturn's rings." When viewed with bright Rho outside the field of view, the halo nearly reaches the galaxy's companion star, and the ringed-planet shape spans about 1½′. NGC 4596 is a bigger and brighter but blurrier-looking Saturn, with a 3½′-long halo.

All the galaxies above are members of the Virgo Cluster, centered 55 million light-years from us.

For a bit of variety, let's plunge southward to Gamma (γ) Virginis, also known as **Porrima**. From a minimum separation of 0.4″ in 2005, its twin components have widened the space between them to 2.2″, placing them within reach of a small telescope. These pale yellow-white suns are aligned north-south and are nicely split through my 105-mm scope at 122×.

A charming asterism known as the **Virgo Diamond** sits 2.2° west-northwest of Porrima. Noah Brosch introduced it in the December 1991 *Monthly Notices of the Royal Astronomical Society* because he thought it could be an "evaporating small cluster in the Galactic halo."

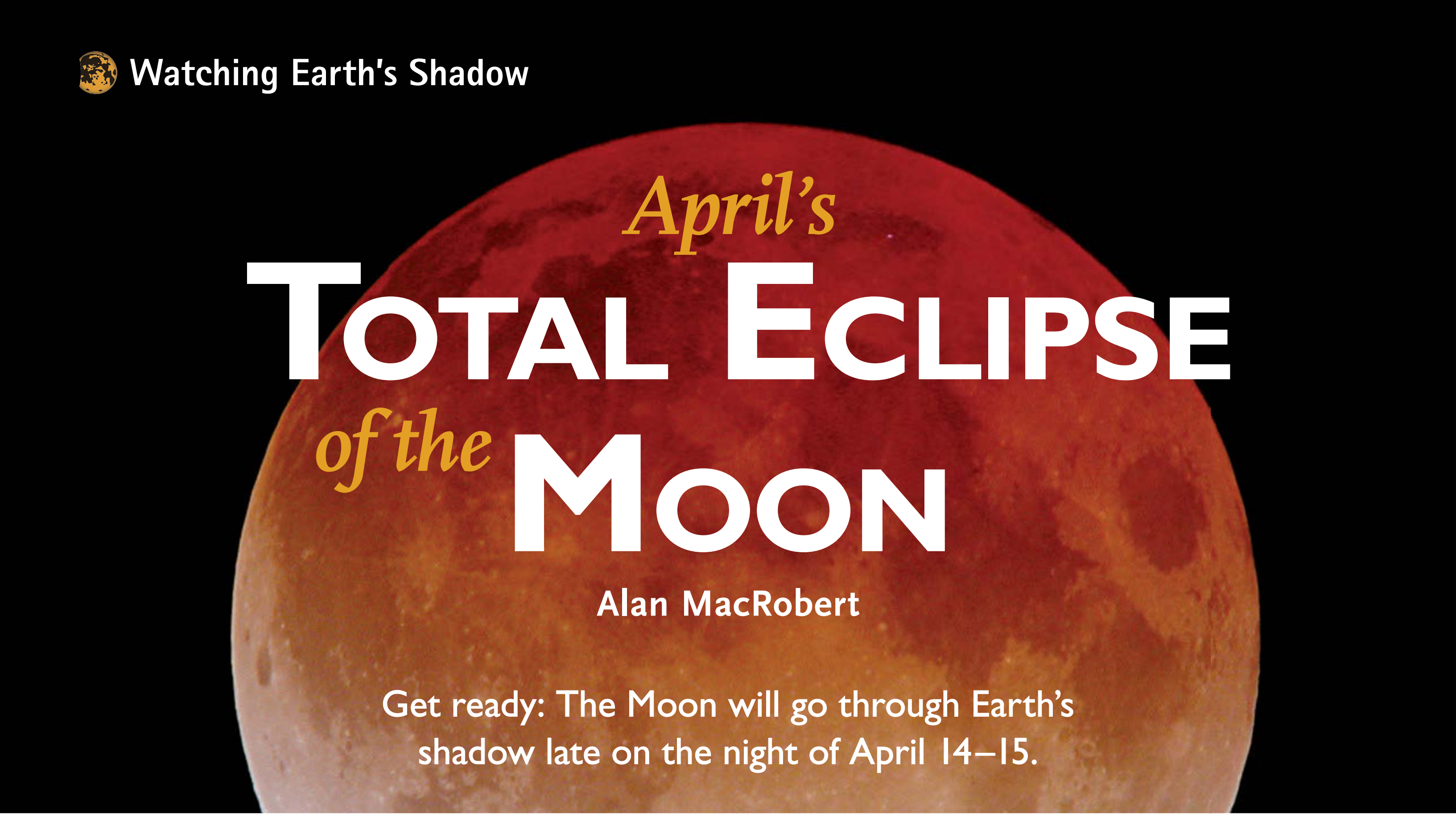
Through my 130-mm refractor at 23×, the Virgo Diamond is a teensy fuzzspot. I can just see four stars marking the corners of a square at 63×, and they show quite nicely at 117×. At 164× the western star blossoms into a close pair, better appreciated at 234×, with the dimmer star east-southeast of the primary. Although most, and possibly all, of its components are now thought to be physically unrelated, this Diamond is a pretty little gem with which to end our tour. ✦




POSS-II / CALTECH / PALOMAR OBSERVATORY

**The lovely, compact Virgo Diamond asterism stands out in a relatively star-poor background field.**

TelescopeS.NET
by Woodland Hills Camera & Telescopes
MEADE
LX850
Built-in guiding for imaging
CELESTRON
CGE Pro 1400 HD
Your ultimate portable 14" scope
PlaneWave INSTRUMENTS
Why wait for your favorite CDK when you can have one now?
EXPLORE SCIENTIFIC
100 degree eyepieces for as little as $249
TAKAHASHI
An amazing wide field refractor
Apogee IMAGING SYSTEMS
The Aspen by Apogee The 16803 chip that never quits
OFFICINASTELLARE
Veloce RH 200
8" f/3.0 astrograph
SBIG ASTRONOMICAL INSTRUMENTS
STi
The must have guider from $595
Shelyak INSTRUMENTS
Exciting and affordable spectrograph from Shelyak
$759
iOptron
SkyTracker w/Polar Scope
Easy setup, Excellent performance
$399
CORONADO
Rich View SolarMax II
An amazing H alph as little as $1299
LUNT SOLAR SYSTEMS
LS35TH Dedicated H-Alpha Solar Telescope
Basic $598
Deluxe (shown) $673
Paramount MX
Engineered for productivity
SOFTWARE BISQUE
FLI Finger Lakes Instrumentation
Atlas Digital Focuser
High payload precision focuser
TeleVue Visionary
Tele Vue NP127 IS, Incredibly sharp, astrophotography ready
Canon
EOS 60Da DSLR Astrophotography Camera
Last call while supplies last!
Incredible StarLapse System
Performance and versatility
$695.00
LOSMANDY
Vixen Optics
Special Closeout
Sphinx SXD w/tripod
Regular: ~~$2,899~~
Now $1,495!
While supplies last
ATIK CAMERAS
Titan CCD Camera
Planetary and deep-sky imager
$689
888-427-8766 Intnl: 818-347-2270 • 5348 Topanga Canyon Boulevard, Woodland Hills, CA 91364



# April's TOTAL ECLIPSE of the MOON

Alan MacRobert

Get ready: The Moon will go through Earth's shadow late on the night of April 14–15.

S&T: DENNIS DI CICCO

NORTH AMERICA HASN'T had a total eclipse of the Moon since 2011. That long dry spell will break on the night of April 14–15, when the full Moon passes through the umbra (dark inner part) of Earth's shadow.

Adding to the late-night spectacle will be Spica shining only about 1° or 2° from the Moon (depending on the time and your location), and bright Mars about 9° to their west.

On the facing page, the bottom diagram shows the Moon's passage through the umbra and penumbra (pale outer fringe) of Earth's shadow. The table lists the times for each step in North American time zones.

The eclipse will also be visible from South America and much of the Pacific, as shown on the world map. In eastern Australia the Moon doesn't rise until the total eclipse is already underway on the evening of the 15th local date.

### TWO OBSERVING PROJECTS

• Roger Sinnott continues to collect amateurs' *crater timings* — telescopic timings of when the umbra's edge crosses lunar craters — following a decades-long project tracking slight unpredictability in the umbra's diameter. Go to **skypub.com/cratertimings** for instructions, a crater map, and where to report.

• John Westfall seeks naked-eye timings of the four *eclipse contacts:* when the partial phases begin and end before and after totality. These will help calibrate the pre-telescopic timings made by mariners and others when this was the only way to determine longitude. See **alpo-astronomy.org/eclipseblog/?p=24**.

## What to Look For

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

The first *penumbral* stage begins when the Moon's leading edge enters Earth's penumbra. But not until the Moon intrudes about halfway across the penumbra does the weak, pale shading begin to be visible on the Moon's leading (celestial eastern) side. As the minutes advance and the Moon moves deeper in, the penumbral shading becomes much stronger.

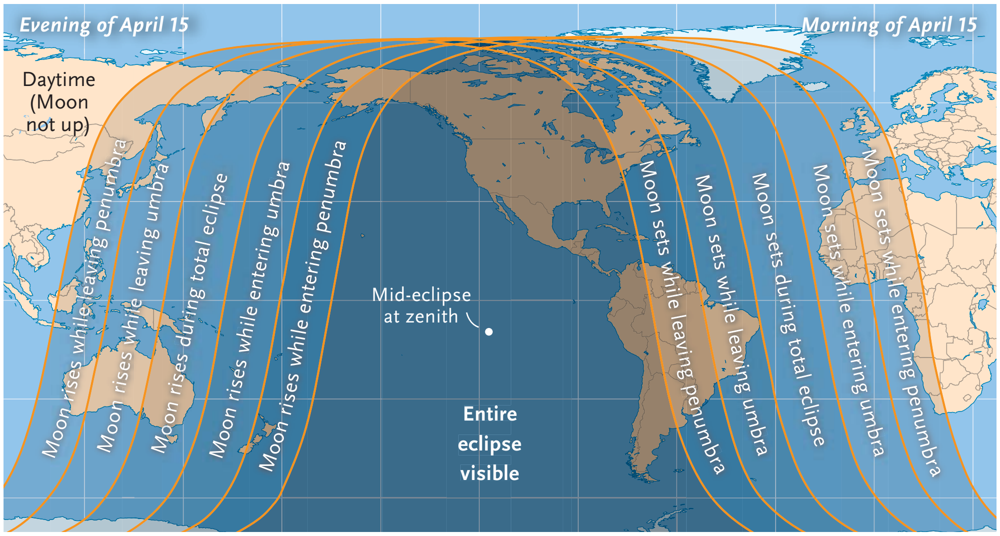
The second stage is *partial eclipse*. This begins much more dramatically, when the Moon's leading edge enters the umbra: the zone where no direct sunlight reaches. Few sights in astronomy are more eerie and impressive than watching this red-black shadow creeping, minute by minute, across the lunar landscape.

As more of the Moon slides into the umbra, look around the sky. A second, deeper night is falling — night within night, with more stars coming out in what had been a bright, moonlight-washed sky.

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

The third stage is *total eclipse,* beginning when the last rim of the Moon slips into the umbra. This is the part of Earth's shadow where the Sun is completely hidden.

*Facing page*: An eclipsed Moon can be anything from bright orange to the color of dried blood. *S&T*'s Dennis di Cicco took this image on November 8, 2003. *Right*: For your location, see if the Moon will set or rise during any stage of the eclipse. Because an eclipsed Moon is always full, the Sun rises or sets at almost the same time on the opposite horizon. This means that a lunar eclipse moonset or moonrise always happens in a bright sky.




S&T: LEAH TISCIONE

So why does a fully eclipsed Moon usually glow deep orange or red, rather than being completely blacked out?

The red light on the eclipsed Moon comes from all the sunrises and sunsets that ring Earth at the moment. Our atmosphere scatters and refracts sunlight that grazes the rim of our globe, diverting some of it into Earth's shadow. To an astronaut standing on the Moon, the Sun would be hidden behind a dark Earth ringed with a thin, brilliant band of sunset- and sunrise-colored light.

On rare occasions the eclipsed Moon goes almost black. Other times it's as bright and coppery as a new penny. Or dull ruddy brown. Nor is the shading uniform.

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

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

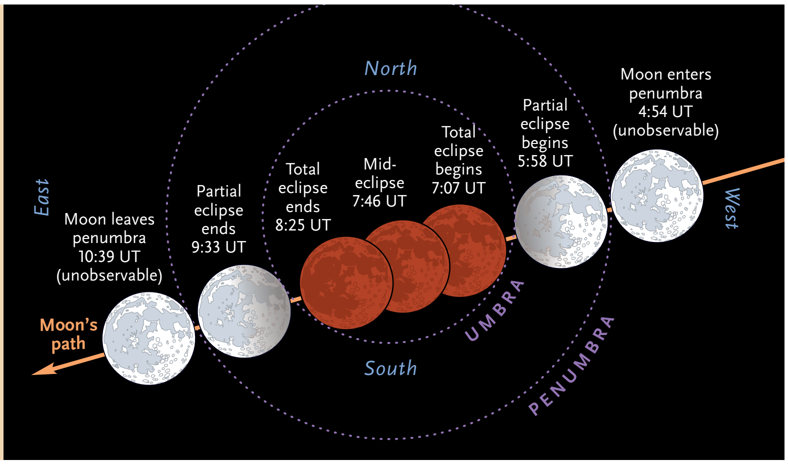
In addition, blue light refracted by Earth's ozone-rich upper atmosphere can contribute to the scene, especially near the umbra's edge, creating a subtle mix of changing colors. Time-lapse photography may show "flying shadows" crossing the Moon's face during totality. These result from different cloud features along Earth's sunrise-sunset ring fading and brightening as the Sun shifts position behind Earth.

Totality will last for 1 hour 18 minutes. And then, as the Moon continues moving eastward along its orbit, events unfold in reverse order. The Moon's leading edge re-emerges into sunlight, ending totality and beginning stage four: when the eclipse is again partial. When all of the Moon escapes the umbra, only the last, penumbral shading remains for stage five. This weak duskiness slowly disappears, leaving the full Moon as bright as ever.

If it's cloudy, North Americans won't have another long wait for more total lunar eclipses. The next three come at 6-month intervals: On the morning of October 8th for the whole continent except the farthest northeast; on the morning of April 4, 2015, for the West; and on the evening of September 27, 2015, for all but Alaska. ✦

## Total Eclipse of the Moon, April 14–15, 2014

| Eclipse event | EDT | CDT | MDT | PDT |
|---|---|---|---|---|
| Penumbra first visible? | 1:20 a.m. | 12:20 a.m. | 11:20 p.m. | 10:20 p.m. |
| Partial eclipse begins | 1:58 a.m. | 12:58 a.m. | 11:58 p.m. | 10:58 p.m. |
| Total eclipse begins | 3:07 a.m. | 2:07 a.m. | 1:07 a.m. | 12:07 a.m. |
| Mid-eclipse | 3:46 a.m. | 2:46 a.m. | 1:46 a.m. | 12:46 a.m. |
| Total eclipse ends | 4:25 a.m. | 3:25 a.m. | 2:25 a.m. | 1:25 a.m. |
| Partial eclipse ends | 5:33 a.m. | 4:33 a.m. | 3:33 a.m. | 2:33 a.m. |
| Penumbra last visible? | — | 5:10 a.m. | 4:10 a.m. | 3:10 a.m. |




S&T ILLUSTRATION

 Dennis di Cicco & Sean Walker

# Skyris Planetary Cameras from Celestron

*Two industry leaders team up to create the next generation of video cameras for the Sun, Moon, and planets.*


**Apart from a suitable telescope and computer, the Skyris video cameras come with everything you need to start imaging the Sun, Moon, and planets. The CD-ROM includes the highly regarded image-processing program *RegiStax 6*. The cameras are backward compatible with USB 2.0 equipment.**

WE ALL KNOW that the rise of digital imaging created many sea changes in the world of astrophotography. No event, however, is easier to pinpoint in time than the one that revolutionized planetary imaging. It was August 2003, and Mars was making its record-setting close approach to Earth. Everyone was gawking at the planet, and elite planetary imagers were cranking out their usual spectacular views of our ruddy neighbor. But when word got out that the best images — ones showing more detail than people were seeing in telescope eyepieces — were made with inexpensive "webcams" and free image-processing software, the die was cast (*S&T:* December 2003, page 30). It wasn't long before people just dabbling in planetary imaging were shooting better pictures of the Sun, Moon, and planets than anyone ever obtained during the previous century and a half of photography.

The typical key to successful planetary imaging is to use a small digital camera to shoot short video clips comprising a few hundred to a few thousand individual frames and then use software to cull, register, and stack (combine) the sharpest frames captured during those elusive moments of good atmospheric seeing. The video cameras favored by serious planetary imagers have varied with time, but in recent years models made by The Imaging Source in Germany have been near the top of most

**WHAT WE LIKE:**

Excellent image quality

Easy to use

Small and lightweight

**WHAT WE DON'T LIKE:**

Difficult to keep dust off sensor.

## Skyris Planetary Cameras

**U.S. price:** from $499.95

Available from Celestron dealers worldwide

ALL PHOTOS BY THE AUTHORS

peoples' list. Now this company has joined forces with telescope giant Celestron to introduce the latest generation of planetary video cameras. Called Skyris, they are the first ones marketed specifically for planetary imaging that use high-speed USB 3.0 computer connections. As such, they are capable of capturing full-frame, full-resolution, uncompressed video streams at very high frame rates. We'll get back to this in a moment.

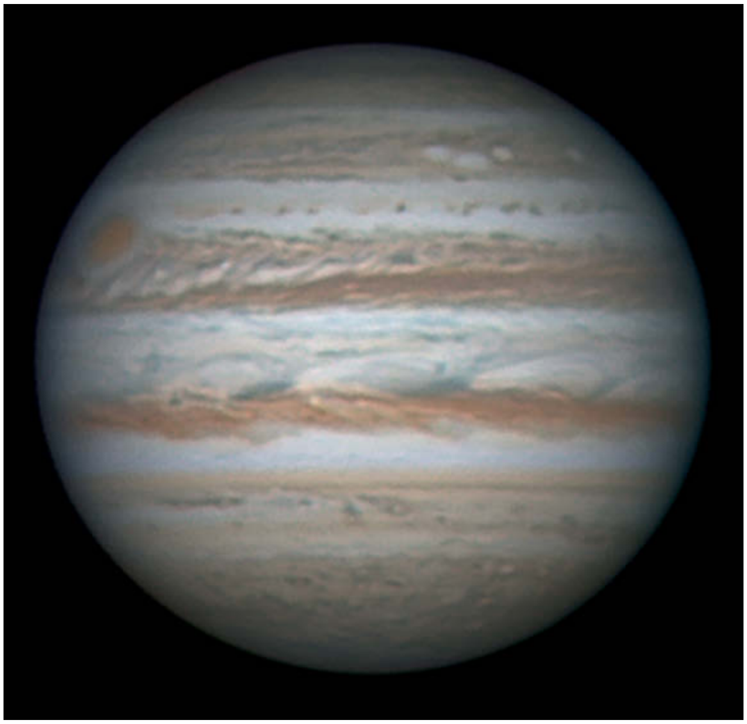
Based on monochrome and color versions of three digital detectors made by Sony, there are a total of six models in the Skyris line. We'll save space here by pointing you to the Celestron website (**www.celestron.com**), where there are detailed specifications and comparison tables.

To get a feel for how the Skyris cameras perform, we borrowed the monochrome models at both ends of the camera line. The Skyris 618M has the smallest detector. It is the same Sony ICX618ALA CCD found in The Imaging Source's DMK 21AU618.AS camera that we reviewed in the April 2012 issue, page 62. You can read a detailed account of that chip's astronomical performance in that review. The Skyris camera, however, ups the maximum frame rate from 60 to 120 frames per second (FPS). The Skyris camera with the largest detector is the 274M. It is built around the 2.9-megapixel Sony ICX274AL CCD, which has more than six times the active imaging area of the 618M, but with a maximum frame rate of only 20 FPS. The model we didn't test, the Skyris 445, has a 1.2-megapixel CCD and a maximum rate of 30 FPS. The cameras allow you to vary the exposure time for a given frame rate, but the rates themselves are available only in fixed steps.

Like their DMK predecessors from The Imaging Source, the Skyris cameras are very small and lightweight, being barely larger than a typical 1¼-inch eyepiece. All have a standard C-thread mount for video lenses and come with a 1¼-inch nosepiece that allows the camera to come to focus with virtually every telescope that works with 1¼-inch eyepieces.

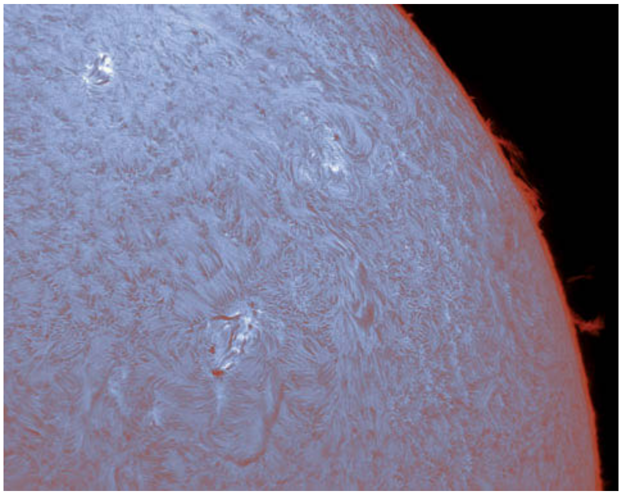
The cameras are powered by, and communicate with, your PC computer (running Windows XP or higher) using a 10-foot-long (3-meter) USB 3.0 cable. The computer end of this cable is compatible with all conventional USB ports, and the cameras work just fine using older USB 2.0 connections, but with maximum frames rates of about half that possible with a USB 3.0 connection.

The camera end of the cable is a very solid, thumbscrew-locking plug that is unique to female USB 3.0 ports (see the photo below), so you can't simply swap the cable supplied with the Skyris cameras for shorter or longer USB 2.0 cables you're likely to have lying around. Never-



**Sean Walker recorded Jupiter with the Skyris 618M and his 12-inch Newtonian reflector last January 10th. He assembled the image from short video clips made at 60 frames per second through color filters. The planet's Great Red Spot (upper left) is more intensely colored than is has been in recent years.**

***Left:*** **The CCD detector in the Skyris 274M (left) has more than six times the active imaging area of the 618M's CCD (the color seen on the chips is an artifact of the studio lighting).** ***Right:*** **The ends of the USB 3.0 cable, described in the text, are pictured here.**



Walker's view of the Sun on August 21, 2013 was made with the Skyris 274M and a 4-inch solar telescope (color was added to the monochrome image during processing). The camera's large field of view is handy for making mosaic images of the Sun and Moon.

theless, we both found that the 10-foot cable was more than long enough for all the setups we tried using different telescopes and laptop computers.

Although the USB 3.0 standard was introduced in 2008, it's not a given that all computers manufactured after that date have USB 3.0 ports, and even the ones that do often include slower USB 2.0 ports as well. You should check your computer's specifications to make sure what you have. It's worth noting that all the USB 3.0 ports we've seen on computers have distinctly blue plastic bits visible when you look into the end of the port.

Running the Skyris cameras at the high frame rates available with a USB 3.0 connection is nice, but it's not as important as you might think at first blush. High frame rates are certainly great for bright objects such as the Sun and Moon. But other than Venus, the planets are not bright enough to be recorded well at high frame rates, at least not with typical amateur telescopes used with sufficient magnification to record planetary detail.

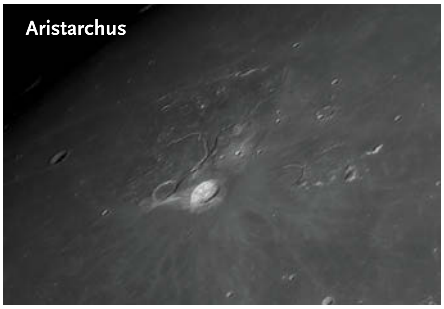
Installation of the Skyris camera drivers and image-capture software (supplied on a CD-ROM) is straightforward and takes only minutes. The control program, called *iCap,* is identical to the *IC Capture.AS* program provided with The Imaging Source's DMK cameras. It's easy to use, and many people will likely figure out the basics without having to look further than information in the small, 16-page, printed manual shipped with the camera.

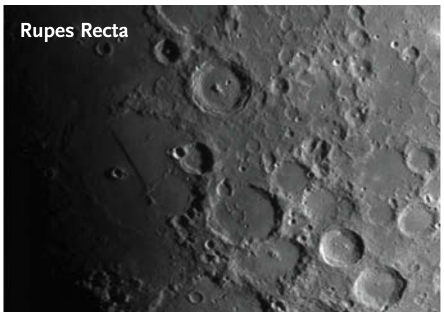
The CD-ROM also includes the well-known image-processing program *RegiStax 6*. It does a very good job creating highly detailed images from the AVI video streams recorded by *iCap*. First-time users will find this program a bit daunting, but there are well-chosen default settings to get you started. There are also online tutorials, including one on our website at **www.skypub.com/planetary**.

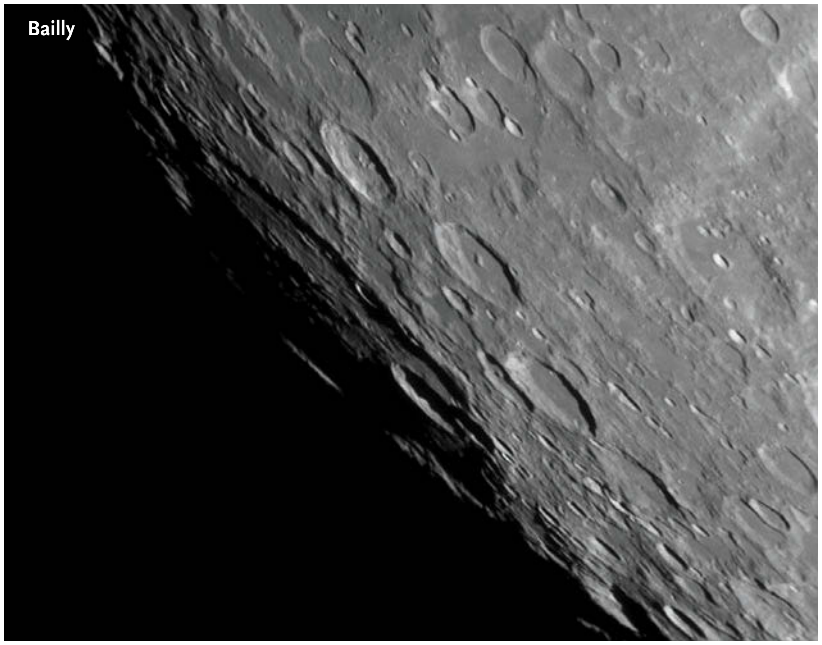
The accompanying pictures speak for themselves. We were very pleased with the results, and we found nothing significant to fault with the Skyris cameras or the supplied software. Our biggest issue was trying to keep dust off the chips — the 618M especially, seemed like a dust magnet. It would be nice if the cameras came with a clear filter for the front of the 1¼-inch nosepiece to keep dust away from the detector, but this is a pretty minor quibble given the overall fine performance of the cameras. ✦

---

S&T*'s senior editor* **Dennis di Cicco** *and imaging editor* **Sean Walker** *have been teaming up on astrophotography projects for more than a dozen years.*

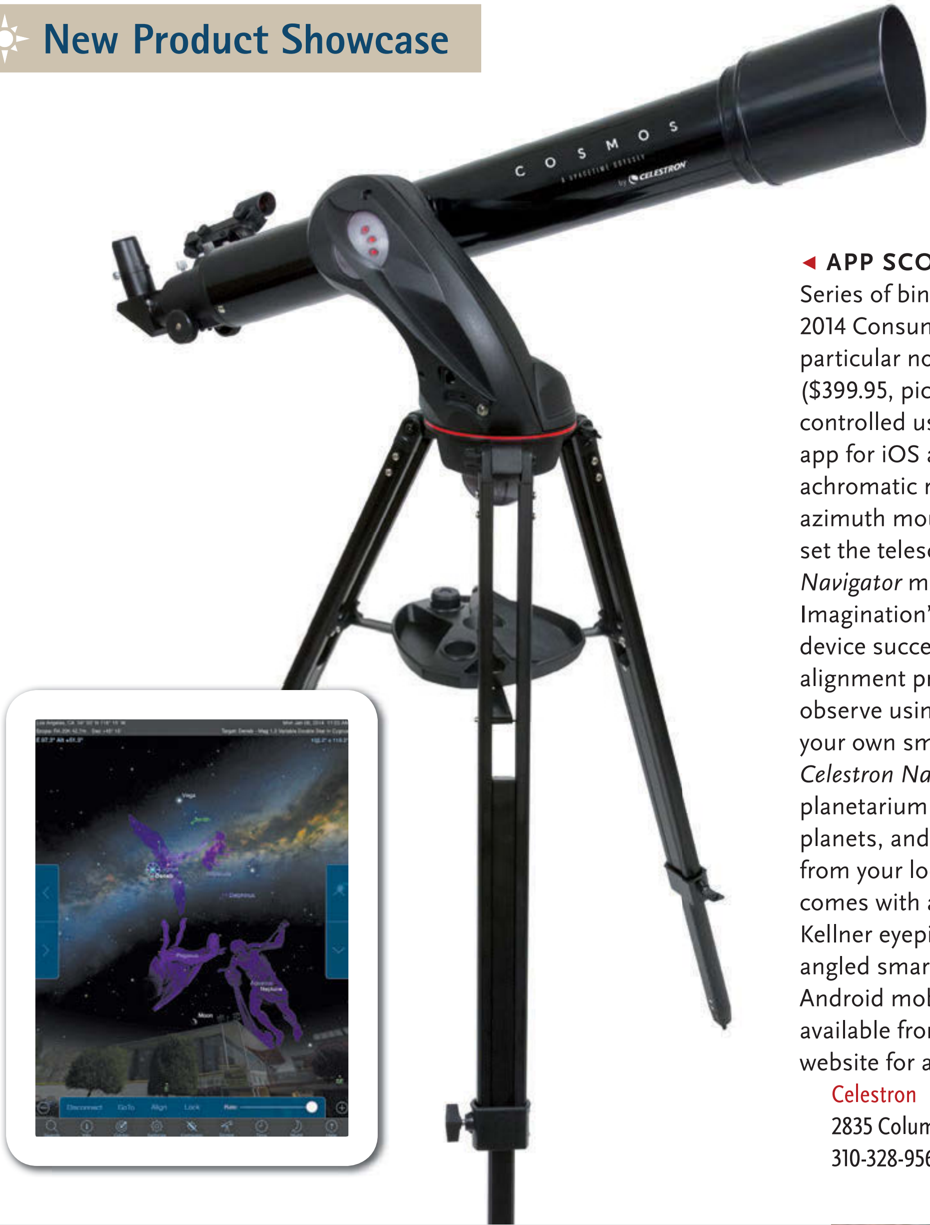



The authors' images of the Moon made with the Skyris 274M camera include views of the craters Aristarchus and Bailly made with a 12-inch reflector, and the lunar fault Rupes Recta (the Straight Wall) captured with an 8-inch Schmidt-Cassegrain.

# New Product Showcase




◂ **APP SCOPE** Celestron introduced its new COSMOS Series of binoculars, microscopes, and telescopes at the 2014 Consumer Electronics Show in Las Vegas. Of particular note is the COSMOS 90GT WiFi Telescope ($399.95, pictured at left), a Go To refractor completely controlled using the free *COSMOS Celestron Navigator* app for iOS and Android devices. This 90-mm f/10 achromatic refractor is mounted on a single-arm alt-azimuth mount with a sturdy aluminum tripod. Simply set the telescope down, open the *COSMOS Celestron Navigator* mobile app, and the "3D Spaceship of the Imagination" design on the fork arm lights up when your device successfully connects to the mount. Follow the alignment procedure of your choice, and you're ready to observe using a controller you're most familiar with — your own smartphone or tablet device. The *COSMOS Celestron Navigator* mobile app contains a complete planetarium program, enabling you to seek out the Moon, planets, and many of the brighter deep-sky objects visible from your location. The COSMOS 90GT WiFi Telescope comes with a StarPointer red-dot finder, 25- and 10-mm Kellner eyepieces, and a rubberized accessory tray with an angled smartphone platform. If you don't have an iOS or Android mobile device, an optional hand controller is available from the manufacturer. See the company's website for additional details.

Celestron
2835 Columbia St., Torrance, CA 90503
310-328-956; www.celestron.com

▸ **COMPACT ASTROGRAPH** Takahashi has updated and reintroduced its smallest Epsilon series telescope, the ε-130D Hyperbolic Astrograph ($2,995). This 5-inch f/3.3 optical system features a hyperbolic primary mirror mated with a digital corrector to record pinpoint stars across a large 44-mm image circle. With a newly redesigned collimation system, secondary assembly, and heavy-duty focuser, the ε-130D will hold alignment at any angle as you track your targets across the sky. Its compact Newtonian design measures just over 18 inches and weighs in at 10.8 pounds (4.9 kg), making the ε-130D airline transportable. The reduced size and weight also allow it to be used on smaller equatorial mounts than its predecessor could. See the company's website for additional options.

Texas Nautical Repair
1925A Richmond Ave., Houston, TX 77098
713-529-3551; www.takahashiamerica.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 70-inch Amateur Telescope

*Chuck Hards*

***This monster Dob is likely the largest transportable amateur scope in the world.***

**While most, if not all,** amateur telescope makers get a touch of aperture fever now and then, only a handful have ever been as badly afflicted as Mike Clements. A 51-year-old long-haul truck driver from West Jordan, Utah, Mike has been fascinated with the night sky since his childhood in California. As an adult he built a 40-inch (1-meter) Dobsonian with the help of friends. It earned him the nickname One Meter Mike. But even that impressive instrument eventually proved too small, so he set his sights on a larger telescope.

In 2005 his friend Vaughn Parsons, a professional optics manufacturer, purchased an unaluminized, fully figured 70-inch (1.8-meter) mirror at a surplus auction. It was originally fabricated for a Cold War-era spy satellite, but a minor edge chip doomed it to storage and eventual sale. Parsons promptly called Mike, who had often spoken of wanting to build a telescope larger than 1 meter.

"I couldn't believe it," Mike said when he heard the news. "I had to have it." He purchased the mirror from Parsons without knowing its exact optical figure. "I wasn't sure if it was intended to be part of some complex optical system. None of us knew if it would even work in a visual telescope." At least the edge chip that kept the mirror from going into space didn't extend onto the optical surface. And though the mirror blank was a "lightweight" honeycomb structure, it still weighed about 900 pounds (400 kg).

Although a few people tried to dissuade Mike from tackling such a big project, he forged ahead with his big-scope dream. "He built a model out of Popsicle sticks," recalls Steve Dodds, owner of Nova Optical Systems and Mike's friend and mentor on the project. "I bought him a computer-aided design program, but he never touched it." Instead the telescope came into being one sub-assembly at a time — from Mike's imagination, directly to steel. He even taught himself to weld while building the scope.

At f/6.1, the primary mirror has a focal length of almost 36 feet (11 meters). So Mike used a 29-inch, round secondary mirror to fold the light path back on itself at a slight angle, enabling him to have the focuser at the side of the telescope's "tube" only about 14 feet off the ground when the 35-foot-long telescope points overhead. He used a regular 2-inch star diagonal as a tertiary mirror to place the eyepiece at a nearly horizontal angle, like a conventional Dobsonian. The finished telescope is about the size of a bus, but for viewing a large part of the sky, only a few steps up a ladder are needed to reach the eyepiece.

"Every spare dime he made went into it," says Dodds, who volunteered one of Nova Optical's buildings as a workshop for the project when Mike started fabricating

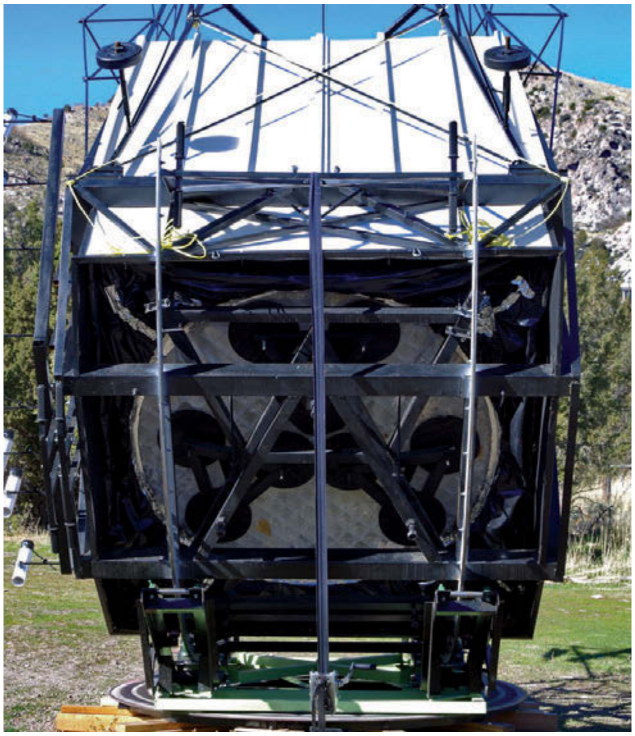
*Left:* Utah telescope maker Mike Clements is dwarfed by his 70-inch f/6.1 monster Dobsonian. The telescope is likely the largest transportable amateur instrument in the world.

*Right:* Mike Clements stands at the eyepiece of his 70-inch reflector. Thanks to a flat secondary mirror that folds the instrument's 36-foot light path, the eyepiece is never more than 14 feet off the ground. All photos by the author.

the scope in late 2011. Only when a structure to hold the primary was completed could the mirror's figure be evaluated. The testing was done outside since the focal length of the primary prevented indoor testing. "Steve was testing it with a Ronchi screen at the radius of curvature," Mike says, "so he had to be nearly 70 feet away from the mirror. I was nervous and holding my breath waiting to hear what Steve was going to say after looking at the mirror!" Nevertheless, Mike's jitters were relieved when Dodds announced that the mirror was a good paraboloid, showing just a little overcorrection, but well within acceptable limits.

Almost as daunting as building the telescope was the prospect of aluminizing the primary and secondary mirrors. "We got a bid of $7,000 for just the primary from an out-of-state company," says Mike, "and there was no guarantee that the mirror wouldn't be damaged in the process." A solution was found in the form of a spray-on silvering process that professional opticians use when they need to quickly test a mirror. Applying the coating requires a weed sprayer or automotive paint gun.

"I had to practice a bit," says Mike, "since it takes a while to get the method down, and I botched my first attempt." But eventually he successfully silvered the primary and secondary mirrors. Dodds thinks that with some protection, the mirrors will only need recoating once or twice a year. The coating is inexpensive and about 5% more reflective than standard aluminizing. Furthermore, Dodds's tests revealed that the mirror's figure was not compromised by the spray-on coating.



The scope's 70-inch mirror is supported on a 9-point cell, a configuration adequate for a cellular mirror that is nearly a foot thick. The short, white tubes on the left side of the mirror box are sight tubes for rough aiming of the scope.

The instrument's finder and focuser are mounted at the side of the scope where a 2-inch star diagonal places the eyepiece horizontal for comfortable viewing. A length of tubing ahead of the focuser prevents stray light from reaching the focal plane.

First light for the 3,000-pound telescope came on a cool, late-summer evening in 2013. Mike's target was M57, the famed Ring Nebula in Lyra. Usually a small object in most amateur telescopes, the ring filled much of the eyepiece field of view. The seeing wasn't ideal that night, but on better nights the central star was easily visible. The telescope worked — and it worked well. The behemoth has a usable magnification range from a low of about 280× (limited by the shadow of the secondary mirror visible in the exit pupil) to as high as the seeing will allow. Typically, 400× is the maximum useful power, but on rare nights Mike can push it higher.

The telescope is regularly used by Mike, his friends, and members of the Salt Lake Astronomical Society, but there are still some tweaks to be made. Mike is adding motor drives for automated tracking, and he plans to buy a trailer so that he can transport the monster Dob to National Parks and star parties. He hopes to have all this ready in time for the May 2014 RTMC Astronomy Expo, held near Big Bear Lake in Southern California. "I want to take it all around the country and let as many people as possible look through it," says Mike. "That's always been a high priority for me — I want to share it."

Although some contend that the 70-inch is not the largest amateur-made telescope (citing the 72-inch at Ireland's Birr Castle made by Lord Rosse in the mid-19th century), Mike's is certainly the largest transportable amateur-made scope. At least for now. Knowing Mike's passion for showing people the sky, and his determination to finish big projects, I would not be surprised if one day we might have to call him "Hundred Inch Mike!" ✦

---

***Chuck Hards*** *is an avid amateur telescope maker and member of the Salt Lake Astronomical Society. He can be contacted at chuck.hards@gmail.com.*

# John Lowry Dobson, 1915–2014

*There's more to the Dobsonian revolution than a telescope design.*

OUR LONGTIME READERS need no introduction to John Dobson: he was quite possibly the best-known amateur astronomer on the planet when he died peacefully in Burbank, California, on January 15th at age 98. Anyone wanting a refresher course will find endless material just a few mouse clicks away on the internet.

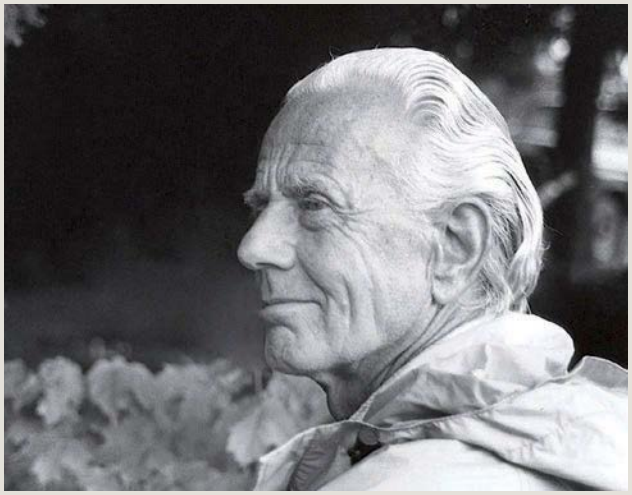
Dobson was born in China to missionary parents and was educated as a chemist at the University of California, Berkeley. After working on defense-related jobs, he spent 23 years as a Vedantan monk until he was expelled from the order in 1967, partly because of his unauthorized forays to the streets of nearby Sacramento to show people the heavens with his homemade telescopes.

Dobson's exploits as a telescope maker, as cofounder of the San Francisco Sidewalk Astronomers, and as an ardent astronomy popularizer are all chronicled online. But you may read that he invented the alt-azimuth telescope mount. He did not. That, however, is a minor point, since Dobson's overall contributions to telescope making and amateur astronomy are far more important.

Dobson frequently attended amateur gatherings, especially ones devoted to telescope making, where his presence to some was no less profound than if Isaac Newton walked among them. But it wasn't always that way.

I first met John in 1978 during one of my then-annual treks to California to cover the Riverside Telescope Makers Conference near Big Bear. John and his band of Sidewalk Astronomers were en route to give a public star party at the Grand Canyon but had detoured to attend the conference. They arrived in a beat-up old school bus hauling gigantic 22- and 24-inch reflectors. The whole procession was surrounded in an aura of 1960s flower power, making it seem a bit out of place at Riverside. But John was an immensely affable, quick-witted individual who could easily entertain a crowd. At night, long lines formed as people waited for a peek at the sky with what were the biggest telescopes most of them had ever looked through.

John's presence at the gathering also struck me as odd when he emphasized that he built his telescopes "for bringing astronomy to the people," rather than to entertain amateur astronomers. I got the sense that he showed up to subtly thumb his nose at traditional telescope makers who had been dismissing his construction methods as too crude to produce acceptable results. He


SAN FRANCISCO SIDEWALK ASTRONOMERS

wanted to prove that you didn't have to walk and talk like a machinist to build a telescope. And John was right. Just ask anyone who climbed the stepladder to look through the eyepiece of his 24-inch scope that night.

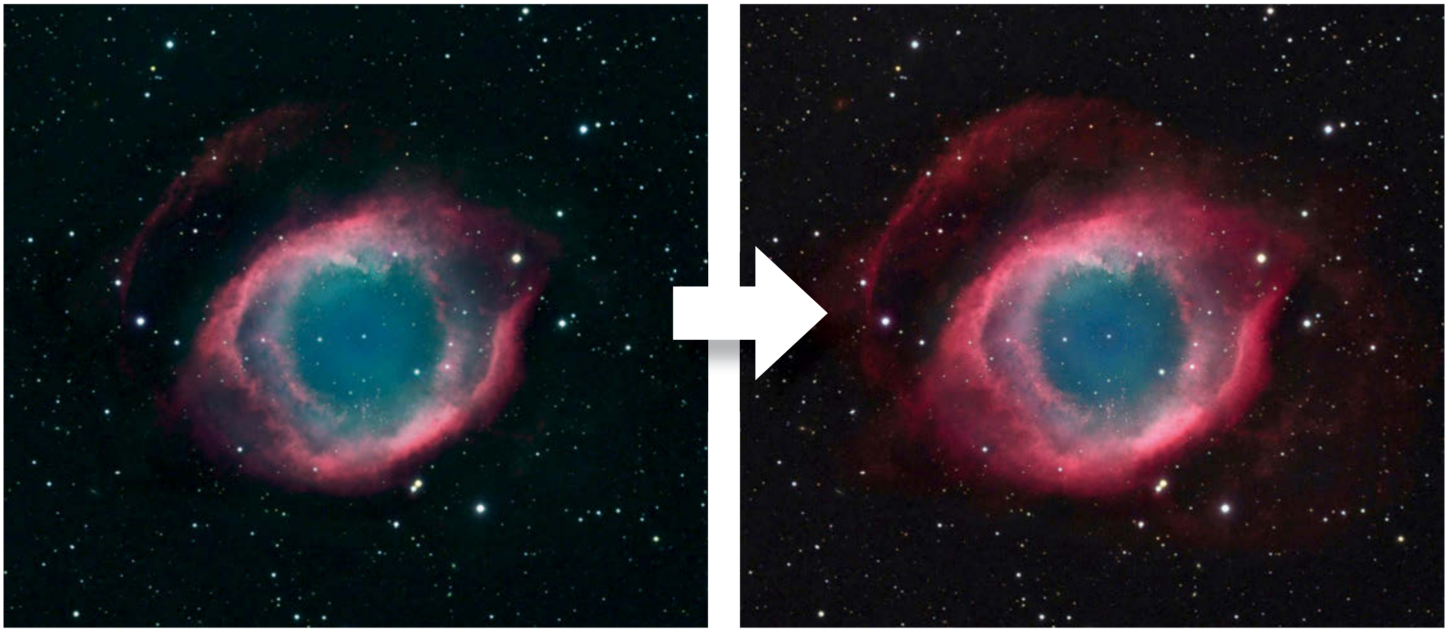
John's scopes were largely made from scrap materials, but his clever design sowed the seeds for the large-aperture revolution that was soon to sweep the amateur community. "Traditional" telescope makers later embraced and refined John's ideas, but the essence of his concepts remained, and the scopes were aptly dubbed Dobsonians.

Although Dobsonian telescopes are John's most visible legacy, they are not his biggest contribution to our hobby. The reason he built scopes in the first place was to give everyone a chance to see the heavens, hoping to ignite their curiosities. While his beliefs about the universe's creation didn't align with observational data (a view that made him unpopular in some corners of the community), his passion for getting people to think about the universe was truly extraordinary. His devotion to star parties on the streets of San Francisco and at our national parks gave tens of thousands that chance. And if you count the people worldwide who've peered into the night sky because of the Dobsonian revolution, then the numbers reach into the millions. That, in my opinion, is John's greatest legacy. He will be missed. ✦

---

***Dennis di Cicco** built his first Dobsonian-style telescope only months after meeting Dobson in 1978.*

# Red Luminance Layering



*Boost the nebulosity in your astrophotos with this novel technique.*

**Edward Henry**

*In recent years,* DSLR and one-shot color (OSC) CCD cameras have surged in popularity with astrophotographers. The sensitivity and noise levels in these camera designs have improved to the point that serious imaging is no longer solely the province of dedicated monochrome CCD cameras with color filters. However, because of the very nature of the DSLR and OSC permanently filtered detectors, it's difficult to do the specialized imaging involved in narrowband enhancement of nebulae and other objects.

Fortunately, you can boost the nebulosity recorded with these cameras by using the *red luminance layering* technique. This method doesn't require any additional filters.

I prefer to image with an OSC camera because it allows me to capture color images in a single exposure. This saves me the expense of having to buy filters and a filter wheel. It also ensures that every time I shoot, I'll automatically have an exposure in every band: unexpected clouds or equipment failures don't interfere with my ability to capture a full set of red, green, and blue images, as can sometimes occur when imaging with monochrome cameras. But often I find that my result lacks the impact of a comparable image recorded using a monochrome camera with color and narrowband filters.

***Left:*** **In this one-shot color (OSC) image, it's difficult to see hydrogen nebulosity in the outer regions of the Helix Nebula (NGC 7293).** ***Right:*** **Creative mixing of the red channel with the other color channels and luminosity in the image makes these faint wisps much more apparent. All images are courtesy of the author.**

To combat this problem, I've developed an easy technique to enhance my images by layering in new data and mixing the color channels using the software *ImagesPlus* (**www.mlunsold.com**). *ImagesPlus* was written specifically for processing astrophotos from OSC and DSLR cameras as well as standard monochrome CCD cameras.

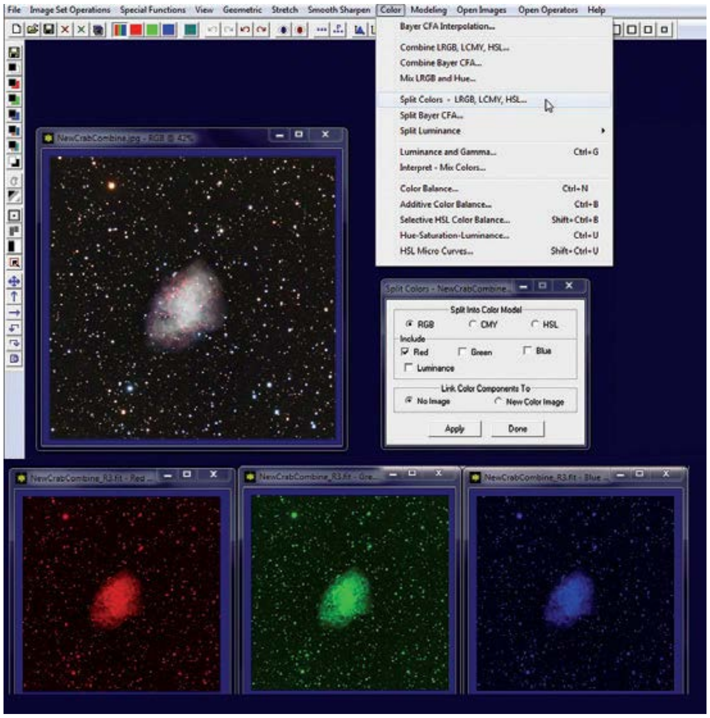
## Isolating Nebulosity

An OSC camera incorporates individual color filters over every pixel, commonly known as a Bayer filter. This filter array divides the pixels of your camera into three colors, much like a television screen: 50% of the pixels have green filters, 25% have blue, and the other 25% are red. When this array records a photo, software interpolates the gaps between the pixels in a single color channel to create the full-color image. In the past, the result was of perceptibly lower resolution than those made with monochrome images recorded through color filters. Interpolation algorithms have improved to the point that today the difference is almost imperceptible.

Roughly a decade ago, noted astrophotographer Robert Gendler proposed that, much like combining narrowband hydrogen-alpha (Hα) images with color data, a red-filtered image mixed with the luminosity information in an astrophoto will produce a "poor man's" Hα-enhanced image. After all, Hα is captured in red-filtered images recorded with OSC and modified DSLRs. This technique turns out to be quite useful for OSC cameras.

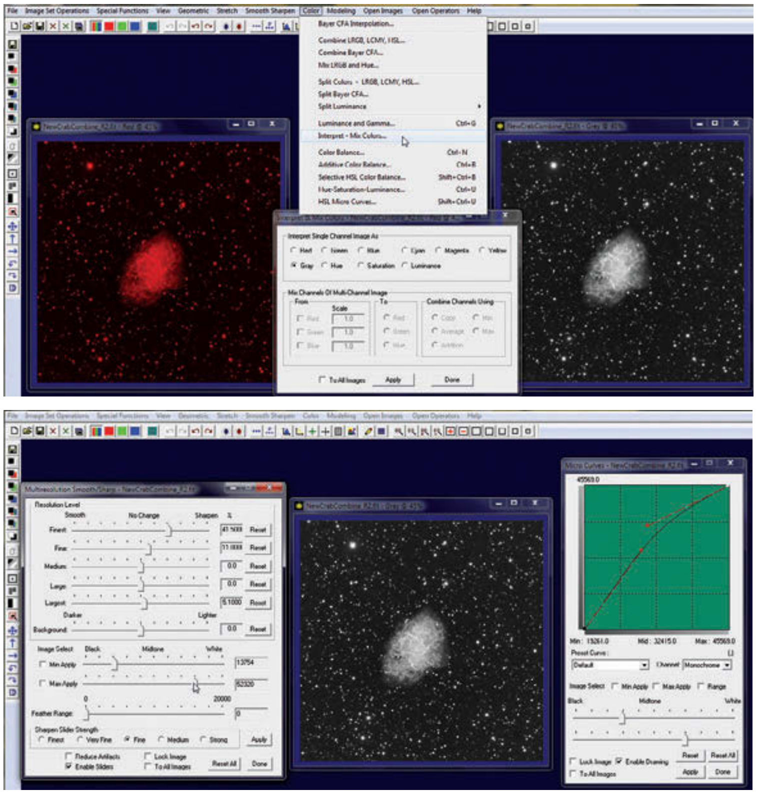
For example, in an average color image of the Crab Nebula (M1), the red tendrils of gas are muted and difficult to see. With an Hα exposure added to the photo, these tendrils become much more pronounced and vividly colored. We can obtain a similar result by using a red luminance image, since the detail we wish to enhance is already recorded in the red channel. Instead of taking additional exposures through an Hα filter, we can record more color exposures, combine them into a single new RGB image, and extract the red channel for use as a luminance image. Since you will only be using the red data, try to take almost twice as much exposure time for this red luminance as you did for the original unenhanced color result to ensure a deep, smooth result.

Most emission nebulae contain large amounts of Hα light. But they also contain smaller amounts of hydrogen-beta (Hβ), which emits in the blue/green spectral region, and hydrogen-gamma (Hγ), which emits in blue. If we tried to simply layer the red luminance onto the original color image, the nebula would appear an odd salmon




**The first step to red luminance layering in *ImagesPlus* is to separate your image into its individual color channels. Once accomplished, the program helpfully displays each channel in its assigned color, as shown here.**

**Extended nebulosity is contained in all of your images taken with OSC and modified DSLR cameras. But mixing a red luminosity channel requires a little more work to enhance your image while still retaining a pleasing color balance. The Crab Nebula (M1) image at left is a normally processed OSC color photo, while the center image replaces the luminosity channel with the red channel data, distorting the overall color in the photo. By mixing a small percentage of the red channel with the blue and green, a pleasing result is achieved at right.**



***Top:*** **It's difficult to see the entire range of values in the red channel when it's displayed in its red color in *ImagesPlus*, so the channel needs to be "reinterpeted" as a grayscale image.** ***Bottom:*** **Additional stretching to enhance the fainter nebulosity is easiest using the Micro Curves tool, whereas sharpening is best accomplished in *ImagesPlus* with the various sliders within the Multiresolution Sharpening Tool. Both can be used simultaneously on an image to give you greater control over the final result.**

color, skewed because we left out the data from Hβ and Hγ. Fortunately, imagers have devised a fix.

## Luminance Layering in ImagesPlus

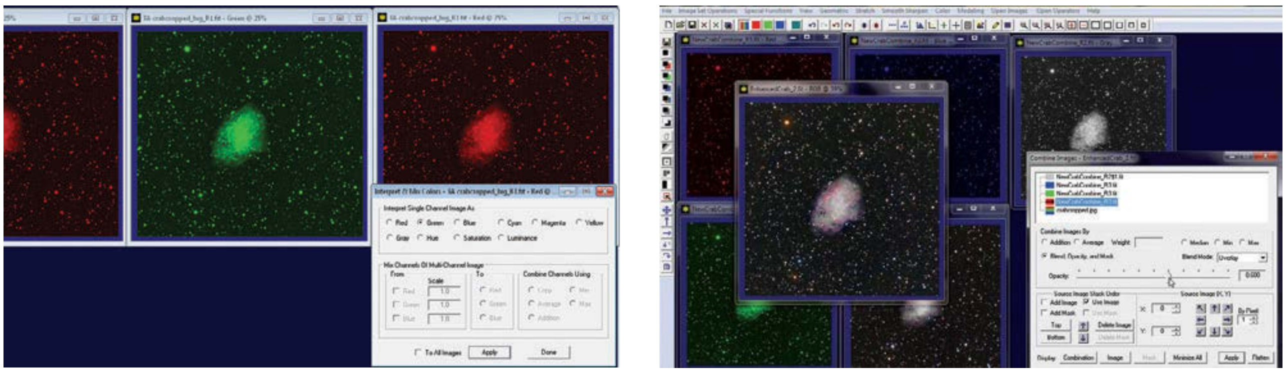
We can produce a more natural color balance by blending our red image with each of the remaining color channels of our new RGB image in varying percentages of intensity. At that point, we can then add the red luminance layer to bring out more detail. In order to make these combinations possible, it's first necessary to calibrate, align, and combine all the images we'll be using. Once done with that, split the color channels of the new RGB image using the Color / Split Colors function. A new window opens, where you can choose from a number of color models to work with; select the RGB option. In a moment, you'll have each color channel displayed as a new image, along with the color result. The individual channels are also displayed in their respective colors.

At this point, we need to make a copy of the red channel by clicking on the red image and selecting View / Duplicate Image to Scale. Next, change one of the red images to grayscale by choosing Color / Interpret & Mix Colors. Another dialog window opens, where you'll click the Gray button in the section Interpret Single Channel Image As. Click Apply, and then close the green and blue channel images. Now save and close the original red channel image; you will need this later.

It's important at this point to save this new "red luminance" image. Then you can stretch it to bring up the nebulosity you want to enhance in your final color result.

Stretching an image in *ImagesPlus* is best done using the Micro Curves tool (Stretch / Micro Curves). You set the grayscale range that you'd like to boost using the two sliders, and you manipulate the curve using the two red points on the graph.

You can sharpen exposures in *ImagesPlus* with The Multiresolution Sharpening Tool (Smooth Sharpen / Multiresolution Smooth / Sharpen...). This tool has many options for sharpening large and small details, controlling background brightness, and feathering your sharpening area. I prefer to concentrate on sharpening brighter



***Left:*** **To ensure a pleasing color balance in your final result, you'll want to blend a slight amount of the unenhanced red channel with the green and blue channels by opening the unenhanced red image, making two copies, and then reinterpeting one as green and the other as blue.** ***Right:*** **All your images are combined as layers in the Combine Images window from bottom to top, so make sure your color photo is at the bottom, the unenhanced red channel copies are in the middle, and your red luminance is at the top of the stack.**


Most nebula images can be enhanced using the red luminance layering technique. The author enhanced this deep photo of the Cone Nebula to bring out the subtle nebulosity in the very corners of the frame.

parts of my image while avoiding the dark background regions. The brighter areas in your red luminance image will translate into more vivid colors in your final result. Once you're satisfied with your adjustments, save the processed red luminance image.

## Recombining Channels

Before combining the images, you'll need to open the unenhanced red image and make two additional copies of it. Use these three copies to simulate the Hβ and Hγ in each of the color channels of the original result to retain a natural color balance when the red luminance is applied. To do this, you'll need to reinterpret each copy of the red channel to the respective color it will modify. Select Color / Interpret – Mix Color, and change one of the copies to blue, the second to green.

Next, using Special Functions / Combine Images Using / Blend Mode, Opacity, and Masks, you can start to build your new enhanced image by placing the original RGB image on the bottom of the image tree in normal mode, opacity 100%, and the processed grayscale luminance above it. Simply click OK in the Combine Images Setup window, and in a few moments, your list of open images will appear in the Combine Images dialog window.

*ImagesPlus* combines image layers from the bottom up, so ordering your images here is important to the final result. Click on the RGB image in the list and at the bottom left, select the Bottom button. This moves the image to the bottom layer. Make sure your red luminance file is on top and the three faux color channels are in the middle.

Your image will appear as grayscale at this point because we have to change the blending mode on each layer. The unenhanced original RGB image at the bottom will remain the same, with its blending mode set to Normal with 100% opacity. To change the level that each enhanced red will contribute to each color, select Overlay for the red, green, and blue layers. Next, adjust the Opacity slider for each of these enhancement channels — I use 60% for the red, 20% for the green, and 27% for the blue, though you can adjust these until you're pleased with the final blend.

Finally, select the red luminance layer and change the Blend Mode to luminosity. Watch as the results finally come together. The detail contained in the luminance layer translates to each of the layers beneath it. This is the key to getting the stretched and sharpened appearance into the final combined image.

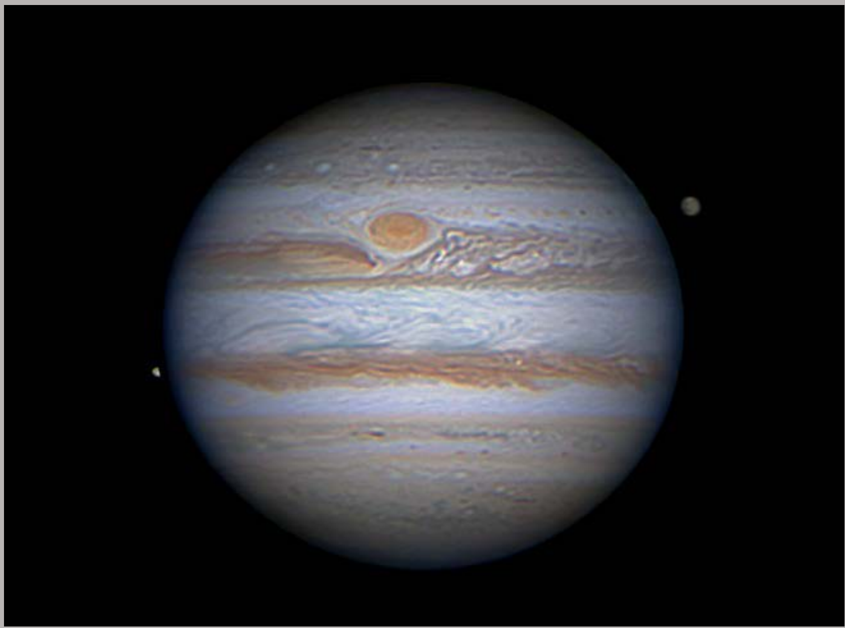
You can lower the opacity level of the red luminance to blend the layers to your liking. Once you're pleased with the result, you'll need to click the Flatten button at the bottom right to complete the action. Now you can boost the color saturation or brightness if necessary before saving the final result. Comparing this to the original image shows remarkable improvement with more colorful detail, all from the same source data.

Whether you already take astrophotos or are the new owner of a DSLR or OSC camera dreaming about future astronomical vistas, red luminance layering is a technique that can expand the use of your camera and help produce stunning results just by using data already available in your color images. ✦

---

***Edward Henry*** *images the night sky from his private observatory in rural northwest Wisconsin.*

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



◂ **JOVIAN FAMILY PORTRAIT**

Mike Phillips

Jupiter displays its orangish Great Red Spot as its attendant moon Io (left) slips behind the planet. Larger Ganymede, with its subtle albedo markings, lurks at right. South is up.

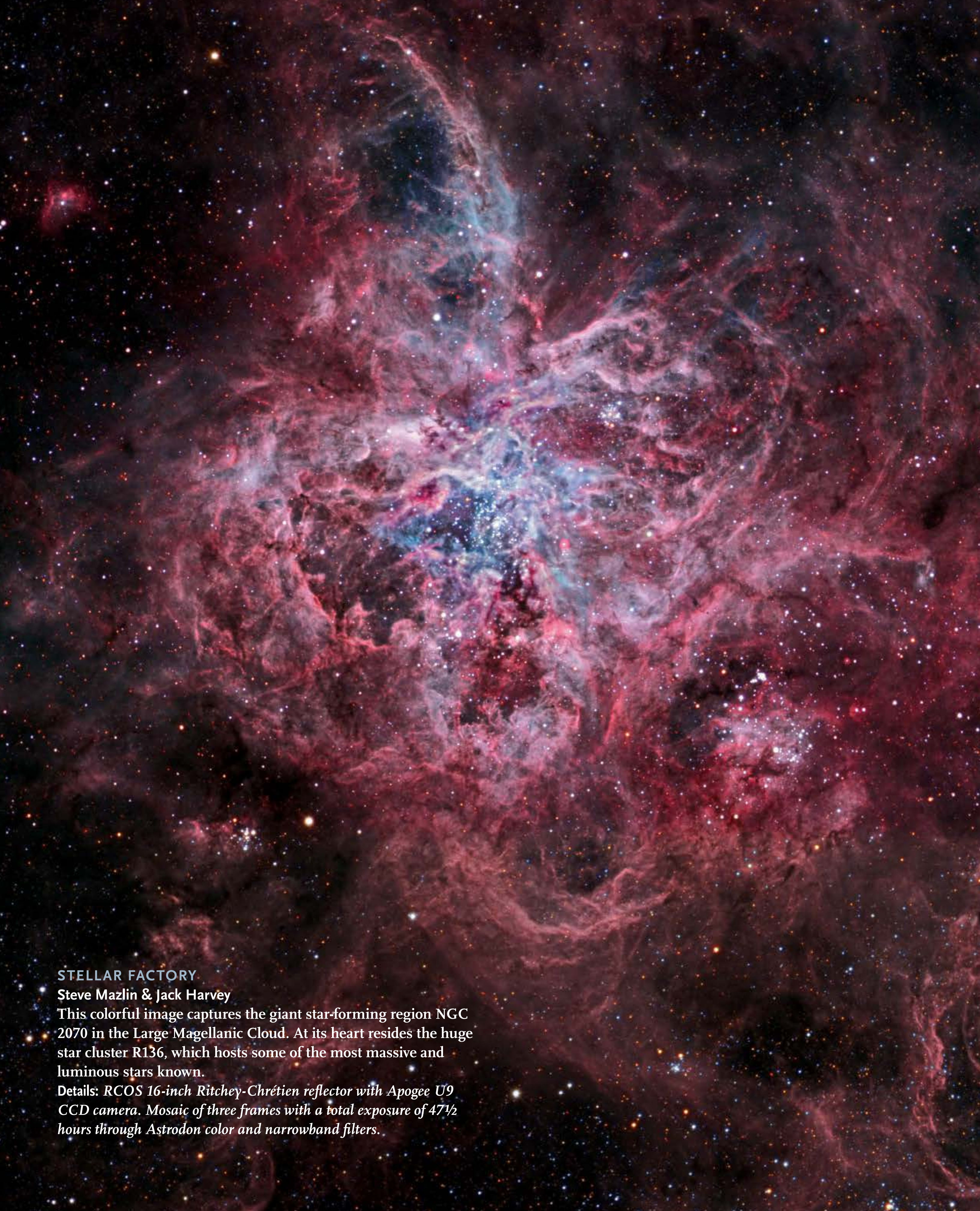
**Details:** *Custom-built 14-inch Newtonian reflector with Point Grey Research Flea3 video camera. Multiple stacked video frames captured on January 4th at approximately 6:04 UT.*

▾ **DOUBLE STELLAR DOSE**

Fred Herrmann

A treat to see in any telescope, the Double Cluster in Perseus comprises two young open star clusters containing many luminous blue-white stars. It's just visible to the naked eye under dark skies.

**Details:** *Takahashi TOA-130 refractor with SBIG STT-8300 CCD camera. Total exposure was 5⅚ hours through color filters.*

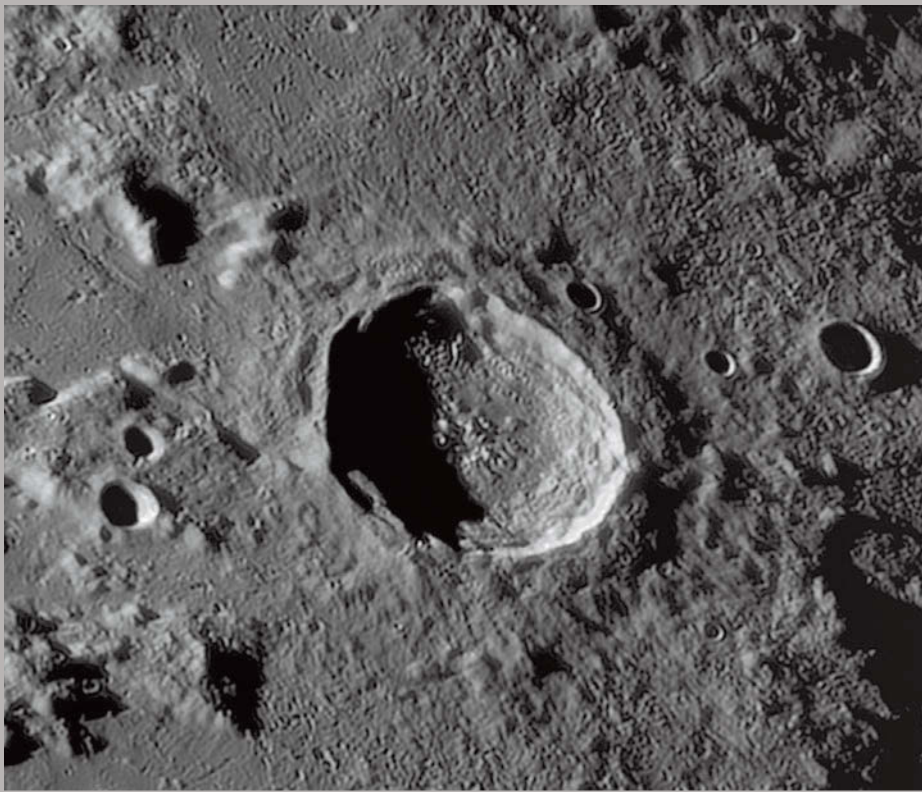


STELLAR FACTORY

**Steve Mazlin & Jack Harvey**

This colorful image captures the giant star-forming region NGC 2070 in the Large Magellanic Cloud. At its heart resides the huge star cluster R136, which hosts some of the most massive and luminous stars known.

**Details:** *RCOS 16-inch Ritchey-Chrétien reflector with Apogee U9 CCD camera. Mosaic of three frames with a total exposure of 47½ hours through Astrodon color and narrowband filters.*



◀ **LUNAR CAUCASUS CRATER**

Alessandro Bianconi

This detailed view of Eudoxus within Montes Caucasus reveals the terraced inner walls and cluster of low hills near the crater's center.

**Details:** *Celestron EdgeHD 14-inch Schmidt-Cassegrain telescope with QHY5L-II video camera. Stack of multiple video frames.*

▼ **NEBULOUS JELLYFISH**

Eric Africa

This colorful region in Gemini features the nearby supernova remnant IC 443 (bottom right) and the larger H-II region known as Sharpless 2-249 at left.

**Details:** *Takahashi FSQ-106N refractor with SBIG STL-11000 CCD camera. Total exposure was 12 hours through Astrodon narrowband and color filters.* ✦

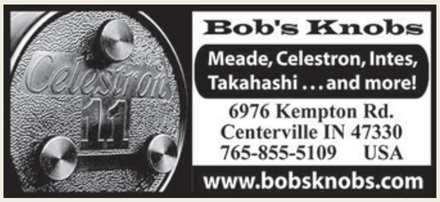
Visit SkyandTelescope.com/gallery for more of our readers' astrophotos.

# SKY & TELESCOPE Market Place

*Your essential source for astronomical products*

## ACCESSORIES



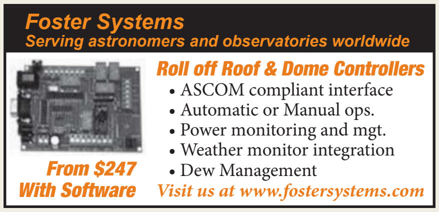




## ACCESSORIES



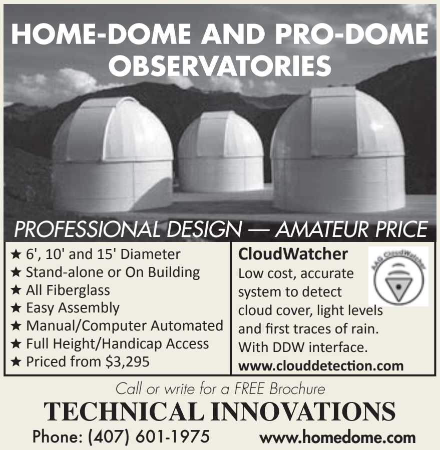

## ACCESSORIES





BOOKS


OBSERVATORIES / DOMES




OBSERVATORIES / DOMES


COMPUTER SOFTWARE



ORGANIZATIONS


TELESCOPES


TELESCOPES



TRAVEL



CLASSIFIEDS

**ROLL-OFF-ROOF OBSERVATORY** with 11" Celestron and Hyperstar, in unique southeast Arizona location. 3 Bdrm 3 Baths 2787-sq-ft home on 10 acres, built 2003, 40x40 RV/workshop & views! Pure enjoyment under the stars! $499k Sonoita Realty, Kathy O'Brien 520-405-1800.

**MAJOR $200,000 PRICE REDUCTION!** Stunning, unique, one-of-a-kind research grade 12-inch f12.2 D&G refractor of superb optical quality (plus companion telescopes) on unique, custom-made Byers Series III mounting. Details in February 2013 issue of S&T, pp 66-69. See more details (plus a video) on SkyandTelescope.com's online MarketPlace under "refractors." Entire package now offered at $595,000. Contact Ed Noffsinger: TheDigmaModel@aol.com or 831-427-1011.

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

**FOR RENT:** 3 BR/2BA fully furnished adobe home in ARIZONA SKY VILLAGE in Portal, AZ. Observe and photograph under the darkest, clearest and most transparent skies with astronomers from all over the world. Contact irkitzman@gmail.com 520-203-8500 www.arizona-dreaming.com.

**FOR SALE:** TAL 200mm Klevtsov-Cassegrain Telescope. TAL200K 8.5 Klevtsov/Cassegrain optical design telescope in excellent condition. 200mm aperture, includes these accessories: 8X50 Finderscope with mounting bracket, 90 degree star diagonal, 2X Barlow lens, 10mm Super Plossl eyepiece, 25mm Super Plossl eyepiece, crosshair reticle for eyepiece. Manufacturer's web page: www.talteleoptics.com/tal200k.html Price: $1,795 plus shipping. Write ads@SkyandTelescope.com .

Classified ads are for the sale and purchase of noncommercial merchandise, unique items, or job offers. The rate is $1.50 per word; minimum charge of $24; payment must accompany order. Closing date is 15th of third month before publication date.

## Introducing our new

# Mercury Globe

## Meet the planet nearest our Sun

Our solar system's innermost planet has long been shrouded in mystery. Thanks to NASA's Messenger spacecraft, scientists now realize that Mercury is a unique world with a complex history. Launched in 2004, Messenger flew past Mercury three times at close range before slipping into orbit in March 2011. The spacecraft maintains a highly elongated path that comes within 130 miles of Mercury's surface. To create this dramatic portrayal, the editors of Sky & Telescope worked with Messenger scientists to produce the globe's custom base map. Thousands of frames taken by the spacecraft's wide-angle camera were merged to create a global composite image with a resolution of roughly 1 km per pixel. Special image processing has preserved the natural light and dark shading of Mercury's surface while allowing the labels to stand out clearly. The names of more than 350 craters and other features are shown. Never before have researchers been able to study details on the innermost planet's entire surface — and the Sky & Telescope Mercury Globe enables you to follow along with each new discovery.


$99.95
Item # MERCGLB

**888-253-0230**

**www.ShopatSky.com**

## Index to Advertisers



SKY & TELESCOPE

SkyandTelescope.com
*800-253-0245*

## IN THE NEXT ISSUE

### May 24th Meteor Storm?

A bevy of bright meteors could come streaking out of Camelopardalis on the morning of May 24th.

### Exoplanet Weather Report

Astronomers have moved beyond counting exoplanets to studying the atmospheres of these alien worlds.

BOTTOM: NASA; TOP: S&T: DENNIS DI CICCO

### A New Telescope in Space

An instrument developed for amateur astronomers is now flying on the International Space Station.

### Planetary Imaging with Color Cameras

Learn how to get the most out of your color planetary camera.

**On newsstands April 1st!**

Find us on Facebook & Twitter

John E. Bortle

# Epilogue for Comet ISON

*All the signs were there that the "comet of the century" would fall short of its hype.*

The Comet of the Century has gone, leaving the scientific community once again with egg on its face in the eyes of the public. ISON joins comets Cunningham (1941) and Kohoutek (1973) among the embarrassing failures of comets widely heralded to become the "comet of the century" only to disappoint the general public and confound scientists. But ISON did so on an even grander scale than ever before!

All the warning signs were there, some even from the very beginning. ISON's future magnitude and brightness behavior was based on the erroneous assumption that its luster would grow at the rate of an inverse fourth power of its solar distance. But astronomers have long known that this behavior does not normally represent that expected from dynamically "old" Kreutz sungrazing comets and is virtually never observed in "new" comets. Comparing ISON to Cunningham's and Kohoutek's brightness behavior implied that ISON was likely an even smaller, fainter version of its predecessors. Thus, any potential for a real show from ISON was very small.

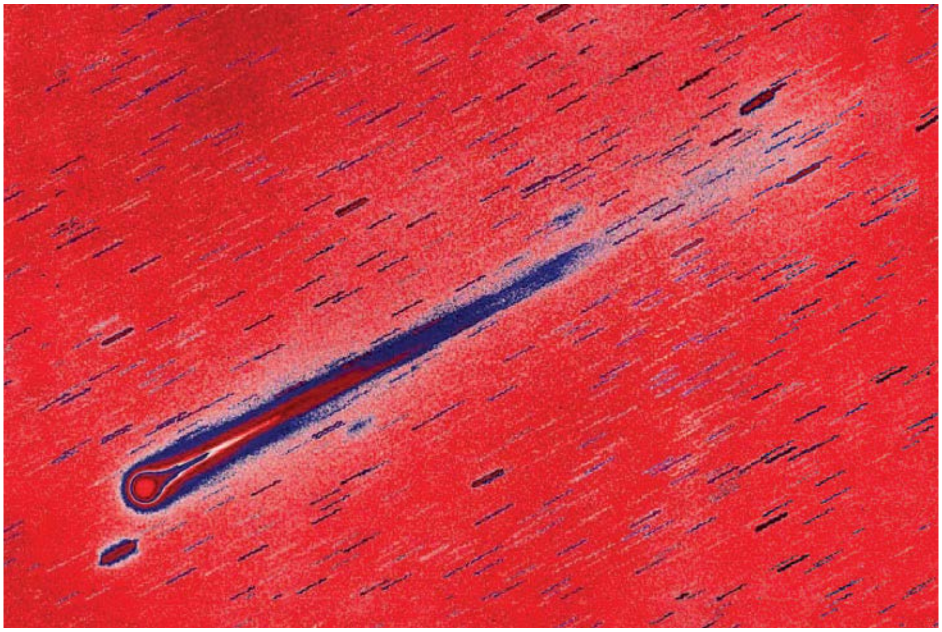
After a summer interlude when ISON was lost in the Sun's glare, its apparent brightness at recovery in August 2013 further suggested that it might be too small and faint to survive its coming encounter with the Sun. This is clearly implied in my article in the December 2013 issue of *S&T,* and I had declared it an almost certainty in earlier postings made to an online comet observers' forum.

When the countdown to perihelion had dwindled to a few days, ISON seemed to experience a permanent 2-magnitude increase in its brightness. As it entered the field of the C3 camera on SOHO's LASCO instrument, ISON looked healthy and even my doubts shrank for a moment as it attained magnitude –2.5 with a long tail. But then it faltered, dwindling before our spacecraft-aided eyes to merely the tail's shrinking sunward terminus as the LASCO C2 camera lost sight of the comet. Shortly thereafter, at perihelion, the Solar Dynamics Observatory camera failed to indicate any trace of the object and our hearts collectively sank.

But just an hour or two later, a bright, dart-shape smudge appeared over the edge of the C2's occulting disk. Could ISON have somehow survived after all? Unfortunately, it proved to be no more than the leading edge of a dispersing dust cloud; the destroyed remnants of ISON's nucleus. The multi-tailed cloud grew ever more diffuse thereafter, all but fading away entirely by the last images taken on December 5th. After a couple of erroneous ground-based visual sightings, further visual and imaging attempts on December 9–11 proved negative. ISON was gone.

The story of Comet ISON really should not have played out as it did. The astronomical community had been forewarned that ISON could well be yet another in a long line of cometary charlatans that seemingly held great promise, but in reality had openly hinted at carrying the seeds of their own likely demise. If only some astronomers had looked more carefully and had not allowed themselves to be caught up in "comet fever," things might have concluded in a much more dignified manner for all concerned.

The quotation, "Those who cannot remember the past are condemned to repeat it," seems to me never more applicable than here. ✦



GREGG RUPPEL

*S&T contributing editor* ***John Bortle*** *has observed and written about comets for more than 50 years.*


SERIES 6000
ED APO TRIPLETS
SUPERIOR OPTICS. EXCEPTIONAL QUALITY.
130mm ED APO
REGULARLY: $2,999
PROMO PRICE: $2,799
CRAYFORD-STYLE 3" 10:1 DUAL-SPEED FOCUSER*
COMES COMPLETE WITH CRADLE RINGS, 8X50 FINDER*, 2" DIELECTRIC DIAGONAL
OPTIONAL 3" FIELD FLATTENER*
PART #: 07585
INCLUDES CUSTOM HARD CARRYING CASE
115mm ED APO
REGULARLY: $1,999
PROMO PRICE: $1,849
80mm ED APO
REGULARLY: $999
PROMO PRICE: $899
*Finder scope included with 115mm and 130mm OTAs only. 80mm OTA comes with 2" dual-speed Crayford focuser. Optional field flattener compatible with 115mm and 130mm OTAs only.
©2014 Meade Instruments Corp. All rights reserved. Specifications subject to change without notice, 30-13072
DURING THE MONTH OF MARCH 2014, PARTICIPATING MEADE DEALERS WILL OFFER PHENOMENAL DEALS ON THE SERIES 6000 ED TRIPLET APO REFRACTORS. SAVE UP TO $200!
GO TO WWW.MEADE.COM/APODEAL FOR COMPLETE DETAILS.
3" 10:1 DUAL-SPEED CRAYFORD FOCUSER*
8X50 FINDER SCOPE*
PREMIUM 3-ELEMENT AIRSPACED ED APO OPTICS
2" DIELECTRIC DIAGONAL WITH 99% REFLECTIVITY
Optics Planet 800.504.5897 www.opticsplanet.com
OPT Telescopes 800.483.6287 www.optcorp.com
B & H Photo 800.482.8143 www.bhphotovideo.com
Telescopes.com 800.303.5873 www.telescopes.com
Woodland Hills 888.427.8766 www.telescopes.net
Adorama 800.223.2500 www.adorama.com
Canada • Khan Scopes 800.580.7160 www.khanscope.com
MEADE INSTRUMENTS
www.meade.com