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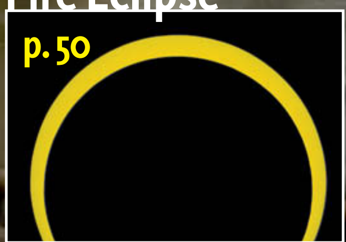
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ST-8300 Image of Vdb142 by Peter Clausen

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May 2012

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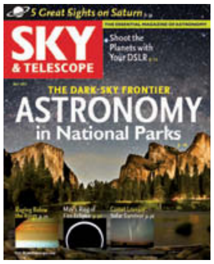
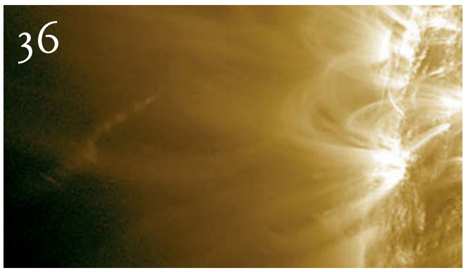


On the cover: The breathtaking scenery of Yosemite Valley gives a superb setting to celestial jewels.

PARK PHOTO: TYLER NORDGREN



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Robert Naeye
Spectrum

Going Deep at Yosemite

EDITING TYLER NORDGREN'S cover story about astronomy in U.S. national parks triggered some of the fondest memories of my life, and not just from my time in astronomy. From 2000 to 2003 I worked for the Astronomical Society of the Pacific in San Francisco. Soon after moving to California I learned that most of the Bay Area amateur astronomy clubs participated in the Yosemite Star Party, held every Friday and Saturday night throughout the summer at one of the world's most spectacular overlooks, Glacier Point. Every club was assigned a weekend. I ended up joining *five* clubs partially because I wanted to go to these events several times each year.

An hour or so before sunset, club members would set up telescopes in a small amphitheater and would give an astronomy slide show as twilight faded. For the first hour or two after sunset my fellow astronomers and I basically held a public star party, where we shared views of various objects with dozens to hundreds of visitors, with many different languages being spoken. After the tourists headed back to their lodges and campsites, we had Glacier Point all to ourselves, all night.

San Jose Astronomical Association, 2003

S&T: ROBERT NAEYE

Under exceptionally dark skies and an elevation of about 7,200 feet, I enjoyed incredible views of deep-sky objects through my 12½-inch Portaball reflector and the scopes of other club members. It was there that I fell in love with observing the Veil Nebula through an O III filter. I also gained a fuller appreciation for the superb deep-sky capabilities of my 102-mm Tele Vue refractor. When I scrutinized dark nebulae, no longer were they simply regions devoid of stars. The refractor's outstanding contrast dramatically showed these clouds as they really are: beautiful discrete objects in front of background star fields.

We also scoped out the headlamps of rock climbers suspended against the cliff face of Half Dome. And always in the background were the soothing rumbles of Nevada and Vernal Falls. My most memorable sight, however, was using my refractor to watch the Moon rise over a faraway Sierra Nevada peak, with a distant ponderosa pine silhouetted in front. The air was so steady that night I could resolve individual branches. It was a "Wow!" moment.

The California astronomy clubs are still holding Yosemite Star Parties. If you're in or near Yosemite National Park this summer, check out Glacier Point on Friday or Saturday night!

Robert Naeye
Editor in Chief

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Another Black Hole Spy?

As a follow up to your article "Einstein's Shadow" (*S&T*: February 2012, page 18), I have the following question: the Russian radio telescope RadioAstron was recently launched into space and has started operations. Is there an intention to include this instrument in the Event Horizon Telescope, thereby extending the interferometry baseline into space?

Valentin Petrov
Moscow, Russia

Editor's Note: *Sadly, no. RadioAstron will not be part of the EHT because its frequency bands (highest is 18-25 GHz) are far lower than the EHT's (230 GHz and 345 GHz, the latter being preferred). Some of RadioAstron's bands overlap ones observed with the NRAO's Very Long Baseline Array, but while astronomers have used the VLBA to look at M87's core, the higher frequencies are needed to peer deeply at black holes.*

The Black Drop Effect

A box in the important preparatory story by Fred Espenak and Jay Anderson about observing June 5/6's transit of Venus (*S&T*: January issue, page 70) correctly states that "the smaller the telescope and the worse the atmospheric seeing," the more obvious the black drop effect is. But the three causes the article mentions leave out an additional, important explanation. Glenn Schneider (University of Arizona) and I showed, based on space observations of the 1999 transit of Mercury made in collaboration with Leon Golub (Harvard-Smithsonian Center for Astrophysics), that the Sun itself also plays a role. So-called limb-darkening is the culprit there, whereby the brightness of our Sun diminishes rapidly and drastically very near the edge of its disk. Only when limb-darkening is also included can the observed black drop be accounted for.

Another effect observers should look for during the June transit is the Venusian atmosphere, which our space observations of the 2004 transit showed begins to be visible about a half hour before second contact and remains visible for about a half hour after third contact.

This year my colleagues, students, and I will study Venus's atmosphere with multiple ground- and space-based telescopes in order to leave the best possible legacy for the astronomers preparing to observe the next transits, in 2117 and 2125 — just as we have benefitted from detailed descriptions from 1761, 1769, 1874, and 1882.

Jay M. Pasachoff
Williamstown, Massachusetts

In Horrocks's Footsteps

I was interested to read Eli Maor's article in the January 2012 issue on Jeremiah Horrocks and the 1639 transit of Venus. I am arranging a June visit to Carr House at Bretherton and St. Michael's Church in the village of Much Hoole on behalf of the Society for the History of Astronomy. In preparation, I recently met Carr House's owner, Dr. Clive Elphick, and was shown the window from where Jeremiah Horrocks is thought to have made the first observation of Venus's transit.

My visit on December 3rd was timed to closely match the date of Horrocks's observation. This oblique photograph was taken at 14:41 UT, within 25 hours of the 372nd anniversary. The Sun just peeks around the window mullion. There is no doubt that the sightline is tightly squeezed. I returned in January to watch the Sun sink within 3 arcminutes of the 1639 sunset. My tests suggest that an experienced observer like Horrocks almost certainly wouldn't use this window.

Kevin Kilburn
New Mills, England

KEVIN KILBURN

Jeremiah Horrocks may have observed the 1639 transit of Venus through this window, but as apparent above, the view of the Sun is a tight fit.

Ingenious Design

By far my favorite of Gary Seronik's articles thus far is the one about Mel Bartel's design for a Dobsonian (*S&T*: January 2012, page 62). The design is perfect for people like me, who purchased a bulky Dobsonian back when I had my own condominium backyard but have since downsized to a third-story apartment in a village for "active seniors." In my opinion, Mr. Bartel's design deserves its own name — or at the very least, a hyphenated name. "Bartelian-Dobsonian" scope, perhaps?

Eric F. Diaz
Indianapolis, Indiana

Norman Edmunds's Death

My uncle was Norman Edmunds's TV repairman, and it was through my uncle that I met the renowned Mr. Edmunds. We talked for a long time about my interest in telescopes. He was indeed a gracious person, sharing his wisdom with my childhood self. After that meeting, my family and I went back to his store, where I used my savings to buy my first real telescope, a 3-inch white tube reflector. That scope offered me my first wonderful view of the Moon, paralyzing me until my mother's insistent calls brought me in for dinner. I still have the scope.

I owe Norm and his staff a lot. His store was the only place I knew in which a kid could learn, touch, explore, and discover the world of science. They were never too busy; they didn't care if you were spending $0.75 or $750. For me, there will never be another place like Edmunds, and I will always appreciate men like Norm.

Nick Oshana
Bristol, Connecticut

There's Nothing Like Paper

In 1963 *S&T* captured my imagination sufficiently for me to grind a 6-inch mirror at age 15. Today I have a small dome


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in my front yard with a 5- and 8-inch Schmidt-Cass. After retiring from 30 years of social work, I now find myself the lucky director of a small planetarium in Ohio, where your magazine continues to prove invaluable. I just finished reading the March issue, but I first read the online version last week. The digital edition looks splendid, is well designed, and is easy to navigate . . . but the paper copy I hold in my hand is irreplaceable. Of course, that's only the opinion of one old guy.

iPhone-, iPad-, and Kindle-less at the Hoover-Price Planetarium—

David L. Richards
Canton, Ohio

For the Record

✷ *The March cover story listed Simon Portegies Zwart's institution as the University of Amsterdam. He works at Leiden University in the Netherlands.*

✷ *In the timetable on page 69 of the February article "May's Great Annular Eclipse," the times for Arizona were wrongly corrected for Daylight Savings Time. (Arizona does not observe DST.) All times listed for Arizona should be one hour earlier. You can also go to the map at* **eclipse.gsfc.nasa.gov** *to see predictions in Universal Time.*

For a list of past errata, please go to **SkyandTelescope.com/Errata**.

75, 50 & 25 Years Ago

Roger W. Sinnott

May–June 1937

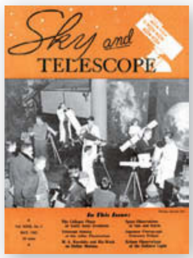
Ghost Images "Not long ago the discovery of a faint southern comet was announced [by Harvard Observatory, relayed from a Southern Hemisphere amateur astronomer]. But, alas! there was no new comet. The experienced amateur was not careful enough about the reflection in his telescope from the nearby planet Mars. He had observed and reported a ghost. . . .

"[Ghost images] are even more dangerous than the nebulae and star clusters that try to look like comets, since the ghost will appear to move in the course of an hour because of [the] changing relative position of observer's eye and telescope . . . and this apparent motion of an apparent comet so excites the observer that judgment abandons him and he dashes for the telegraph office."

Then as now, ghost images are usually caught before the official announcement of a new discovery.

May 1962

Stellar Giant "One of the largest known stars — the red supergiant component of the eclipsing binary VV Cephei — has a diameter 1,620 times the sun's, according to Indiana University astronomer Benjamin F. Peery, Jr.

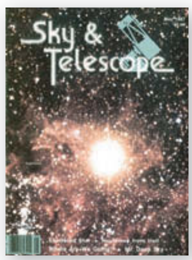


"This finding came from his spectroscopic study of the unusual 20.4-year binary. . . . [Knowing the orbits' sizes,] the Indiana astronomer could evaluate the diameter of the M star from the orbital elements and the known duration of the eclipses. This red supergiant, he finds, is so enormous that the orbit of Jupiter could be fitted inside it."

Peery's result holds up well today. VV Cephei has just a few contenders for largest known star; recent studies put it from 1,600 to 1,900 times the Sun's diameter, nearly the size of Saturn's orbit.

May 1987

Neutrinos from Hell "Neutrino astronomy, for decades the sole concern of theorists, became a genuine observational science early on February 23rd. That day, a handful of these elusive particles were detected from Supernova 1987A in the Large Magellanic Cloud. . . .

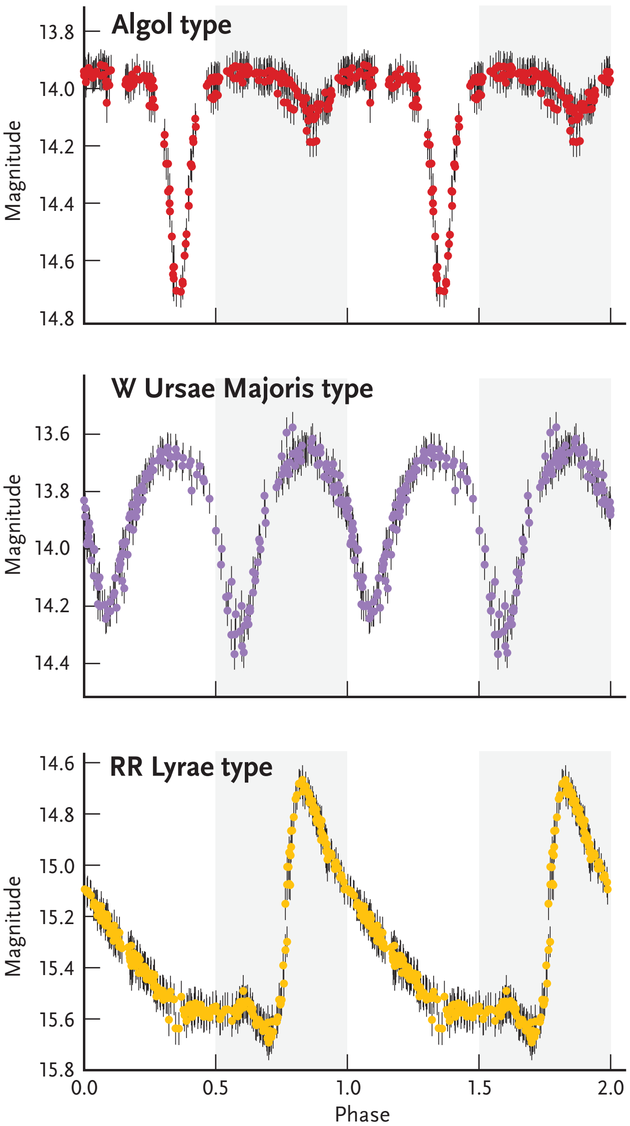


"The observations represent the first neutrino detections from a known extraterrestrial source."

Technical editor Ronald A. Schorn spearheaded S&T's coverage of the nearest supernova observed in modern times.

To get astronomy news as it breaks, visit SkyandTelescope.com/newsblog.

Vast New Trove of Variable Stars



These light curves of faint variable stars were plucked from the tens of thousands now online courtesy of the Catalina sky surveys. The thin vertical lines are the error bars for each brightness measurement. Algol stars are eclipsing binaries in which the two stars are separated; W Ursae Majoris stars are contact binaries resembling figure 8s; RR Lyraes are pulsators. These three variables have periods of 0.536934, 0.74429, and 0.331798 days, respectively.

S&T: LEAH TISCIONE, SOURCE: CATALINA SKY SURVEY / ANDREW DRAKE

We live in a golden age of automated sky surveys, and it's getting more golden all the time.

One way that massive sky surveys are changing astronomy is by producing gigantic numbers of uniform, high-quality light curves for new variable stars. Usually these are merely the byproducts of surveys designed for other purposes. But when some project measures the brightnesses of millions of stars over and over, why not save the data and mine it?

The largest such variable-star database yet has been compiled by the Catalina Sky Survey and the Catalina Real-Time Transient Survey. Their main jobs are looking for near-Earth asteroids and watching for transient events among the stars and galaxies. But along the way they have collected 20 billion brightness measurements of 198 million stars and other objects since 2004. That's an average of 100 magnitude measurements for each one. The objects range from magnitude 12.5 to 20 and span a little more than half the celestial sphere.

The new light curves include more than 1,000 distant supernovae, some of unusual or new varieties; about 3,000 other transient objects including flare stars, dwarf novae, and erupting galactic nuclei; and tens of thousands of other new variable stars of every kind.

By comparison, the official *General Catalog of Variable Stars,* the bible of the field since 1948, contains 43,675 named variables.

The Catalina light curves are uniform and consistent, with measurements typically accurate to 0.06 or 0.08 magnitude. "This set is an order of magnitude larger than the largest previously available data sets of the kind," says Andrew Drake (Caltech) of the Catalina project. He also notes, "We discover transient events and publish them electronically in real time, so that anyone can follow them and make additional discoveries."

In this way the program is a precursor to the much bigger Large Synoptic Survey Telescope (LSST) project, which should begin watching the sky with a unique, wide-field 8.4-meter scope around the end of this decade. The LSST's capabilities will be mind-boggling: it's designed to measure everything across half the celestial sphere from magnitude 16 to 24.5 in six colors an average of once every three or four days for at least 10 years.

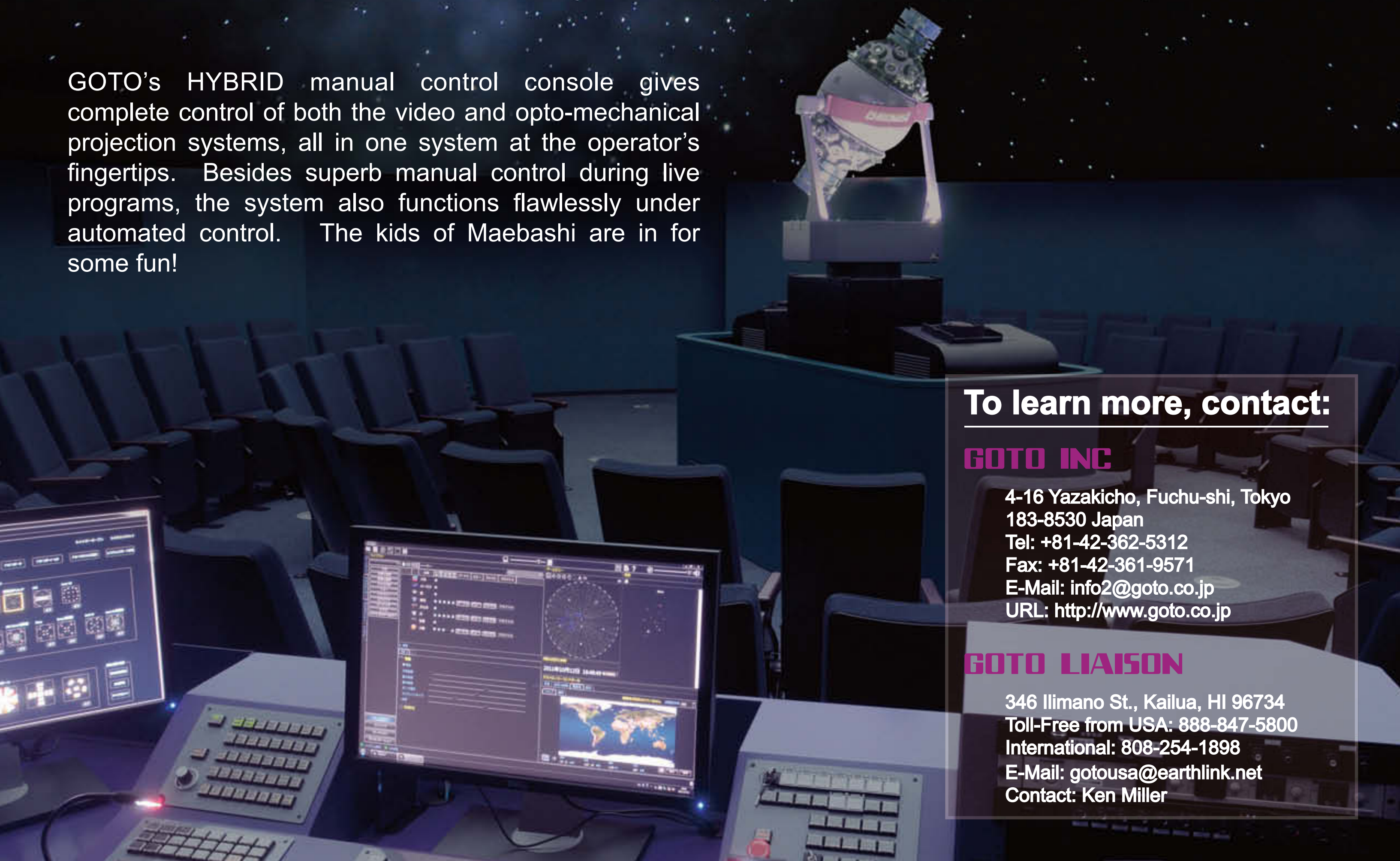
Catalina's observations so far come from the Univer-

More Stars for Maebashi!

The Maebashi Kids' Cultural Center in Maebashi, Japan was first opened in 1969 to support the physical and mental development of children in their community. They started in a small, 8-meter dome using a GOTO Model S-3, then in 1980 moved up to a GOTO Model GS-T. And now, in January of 2012, they have proudly opened a brand new building with a new 12-meter planetarium seating 100 children.

The new dome features GOTO's new CHRONOS II HYBRID system. The LED-powered stars of the CHRONOS II are synchronized with vivid, colorful, dynamic, moving video from two GOTO HD video projectors. These 2K video projectors use custom-designed GOTO fisheye lenses to paint the dome with seamless images.

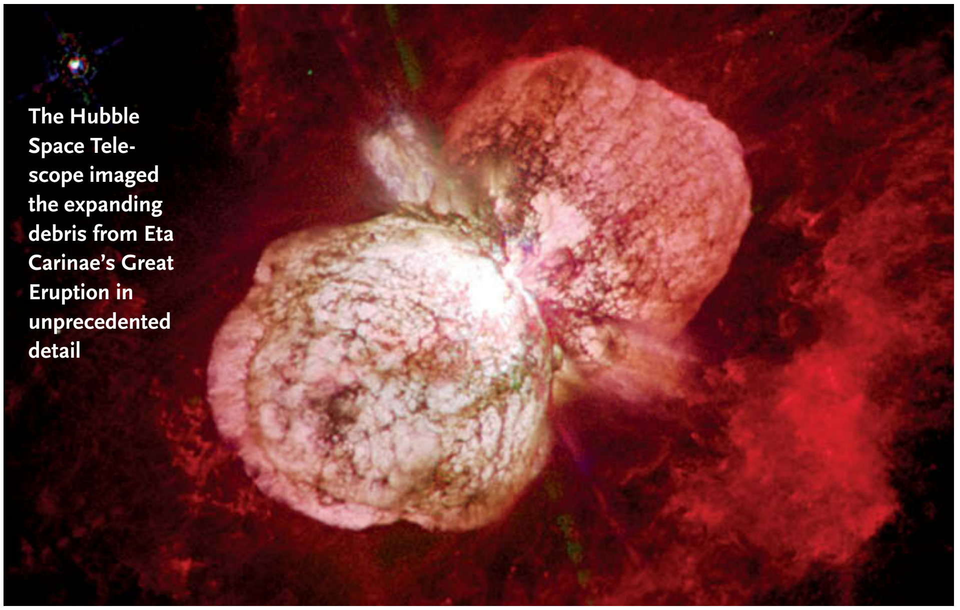
GOTO's HYBRID manual control console gives complete control of both the video and opto-mechanical projection systems, all in one system at the operator's fingertips. Besides superb manual control during live programs, the system also functions flawlessly under automated control. The kids of Maebashi are in for some fun!



sity of Arizona's 0.7-meter telescope on Mt. Bigelow in Arizona. The team plans to start including data taken with a 1.5-meter telescope on Mt. Lemmon in Arizona and a 0.5-meter telescope in Australia.

Such data riches do not make traditional variable star observing obsolete, Drake emphasizes. The Catalina surveys can't measure stars brighter than 12th magnitude; they saturate the pixels. And the surveys avoid the broad band of the Milky Way completely, because there the stars are so numerous that their images in the system often overlap.

More broadly, amateurs in the coming decades will have plenty of new work doing fast, detailed follow-ups on interesting objects as surveys discover them.



The Hubble Space Telescope imaged the expanding debris from Eta Carinae's Great Eruption in unprecedented detail

NATHAN SMITH / JON MORSE / NASA

A Light-Echo Replay of Eta Carinae's Blast

Weighing in at about 90 Suns, the hot supergiant star Eta Carinae shines inside a massive, double rose-blossom of a nebula called the Homunculus. The two outward-spraying globes were thrown off during the star's so-called Great Eruption from 1838 to 1858, during which Eta Carinae peaked as the second-brightest star in the night sky after Sirius. The globes contain an impressive 10 solar masses of ejecta. Somehow the rest of the star survived, and with its remaining high mass, it's a prime candidate to have an even brighter blast someday as the next supernova in our part of the Milky Way.

"The cause of the Great Eruption is without doubt one of the biggest puzzles in stellar astronomy," says Michael Corcoran (NASA/Goddard Space Flight Center). Astronomers have long wished they could take modern instruments back in a time machine to watch what really happened.

Now, in a sense, they can. A team using sensitive detectors on large telescopes has found *light echoes* of the Great Eruption — light from the outburst reflected off nebular matter more than 80 light-years from Eta Carinae itself. This light is providing a replay of the 19th-century eruption.

And already it presents a surprise. A prime theory has been that radiation pressure from an increase in Eta Car's luminosity blew a massive, opaque stellar wind from the star's surface. But Nathan Smith (University of Arizona) suggested a few years ago that an internal explosion, perhaps a sort of pre-supernova, was the cause instead. He and his team have analyzed the faint light-echo light and find that the Great Eruption's temperature was about 5,000 kelvins (8,500°F), which he says is at least 2,000 kelvins too low for the wind model to work.

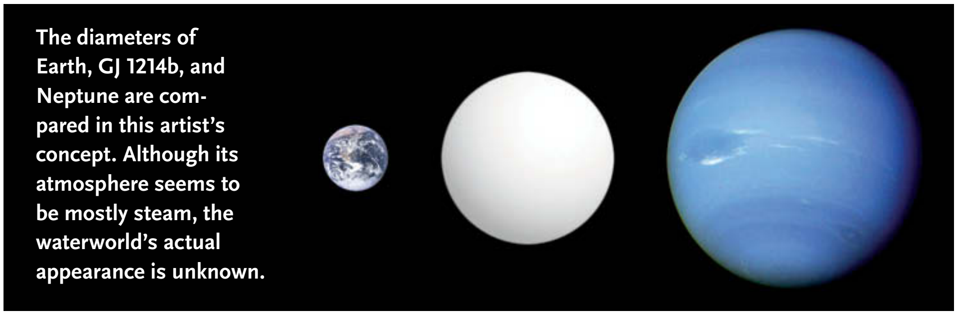
Other astronomers say the evidence still falls short of ruling out the wind scenario. But the light echoes, though dim and elusive, may have more to say on the matter. In particular, they may show whether the initial brightening was a slow rise or a sudden spike, says Theodore Gull (also of NASA Goddard). "That will be the proof of the pudding."

GJ 1214b: A Steam-Bath World

The case has firmed up that exoplanet hunters have identified a "waterworld," a planet that's not just completely covered with water but consists of water for much of its bulk. Earth, by comparison, is only 0.02% water by mass, despite the fact that oceans cover 71% of its surface.

GJ 1214b is a "super-Earth" with 2.7 times Earth's diameter, orbiting a red-dwarf star 40 light-years away in Ophiuchus. It's close enough to the dim little star that its average temperature must be several hundred degrees Celsius, well above the boiling point of water at Earth's normal pressure. What makes the planet so interesting is that we also know its mass (from the gravitational wobble it induces in the star) and hence its density: 1.9 grams per cubic centimeter. That's too low for rock and too high for gas, but a water-rock combination would fit. In fact, follow-up spectroscopic studies with the Very Large Telescope suggested that its atmosphere is dominated by steam.

That looks more likely now, thanks to near-infrared spectra collected by Hubble. A team led by Zachory Berta (Harvard-Smithsonian Center for Astrophysics) examined the star's light while the planet



The diameters of Earth, GJ 1214b, and Neptune are compared in this artist's concept. Although its atmosphere seems to be mostly steam, the waterworld's actual appearance is unknown.

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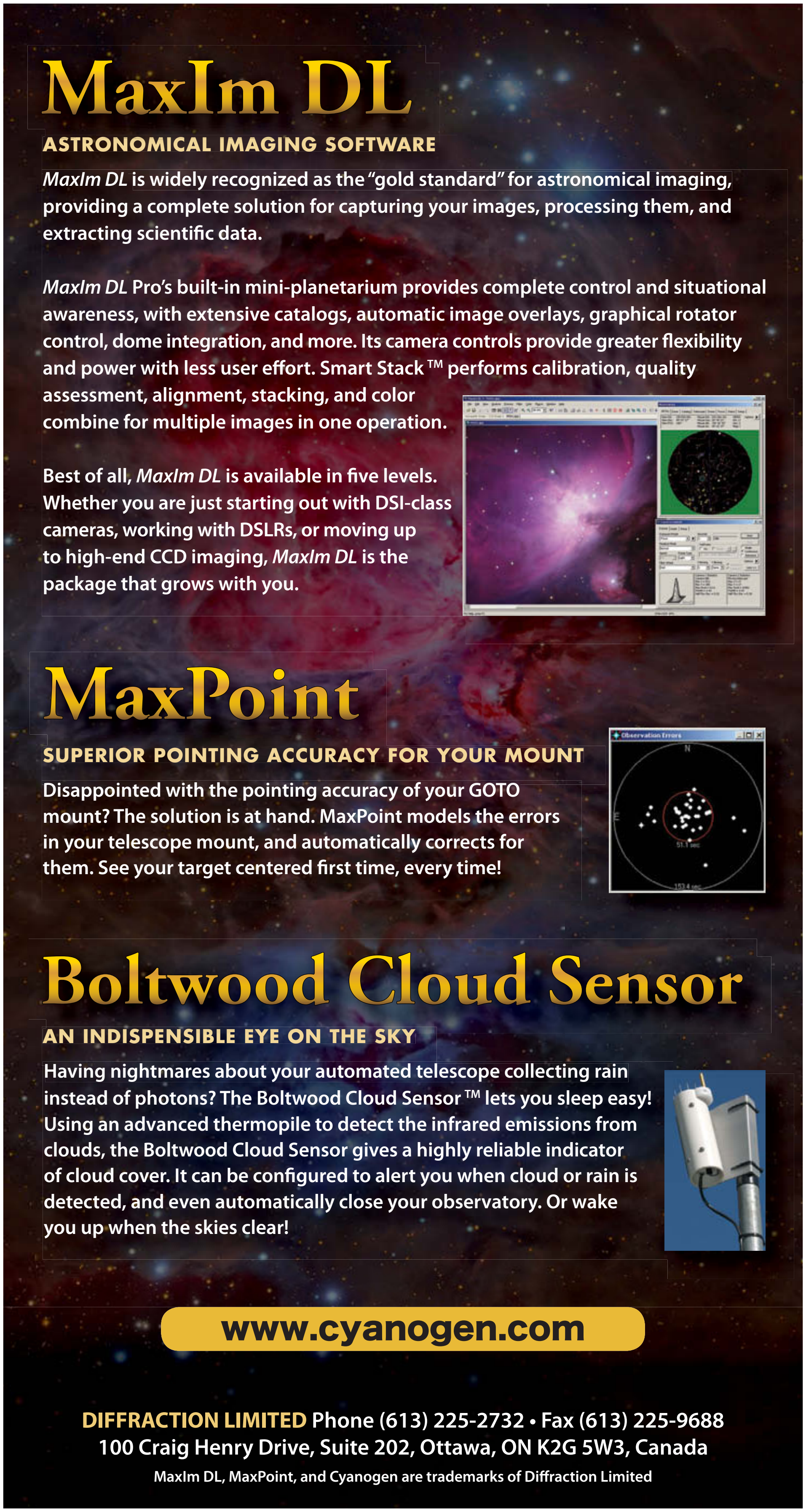

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was, and was not, silhouetted in front of it. The difference between the two states included a tiny fraction of the star's light skimming the planet's edges through its upper atmosphere on its way to us. From this, the group was able to derive a crude absorption spectrum for GJ 1214b's upper air. Their conclusion: water vapor seems to be at least 50% of it. On Earth, water vapor is only about 1% of the atmosphere.

Although the exoplanet's roasting heat must increase with depth, higher pressures at greater depth should make the water liquid rather than gas — a weirdly alien ocean. In the very deep interior, the extreme pressures and temperatures should turn the water into unearthly phases of superfluid and white-hot ice.

An Unexpected Secret of Sunspots

Hydrogen is by far the most abundant element in the universe, but most of it is *atomic* hydrogen: single H atoms. The *molecular* hydrogen familiar here on Earth, H_2, is rare in the cosmos; it's mostly confined to interstellar-cloud interiors that are cold and dense enough, and protected enough from ultraviolet radiation, for the molecules to hold together.

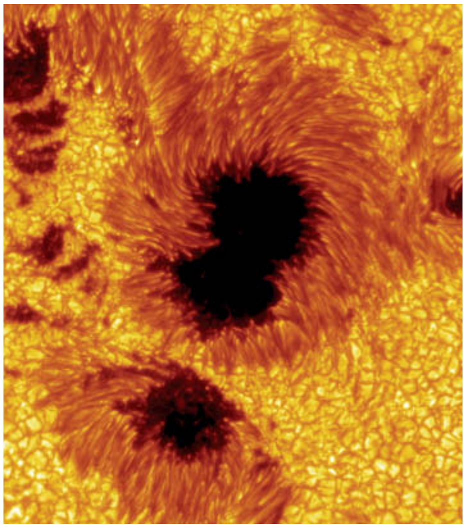
So you might not expect to find H_2 on the Sun. But a team from the University of Hawaii and the National Solar Observatory has measured it there — and finds that it plays a role in the formation and maintenance of sunspots.

Sarah Jaeggli and colleagues used the National Solar Observatory's Dunn Solar Telescope in New Mexico to observe 23 sunspot regions. They inferred the presence of H_2 amounting to as much as 2.3% of the hydrogen over cool sunspot umbrae.

Sunspots form where bundles of magnetic-field lines emerge from the Sun's interior. The magnetic field locks ionized solar gas in place, preventing it from participating in the general up-and-down boiling of the solar surface and thus allowing it time to cool. And this opens a window of opportunity for H_2 to form.

The group argues that the formation of H_2 in turn encourages "a rapid intensification of the magnetic field," helping to keep sunspots compact and long-lasting. Replacing two atoms with one molecule lowers the gas pressure inside a spot, causing the gas to shrink inward — dragging the magnetic-field lines with it.

This may add an important new piece to the puzzle of sunspots' compactness and persistence, and may ultimately help improve forecasts of solar flares and space weather in Earth's environment.



Formation of hydrogen molecules (H_2) in sunspots should intensify the strong magnetic fields that keep sunspots compact and long-lasting. Astronomers using the 1-meter Swedish Solar Telescope took this high-resolution image on July 15, 2002.

Closure for the Keck Interferometer

The twin 10-meter Keck telescopes atop Hawaii's Mauna Kea are nearly the largest optical telescopes in the world. A prime reason for building two of them was to use them as an *interferometer:* combining their light beams with extreme precision, light wave to light wave, to gain super-high resolution approaching that of a single telescope aperture as wide as their separation: 85 meters (280 feet). It wasn't easy — large optical interferometry is right at the edge of modern precision engineering — but Keck Observatory got the system working. It has been used to measure disks of stars and the dust structures of planetary systems forming around young stars.

But no more. Last summer NASA managers quietly decided to stop funding the interferometer, and it will be mothballed in July. After that, the two Keck telescopes will always each work alone.

Light from Keck Observatory's two 10-meter telescopes can be microscopically matched, wavefront to wavefront, to create the world's most sensitive optical interferometer — until the system is shut down in July.

NASA's official position is that the Keck Interferometer has completed its primary task of examining dusty disks around nearby stars. That fooled nobody. The reason is that it simply proved too difficult and expensive to link the giant eyes through the necessary system of optical pathways and adjustments, for use just a few dozen nights each year.

"This is tremendously bittersweet to me," laments Gerard van Belle (Lowell Observatory), whose team has been using the Keck Interferometer on dim dwarf stars. "I spent hundreds of nights on the summit from 1998 to 2001 getting this system to work."

Another reason for the closure was Keck Observatory's inability to add the four smaller, 1.8-meter "outrigger" telescopes that were intended to combine with the large two to create a more complete interferometer. The "sideKecks" were built (at a cost of about $15 million) but remain in storage, victims of NASA budget cuts and the touchy Hawaiian politics of adding more domes to the mountaintop. The sideKecks have been turned over to the U.S. Naval Observatory, which hopes to integrate them into its Navy Optical Interferometer in northern Arizona.

This leaves the European Southern Observatory's Very Large Telescope Interferometer in Chile, with four 8.2-meter scopes and four movable, 1.8-meter outriggers, as the unchallenged leader in large-aperture optical interferometry.

For more: **skypub.com/may2012keck**.

WIKIMEDIA COMMONS

Claudius Ptolemy (circa 150 A.D.) as imagined by a 16th-century artist.

Ancient Astronomers: Smarter Than We Knew?

Ancient astronomers were clever in lots of ways, and with so many of their texts now lost, they probably had more going on than we know. Now Bradley Schaefer (Louisiana State University) thinks he has found a new piece of astronomical knowledge they used: a formula for the dimming of starlight by Earth's atmosphere. He says they apparently corrected for this effect ages before anyone had a physical model for why it happens.

The dimming is called *atmospheric extinction*. It happens because a star at a low altitude is seen through more of Earth's atmosphere than a star overhead. This is why the Sun and Moon look dimmer near the horizon than when they're high. If the amount of air straight up is defined as "one air mass," you look through 2 air masses when you look 30° above the horizon, 5.6 air masses at 10°, and 40 at the horizon. Any naked-eye skywatcher notices the effect. But putting good numbers to it is another matter.

Astronomers compiled the first large star catalog about two millennia ago. Claudius Ptolemy of Alexandria included it in his great compendium of 13 books on astronomy known as the *Almagest* around 150 A.D. It classifies 1,022 stars by their "magnitude," setting the basis of the brightness-measuring system we use today. But historians have debated whether Ptolemy observed the stars himself or copied the star data from a now-lost catalog made by Hipparchus of Rhodes about 300 years earlier.

Schaefer had a brainstorm for a new way to try to find out. Rhodes is at 36° north latitude; Alexandria is at 31°. So in the southern part of the sky, stars would appear 5° lower — and therefore dimmer — from Rhodes than from Alexandria. Would the magnitudes in the *Almagest* give away the latitude of the author? To take an extreme example, Canopus at its highest would have looked 4th or 5th magnitude to Hipparchus but 2nd magnitude to Ptolemy.

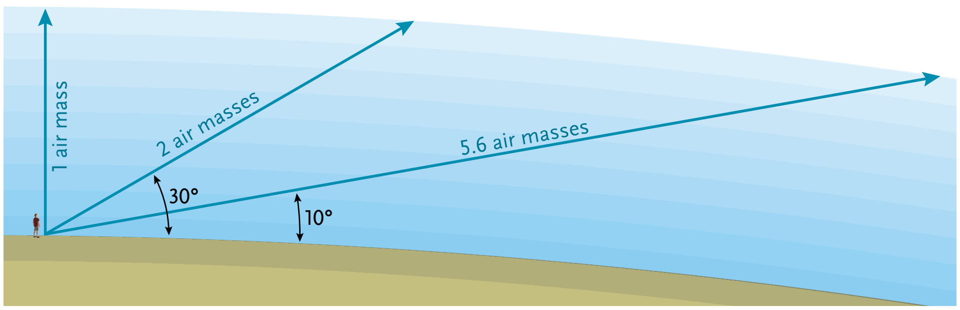
Schaefer, however, discovered a problem. No such effects appear at all. No matter how near the horizon stars were viewed (from whatever latitude), any effect of extinction averages out to about zero. "Somehow somebody corrected the *Almagest* magnitudes for extinction," says Schaefer. "It's the only way."

When Schaefer examined catalogs from two later astronomers, al-Sufi in the 10th century and Tycho Brahe in the 16th, he also found extinction corrections.

This is a surprise, because no records mention extinction at all until the 1700s. Says Schaefer, "It's rather surprising that [the ancients] did a sophisticated and pretty accurate correction for something they don't talk about and no one ever knew they knew about."

Several astronomers remain skeptical and argue that scatter in the data may undermine Schaefer's result, which he has not yet published. Still, the consensus seems to be that he's onto something.

How did the ancients do it? Probably they watched stars that traversed a large range of altitudes, determined how bright they appeared at different heights compared to stars at greater heights, and compiled a correction table accordingly. Schaefer did this himself while vacationing in the American Southwest, with pretty good results. He says it was "naked-eye backyard astronomy to the rescue of historical astronomy."



S&T ILLUSTRATION

The lower a star appears over your horizon, the more air its light has to go through to reach you. The amount of air straight over your head (whatever your height above sea level) is called one air mass.

End of an S&T Era

ROGER W. SINNOTT

Clearing out the former editor in chief's office.

The buildings that housed *Sky & Telescope*'s editorial offices for nearly half a century bit the dust on February 24th, literally, while camera-wielding former occupants looked on with mixed emotions. The former houses at 48 and 50 Bay State Road, Cambridge, Mass., served as our offices from 1957 until 2006 when we moved to more modern quarters nearby. Condos are going up in their place.

But a proud memorial stands across the street: *S&T*'s third and much larger former building now houses the American Association of Variable Star Observers. ✦

Saturn's Raging Superstorm

A mysterious Great White Spot erupted on Saturn in late 2010, only the sixth such storm in recorded history.

AGUSTÍN SÁNCHEZ-LAVEGA

NASA / JPL-CALTECH / SPACE SCIENCE INSTITUTE

IN THE AUGUST 1989 *S&T* I wrote about the most spectacular meteorological phenomenon in Saturn's atmosphere: a Great White Spot (GWS). Only four GWS events were known at that time, occurring in 1876, 1903, 1933, and 1960. Information on them was rather sparse, just a few photos and drawings. But the apparent regularity of this phenomenon, with one GWS per Saturn year (29.46 Earth years), encouraged me to predict that a new one would soon break out.

Sure enough, the fifth storm erupted in September 1990, in the planet's equatorial zone, just like the 1876 and 1933 events. Professional astronomers imaged the storm with new CCD cameras on ground-based telescopes and with the still-uncorrected optics on the Hubble Space Telescope. This fifth storm bolstered our view that the GWS phenomenon is seasonal and concentrated in the summer of Saturn's northern hemisphere. According to this periodicity, the next event should have flared up around 2020.

But to our great surprise, in early December 2010 amateur astronomers around the world obtained images of the outbreak of a sixth GWS, again in the northern hemisphere, but at mid-latitudes as was the case in 1903. The storm erupted in the northern hemisphere's early spring, about 10 years *before* summer.

This time, astronomers were equipped with better astronomical detectors in the visible and infrared, both from the ground and from NASA's Cassini spacecraft in orbit around Saturn. Amateur astronomers using advanced imaging techniques provided daily coverage that gave scientists their most detailed view yet of a storm's evolution. Papers later published in the prestigious journals *Science* and *Nature* included the contributions of several dozen amateur astronomers, among them *S&T* imaging editor Sean Walker.

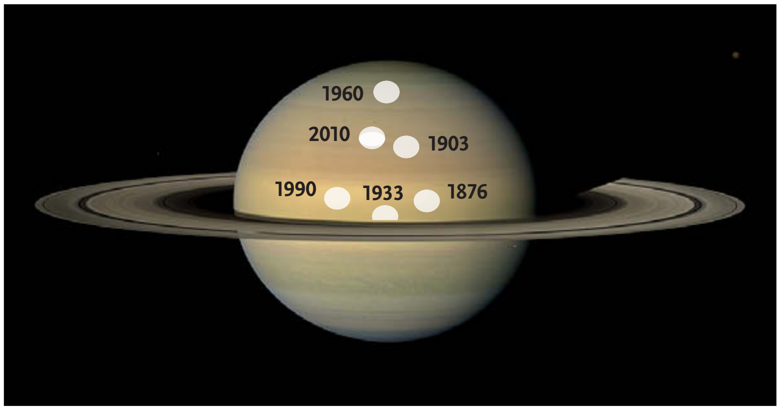
Discovery by Amateurs

Amateur astronomers Sadegh Gomizadegh in Iran and Teruaki Kumamori in Japan provided the first clear evidence of the 2010 GWS outbreak in images taken on December 8th and 9th, respectively. But a reanalysis of earlier Saturn images showed that in a December 5th picture from Japanese observer Toshihiko Ikemura, a very small white spot was located at the same position (latitude 37.7° north) as the eruption.

This date coincides with Cassini's first detection of the spot with two instruments. Its Radio Plasma and Wave Science (RPWS) experiment captured powerful radio emissions from intense lightning activity coming from the spot's position, and in its routine study of the planet, the Imaging Science Subsystem (ISS) caught a 1,000-km-wide bright spot.

From humble beginnings, the GWS quickly swelled to a complex phenomenon of planetary scale. December 10th images from Anthony Wesley in Australia and

SATURN STORMS *Left:* Cassini took this image of the storm's tail on February 25, 2011. *Right:* All six observed Great White Spots broke out in the northern hemisphere. The white dots on this Cassini image show the latitudes where each storm erupted. *Below left:* Spanish astronomer Josep Comas I Solà drew this illustration of the 1903 storm, which erupted at a similar latitude as the 2010 GWS. *Below right:* A GWS broke out near Saturn's equator in September 1990. In November 1990, before corrective optics were installed, the Hubble Space Telescope took this image after the storm had wrapped around the planet. North is up in all images in this article.



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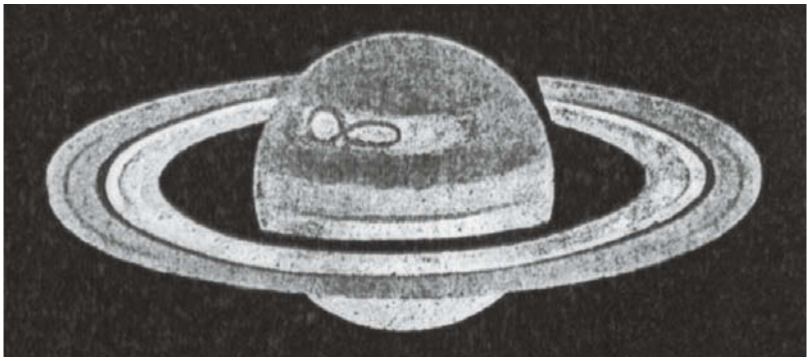

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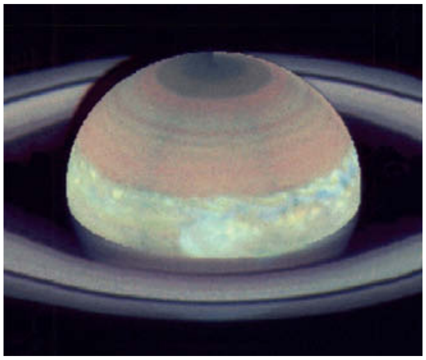

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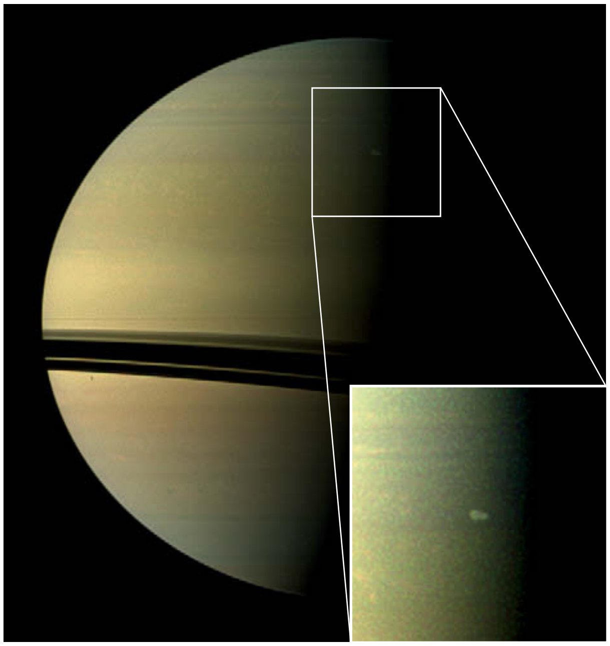


NASA / JPL-CALTECH / SPACE SCIENCE INSTITUTE (2)

THE SPOT EMERGES The new Great White Spot was discovered in amateur images taken on December 8 and 9, 2010. But analysis of this Cassini image taken on December 5th revealed a small white spot at the site of the eruption.

Jean-Jacques Poupeau in France showed that the spot had grown to a width of 8,000 km while simultaneously increasing in brightness at red, green, and blue wavelengths. Two days later, images from multiple observers around the world showed that the spot was expanding eastward, developing a tail. All of these lines of evidence — the large size, high brightness, and zonal expansion — were unambiguous signatures of a sixth GWS event.

In a matter of a week its head (the GWS proper, i.e. the "source" of the disturbance) grew to 10,000 km in diameter — almost the width of Earth. The feature's brightness made it easily visible through small amateur telescopes against Saturn's usual pale-yellow clouds and featureless disk. The GWS was magnificent in its high reflectivity at visible wavelengths and in its size, about six times that of the most frequent bright spots detected from Earth-based telescopes under good seeing conditions.

Amateur images were of fundamental importance to capturing the initial stages of the disturbance's evolution. They enabled my planetary science colleagues and I to determine the spot's growing size and brightness, which in turn allowed us to constrain the storm's early dynamics and vertical cloud structure. Except for the ISS's initial December 5th image of the spot, no Cassini picture was obtained until December 22nd. During this critical period, amateurs around the world took images every planet rotation (about 10 hours, 39.37 minutes). This major effort provided the most complete database of high-quality images of a GWS. You can see these contributions at the Planetary Virtual Observatory and Laboratory's website at **www.pvol.ehu.es/pvol**.

The Spot Grows a Tail

The head remained alive for several months. But high-speed winds quickly drove the disturbance eastward, forming a tail. Similar to previous storms, the tail of the 2010 GWS fully encircled the planet in about 55 days, producing a band of patchy bright clouds ringing Saturn.

The tail's pattern resulted from the complex turbulent motions and eddies generated in the head's wake as it interacted with high-altitude winds. The shapes of the storm's head and tail were sculpted by the shear of the permanent zonal winds, which consist of parallel bands that alternately blow east and west. The 2010 GWS head, centered at 40° north, moved westward, dragged by easterly winds of 30 meters per second (67 mph). But at 35° north, the wind blows eastward and the speed increases to 50 m/s (112 mph). At 44° north, the winds blow eastward at only 20 m/s (45 mph). Thus the tail's structure depended on the outbreak latitude and how the winds changed in speed north and south of the outbreak point. In the 1990 equatorial event, for example, the cloud pattern moved eastward *and* westward from the head, forming a tail on each side of the original GWS.

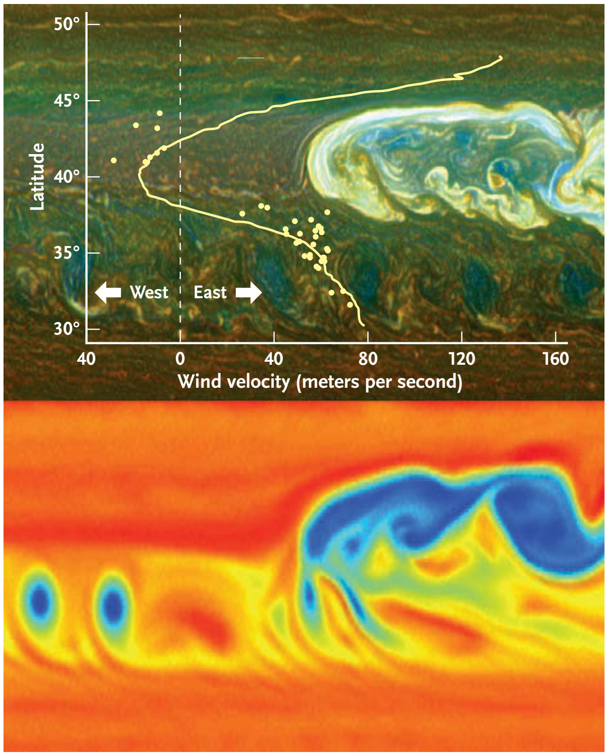
OUTBREAK These amateur images from December 2010 were critical in showing the eruption and early expansion of the Great White Spot.

Rising from the Deep

Amateur data also helped scientists decipher the storm's vertical motion. In Florida, Donald Parker obtained a series of images at ultraviolet wavelengths sensitive to cloud altitude and another sequence at a methane (CH_4) absorption band in the infrared. Together with pictures taken by professionals at Pic du Midi Observatory in France and at Calar Alto Astronomical Observatory in Spain, the data showed the GWS to be 10% to 20% brighter at optical wavelengths than its surroundings. The storm's brightening at all wavelengths indicated that the GWS contained highly reflective particles (probably ice crystals) that ascended with warm gas from deeper layers, with few of the contaminating aerosols that are abundant in Saturn's upper hazes.

But the original disturbance showed up only slightly in the methane-band images. Different filters show clouds at different altitudes, giving us important clues about the GWS's vertical structure. High clouds have little methane gas above them, so they reflect sunlight and shine brightly in methane-band images. Deeper clouds have more methane above them, so they reflect less sunlight and thus appear dark in the same band. Due to low temperatures in Saturn's atmosphere, its upper clouds consist of ammonia (NH_3) ice crystals that form around the altitude level of 1 bar, the same pressure at sea level on Earth. According to our calculations, the icy cloud tops of the GWS disturbance were immersed in a 100-km-thick haze layer that pokes about 40 km on average above the ammonia clouds. With its high altitude, the GWS appeared bright in the ultraviolet but dark in the methane band.

The GWS disturbance also made its presence felt high above the clouds, in Saturn's normally calm stratosphere. The storm produced two strong temperature anomalies nicknamed *beacons* on each side of the central disturbance. These beacons were distinct oval-shaped regions of air with temperatures much higher than their immediate surroundings, causing them to shine brightly when viewed in infrared light between 7 and 14 microns. The beacons' size and intensity varied during the storm, with



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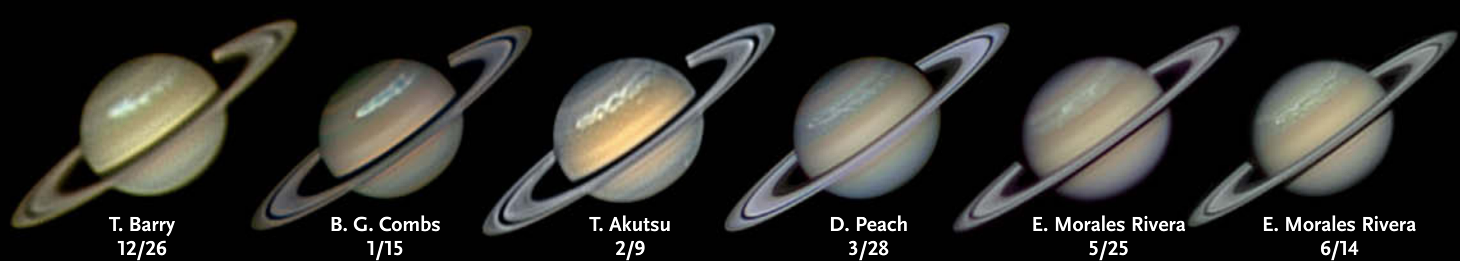
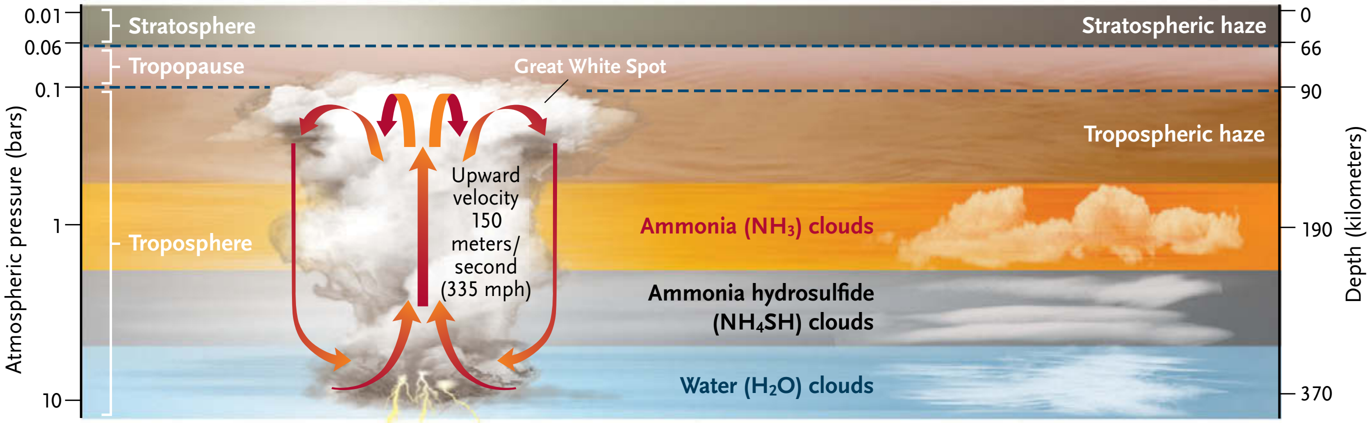
MODEL VS. REALITY *Top:* A false-color Cassini image of the head and tail, taken on March 6, 2011, is compared to wind-velocity measurements by latitude taken before the storm erupted. *Above:* A computer model of the tail from the author's research group closely matches the actual storm, indicating a general understanding of how upper atmospheric winds caused the tail to spread eastward.

a maximum horizontal extent of around 50,000 km.

Recent observations of Saturn's upper atmosphere showed that the two beacons intensified and merged in late April 2011, creating a large single mass of warm air some 70° to 80°C (125° to 145°F) warmer than the quiescent part of the atmosphere. This warm beacon has persisted long after the storm had ceased at deeper altitudes. The temperature differences induced high-altitude



THE TAIL SPREADS Amateur images from December 2010 to mid-2011 captured the dramatic eastward expansion and evolution of the tail.



S&T: LEAH TISCIONE / SOURCE: AGUSTÍN SÁNCHEZ-LAVEGA

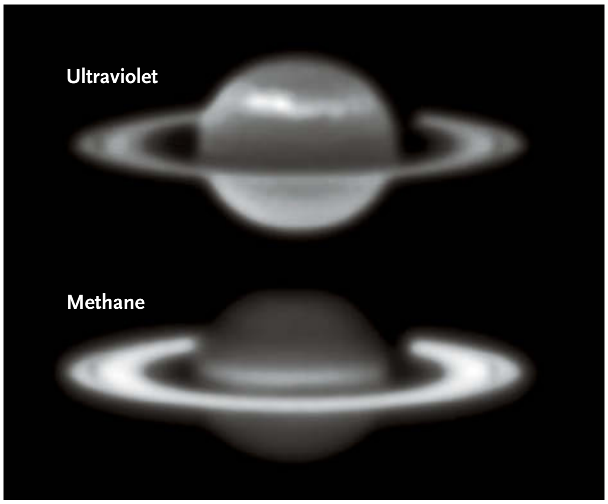
CLOUD STRUCTURE According to the author's model, the 2010 Great White Spot originated as a thunderstorm in a water cloud deep below the visible layers of Saturn's atmosphere. The storm ascended rapidly into the troposphere, where it could be easily spotted by amateur and professional astronomers.

changes in the stratospheric winds and in the abundances of some minor gases that were detected with infrared instruments on ground-based telescopes and Cassini.

A Giant Thunderstorm

All of the evidence suggests that the initial GWS was a giant thunderstorm about 100 times the size of typical Earth storms. For example, intense lightning activity within the storm produced the radio outbursts in the head detected by Cassini on December 5, 2010.

My colleagues and I have developed computer models of the GWS phenomenon that try to reproduce the observations and also probe the dynamical structure of Saturn's atmosphere below the upper ammonia cloud layer. According to our models, Saturn's 2010 GWS grew rapidly in brightness and area due to the formation and expansion of dense cumulus clouds of ammonia crystals — behavior somewhat like terrestrial thunderstorms. This is why we usually say that the GWS "erupts" in the planet.



PROBING THE DEPTHS Don Parker took these images on January 2, 2011. The GWS appeared bright through an ultraviolet filter but was barely visible in an infrared (methane) filter. Images such as these show conditions at different altitudes, and support the idea that the original disturbance consisted of warm gas and ice crystals that ascended from deeper in the atmosphere.

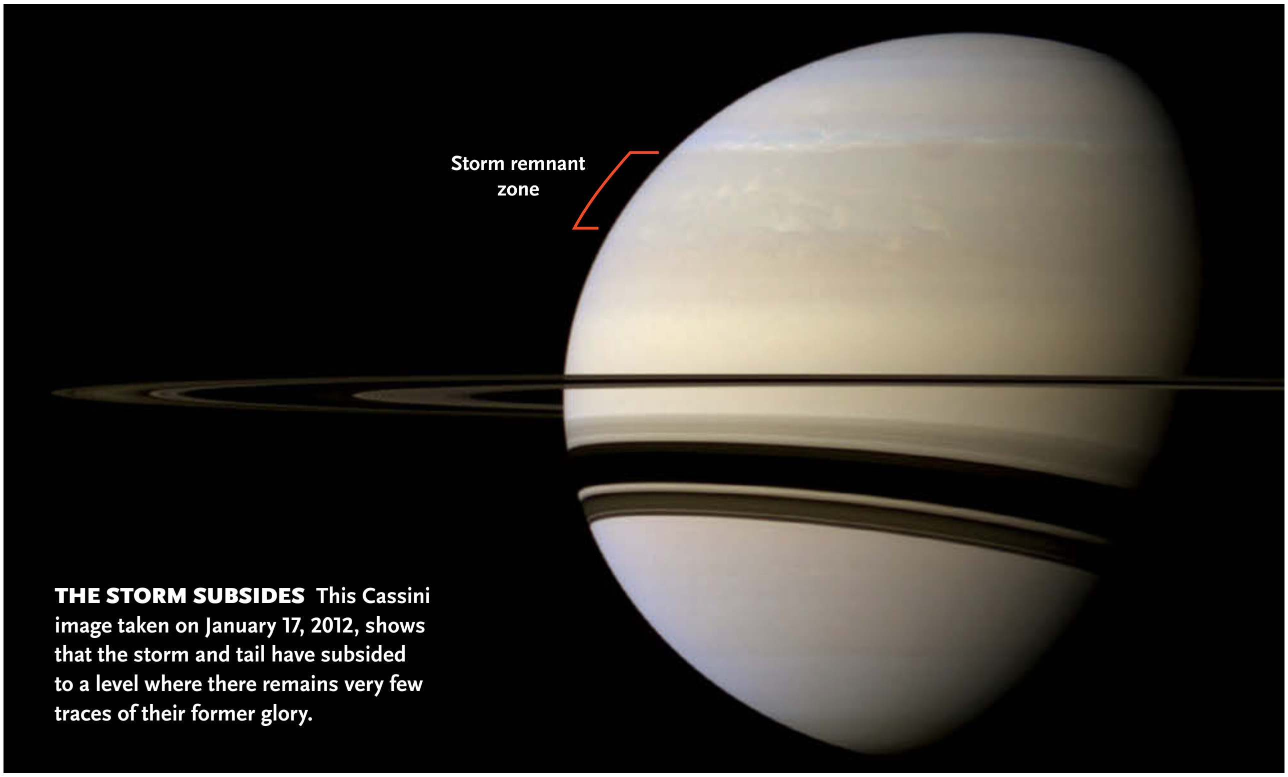
SATURN'S SEASONS

Saturn seasons are due to the 26.7° tilt of the planet's rotational axis with respect to the orbital plane. But at tropical and equatorial latitudes, the ring shadowing of the upper atmosphere varies during Saturn's orbit, which amplifies seasonal effects. Measurements of Saturn's east-west zonal winds during the last Saturn year show that they remained stable despite the planet's strong seasonal cycle.

Accordingly, the storm clouds in the head resulted from hot, moist gas rising rapidly from Saturn's deeper atmosphere. On Earth, the air is a mixture of nitrogen and oxygen, with water providing moisture. In contrast, Saturn's drier atmosphere consists mainly of hydrogen and helium, with ammonia and water providing most of the moisture. Based on models of moist convection in Saturn's atmosphere, we think that within the storm head, water-moist gas ascended from a depth of about 250 km below Saturn's upper clouds at speeds of 150 meters per second (335 mph), about three times faster than the velocities typical of severe thunderstorms on Earth.

High-resolution Cassini images of the GWS head showed abundant clusters of cumulonimbus (tall, vertical) clouds that appeared as a single compact bright spot in unresolved ground-based images. This observation supports our thunderstorm model.

Another important conclusion from our models is that Saturn's water abundance must have been high where the GWS erupted, about five times or more than the amount we expected from the Sun's abundance of oxygen, which is taken as a reference for the giant planets because they



THE STORM SUBSIDES This Cassini image taken on January 17, 2012, shows that the storm and tail have subsided to a level where there remains very few traces of their former glory.

NASA / JPL-CALTECH / SPACE SCIENCE INSTITUTE / ADDITIONAL PROCESSING BY S&T: SEAN WALKER

all formed from the same elements in the solar nebula.

In order to reproduce the structure and motions of the GWS clouds, the winds we measured at the upper-ammonia-cloud level must extend in depth without diminished speed to at least the water clouds, below the level where solar radiation penetrates. The development of the GWS produced small changes in the structure of the wind system at the latitude of the storm. But the westward jet at 40° north remained essentially unchanged by the action of the GWS.

All of these characteristics of Saturn's winds suggest that motions in the upper cloud layers are probably deeply rooted to the massive atmosphere that extends down to about half the planet's radius (30,000 km). The internal heat emanating from Saturn's depths, coupled to the planet's rapid rotation, could be driving the high-speed winds we observe at the cloud tops. This is different than on Earth, where winds are driven by solar radiation.

Remaining Mysteries

Despite the groundbreaking observations of the 2010 storm, there are many unsolved questions raised by the GWS phenomenon. For example, why are these giant storms so rare, with only one per Saturn year? Probably different contributing factors must occur simultaneously in the atmosphere to trigger a GWS. On the other hand, if these giant storms are seasonally forced, how does the small and slow seasonal temperature variation in the upper atmosphere propagate 250 km downward to the water cloud level? And why did the 2010 event take place about 10 years before the usual summertime period when other Great White Spots were observed?

Another mystery is the GWS's confinement to three latitude bands in the northern hemisphere (three at the equator, two at mid-latitudes, and one at a sub-polar latitude). Perhaps this effect is related to the shear of the zonal jets that change with latitude. But Saturn's jets are symmetrical by hemisphere, and don't seem to favor the north or south. It's possible that GWS phenomena many decades ago went undetected in the southern hemisphere, where they were obscured by the rings and their shadows on the globe, or that they took place when Saturn was hidden behind the Sun from Earth's perspective.

If the GWS occurs at a rate of one per Saturn year, the next one should not erupt until the 2040s. Perhaps then new observations will solve these and other mysteries. But before the next outbreak, scientists will continue to analyze and interpret the plethora of data from the 2010 storm retrieved by Cassini and ground-based observatories. ✦

To see more images of Saturn's superstorm, visit skypub.com/saturnstorm.

***Agustín Sánchez-Lavega** is Professor of Physics at the Universidad del País Vasco in Spain. He is author of the book* An Introduction to Planetary Atmospheres *(2011).*

Stars Above, Earth Below: Astronomy in

TYLER NORDGREN

As a professional astronomer, my luggage is covered with buttons and stickers from places familiar to astronomy enthusiasts, sites such as Palomar, Mauna Kea, Siding Spring, and Arecibo. But for the past five years my astronomical career has taken me to new destinations with names like Yellowstone, Yosemite, Grand Canyon, and Glacier. As artificial lights creep toward our observatories and make it increasingly difficult to see stars from urban areas, the national parks that protect our last unspoiled wilderness by day are also protecting our sky at night.

Tonight I've driven to Great Basin National Park in central Nevada. Created around Lehman Caves National Monument in 1986, Great Basin is one of the newest national parks, and its isolation invokes a feeling of having stepped back into yesteryear. Instead of long lines of cars at multiple entry stations, there's a single lonely road leading up into mountains that are dotted with aspen trees and that still carry patches of snow in July.

This feeling of having stepped back in time continues after nightfall. As far as my eyes can see to the distant mountains, there's not a single city light dome visible at all, and only a dozen or so house lights shine faintly in the distance. I can't remember when I last saw a sky this dark. Even with the lights of my GPS and dashboard streaming into my eyes, I can still discern detail in the Milky Way that normally takes forever to tease out of the sky's background glow. In Great Basin National Park, like the mountains, caves, aspens, and glacier that attract visitors by day, the galactic plane overhead is preserved the way everyone used to see it.

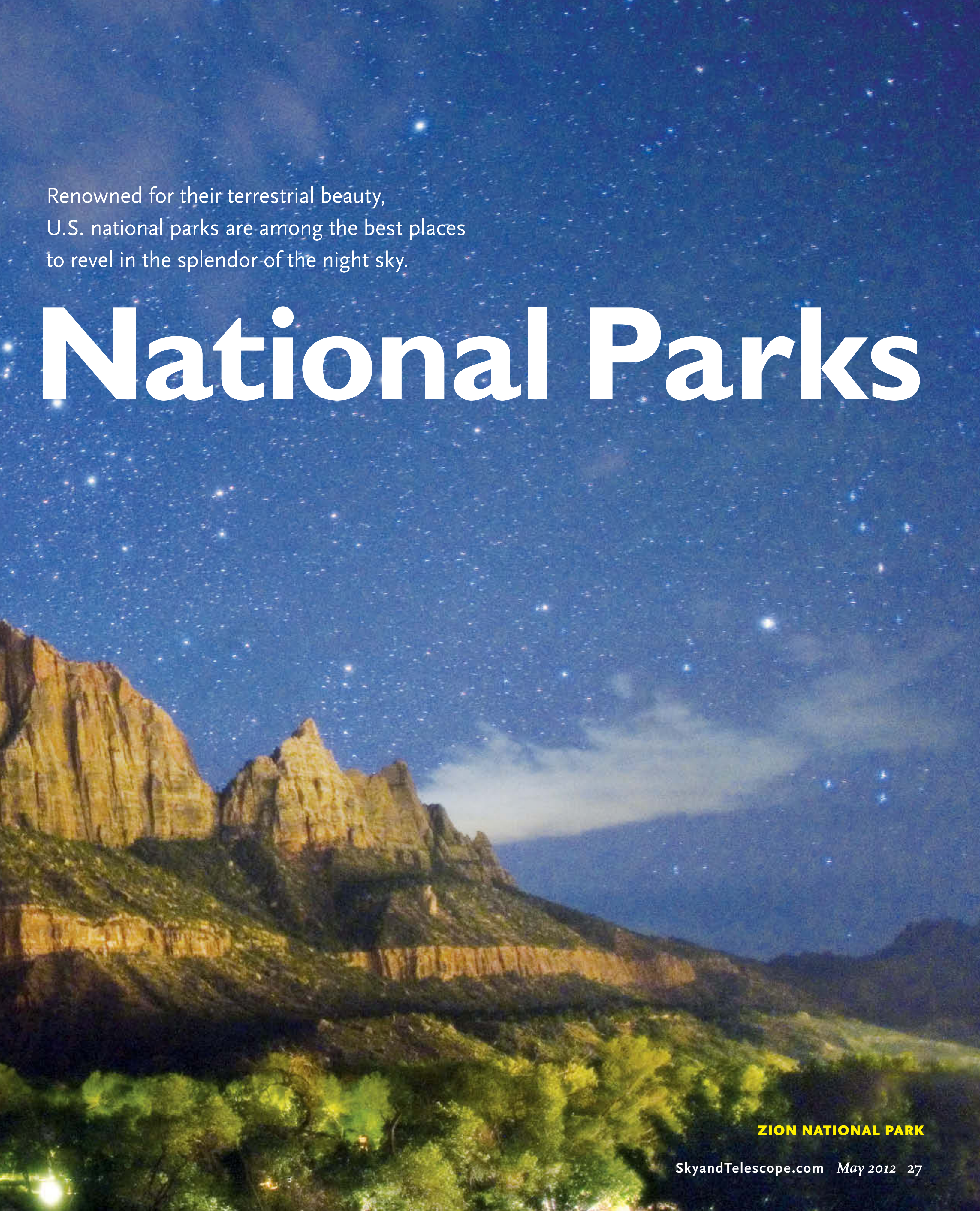
Star Parties and Festivals

Current estimates suggest that 60% of Americans no longer live where the Milky Way is even faintly visible, and worldwide roughly half of the children born in 2012 are expected to never see it at all. U.S. national parks are among the greatest locations guaranteed to reveal the splendor of the night sky. The public has noticed this. Surveys reveal that a star-filled sky is now as integral to a visitor's park experience as seeing waterfalls and wildlife. To help protect this celestial resource for future generations, a small team of park rangers and professional astronomers are working together to measure and monitor the night sky of the parks, looking to quantify its darkness and the major sources of light pollution from inside and outside the park (see sidebar, page 32).

The National Park Service Night Sky Team not only travels the country monitoring light pollution, it also helps coordinate astronomy volunteers for those parks looking to put on evening astronomy programs. These programs take the form of everything from hikes under a full Moon to telescope tours around the time of new Moon, all of which are among the most popular evening programs that parks offer. In smaller parks, these night-sky programs may stem from the astronomy passion of a single ranger or volunteer, while at larger parks, local astronomy clubs work with rangers to regularly operate multiple telescopes for the public's enjoyment.

In Yosemite National Park, California astronomy clubs take turns setting up telescopes every summer weekend at Glacier Point, a spectacular vista that overlooks Half

The Milky Way and Scorpius rise above Zion Canyon, the centerpiece of Zion National Park in southern Utah. PHOTO BY WALLY PACHOLKA



Renowned for their terrestrial beauty, U.S. national parks are among the best places to revel in the splendor of the night sky.

National Parks

ZION NATIONAL PARK

Carved by the Colorado River over millions of years, the Grand Canyon (in northern Arizona) is one of Earth's greatest natural wonders. About 5 million tourists visit the park each year.

ALL PHOTOS COURTESY OF THE AUTHOR UNLESS OTHERWISE CREDITED

HOW YOU CAN HELP

If you're an astronomer and want to reach out to visitors in a national park, contact the park and ask if a ranger gives evening programs. Offer to volunteer time with your telescope, or present astronomical information as a scientific resource. And since astronomy programs generally occur after typical business hours when many park administrators have gone home, the next time you enjoy the night sky at a park, drop by the visitor center the next day and let the staff know how much you valued the star-filled sky. You'll raise the profile of astronomy and ensure that the night sky continues to be a resource protected for future generations.

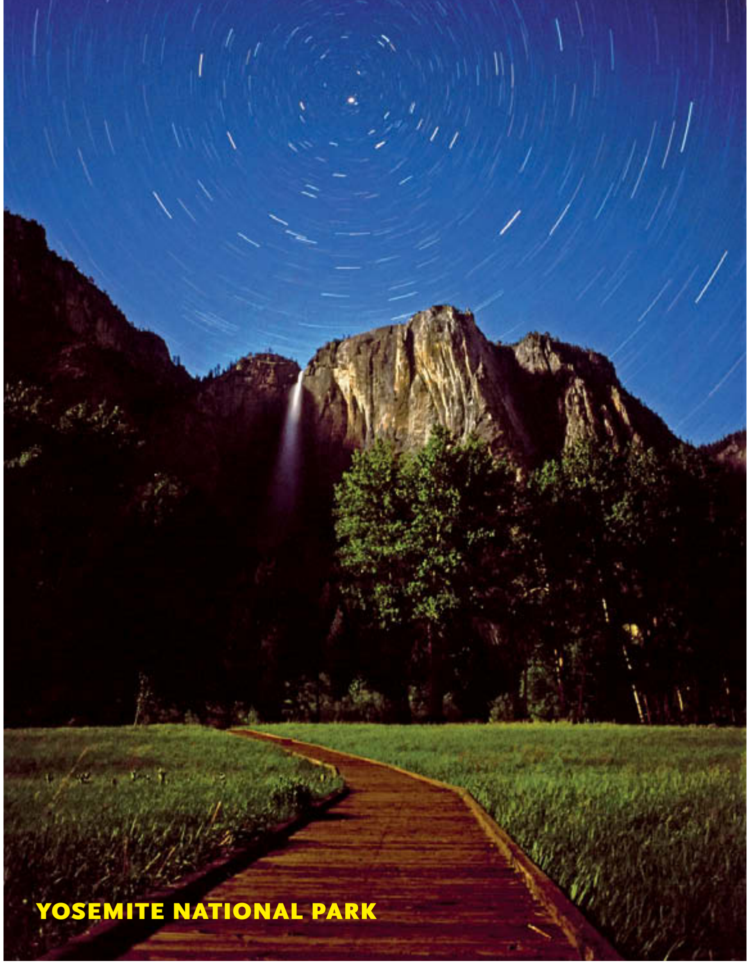
Dome and Yosemite Valley (see page 6). In Rocky Mountain National Park, near Boulder, Colorado, the local Estes Valley Astronomical Society has teamed up with park rangers to install permanent polar-aligned telescope piers in the Upper Beaver Meadows picnic area. These piers are pre-drilled for most standard Meade or Celestron telescopes and are free to use on a first-come, first-served basis. Just bring your own telescope and screws.

In addition to nightly astronomy programs, an increasing number of parks have begun to host multi-night astronomy festivals. I'm here in Great Basin for its second annual Night Sky Festival, where amateurs from the Las Vegas and Salt Lake Astronomical Societies have driven four hours to set up telescopes for visitors. During the day, a series of "Astro 101" sessions teach visitors where we fit into the universe and what they can expect to see at night. In addition, the Nevada Arts Council has helped bring a couple of writers to the park for readings on the beauty of the night sky. One such author is Paul Bogard, editor of an anthology of night-sky essays titled *Let There Be Night: Testimony on Behalf of the Dark*. Once the Sun sets, the park hosts a series of speakers, followed by guided trips to the telescope field for stargazing. For a few nights each year, astronomy volunteers become honorary "dark rangers" who help show visitors the beauty of the sky.

Although the 2012 Great Basin Night Sky Festival (the weekend of June 14–16) will only be its third, other parks, such as Bryce Canyon, have put on festivals for much longer. This year marks the 12th annual Bryce Canyon Astronomy Festival (May 17–20), with three parallel evening ranger astronomy talks and free shuttle buses to carry visitors to the telescope field, where Salt Lake astronomers set up more than four-dozen telescopes. Past speakers at Bryce's festival have included astronaut Story Musgrave and filmmaker Ian Cheney, who showed his award-winning light-pollution documentary *The City Dark*.

In September 2011, Acadia National Park in Maine hosted an Astronomical Society of the Pacific training program for rangers coinciding with its annual astronomy festival. The Acadia Night Sky Festival was created four years ago when local advocates partnered with the park and the regional Chamber of Commerce to demonstrate

Right: Upper Yosemite Falls is one of many attractions in Yosemite National Park, which is centered around a glacier-carved valley in central California. _Below:_ You can see actual glaciers in Glacier National Park in northern Montana. The brightest point of light is Saturn, hovering over Swiftcurrent Lake.



BABAK TAFRESHI

WALLY PACHOLKA

ARCHES NATIONAL PARK

Erosion carves stone arches as water dissolves the bonds that hold sandstone together in Arches National Park, Utah.

that dark, starry skies could be an important tourist draw along with the more traditional fall leaves and lobsters. This year's event will take place September 13–17.

See Mars on Earth

The opportunity to be an astronomical tourist doesn't end when the Sun rises. The parks protect many landscapes that are the result of geological forces that are also at work on other planets and moons in our solar system. A visit to our national parks can be a surrogate to a visit to worlds beyond Earth and a chance to see our world as one of an increasing number of known planets in our galaxy.

The next time you visit Yellowstone National Park and are waiting for Old Faithful to erupt, consider the following: volcanism produces the heat that warms the water that fuels the high-pressure geyser you're about to see. Thanks to NASA's Cassini spacecraft at Saturn, we now know that tidal heating of Enceladus warms the interior

YELLOWSTONE NATIONAL PARK

Old Faithful geyser, captured here at night, is one of the iconic symbols of the entire U.S. National Park system.

LEROY ZIMMERMAN

rock that melts the overlying ice, producing pockets of water that erupt as plumes similar to Earth's geysers. Computer simulations indicate that as Enceladus orbits Saturn, changing tidal forces may regularly open and close the cracks through which the plumes erupt. The plumes on Enceladus may therefore be "Cold Faithfuls."

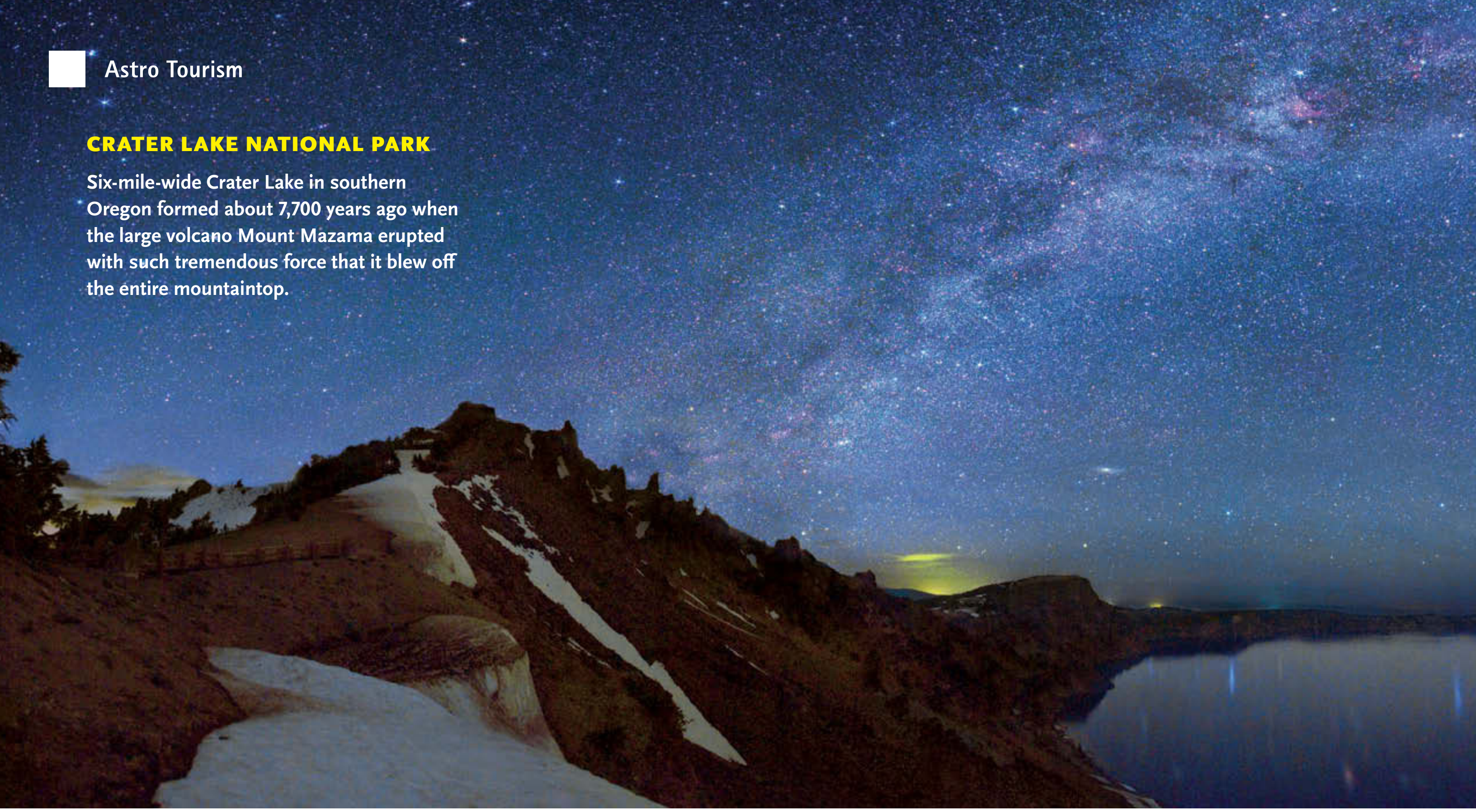
At Great Basin, and indeed all across the American Southwest, the most obvious planetary parallels are to Mars. Eleven thousand feet up in the tiny range of mountains at the center of this park sits Nevada's last remaining glacier. At the base of this glacier is a rock glacier, a river of stones held together by buried ice that slowly flows down the glacial ravine. Imagery from NASA's Mars Reconnaissance Orbiter shows a number of features that may be similar to rock glaciers on the Red Planet, evidence of water ice just beneath the dry, dusty surface.

One primary line of evidence that Mars's climate has

Each year thousands of visitors are shown the beauty of the Milky Way as local astronomers and park rangers set up telescopes for Bryce Canyon's Night Sky Festival.

ACADIA NATIONAL PARK

In Maine's Acadia National Park, the local community helps protect one of the premier dark-sky sites in the eastern U.S.



CRATER LAKE NATIONAL PARK

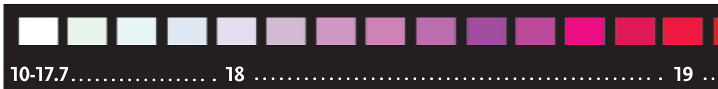
Six-mile-wide Crater Lake in southern Oregon formed about 7,700 years ago when the large volcano Mount Mazama erupted with such tremendous force that it blew off the entire mountaintop.

changed, and that subsurface water was once liquid, is found in the Martian "blueberries" imaged by the rover Opportunity on Meridiani Planum. These small hematite-rich spheres form where iron, carried by water in solution, precipitates out to form small pearl-like spherules. Journey to Grand Staircase-Escalante National Monument in the red-rock country of southern Utah and you can see similar iron spheres littering the sandstone surfaces. If you want to know what it might be like to explore Mars, visit Utah.

Astronomers of Years Past

But there's even more astronomy in the parks that can't be revealed by spacecraft or telescopes. For more than 10,000 years, astronomers have lived in and around what would become the national parks. Observing the sky is common to cultures all over the world, and out west where rock and wood are not covered by lush vegetation (and do not rot under the moisture of centuries), their creations from the past are still in evidence. Consider Chaco Culture National Historical Park in northwestern New Mexico. Archaeologists have found that the enormous, thousand-year-old stone "Great Houses" that dominate the broad canyon have numerous astronomical alignments. Every year on the summer and winter solstices, visitors flock to this remote park, as they did a millennium ago. They see the first rays of the rising Sun shine through carefully constructed windows to illuminate specific niches and alcoves as ceremonial markers for the changing seasons.

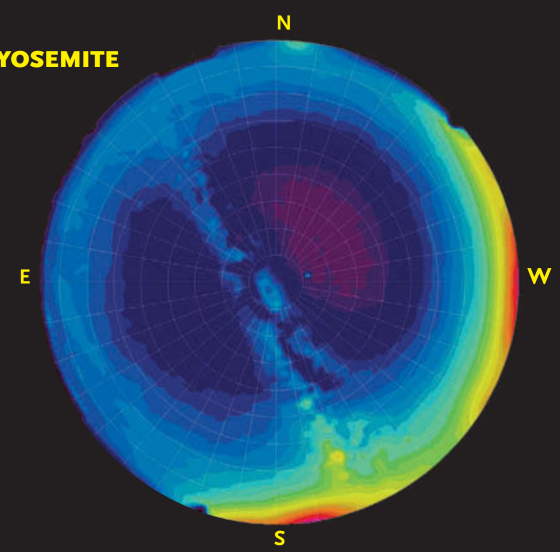
Magnitude per Square Arcsecond



A New Ally for Amateur Astronomers

Dark skies are a fleeting sight, and the U.S. National Park Service (NPS) has not overlooked this sobering trend. In 1999 two park scientists with amateur-astronomy backgrounds — Dan Duriscoe and I — joined to form the NPS Night Skies Team. We first set out to develop instruments and methods to accurately quantify night-sky brightness. To date, the NPS all-sky camera system has been

YOSEMITE



WALLY PACHOLKA

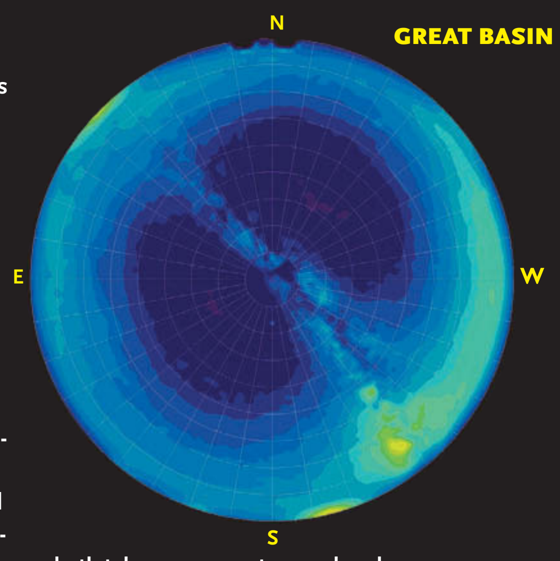
deployed at 94 parks, allowing the agency to quantify light pollution and track its sources.

Our data shows that parks such as Great Basin offer outstanding skies. From atop one of the park's highest peaks, Las Vegas and Salt Lake City are barely evident in our CCD imagery. Large metropolises can leave their mark at distances exceeding 200 miles (320 km). In more than 10 years of data collection and thousands of hours in the field, only a handful of Bortle Scale Class 1 skies have ever been glimpsed (www.skyandtelescope.com/resources/darksky/3304011.html). Our work illuminates the hard truth that a pristine night sky is exceedingly fragile, and what many stargazers consider to be a "dark" sky is often far from it. Without action, future generations may lose the opportunity to look beyond our planet into the deep cosmos.

Today, our NPS team has expanded to five full-time scientists and has widened its scope to all aspects of the protection and restoration of "natural lightscapes." Current projects include the development of a sky-quality index, establishment of park-appropriate lighting guidelines, retrofitting in-park lighting, light-pollution education, and leveraging parks as the core of dark-sky reserves. The NPS works closely with the International Dark-Sky Association, amateur astronomers, and other public-land managers to protect the inspirational view of the cosmos and the darkness that is essential for a balanced ecosystem.

Such an ambitious vision requires broad public support, and this is where national parks and amateur astronomers can form potent partnerships. Visitors to parks and other areas are attuned to nature and feel relatively free of the hurried urban lifestyle that takes the sky for granted. A well–orchestrated viewing of the cosmos paired with a night-sky-conservation message can make a difference.

The NPS Night Skies Team manages a nationwide Night Sky Ambassador program (http://nature.nps.gov/air/lightscapes/astroVIP) where service-oriented amateur astronomers can work alongside park rangers to interpret the cosmos for starlight–deprived citizens. Such programs being undertaken in nearly 20 parks take star parties to a new level of astronomy outreach; and these programs are typically paired with cross–training for



both telescope operators and park rangers. Though some astronomers may have resigned themselves to a future without the delicate structure of the Milky Way arching overhead, others find hope in those dark places that still remain. For the latter, you have a new ally.

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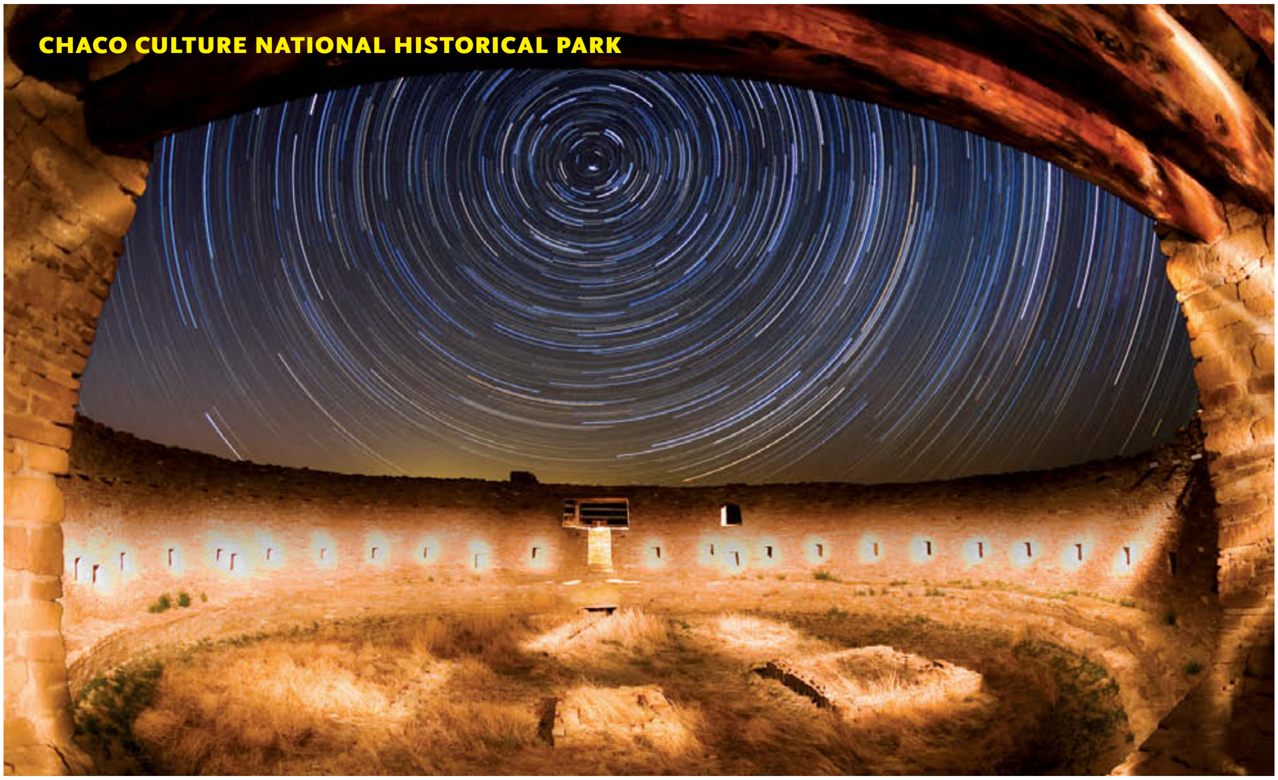
*For 12 years **Chad Moore** (chad_moore@nps.gov) has led the U.S. National Park Service Night Skies Team. He still drives a 6-inch Newtonian he's owned since age 16.*



Ancient Pueblo Peoples created Casa Rinconada approximately 1,000 years ago, in what is now northwestern New Mexico.

From the great houses of Chaco to the cliff palaces of Mesa Verde in southwestern Colorado, and even to the remains of a contemporaneous Freemont Culture village outside Great Basin, we see signs of inhabitants who paid attention to the sky and the motions of the Sun and possibly the Moon in order to survive. These astronomical traditions live on in the modern pueblos of the Southwest today and are therefore our link to people across cultures and time. Astronomers have long been here.

As I get ready to leave Great Basin National Park and prepare for my long drive back to the bright lights of Los Angeles, I take a moment to reflect and walk through a small cabin set up next to the old Lehman Caves National Monument visitor center. On its walls are framed photos of the first Westerners to come here looking for gold, then tourism. On the very last wall I see a newspaper article from April 1885 announcing the "discovery" of these caves of "wondrous beauty" and that a stalactite weighing about 500 pounds (230 kg) has been removed from inside the cave and placed there beside a monument to mark the recent transit of Venus. Yes, astronomers have been here for a very long time, and due to the encroaching lights of civilization, now more than ever the parks will be a haven for astronomers in the future. ✦

Listen to a **BONUS AUDIO INTERVIEW**

To view more images and to listen to an interview with author Tyler Nordgren, visit skypub.com/natparks.

FOUR ANNUAL NIGHT SKY FESTIVALS

Bryce Canyon
May 17–20, 2012

Great Basin
June 14–16, 2012

Grand Canyon
June 16–23, 2012

Acadia
September 13–17, 2012

Contact local astronomy clubs for more information about smaller star parties in nearby national parks.

Tyler Nordgren is an astronomer at the University of Redlands and author of the 2010 book Stars Above, Earth Below: A Guide to Astronomy in the National Parks.

The Remarkable Case of Comet Lovejoy

Despite the odds against it, Comet Lovejoy survived its swing by the Sun and became one of the most spectacular comets in the past few decades.

JOHN E. BORTLE

The comet left only the vaguest smudge on the November 27th discovery images. Nevertheless, it was enough for keen-eyed Australian amateur Terry Lovejoy to pick it out from background stars. Although it didn't look like much at the time, only three weeks later it would become the most spectacular comet in years! And its discovery gave us an unprecedented opportunity to study a sungrazing comet before, during, and after its brush by the Sun's surface.

Comet Lovejoy, C/2011 W3, was officially announced on December 2nd (see page 41). But the real rush of excitement came a few days later when its orbit revealed it to be a sungrazer that would rendezvous with the Sun on December 16th, passing within a scant 200,000 kilometers (125,000 miles) of its visible surface.

Among the most extraordinary of all comets, the family of sungrazers is thought to be the remnants of a huge comet that broke apart millennia ago, and it might even have been the one Aristotle wrote about in the year 371 BC that had a tail that spanned a third of the heavens. Progressive fragmentation at each subsequent swing by the Sun broke up the major fragments of this progenitor to spawn a host of ever smaller pieces.

When near perihelion, the largest of these surviving pieces become so brilliant that they are visible in the daytime and thereafter may unfurl tails as long as 60°. Some *Sky & Telescope* readers will undoubtedly recall the brilliant sungrazer Comet Ikeya-Seki in 1965, which was one of the most spectacular comets of the 20th century.

In addition to these showpiece comets, several solar-monitoring satellites have discovered more than a thousand pygmy sungrazers during the last three decades. They are the flotsam from the repeated break-ups experienced by the larger pieces at previous perihelion passages, and they now form an almost steady stream of debris spread along the parent comets' orbits. These fragile fragments are more than a thousand times fainter than sungrazers such as Comet Ikeya-Seki and are unable to withstand the Sun's furious heat and gravity. Not one of them has been observed to survive its fiery brush with the Sun, typically vaporizing completely in the final hours before perihelion.

At the outset it seemed that Comet Lovejoy's intrinsic faintness grouped it with the pygmy sungrazers, but the internet was still set abuzz by an early suggestion that the comet might reach magnitude –7 before its demise in the solar inferno. Nevertheless, the faintest sungrazer seen to survive its perihelion had an intrinsic brightness of about magnitude +7 or +8, or roughly a thousand times brighter than Comet Lovejoy. Thus, it seemed that the odds were all but nil that the comet would come through its rendezvous with the Sun unscathed.

In the days leading up to Christmas 2011, Comet Lovejoy appeared increasingly spectacular as it rose higher in the Southern Hemisphere morning sky. This was the view on December 23rd.

ROBERT H. MCNAUGHT

“I trust that most here appreciate that we are witnessing one of the most extraordinary events in cometary history.”

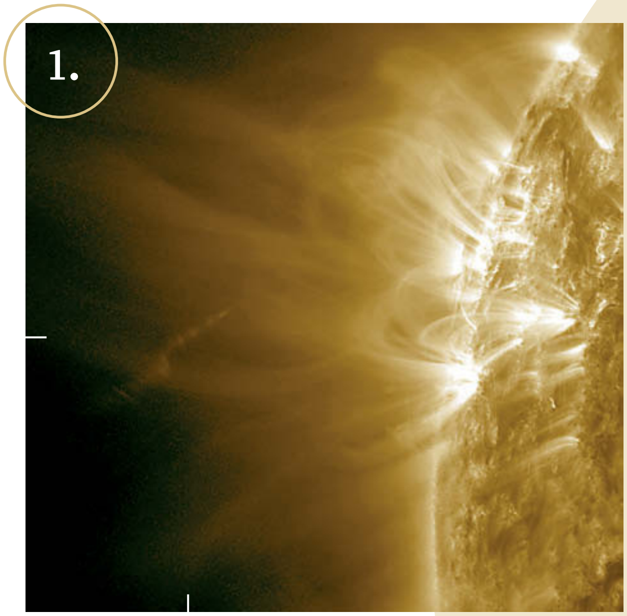
John Bortle writing on the Comets Mailing List on December 16th after Comet Lovejoy had rounded the Sun.

Above: Rising tail first in the morning twilight after its swing around the Sun, Comet Lovejoy was described by many Southern Hemisphere observers as looking like a searchlight beam. It's easy to see why from this photograph taken by Robert McNaught on December 21st.

Approaching the Sun

Terry Lovejoy was able to spot his comet visually late on December 3rd with his 30-cm (12-inch) telescope. It appeared as a small, modestly condensed mass, just 1 acrminute in diameter and glimmering at magnitude 11.6. As the comet slid deeper into the netherworld of morning twilight, visual sightings grew sparse, but astrophotographers in the Southern Hemisphere were able to keep the vigil against the ever-increasing dawn background. Participants in various internet comet forums could hardly contain their excitement as they awaited each morning's new images.

On December 8th, Comet Lovejoy, now with a gossamer tail that grew ever longer by the day, was estimated to be near 8th magnitude and perhaps as bright as magnitude 6 only three days later. Thereafter, with its distance from the Sun shrinking daily, Comet Lovejoy was lost to ground-based observers. It was, however, soon to be followed by solar-monitoring spacecraft.



NASA / SOLAR DYNAMICS OBSERVATORY / STEELE HILL

The extreme-ultraviolet camera onboard NASA's orbiting Solar Dynamics Observatory captured these extraordinary images of Comet Lovejoy (indicated by the tick marks) before (1) and after (2) its swing behind the Sun on December 16th.

A new rush of excitement met the first glimmers of Comet Lovejoy when it entered into the field of view of the STEREO/SECCHI A and B spacecraft on December 12th and then SOHO's C3 coronagraphic instrument on December 14th. At about 14:00 Universal Time on the 14th, the comet's brightness in SOHO images seemed close to magnitude +1, making it several magnitudes brighter than most of the larger pygmy sungrazers seen similar at solar distances. A scant two hours later people monitoring each newly posted SOHO image were stunned to see a tiny companion traveling slightly ahead of Comet Lovejoy. And not long afterwards another comet was spotted slightly trailing the pair.

But the main show was still Comet Lovejoy, which was now brightening dramatically hour by hour. Several experienced observers tried spotting the comet visually in the daytime sky, as had been done with Comet Ikeya-Seki. In New Zealand, John Drummond reported trying to see the comet when it wsa a mere 1.9° from the Sun. His efforts, like those of others observers, proved fruitless.

The SOHO images obtained around 4:00 UT on December 15th showed the comet was about magnitude –1 and sporting a long, bright, slightly curving dust tail. Also visible was a long but decidedly fainter tail of ionized gas, which was a bit of a surprise because an ion tail had never been positively seen on earlier pygmy sungrazers.

As the time of perihelion grew near, the astronomical fraternity remained appraised of the comet's developments in almost real-time with updates that Karl Battams posted on the SOHO Sungrazer Comet website. They included extraordinary images from spacecraft along with a running commentary on their implications. In the final hours before perihelion on December 16.01 UT, observers around the world watched the updated SOHO images in fascination, thinking they were witnessing Comet Lovejoy's final death plunge.

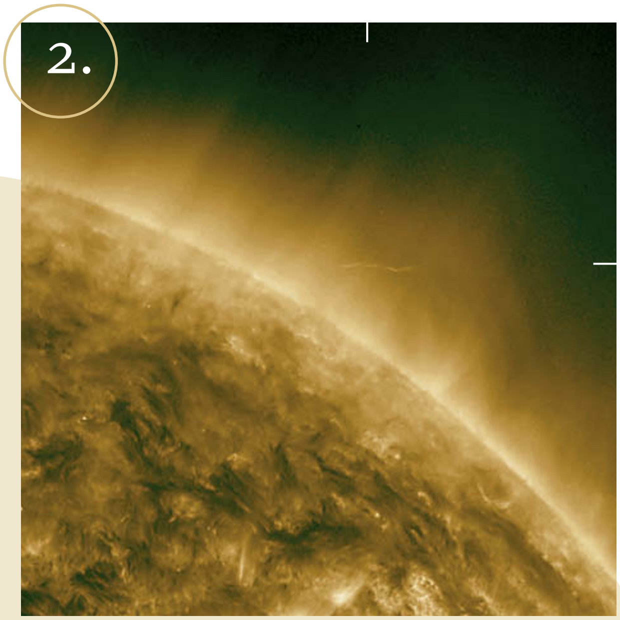
Solar Survivor

When the comet's head disappeared behind the occulting disks of SOHO's coronagraphs, NASA's Solar Dynamics Observatory (SDO) team took up the challenge of following the comet with the extreme-ultraviolet camera onboard the orbiting SDO. Its images showed the comet's tail being violently distorted by the solar corona, looking like cigarette smoke in a turbulent breeze, just before the comet disappeared behind the solar limb. Incredibly, however, the same camera soon captured images of the comet emerging from behind the Sun's opposite limb. Comet Lovejoy had somehow survived its hellish passage through the solar atmosphere.

In the hours that followed, the SOHO cameras also obtained images of the now-outbound comet's extraordinary appearance. The old tail was visible southeast of the solar disk, still drifting sunward. To the southwest of the of the Sun, and no longer connected with the tail, stood the brilliant star-like "head" of Comet Lovejoy. At magnitude –2, or perhaps even –3, it was even brighter than it had been before perihelion! Furthermore, the comet began growing a brilliant new tail.

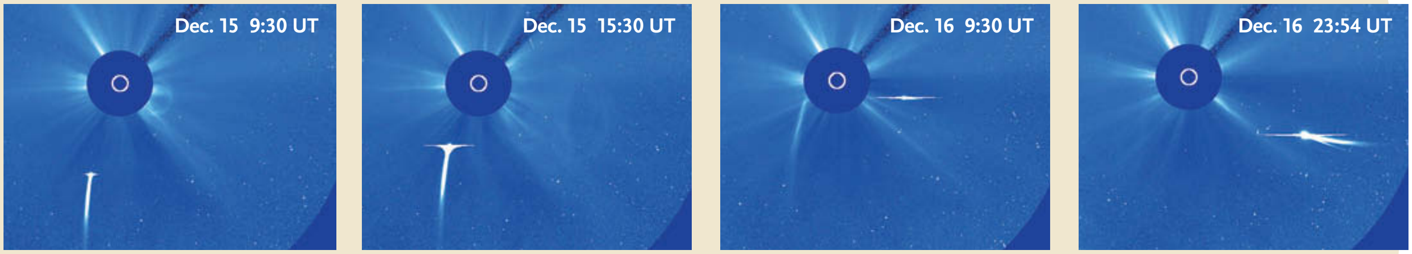
Once again, ground-based visual attempts to see the comet in daylight failed, but it was captured in photographs, especially those taken at near-infrared wavelengths. And beginning about December 19.5 UT, amateurs in the Southern Hemisphere were photograph-

2.



NASA / SOLAR DYNAMICS OBSERVATORY / STEELE HILL

***Below*: Observers around the world awaited each updated image from the coronagraphic instrument aboard the orbiting Solar and Heliospheric Observatory as Comet Lovejoy made what most people thought was its death plunge toward the Sun. But the comet survived its fiery encounter and emerged tailless (third image in sequence) early on December 16th, even while its pre-perihelion tail was still visible on the inbound side of the Sun. Within hours the comet grew a new tail that was far more spectacular than before.**



SOHO / LASCO CONSORTIUM (4)

ing the comet's tail projecting up from the brightly lit dawn horizon.

Until this point, Comet Lovejoy's coma displayed a normal, condensed appearance. But this abruptly changed on December 20th when the comet's head exhibited a long, bright tailward-pointing ray instead of a compact central condensation. This ray grew longer each day as the comet's head became weaker and more diffuse. Comet expert Zdenek Sekanina at JPL proposed that Lovejoy's nucleus completely disrupted about December 17.6 UT, and that the stream of resulting debris was moving rapidly outward into the tail, forming the ray-like feature. This debris ranged from boulder-sized pieces nearest the position of the comet's former nucleus to micron-sized dust stretching well out into the tail. We may well have been witnessing the creation of innumerable future pygmy sungrazers.

With the comet moving away from the Sun and the tailing growing longer each day, Comet Lovejoy looked like a searchlight beam projecting up from the horizon before it was washed out by increasing twilight. On the morning of December 22nd, observers were describing the comet's dust and ion tails as each about 16° long and similar in brightness to the Large Magellanic Cloud. That same day the crew of the International Space Station watched the comet as it rose over Earth's curving limb.

While some observers thought that the fading of the comet's head heralded a rapid demise of the tail, the performance of past sungrazers suggested that the show was just beginning and that Comet Lovejoy might unfurl a truly enormous tail in coming days. And it did just that. By Christmas morning the tail had grown to at least 28°!

As the New Year opened, there were reports of the comet's dust tail stretching across 40° of sky, but the head had faded so much that it could hardly be seen with the unaided eye. Like the Great Southern Comet of 1887, Comet Lovejoy had essentially become only a tail.

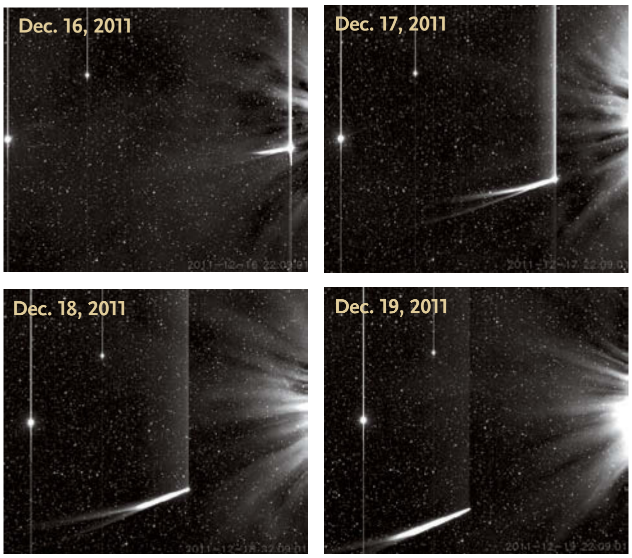
The searchlight appearance of the tail was maintained

ANU / UNIVERSITY OF ARIZONA / NASA / ROBERT H. MCNAUGHT

In the days following perihelion, the bright central condensation at the comet's head evolved into a slender ray-like feature that is thought to have formed as debris from the disrupted nucleus spread outward into the tail. This view was obtained at 17:49 UT on December 24th with the Uppsala Schmidt Camera at Australia's Siding Spring Observatory.

as it faded and grew ever more ghostly and transparent with the passing days. Although the end of the tail faded into the Milky Way in Crux and Centuarus, images showed that its length was an astounding 45° when it peaked in mid-January. This corresponded to a truly enormous 1¼ astronomical units! But because of its faintness, the tail was noticeably shorter to the unaided eye. By January 20th, the comet could only be seen visually from the darkest, pristine observing sites. Photographs in February captured only hints of the grand visitor as the comet disappeared from view, but Comet Lovejoy's legacy will surely be remembered for a long time to come. ✦

Amateur astronomer ***John Bortle*** *has a long history of observing and writing about comets, variable stars, and lunar eclipses from his home in Stormville, New York.*



STEREO IMAGES COURTESY NASA / NAVAL RESEARCH LABORATORY

The changing appearances of Comet Lovejoy's brilliant, sweeping dust tail and slender, straight gas tail are evident in this daily sequence obtained by the Heliospheric Imager on the STEREO A spacecraft between December 16th and 19th as the comet moved away from the Sun. Streaks emanating from bright objects are artifacts due to overexposure. The notably bright "stars" in the field are the planets Mercury (fainter of the pair) and Jupiter, which appeared relatively close together from the spacecraft's vantage about 45° ahead of Earth on our orbit around the Sun.

The Discovery of Comet Lovejoy

By TERRY LOVEJOY

The discovery of C/2011 W3 happened on the morning of November 28th (local time) as part of my routine comet survey. On this morning I imaged 200 separate fields, taking three exposures per field, between declination –35° and –55° and right ascension 9h 00m and 13h 30m. The patrol is set up so that exposures for the same field are separated by 9 minutes, making it easy to detect the movement of comets by "blinking" the images in rapid succession on a computer monitor.

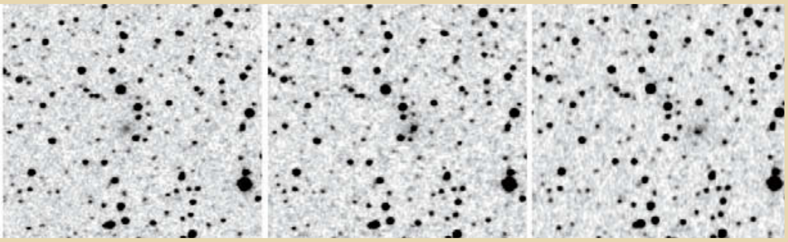
When examining the images the following evening, I immediately noticed a diffuse object moving rapidly eastward in Centaurus. At first I thought it was a reflection from Gamma Centauri, which was a little outside my field of view. But the object's motion was uniform, compelling me to make follow-up observations. On the morning of November 30th there were enough breaks between the clouds for me to take several short exposures. I was elated to find a diffuse object at almost the exact location I had projected from the November 28th positions! Because I was now quite certain this was a new comet, I asked other observers for independent confirmation.

At first there was disappointment. On November 30th two fellow Australian amateurs failed to see the comet — Andrew Pearce searched visually with his 8-inch reflector, and Michael Mattiazzo did not capture it with a Canon 300D DSLR and 300-mm lens. I also heard from Alan Gilmore at New Zealand's Mount John Observatory who could not perform follow-up observations because of high winds. The following night, however, Gilmore and Pam Kilmartin imaged the comet with the observatory's 1.0-meter reflector. The comet was officially announced on December 2nd by the Central Bureau for Astronomical Telegrams as C/2011 W3 (Lovejoy).

This was my third ground-based comet discovery in addition to 11 I found by examining images from the SOHO satellite. While I was focused on finding Kreutz Sungrazing comets in the SOHO images, my ground-based survey was not. So I was very pleased that this latest discovery turned out to be a sungrazer!

TERRY LOVEJOY (4)

Australian amateur Terry Lovejoy with the imaging gear used for his latest comet discovery. The cooled monochrome QHY9 CCD camera and 8-inch Celestron Schmidt-Cassegrain telescope are set up for f/2 HyperStar imaging. His previous two ground-based comet discoveries were made with a DSLR camera and telephoto lens.



Appearing as little more than a smudge near the center of these three November 27th (Universal Time) discovery images, the comet's motion was sufficient to warrant follow-up observations.

Observers on the ground weren't the only ones getting a spectacular view of Comet Lovejoy as it rose above the horizon. Astronaut Dan Burbank aboard the International Space Station captured this image of the comet on December 21st. The green layer above the blue twilight glow is due to oxygen atoms about 60 miles (130 km) above Earth's surface. NASA / DAN BURBANK

The Western U.S. will enjoy an annular eclipse on May 20th.

In This Section

IMAGE: *S&T* PHOTO ARCHIVE

OBSERVING

Sky At A Glance

3 **Evening:** Spica and brighter Saturn are left or lower left of the waxing gibbous Moon.

4 **Evening:** The Moon is now below Saturn and Spica.

5 **Evening:** The largest full Moon of 2012 occurs at 11:35 p.m. EST.

7 **Dawn:** Antares is lower left of the waning gibbous Moon.

20 **An annular solar eclipse** is visible along a path from southern China through southern Japan to northern California and ending in northern Texas. The partial phase is visible across much of Asia, the Pacific Ocean, and North America; see page 50.

21 **Dusk:** Look for the extremely thin crescent Moon far below Venus very low in the west-northwest 15 to 30 minutes after sunset; see page 48.

22 **Dusk:** The thin crescent Moon forms a line with Venus and Elnath low in the west-north west. Telescopes show that the Moon is also very close to 3rd-magnitude Zeta Tauri. Some parts of the U.S. can watch Zeta Tauri disappear behind the Moon's dark limb or reappear from behind the bright limb. See page 52 for details.

28 **Evening:** Mars shines above or upper left of the Moon.

31 **Evening:** Spica is just above the waxing gibbous Moon, with brighter Saturn above Spica.

Planet Visibility

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	Hidden in the Sun's glow all month		
Venus	W NW		
Mars	S W		
Jupiter	Hidden in the Sun's glow all month		
Saturn	SE S W		

PLANET VISIBILITY SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH.

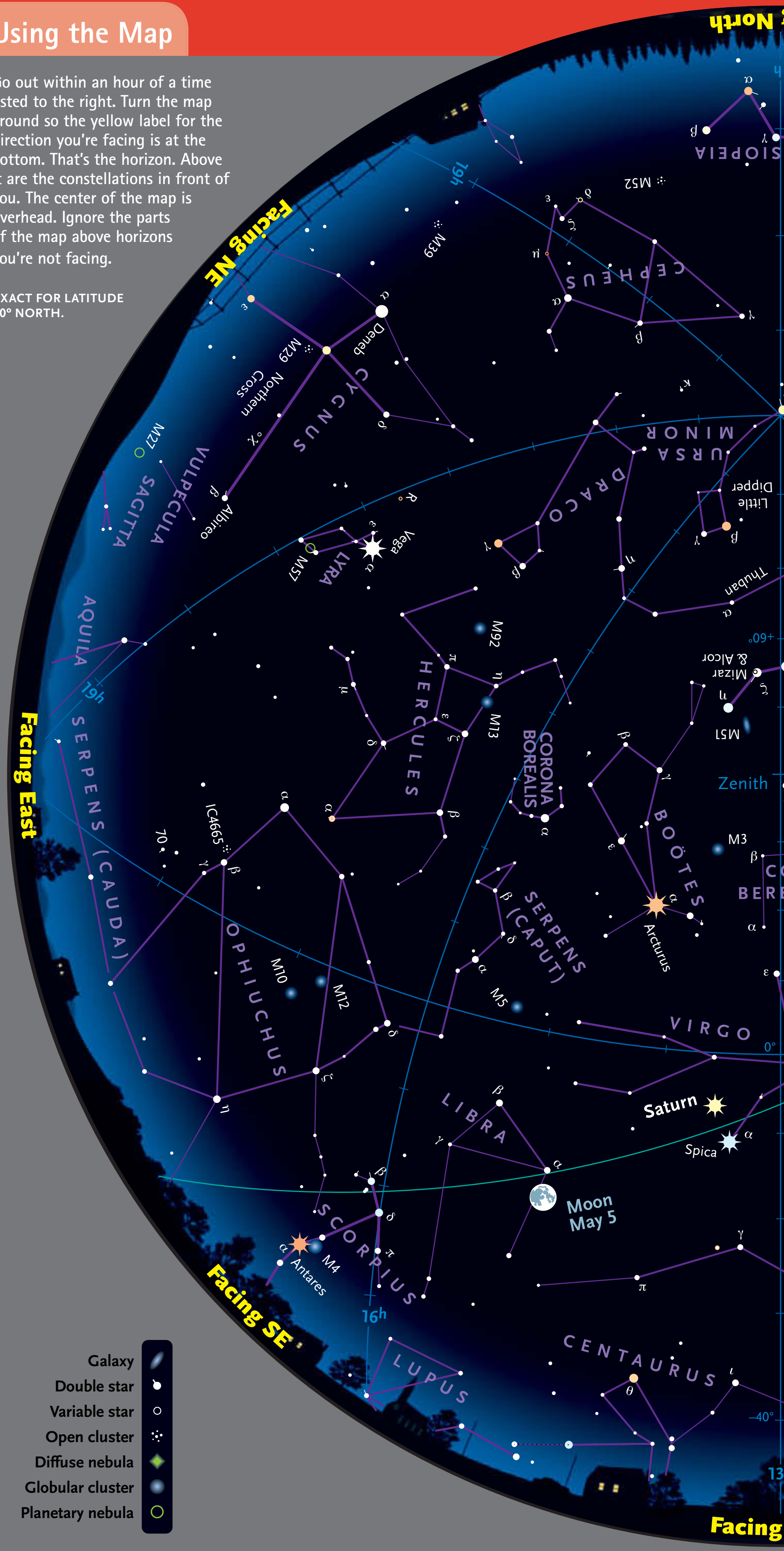
Moon Phases

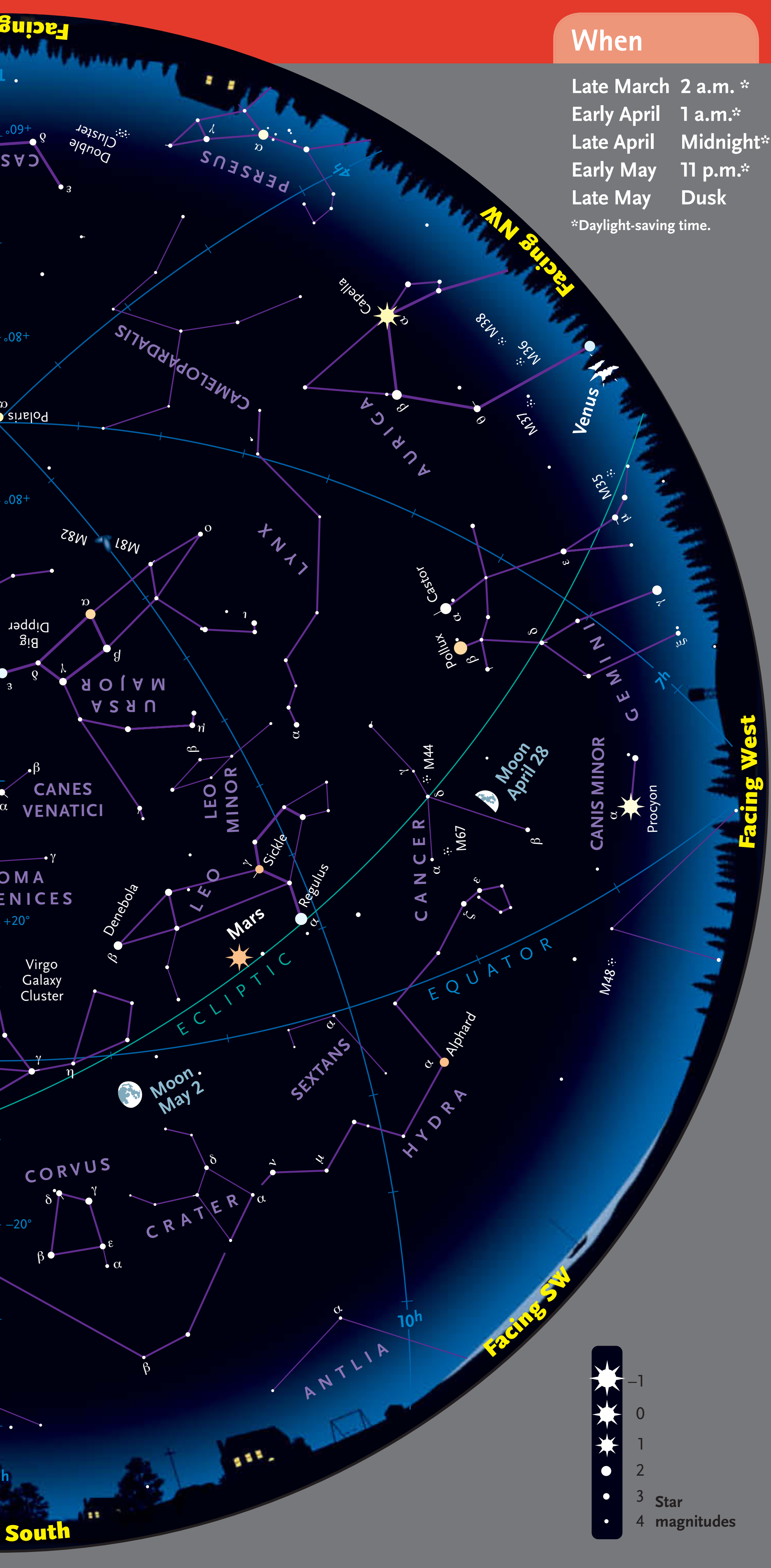
SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

Late March	2 a.m.*
Early April	1 a.m.*
Late April	Midnight*
Early May	11 p.m.*
Late May	Dusk

*Daylight-saving time.

Binocular Highlight

Messiers in Hydra

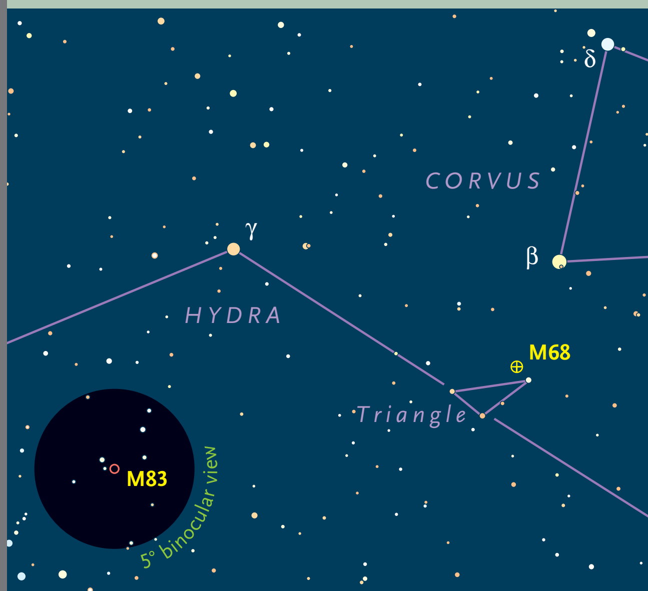
What Hydra lacks in distinctiveness it more than makes up for in size. It's huge! Hydra sprawls across much of the spring sky, from Libra to Cancer. Yet in spite of the fact that it occupies a greater chunk of the celestial sphere than any other constellation, only three Messier objects call Hydra home: M48 (discussed in this column three years ago), **M68**, and **M83**.

Let's begin our Hydra hunt with M68, a 7.8-magnitude globular cluster. It's easiest to find starting from 2.6-magnitude Beta (β) Corvi. The cluster is positioned less than one binocular field south-southeast of Beta, and next to a right triangle of 5th-magnitude stars. M68 isn't an easy catch, but I'm able to see it under decent skies with my 10×30 image-stabilized binoculars. Thanks to the cluster's proximity to the triangle and its slightly fuzzy appearance, identifying M68 is quite straightforward.

While Hydra's Messier globular is near a reasonably bright star, the spiral galaxy M83 lies in a bit of a nowhere land. Luckily, it's the only conspicuous faint fuzzy in that stretch of sky. Indeed, I have little difficulty locating it in my 10×30s by carefully sweeping the area southeast of 3rd-magnitude Gamma (γ) Hydrae. M83 resides within an attractive, cascading curve of 6th- and 7th-magnitude stars that resembles the constellation Scorpius — but without Antares. The galaxy is situated between the stinger and the body of this miniature scorpion.

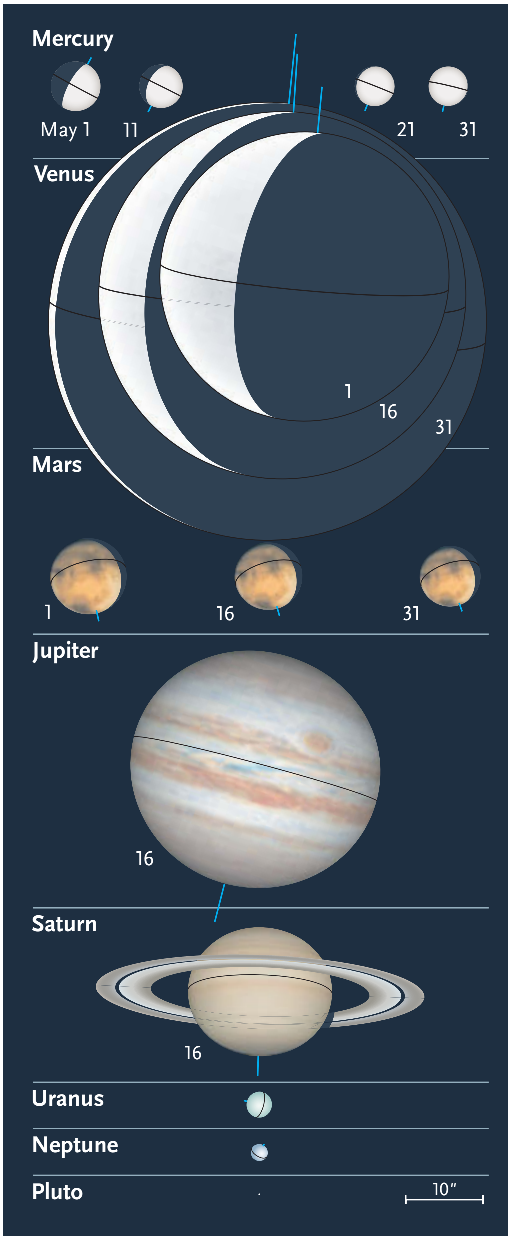
My 10×30s show M83 as a fairly large, round, evenly illuminated glow. Even though it's listed as roughly the same brightness and size as M68, I find the galaxy much easier to snag because it appears both bigger and brighter. Is this how it looks to you? ✦

— ***Gary Seronik***



Watch a SPECIAL VIDEO

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

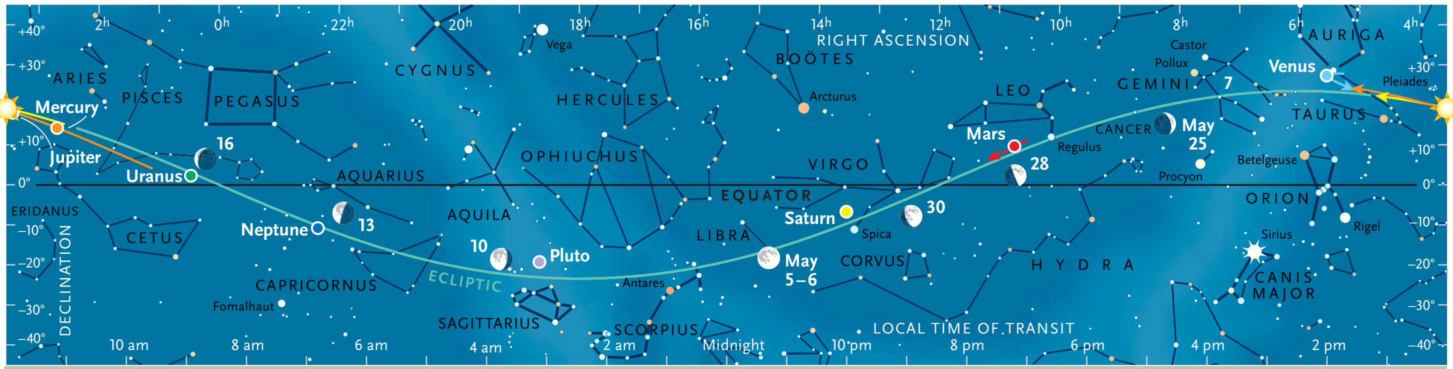


Sun and Planets, May 2012

	May	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$2^h\ 33.7^m$	+15° 05′	—	–26.8	31′ 45″	—	1.008
	31	$4^h\ 32.5^m$	+21° 55′	—	–26.8	31′ 33″	—	1.014
Mercury	1	$1^h\ 05.9^m$	+3° 58′	24° Mo	–0.1	6.4″	64%	1.042
	11	$2^h\ 05.9^m$	+10° 32′	18° Mo	–0.6	5.6″	80%	1.189
	21	$3^h\ 20.7^m$	+17° 46′	8° Mo	–1.5	5.2″	95%	1.300
	31	$4^h\ 50.6^m$	+23° 34′	4° Ev	–1.9	5.1″	98%	1.309
Venus	1	$5^h\ 15.2^m$	+27° 45′	39° Ev	–4.7	37.4″	27%	0.446
	11	$5^h\ 30.3^m$	+27° 39′	33° Ev	–4.7	44.0″	18%	0.379
	21	$5^h\ 29.8^m$	+26° 38′	23° Ev	–4.5	51.1″	8%	0.326
	31	$5^h\ 12.6^m$	+24° 33′	10° Ev	–4.1	56.7″	1%	0.294
Mars	1	$10^h\ 30.9^m$	+11° 34′	114° Ev	0.0	9.9″	91%	0.943
	16	$10^h\ 44.2^m$	+9° 42′	103° Ev	+0.3	8.8″	90%	1.060
	31	$11^h\ 03.4^m$	+7° 16′	94° Ev	+0.5	7.9″	89%	1.180
Jupiter	1	$3^h\ 11.3^m$	+16° 58′	9° Ev	–2.0	32.9″	100%	5.988
	31	$3^h\ 40.1^m$	+18° 45′	13° Mo	–2.0	32.9″	100%	5.987
Saturn	1	$13^h\ 36.2^m$	–7° 03′	164° Ev	+0.3	19.0″	100%	8.755
	31	$13^h\ 29.5^m$	–6° 29′	133° Ev	+0.5	18.4″	100%	9.012
Uranus	16	$0^h\ 27.0^m$	+2° 10′	48° Mo	+5.9	3.4″	100%	20.728
Neptune	16	$22^h\ 20.1^m$	–10° 59′	82° Mo	+7.9	2.3″	100%	30.113
Pluto	16	$18^h\ 38.4^m$	–19° 14′	136° Mo	+14.0	0.1″	100%	31.493

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-May; 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). All Moon dates are in May. "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

Fred Schaaf has authored 13 books on astronomy. Fred Schaaf

How Bright Is Bright?

Nine stars and three planets shine at 1st magnitude or brighter in May.

The all-sky map on page 44 shows the sky at a time on April and May nights when bright stars and planets are very numerous. Four stars brighter than magnitude 1.5 (Sirius, Aldebaran, Rigel, and Betelgeuse) have recently set at this time. But nine more are still in the sky, with a tenth (Altair) about to rise. Added to that number are two planets near zero magnitude, Mars and Saturn — and one more, Venus, that shines immensely brighter, though it's setting at map time.

With all the bright objects visible at this hour, it's a good time to ask a key observational question: How bright is bright?

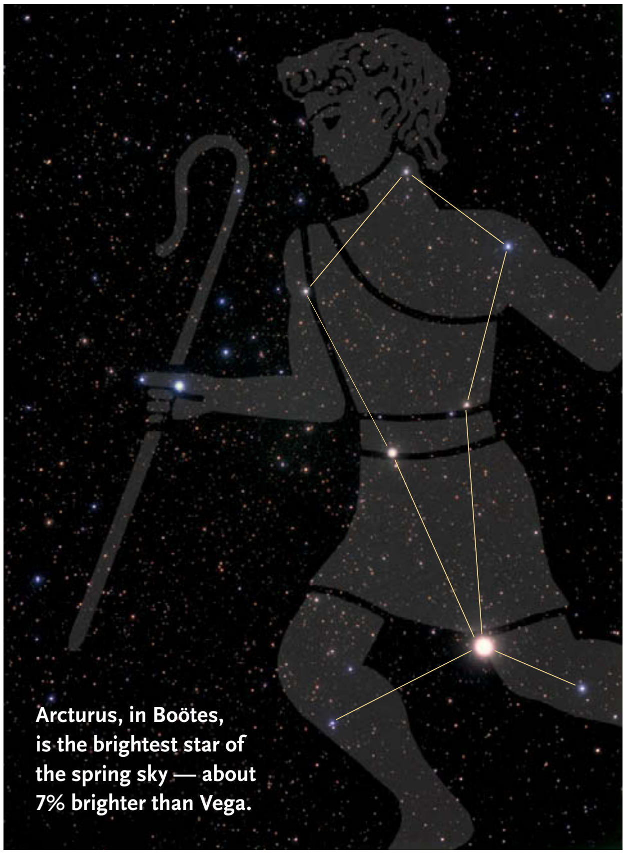
Super-bright versus bright. One way to start answering that question is to compare the objects that are currently visible. And in that endeavor we certainly know where to begin — with breathtakingly brilliant Venus.

In late April and early May 2012, Venus shines at a magnitude of –4.7, its maximum brightness during this apparition. It's also exactly 5 magnitudes (or 100 times) brighter than Saturn, at magnitude +0.3.

A few stars on our all-sky map are slightly brighter than Saturn is at the start of May: Arcturus and Vega at magnitude 0.0 and Capella at magnitude 0.1. But Vega is low enough at this hour to be dimmed significantly by atmospheric absorption — and that's even more true for Capella, which is very low in the northwest.

Mars, Saturn, and their companions. Mars shines at magnitude 0.0 as May begins, also a little brighter than Saturn. But Saturn fades substantially over the next two months, and Mars fades even faster, becoming dimmer than Saturn in June. You can get a better feel for this by comparing them to each other and to the 1st-magnitude stars they're near. Mars was closest to 1.4-magnitude Regulus in April, but moves rapidly away in May. Saturn remains within 5° of 1.0-magnitude Spica through August. August is also when greatly faded Mars will catch Saturn and Spica, forming a dramatic close grouping with them on several nights. Check *Sun, Moon, and Planets* now and in the months ahead to keep track of the changing magnitudes and separations of Mars and Saturn.

Brighter than 10,000 stars. But let's come back to our original statement — that Venus is 100 times brighter than Saturn as May begins. It's correct in terms of actual measurable light output from the two objects, but it's deceptive in terms of our impression of the two objects — especially if we imagine 100 separate Saturns shining in the sky to produce the light output of a single Venus.



Arcturus, in Boötes, is the brightest star of the spring sky — about 7% brighter than Vega.

AKIRA FUJII

Why? Because our eye-brain system actually seems to perceive brightness logarithmically. The ancient Greeks divided stars into magnitude classes based on their intuitive impressions. And when scientists acquired the technology to measure star brightnesses, the first class turned out to be 2.5 times brighter than the second class, second 2.5 times brighter than third, and so on down to 6th magnitude.

Venus is 10,000 times brighter than a star of magnitude 5.3 — perhaps about the average naked-eye limiting magnitude in a technologically advanced country with lots of light pollution. Now let's turn the ancient magnitude system around, so that brighter objects get higher numbers. If the faintest star visible in a typical suburb is 1, Saturn would be a 6 and Venus an 11. ✦

The Plunge of Venus

The brightest planet rushes toward the Sun in May.

People along a band from southern China through southern Japan to parts of the western U.S. can witness an annular eclipse of the Sun on May 20th or 21st. The partial aspect of this solar eclipse is viewable over a huge surrounding area, including much of Asia, the Pacific, and North America (see page 50). And observers worldwide can see Venus in its last month of visibility before it makes a historic transit across the Sun's face on June 5–6.

Seen from mid-northern latitudes, Venus takes a steep, majestic fall in the western twilight over the course of May, appearing noticeably lower each evening. Mars is high in the south to southwest in early evening, and Saturn is moderately high in the southeast to south.

DUSK AND EVENING

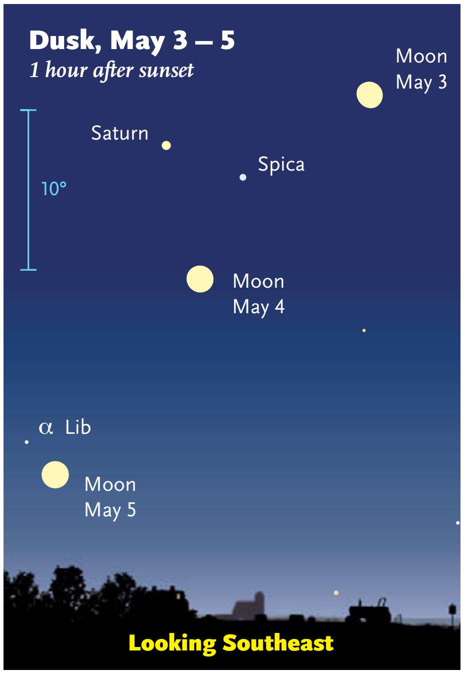
Venus is outstandingly conspicuous at the beginning of May, shining at its maximum brilliance of magnitude –4.7. This is due to Venus achieving, on April 30th, its "greatest illuminated extent" — the largest area of sunlit surface in square arcseconds. On May 1st Venus displays a 38″-wide disk that's 27% illuminated.

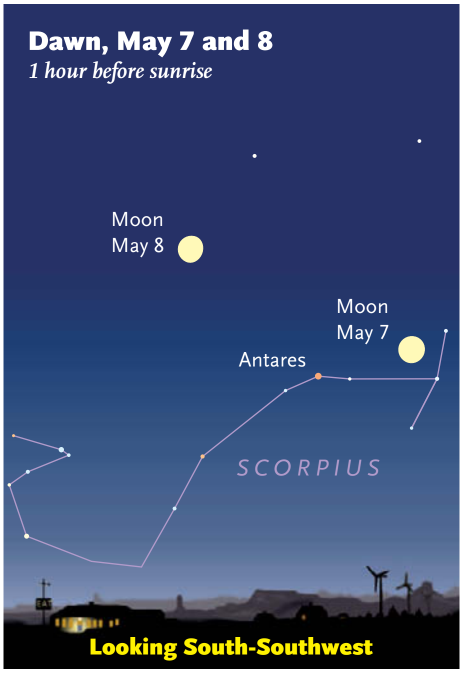
At mid-northern latitudes, Venus is also quite high as May starts. Viewers at latitude 40° north can see it 36° high at sunset and still 28° up when twilight is deepening 45 minutes after sunset. And Venus doesn't set until fully 3½ hours after the Sun, around 11:30 p.m. daylight-saving time. But the fall of Venus during the rest of the month is breathtaking.

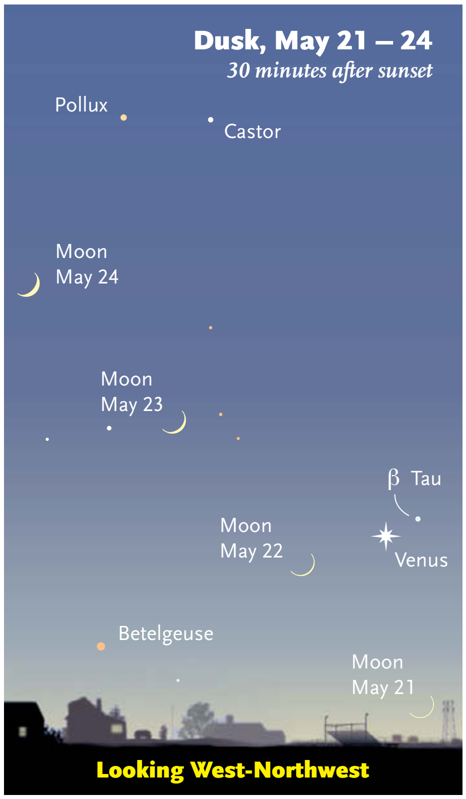
Venus's sunset altitude drops to 25° by May 16th and just 6° or 7° by month's end. Venus's brightness declines only a little during the first part of the month; it still shines at magnitude –4.5 on May 20th, when its crescent is 51″ long and 8% lit. After that it changes rapidly, dimming to magnitude –4.1 and less than 1% lit on the American evening of May 31st, even as the crescent lengthens to 57″. During the last week of May Venus's crescent should be easy to see in binoculars, and may even be visible to sharp naked eyes.

EVENING AND NIGHT

Mars is about 60° high in the south an hour after sunset as May opens, so this time is the best to observe it through a telescope. Unfortunately, the planet is only 10″ wide at the start of May and shrinks to







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

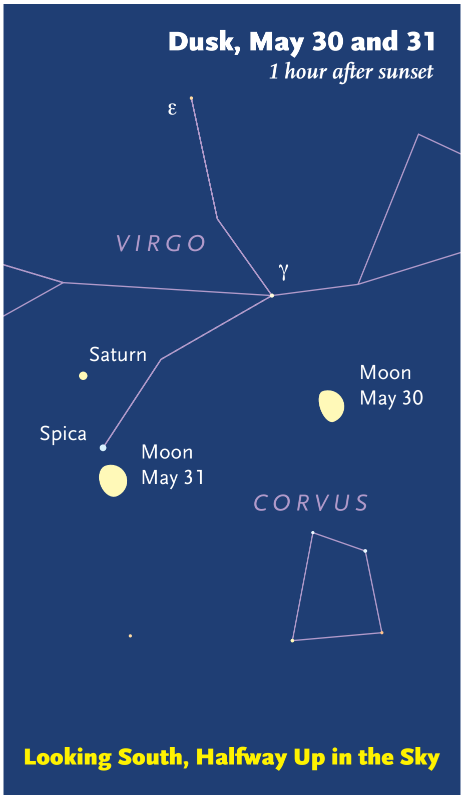
8″ by month's end, making visual observations of Martian surface features difficult.

An interesting rule of thumb is that whenever Mars is 10″ wide it shines at about magnitude 0.0. That's the case as May begins. But Mars fades to +0.5 by month's end. It also picks up speed in direct (eastward) motion, increasing the gap between itself and Regulus from less than 6° to almost 15° during May.

Mars ends the month coming into view about halfway up the southwest sky at dusk and not setting until almost 2 a.m. (daylight-saving time).

Saturn was at opposition on April 15th, when it rose around sunset. As May opens, Saturn is about 25° high in the southeast in the dusk and passes highest in the south around midnight daylight-saving time. By month's end, Saturn crosses the sky's central meridian around the end of twilight. It dims from magnitude +0.3 to +0.5 in May (equaling Mars at month's end), as it recedes and its rings tilt back a little closer to our line of sight (see page 54). Saturn continues to retrograde, passing a bit less than 5° above Spica on May 20th. Saturn will come back a little closer to Spica in early August.

Pluto is highest in the hours after midnight. The June issue will include a finder chart.

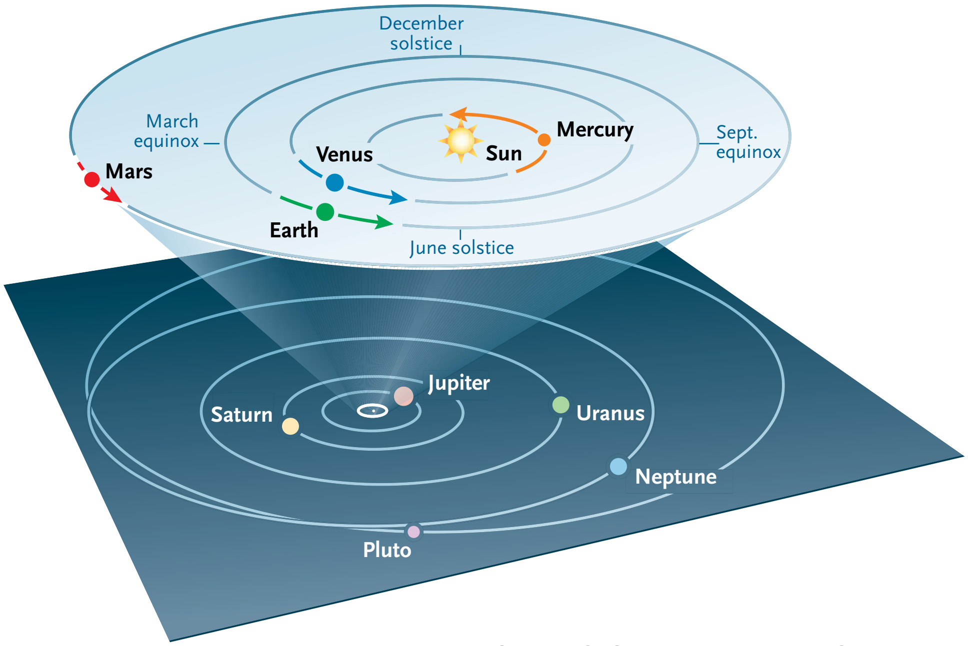


DAWN

Mercury finishes a poor apparition for mid-northern latitudes. It may be visible through binoculars in early May, but it exits the dawn sky by way of superior conjunction on May 27th.

Jupiter is in conjunction behind the Sun on May 13th and rises only about 45 minutes before the Sun at month's end.

Uranus and **Neptune** are far from their highest, but they're observable at dawn. See **skypub.com/urnep** for charts.



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

MOON PASSAGES

The **Moon** is an extremely thin sliver far below Venus shortly after sunset on May 21st. On May 22nd a more substantial sliver makes a handsome line or arc with Venus 5° or 6° to its upper right and 1.7-magnitude Elnath just to Venus's upper right. Binoculars and telescopes also show that the Moon is extremely close to 3rd-magnitude Zeta Tauri, even hiding it from view for a time as seen from some parts of the U.S. (see page 52).

The half-lit Moon is below Mars on May 28th. And on May 31st the waxing gibbous Moon is just below Spica, forming a short line with that star and Saturn above them. ✦

To see what the sky looks like at any given time and date, go to SkyandTelescope.com/skychart.

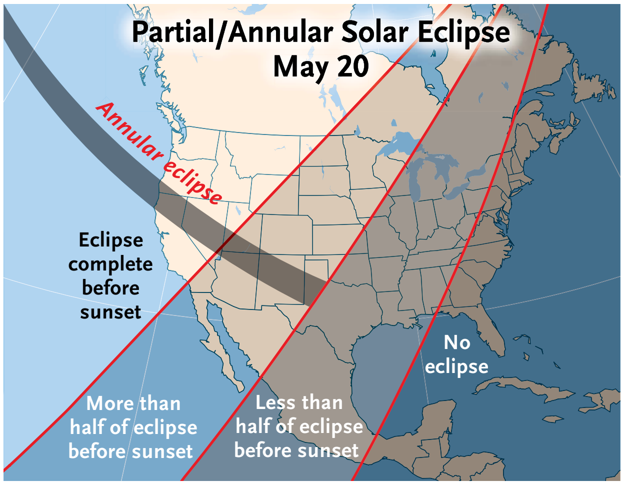
The May 20th Annular Eclipse

Plan now what you'll be doing on this very special Sunday afternoon.

People in all but the easternmost parts of the U.S. and Canada have a red-letter day coming up Sunday, May 20th. Late that afternoon the Sun, lowering in the western sky, will undergo at least a partial eclipse. The eclipse will become *annular,* with the Sun turning into a brilliant ring around the Moon's dark silhouette, for parts of southern Oregon, northern California, Utah, Arizona, New Mexico, and a bit of Texas, as shown below and at the bottom of the facing page.

This is the first central solar eclipse (meaning total or annular) to cross the United States since 1994. Untold numbers of people are planning to park themselves near the centerline for this grand event.

A much larger number across the continent will enjoy the weird spectacle of a *partial* solar eclipse low in the sky. The eclipse will still be in progress at sunset in the region between the red lines below, with the Moon intruding onto the reddened, atmospherically distorted Sun.



Nearly all North America gets at least a partial eclipse, with the Moon taking a big bite out of the Sun. The eclipse will still be in progress at sunset for much of the U.S. and Canada. That will make it scenic indeed, but you'll need a clear horizon to the west-northwest.

The May 20th eclipse will appear very similar to previous eclipses in saros cycle 128, such as this one in 1994, because the geometric circumstances are almost the same. Author Fred Espenak photographed this sequence one saros ago.

North Americans will see the tail end of this eclipse. Its annular part begins at sunrise along the southern coast of China (where the local date is May 21st), then crosses parts of Japan, including Tokyo on the centerline. It then speeds across the empty North Pacific through much of the day, before making landfall on the rugged California-Oregon coast at 6:24 p.m. Pacific Daylight Time. There the Sun will be a good 22° above the western horizon, and annularity will last 4 minutes 47 seconds as seen from the centerline.

The path of annularity continues southeast with the Sun sinking lower. Residents of Albuquerque see the annular eclipse just 5° above the horizon. Western Texas near Lubbock is a particularly interesting location for photographers, because there the annular phase will occur just before sunset.

What to Watch For

"Annular" means "ringlike," and the ring of the Sun at the middle of this eclipse will be unusually thick. The Moon will be practically at the apogee of its orbit, appearing almost as small as it gets, so it will span only 94% of the Sun's diameter. This means only 88% of the Sun's surface area will be blocked during annularity.

The result will be less change in the quality of the daylight than you might expect. Thin clouds would dim the day more. The exposed surface of the Sun itself will remain blindingly bright — literally — so anyone viewing *any* part of this eclipse, total or annular, must use the

same precautions required to observe the Sun on any other day. Read about Sun-viewing methods and precautions at **skypub.com/may2012eclipse**.

Nevertheless, wherever the eclipse is deep or annular, the clear sky will turn an abnormally dark blue, making it possible to spot Venus shining at magnitude –4.3 about 23° east of the Sun. Block the Sun with your hand while searching for the planet. Jupiter and Mercury will be tougher, being just 5½° and 8° to the Sun's west, respectively, and dimmer at magnitudes –2.0 and –1.5.

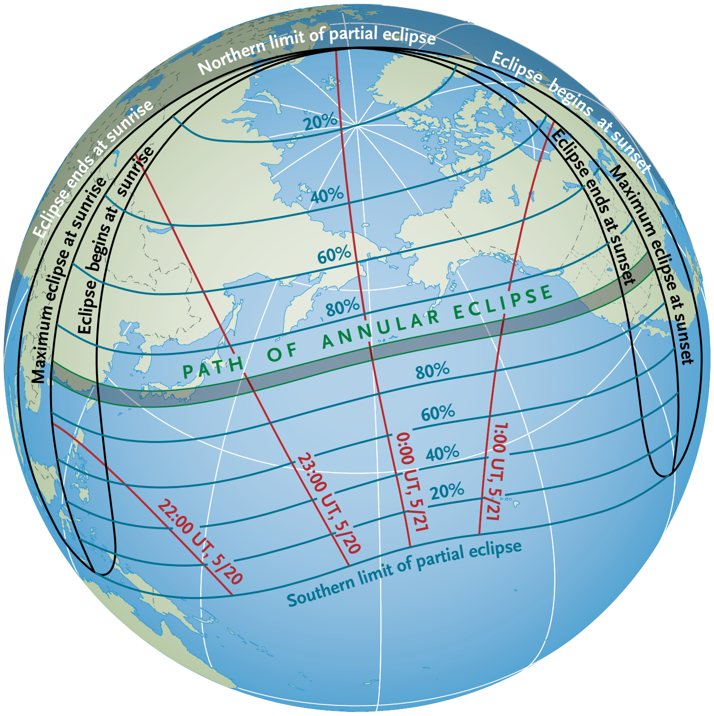
Other things to look for during this eclipse include a silvery or metallic quality to the sunlight around the time of annularity or when the Sun is a thin crescent. Look for images of the crescent or ring Sun being cast on the ground under leafy trees, or formed by small apertures between your fingers.

Weather Prospects

Late May is a poor time to have an eclipse in southern China — it's monsoon season — but a great time for the American West. Average cloud cover is less than 10% in some places between California and Texas. See the map of clear-sky prospects worldwide, and the chart of average cloud cover along the centerline, in the February issue, page 68, or at **skypub.com/may2012eclipse.** There you'll also find other resources, including detailed local timetables.

In the West, clouds are likely to be more pronounced along the coast and over the higher mountain peaks. The best sites will be on the eastern side of a flat, low-altitude valley or plateau, with any mountains low on the western horizon. Many such choices are available in the path of annularity. With reliable weather forecasts available as much as a week ahead, site selection should be straightforward for travelers as the day draws near.

On the day, eclipse chasers should stay close to a highway and keep an eye on forecasts and satellite images to outmaneuver clouds in the final hours or minutes.

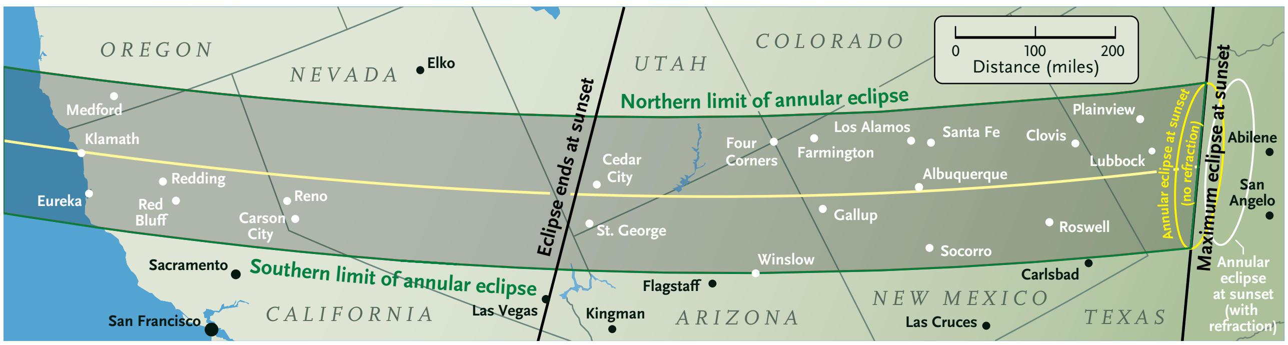


The annular eclipse begins at sunrise in south China, crosses parts of Japan in early morning and the North Pacific through most of the day, then finishes in late afternoon and at sunset for parts of the American West. A much wider region of the globe sees a partial eclipse. The red lines indicate the time of deepest eclipse. Interpolate between the horizontal blue lines to find the maximum percentage of the Sun's diameter that the moon will cover for your location.

Western Texas tends to be a little cloudier than Arizona, but the spectacle of a sunset annular phase will attract some eclipse chasers ready to accept the risk.

A partial or annular eclipse is a rewarding experience in itself, but no match for a total one. Consider this a warmup for the next of *those* to cross the United States: on August 21, 2017, the first good one since 1979.

— Material courtesy Fred Espenak and Jay Anderson



S&T: GREGG DINDERMAN / SOURCE: FRED ESPENAK (3)

The annular phase of the eclipse reaches the Pacific coast near the California-Oregon border at 6:24 p.m. PDT May 20th. It covers much of northern California and central Nevada around 6:30 p.m. PDT, then southern Utah, northern Arizona, parts of New Mexico, and a bit of Texas around 7:35 p.m. MDT (8:35 p.m. CDT). The yellow ellipse at the end shows where the center of the Sun would set during annularity if Earth had no atmosphere. In reality, atmospheric refraction moves this appearance to the area of the white ellipse.

Horn Tip Occulted

After the new Moon is done occulting a big star (the Sun) on May 20th, it moves eastward along its orbit to become a thin waxing crescent that will occult a much more distant star, 3rd-magnitude Zeta Tauri, on the afternoon or evening of May 22nd. Zeta Tauri is the dimmer of the two horn tips of Taurus.

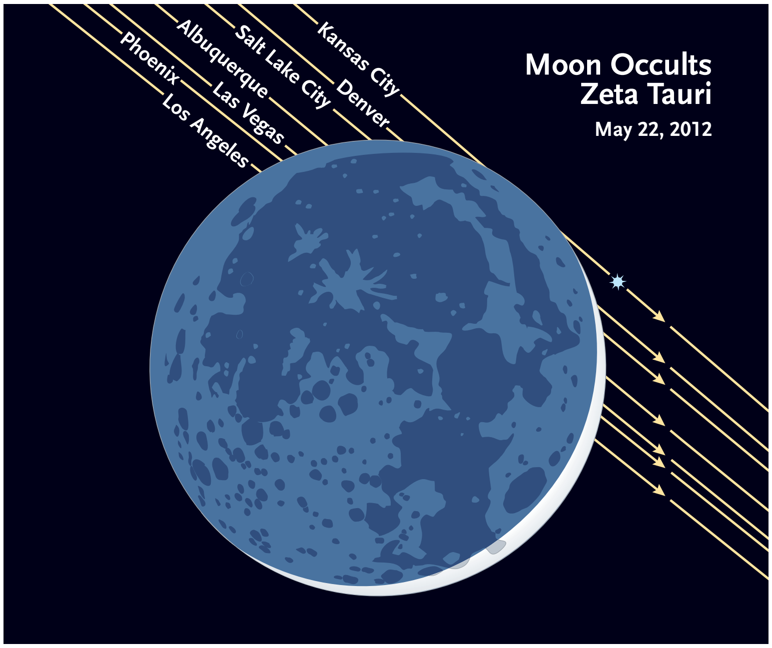
This will be a tricky telescopic observation near the eastern edge of the visibility zone, where the star and Moon will be very low, and in the western part of the zone, where the star and Moon will be fairly high but the occultation will start either in bright twilight or broad daylight. The lunar crescent will be *very* thin, just 4% sunlit, and only about 23° east (upper left) of the Sun.

If you're trying to locate the Moon before sunset, set up your telescope just inside the shadow of a building, so there's no chance of inadvertently viewing the Sun. Then scan carefully with your finderscope or binoculars roughly 18° above and 12° to the left of the Sun. (This will vary with your location.)

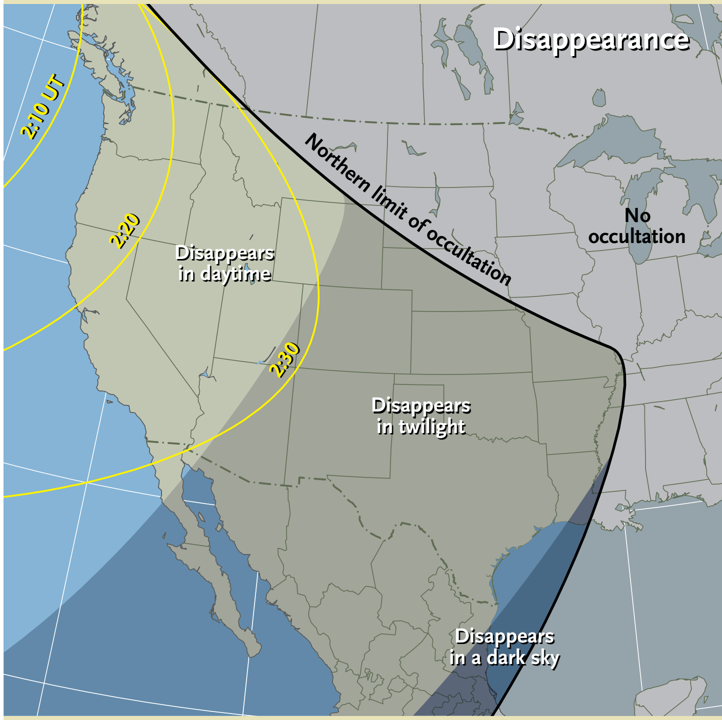
The star's visibility in your scope will depend on sky conditions. It will disappear behind the Moon's dark limb, as almost always happens for occultations when the Moon is waxing, but even with earthshine the dark limb may be invisible in a bright sky. So interpolate very carefully between the yellow lines on the map, or better, see the timetable of local predictions available at **skypub.com/may2012lunaroccn**. When you're watching the star in the eyepiece, don't blink at the critical time or you might miss it!

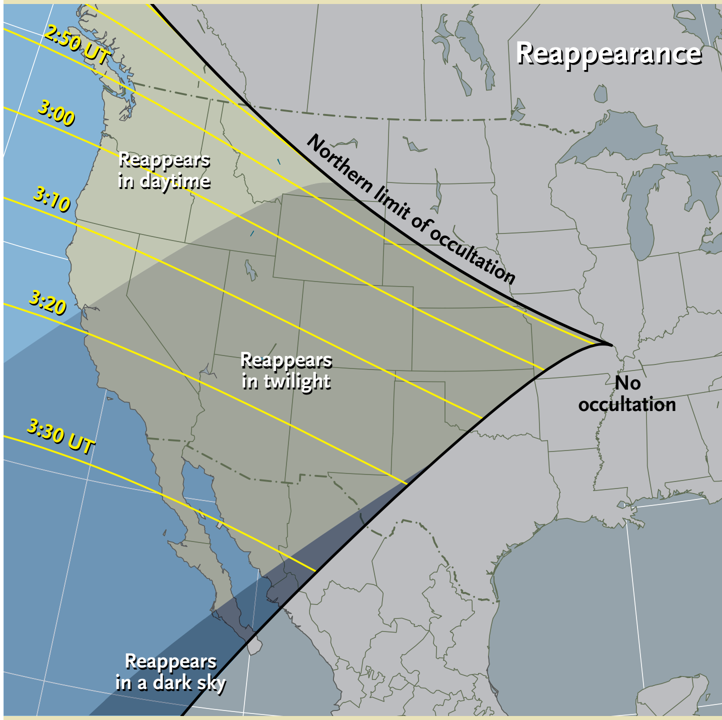
The star reappears up to an hour or more later from behind the crescent's bright limb. By then your sky will be darker but the Moon will be lower. Again, there will be no warning, so watch steadily as the critical time counts down.

The two maps at right tell the story for each event.



S&T: LEAH TISCIONE (3)





Mark your location with a pencil dot, then interpolate between the yellow curves to find the Universal Time of Zeta Tauri's disappearance and reappearance. Remember that 0:00 Universal Time is 7:00 p.m. Central Daylight Time; 6:00 p.m. MDT; 5:00 p.m. PDT. Shading indicates whether the event occurs in daylight, twilight, or (for a tiny sliver of land) in darkness. The farther east you are in the occultation zone, the darker the sky but the lower the Moon will be.

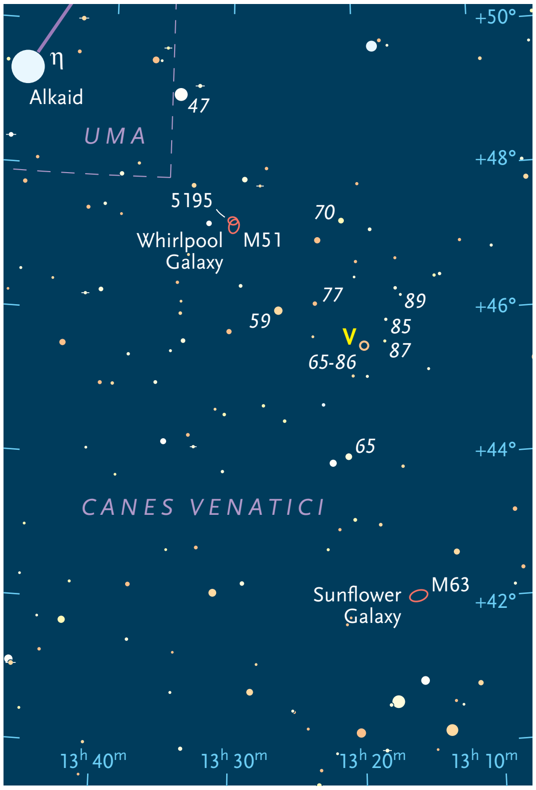
In mid- and late April, when almost all readers will have this issue, three noteworthy asteroid occultation paths cross heavily populated areas of the U.S.:
• Arkansas to S. Carolina: **April 12** • Southern New England, New York: **April 23–24** • NYC to Great Lakes: **April 27.** Details at **skypub.com/may2012asteroids**

Springtime Variable Between Galaxies

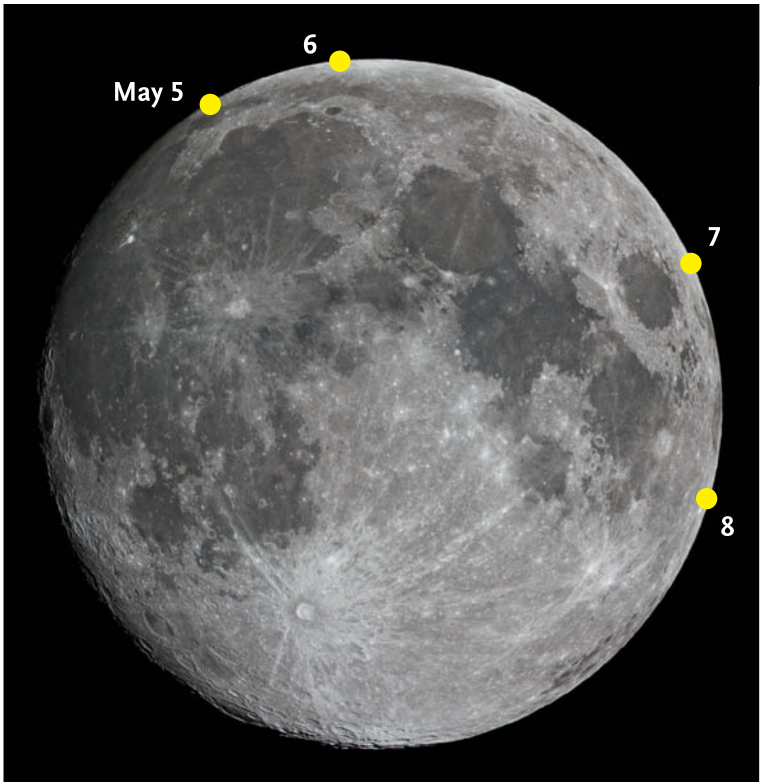
Part of what I love about observing with a good sky atlas or charting program is poking around to find things I wasn't expecting. Once you've mastered how to star-hop to targets with your finderscope (see the crucial tips in last month's issue, page 52), you'll find yourself browsing from field to field for possible points of interest along the way.

Few galaxies are hopped to so often as 9th-magnitude M51 off the end of the Big Dipper's handle, high overhead these evenings. Farther on by 6°, down a straight line of 6th-magnitude stars, is M63, only slightly dimmer. It's just north of a finderscope asterism of 4th- and 5th-magnitude stars that for regular visitors soon becomes an old friend.

A little to the west of this line lies the red semi-regular variable star V Canum Venaticorum. It cycles every 6 months, more or less, between about magnitude 6.5 and 8.6. Usually it fades faster than it brightens, but sometimes it does the opposite. Fast ups and downs sometimes override this cycle. Its next maximum is predicted for early to mid-June. Make a point of checking in on it as you go by. ✦



Starting from the end of the Big Dipper's handle (bright star at top left), countless springtime observers star-hop to the Whirlpool and Sunflower galaxies. But how many know there's a fitful variable star in between? Comparison stars for V Canum Venaticorum are labeled with their magnitudes with the decimal point omitted.



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

S&T: DENNIS DI CICCO

The Moon • May 2012

Phases

FULL MOON	May 6	3:35 UT
LAST-QUARTER MOON	May 12	21:47 UT
NEW MOON	May 20	23:47 UT
FIRST-QUARTER MOON	May 28	20:16 UT

Distances

Perigee	May 6, 4h UT
220,160 miles	diameter 33′ 44″
Apogee	May 19, 16h UT
249,182 miles	diameter 29′ 48″

Librations

Pythagoras (crater)	May 5
Byrd (crater)	May 6
Plutarch (crater)	May 7
Langrenus (crater)	May 8

The King of the Rings

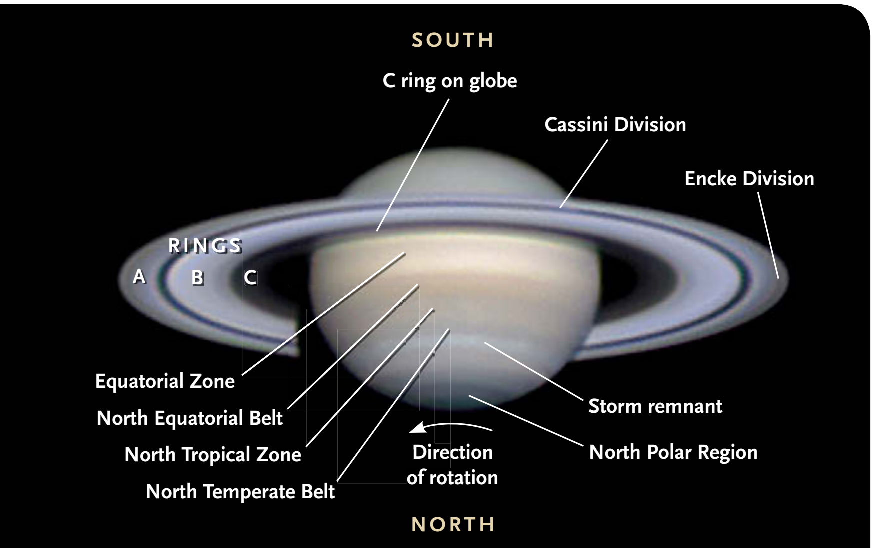
Saturn's tilt for 2012 treats us to the best view of its rings in five years.

While many eyes are focused on brilliant Mars dwindling into the distance in Leo, a bigger showpiece planet beckons one constellation to the east, in Virgo. That's where you'll find Saturn shining with its otherworldly rings. It's at opposition and closest to Earth in mid-April, when most readers have this issue. It remains nearly as large for months to come as it climbs conveniently higher in the early-evening sky.

Saturn is just 5° from Spica this season, outshining the blue-white star by just a bit. Look for this eye-catching pair high in the southeast by 10 p.m. in late April, 9 p.m. in early May, and shortly after nightfall thereafter.

If you've watched Saturn through a telescope in recent years, its most obvious change for 2012 hits you right away: the rings are open again. They've appeared nearly edge-on for the last few years, exactly so in 2009. In April 2012 they're tilted a good 14° from our line of sight, then 13° from May through August. The rings will continue to open until reaching a maximum of 27° in 2017.

Like Jupiter, Saturn is a gaseous world showing us its banded cloudtops. But Saturn is both smaller and farther than Jupiter, and, being colder, its markings are more deeply veiled under high-altitude haze. Even so, my 6-inch scope almost always shows some of Saturn's banding: the bright Equatorial Zone, the slightly darker North Equatorial Belt (the South Equatorial Belt is behind the rings now), and the dusky North Polar Region.



This first-rate amateur image comes from Bob English in Kentucky. He took it on February 7th, when Saturn was well up in the early-morning sky, using a 20-inch Newtonian reflector and a Point Grey Research Flea3 video camera. Note the faint remnant of the northern hemisphere Great White Spot.

During the 2010–11 apparition, the big event for planetary observers was the outbreak of Saturn's now-famous Great White Spot (GWS). The whitish band trailing from this huge storm encircled the globe (see page 20). Now the storm has subsided. NASA's Cassini probe orbiting Saturn no longer detects radio emissions from intense lightning in the storm, but the aftereffect of the disturbance can still be seen as a weak whitish band encircling the planet at about 45° north latitude. In the eyepiece, the band appears detectably brighter than its surroundings. High-resolution images reveal slight kinks and knots.

Large scopes sometimes show additional tiny white spots: smaller round or oval storms, usually in Saturn's mid-latitudes. To predict when a spot will return to the same location on the disk from night to night, remember that Saturn's mid-latitudes rotate once in about 10 hours 38 minutes. Near the equator the planet's visible layer rotates more rapidly, in about 10 hours 14 minutes.

Another noteworthy occurrence in 2011 was the frequent appearance of radial spokes in Saturn's bright, wide B ring (*S&T:* July 2011, page 50). The spokes are almost always beyond visual reach but can sometimes be extracted from images. For months these dusky markings appeared and faded with a regularity that might be connected to magnetic effects involving the GWS. So far this year, spokes have been absent.

Things to Look For

The smallest astronomical telescope should reveal the rings easily and the dark Cassini Division between the A and B rings with a little more effort.

The dusky C ring is more of a challenge to spot where it appears against the dark-sky background, but its dark shading is easier to see where it crosses Saturn's bright face just inside the B ring. The C ring in front of Saturn's face is often indistinguishable from the rings' dark shadow at the same latitude — but not this year. The rings cast no visible shadow on the globe for most of April from Earth's viewpoint, then cast their shadow increasingly *poleward* above the rings for the next few months.

Seeing any further detail in the rings really takes magnification upwards of 200× on a high-quality 8-inch or larger scope. It also takes times and patience. Rare is the night when the atmospheric seeing is steady and sharp enough to let your scope do its best. Moreover, it takes a lot of time gazing into the eyepiece to ferret out everything at the limit of your vision.

Very subtle banding in the rings is occasionally detectable under near-perfect conditions. The fabled spokes have even lower contrast, eluding all but the most experienced visual observers with large scopes. Fortunately, stacked-video imaging has brought these elusive details within reach of backyard observers. To capture spokes if they are present, take short video clips no more than 90 seconds long to stack. Any longer and the rapid orbital motion of the ring material will blur any spokes, resulting in homogenous smoothness.

With the rings opening, we now have a chance to spot Saturn's disk *through* the Cassini Division. Under steady seeing, detecting the planet's light through the Cassini Division helps to reinforce the three-dimensional aspect of the view.

Opposition comes on April 15th. For a few days around then, look for the *Seeliger effect:* a noticeable brightening of the rings with respect to the globe. This is caused by the fact that the solid particles forming the rings backscatter sunlight in the direction it came from more effectively than the planet's cloudtops do.

In the weeks and months after opposition, note the increasingly visible shadow of the planet's *globe* on the *rings*. It's the narrow black gap right where the rings pass behind the globe's celestial east (following) side. After opposition, we start seeing a little around the planet's eastern edge compared to the direction of the incoming sunlight.

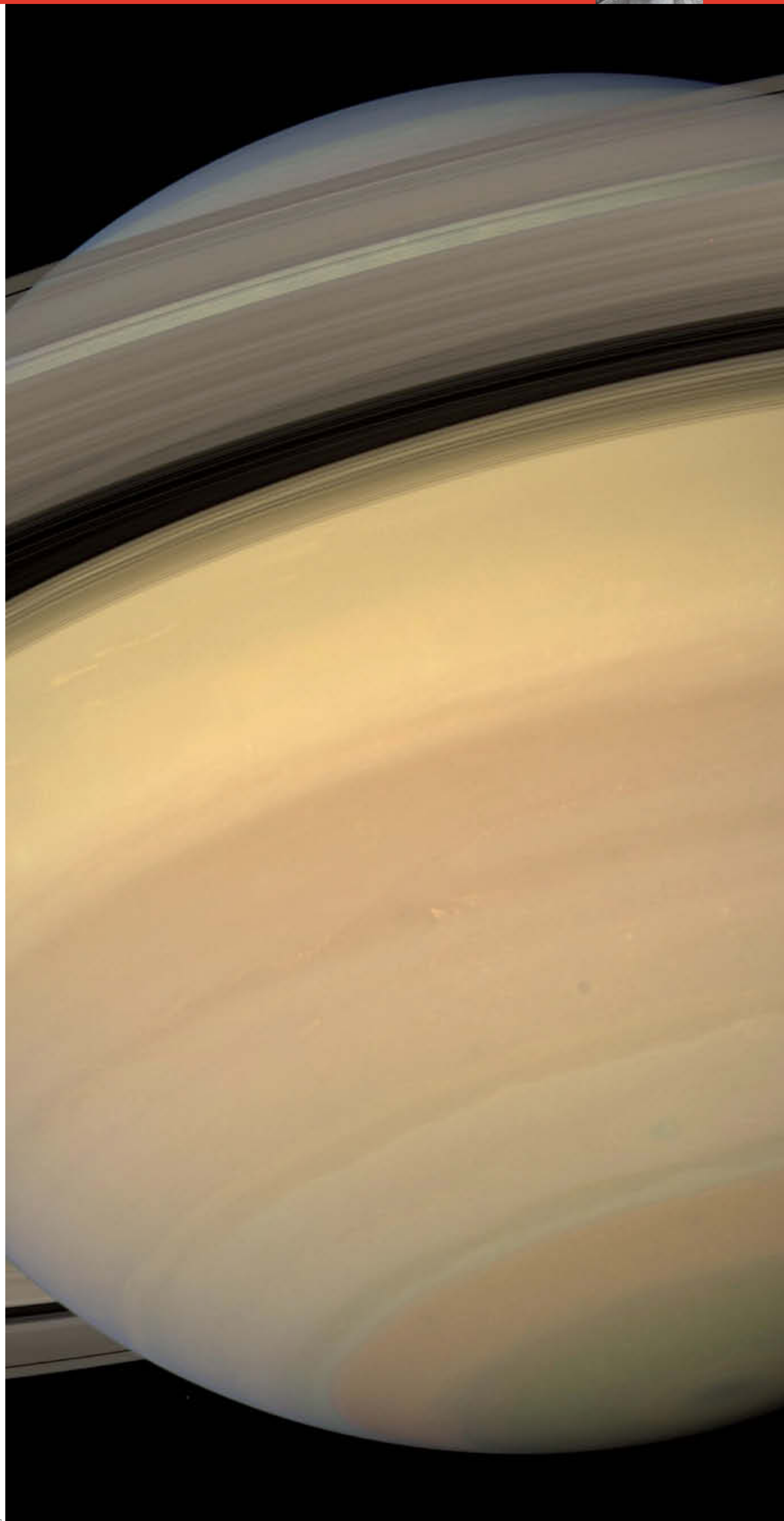
Many Moons

Of course, Saturn and its rings are surrounded by extra bangles: more moons showing in amateur scopes than for any other planet.

Even a 60-millimeter scope will usually reveal Titan, an appropriately named world half again as big as our Moon. A 6-inch will show Titan's orange color: the photochemical smog that makes its thick atmosphere opaque.

A 4- or 6-inch scope will also show Iapetus, Rhea, Dione, and (with a little difficulty) Tethys. An 8-inch may also get you fainter Enceladus closer in. You can identify the moons, or see exactly where to look for them, at any time and date using the interactive observing tool at **SkyandTelescope.com/satmoons**.

What luck that our solar system contains such a wonder as Saturn! If it didn't exist, would anyone even imagine such a thing? ✦



NASA / JPL / SPACE SCIENCE INSTITUTE

The Cassini probe caught this breathtaking view of Saturn's southern hemisphere in 2007. Don't expect your views to be quite this good.

Heavens Within Themselves

Five adjacent galaxies exhibit amazingly varied structures.

The vast sun clusters' gather'd blaze,
World-isles in lonely skies,
Whole heavens within themselves, amaze
Our brief humanities.

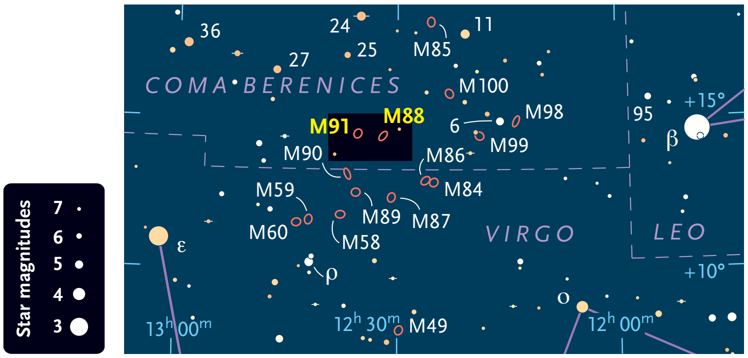
— Alfred, Lord Tennyson,
The Charge Of The Heavy Brigade At Balaclava

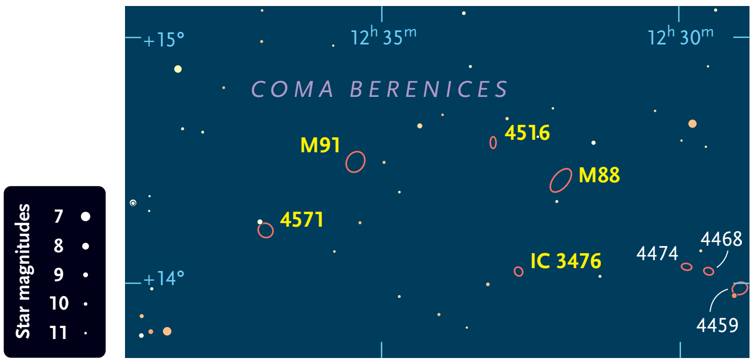
Although I've been writing monthly columns for *Sky & Telescope* for a dozen years, there are two objects from Charles Messier's famous catalog that I've never touched upon. This is the perfect time of year to correct that oversight by featuring these neglected galaxies, M88 and M99 in Coma Berenices.

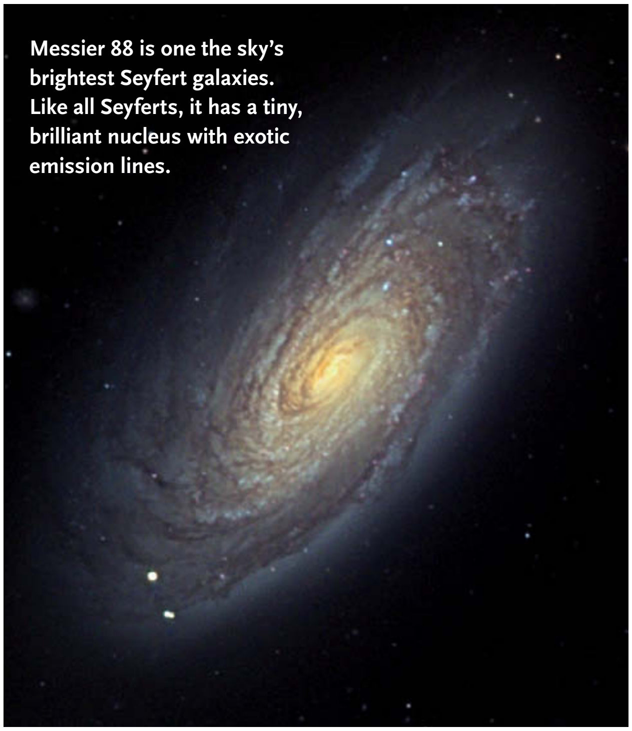
M88 is one of the brightest spiral galaxies in the Virgo Cluster, which is centered about 54 million light-years away from us and contains at least 1,300 members. M88 is a Seyfert galaxy, defined by a brilliant nucleus of variable light intensity coupled with a spectrum indicating that it's powered by a supermassive object (probably a black hole) at the heart of the galaxy. Seyfert galaxies are named for the American astronomer Carl Keenan Seyfert who, in the 1940s, found a number of galaxies presenting these features.

M88 is located 2.9° south-southwest of 25 Comae, and it's yours for the taking through almost any telescope in a moderately dark sky. Admiral William H. Smyth found M88 quite charming through his 6-inch refractor. In his 1844 *Bedford Catalogue*, Smyth writes: "A long elliptical nebula, on the outer side of Virgo's left wing. It is pale-white in colour, and trends in a line bearing *np* [north preceding, or northwest] and *sf* [south following, or southeast]; and with its attendant stars, forms a pretty pageant."

M88 and 25 Comae share the field of view through 15×45 image-stabilized binoculars. From my semirural home, the galaxy is a faint oval with a dim star dangling from its southeastern end. M88 is easily visible and elongated through my 105-mm refractor at 28×. It runs southeast-northwest, and the star that was visible through binoculars now looks fuzzy. At 87× this unsharp star becomes a wide, unequal pair that makes a skinny triangle with a very dim star to the east. Closer to M88, another faint sun perches north of the galaxy's northwest-






Messier 88 is one the sky's brightest Seyfert galaxies. Like all Seyferts, it has a tiny, brilliant nucleus with exotic emission lines.

JIM QUINN / ADAM BLOCK / NOAO / AURA / NSF

Messier 91 is a classic example of a barred spiral galaxy.

ern end. M88's halo covers about 4½′ × 2′ and enfolds a small, brighter core with a stellar nucleus. I can see, but not quite hold constantly, an extremely dim star superposed on the galaxy's southeastern tip.

In my 10-inch reflector at 192×, M88 spans 5½′ × 2½′ and grows gradually brighter toward a small, oval, inner core. Brightness variations in the halo suggest spiral arms that unwrap clockwise. The superposed star now accompanies a fainter companion to its south-southwest. Deep images show that the companion is a snug (1.9″) double star. It might take a very large telescope to separate its 15th-magnitude components. If you give it a try, please let me know how well you succeed.

The galaxy **M91** is only 50′ east of M88, with the two visible in the same binocular field of view. However, M91 is not an easy binocular object. The smallest binoculars through which I've spotted it are 18×50s with image stabilization. Even then it was simply a small, very faint smudge that took a little while to spot.

Through a telescope, you can follow part of Smyth's starry pageant from M88 to M91. The star hovering above M88's northwestern end is the first in an arc of three that curves northeast, each star brighter than the one before. Farther east, three more stars curve back down to M91, the final one lying off the galaxy's western side.

My 105-mm refractor at 28× shows M88 and M91 in the same field, with M91 as a faint spot. At 87× the galaxy grows a small round core with a stellar nucleus. The core has bar-like extensions that run east-northeast to west-southwest. M91 covers about 2′, and its core is less than half that.

My 10-inch scope at 192× reveals a faint wisp reaching north from the western extension of M91 and another reaching south from the opposite extension. The wisps quickly fade to a very faint halo that's somewhat oval and aligned perpendicular to the bar. The oval is about 2½′ wide, but its length is difficult to judge because the halo is rather dim. My 14.5-inch reflector at 170× makes the halo appreciably easier and puffs it out to about 5′ × 3½′.

There's no object at the coordinates given for M91 by its discoverer, Charles Messier, so M91 was long considered a "missing" object. Various hypotheses were put forward in a celestial version of a *Where's Waldo?* hunt. Astronomers and historians suggested that M91 might be NGC 4571, a passing comet, or a duplicate observation of M58. But it was an amateur astronomer from Texas who came up with

Galaxies in Southern Coma Berenices

Object	Mag(v)	Size	RA	Dec.
Messier 88	9.6	6.9′ × 3.7′	12^h 32.0^m	+14° 25′
Messier 91	10.2	5.4′ × 4.3′	12^h 35.4^m	+14° 30′
NGC 4516	12.8	1.9′ × 0.8′	12^h 33.1^m	+14° 35′
IC 3476	12.7	2.1′ × 1.8′	12^h 32.7^m	+14° 35′
NGC 4571	11.3	3.6′ × 3.2′	12^h 36.9^m	+14° 13′

Angular sizes 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 (3)

Left: NGC 4516 is a spiral with a pronounced S-shaped bar. *Center*: IC 3476 is an irregular galaxy whose blue stars suggest ongoing starburst activity. *Right*: NGC 4571 is an unusual ringed spiral galaxy.

the accepted solution to this puzzle, first published in this magazine's *Letters* column for December 1969. William C. Williams found that NGC 4548 fits Messier's description and position for M91 if you assume that Messier mixed up which object he'd used as his reference point. Thus Messier's offsets should be applied to M88, not M58.

The little galaxy **NGC 4516** sits one-third of the way from M88 to M91 and 8′ north of an imaginary line connecting them. With my 105mm scope at 87×, I can see NGC 4516 intermittently with averted vision as a very small glow elongated north-south. (Averted vision is the practice of looking a bit off to one side of a faint object to allow its light to fall on a more sensitive area of your eye's retina.)

The view through my 10-inch reflector at 192× is fascinating. At first glance, I was astonished when the galaxy's tilt seemed to change with averted vision. A more careful look showed a bright region about 1′ long and one-quarter as wide, tipped west of north, that spans a slender, larger oval running nearly north-south. Only the former stood out with direct vision. The bright area is lovely, and consists of a small core with a distinct nucleus at the center of a shallow S curve. Averted vision wraps it all in a delicate cocoon.

Let's drop 24′ south-southeast from M88 to a north-south pair of 12th-magnitude stars 2.7′ apart. The intriguing galaxy **IC 3476** rests 4.4′ east of the northern star. It's readily visible in my 105-mm refractor at 87× as a hazy blot about 40″ across. In the 10-inch scope at 192×, three faint suns join the 12th-magnitude pair to outline a candle snuffer ready to put out the light of IC 3476. The galaxy displays a lumpy brightness distribution and peculiar shape. IC 3476 is about 40″ wide at its northeastern end and tapers down toward the southwest, giving it a candle-flame profile 1¼′ long. The wide end contains a relatively large, blotchy, bright area, and some additional clumpy enhancements line the galaxy's southeastern side.

Strange little IC 3476 has been assigned a morphological type of IB(s)m — a barred, Magellanic-type irregular galaxy with traces of spiral structure. IC 3476 surprised astronomers with a supernova in 1970.

Our final target is **NGC 4571**, found 28′ southeast of M91 with a 9th-magnitude star guarding its northeastern edge. The galaxy appears roundish with a small brighter core in the 105-mm scope at 87×. Its low-surface-brightness halo improves with averted vision and is roughly 2′ to 2½′ across. Although NGC 4571 is more obvious in my 10-inch scope, it discloses no further secrets.

NGC 4571 is an unusual galaxy of type SA(r)c. Its fleecy spiral arms reach inward to a well-defined ring that closely circles the galaxy's core. Such ring structure is rare in a late-type spiral galaxy, that is, one that exhibits a small central bulge and loosely structured arms with prominent condensations.

All these wonderful world-isles dwell in the core of the vast Virgo Cluster, possessing whole heavens within themselves that have long inspired the wondering sky-gazer's amazement. ✦

DID YOU KNOW?

Every issue of Sky & Telescope *since September 2006 has an online table of contents, and many have supplemental information not available in the magazine. Go to* ***skypub.com/skytel****, scroll to the bottom, and select the month and year of the issue that interests you.*

The Coma Galaxy Cluster

This ghostly swarm is fantastically rich and compact.

AT A DISTANCE of about 350 million light-years, the Coma Galaxy Cluster (Abell 1656) is the nearest of the massive spherical galaxy clusters, with thousands of member galaxies. These are mostly ellipticals and lenticulars, so even the brightest ones show few details. Instead, an observer's satisfaction comes from the hunt and from seeing many galaxies simultaneously.

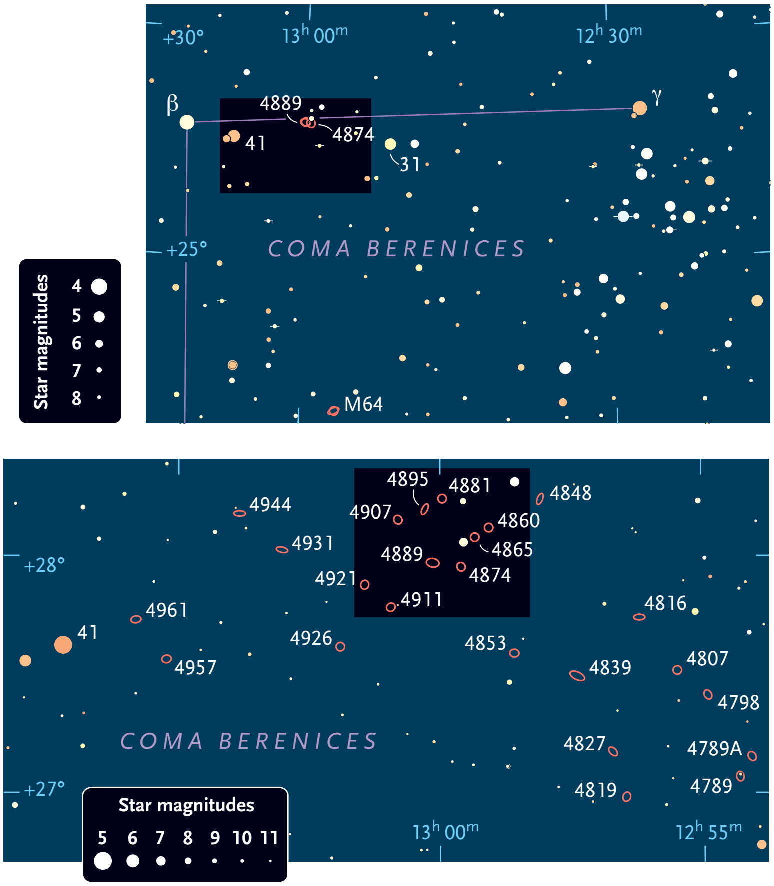
The Coma Cluster isn't as popular as it should be, perhaps because it had bad press early on. The classic late 1970s observing guide *Burnham's Celestial Handbook* says: "NGC 4889 and 4874 are the only two members of the Coma Cluster of Galaxies which are likely to be detected in most amateur telescopes." But one spring night in 1983 I spent two hours in the cluster with my 8-inch f/6 Newtonian, guided only by a photo from the *Palomar Observatory Sky Survey*. In addition to the two giant ellipticals promised by Burnham, I found NGC 4921 and 4860 — so I was very pleased with the results of my hunt.

Now that I know the Coma Cluster well, my ancient 8-inch also reveals NGC 4911 and elongated NGC 4895 without too much difficulty, as well as glimmers of NGC 4865, 4869, and 4881.

As Guy Mackie's sketch on the facing page shows, an increase in aperture to a 12.5-inch Dobsonian reveals a horde of 14th- and 15th-magnitude galaxies. Mackie comments: "What's most striking is my ability to find much more in the field than I saw at first blush."

In recent years I have spent many nights working through the Coma Cluster with my observatory's 16-inch f/4.5 Newtonian on an equatorial mount. This month's tour will concentrate on the richest clump of galaxies, occupying an oval area outlined by NGC 4881 to the north, NGC 4921 and 4911 to the southeast, and NGC 4860 to the northwest. The 16-inch found 37 galaxies swarming within this small area — only 38′ × 24′ — with the long axis stretching northwest to southeast.

My planetarium program charts stars to magnitude 15.0 for starhopping, but it's necessary to galaxy-hop in many star-sparse areas. I used a 12-mm eyepiece yielding 152× and a 24′ field of view, supplemented on steadier nights by an 8-mm eyepiece giving 229× and a 16′ field.



The Coma Galaxy Cluster is easy to locate one-third of the way from Beta to Gamma Comae Berenices. Only the brightest galaxies of the Coma Cluster are shown on this chart. See the photograph on page 62 for details of the highlighted region.

The Northeast Side of the Oval

NGC 4881 and **NGC 4895** are two of the brightest galaxies on this tour. NGC 4881 sports a bright nucleus, and NGC 4895, a lenticular, is elongated 5:2 and brightens gradually in the middle, rising to a nucleus. The next galaxy in line, **NGC 4907**, has a higher published surface brightness than the preceeding two, but I find it less obvious at the eyepiece. On two nights I caught glimmers of the nearby 15th-magnitude galaxy **PGC 44784**. This tiny mote is paired with a 14th-magnitude star only 27″ to its south-southeast.

NASA / ESA / HUBBLE HERITAGE TEAM / STSCI / AURA

The Coma Cluster includes a few fine spiral galaxies as well as a huge number of ellipticals. North is to the upper left in this extraordinary photograph of NGC 4911 from the Hubble Space Telescope.

The Oval's Southeastern End

NGC 4921 is the third-brightest galaxy in the central Coma Cluster after NGC 4889 and 4874, the two huge ellipticals at the cluster's center. Large and amorphous, NGC 4921 is immediately recognizable as a face-on spiral. Slightly elongated **NGC 4923** lies only 2.6′ south-southeast of NGC 4921 while another bright spiral, elongated and relatively large **NGC 4911** (shown above), is 9′ southwest of NGC 4921. Tougher **NGC 4919** lurks almost midway between NGCs 4923 and 4911, and slightly southeast of the line connecting them.

I was able to detect a few photons from 15th-magnitude **PGC 44864** because it lies 2′ west-northwest of NGC 4919 directly along a line to a 12th-magnitude star 6′ farther west-northwest. The task was not made any easier by the need to repeatedly refind my landmark, shy NGC 4919.

North of NGC 4911

An easy star-hop north-northwest from bright NGC 4911 leads to a band of seven galaxies. **NGC 4906** is small and faint, but not difficult. Small **IC 4042** is obvious, but I can only occasionally see **IC 4041** in the sweet spot of my averted vision.

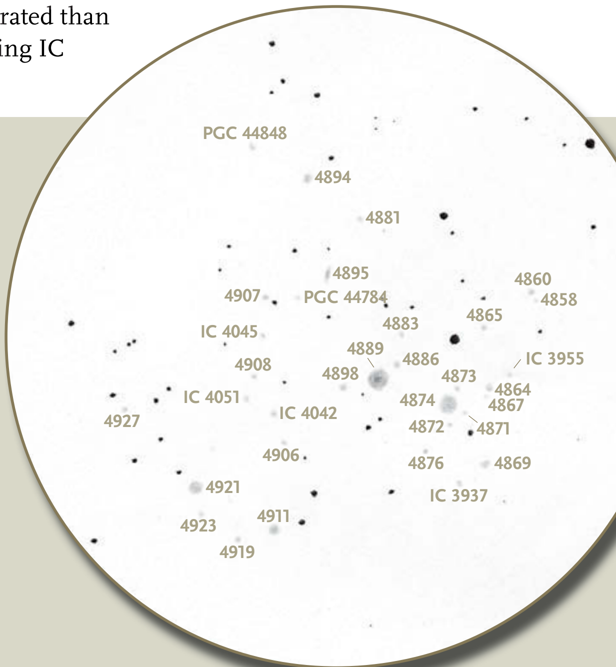
While I was hunting IC 4041 at 229×, a line of three galaxies appeared along the eastern edge of the field of view. **IC 4051** is relatively large and displays a nucleus. **NGC 4908** is fairly small, and more concentrated than the surrounding IC

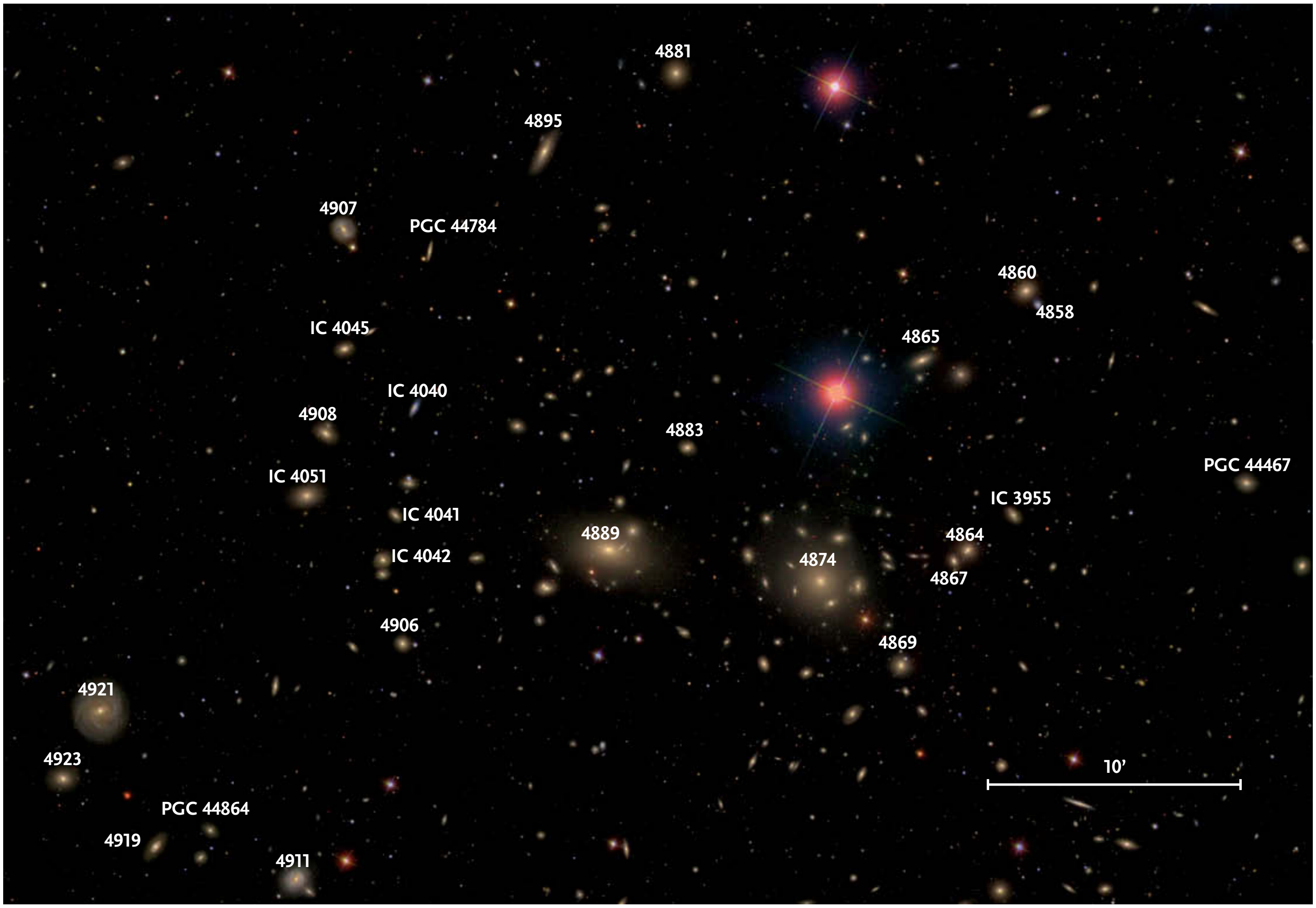
Coma Through 12.5 Inches

It was with great pleasure that I accepted Alan Whitman's invitation to contribute a sketch of the Coma Cluster through my 12.5-inch Dobsonian reflector. I soon realized that capturing what turned out to be 33 objects in a single field of view was a challenge like none that I had ever met before. Instead of sketching the eyepiece view directly, I combined observations over multiple nights at magnifications from 93× to 263×.

BEV HROMEK

***Guy Mackie** observes the deep sky from southern British Columbia.*





This photograph from the Sloan Digital Sky Survey includes all the galaxies described by the author. Labels in the central region are omitted for clarity; see the close-up on the facing page for full details.

galaxies, so its core has a higher surface brightness. It also has a faint nucleus. Small **IC 4045** completes the line. I could find ghostly **IC 4040** only because it makes an equilateral triangle with NGC 4908 and IC 4045.

The Cluster's Heart

The giant elliptical galaxy **NGC 4889** appears significantly brighter than its binary companion, **NGC 4874**. At 229× NGC 4889 is slightly elongated east to west, and strongly concentrated in the center, with a prominent nucleus. Round NGC 4874 is very gradually concentrated to a fairly faint nucleus.

What I find particularly interesting are the tiny satellite galaxies in tight orbits around the two giants —presumbably on their way to becoming lunch! NGC 4874 has three very close companions visible in the 16-inch, **NGC 4871**, **NGC 4872**, and **NGC 4873**. It also has a host of PGC galaxies swarming around it that I look forward to attempting with a bigger scope. It took me several tries to unveil tough **IC 3998**, which lies between the two giants.

NGC 4889 has two very obvious companions at 229×, **NGC 4886** and **NGC 4898**, and two challenging ones, 15th-magnitude **NGC 4894** and **IC 4011**. The latter two were made easier to find by their proximity to the brighter galaxies.

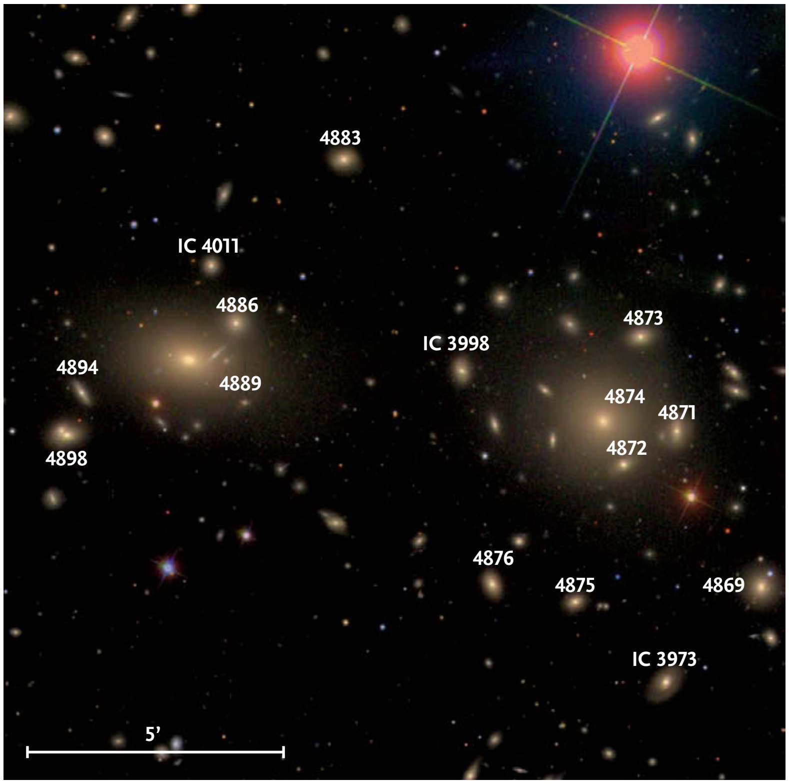
In contrast, there's no nearby landmark pointing the way to 14.4-magnitude **NGC 4883**, which hides 4′ northwest of NGC 4889 in the troublesome glare of the nearby 7th-magnitude star.

NGC 4876 is 3′ southeast of NGC 4874's nucleus. Once I found NGC 4876, I could intermittently see very small, faint **NGC 4875** between the two significantly easier 14th-magnitude galaxies that flank it, NGC 4876 and **IC 3973**. It's surprising that Guillaume Bigourdan, who discovered NGC 4875, missed the much easier IC galaxy only 2′ southwest.

The Western End — and Beyond

Slightly elongated **NGC 4869** is easy, as is **NGC 4864**.

This close-up of the Sloan Digital Sky Survey photo on the facing page shows the host of small galaxies that swarm around the ultramassive elliptical galaxies NGC 4889 and 4874.



NGC 4864 has a tiny near-stellar companion, 14.3-magnitude **NGC 4867**, only 0.6′ southeast, and another companion of similar magnitude, **IC 3955**, 2′ northwest.

NGC 4865 and **NGC 4860** lie northwest of the 7th-magnitude star that makes this end of our oval so hard to observe. Both galaxies show nuclei. NGC 4860 has a minuscule companion, 15th-magnitude **NGC 4858**, that I could only detect intermittently — perhaps due to the fact that the seeing was only fair on that night because the jet stream was overhead. (This is unfortunately all too common in temperate latitudes in springtime.)

There are many more Coma Cluster galaxies lurking beyond the small area that we have explored. On one foray into the cluster my 16-inch swept up a PGC galaxy that I was not even hunting for, 14th-magnitude **PGC 44467**, located 10′ southwest of NGC 4860. How did such an easy prize go unclaimed by the 19th-century observers who discovered the much tougher NGC galaxies nearby? ✦

Alan Whitman looks forward to diving into the Coma Cluster with much bigger glass.

 Johnny Horne

Celestron's Nightscape CCD Camera

This camera takes the work out of creating spectacular deep-sky images.

ALL PHOTOGRAPHS BY THE AUTHOR

The one-shot color Nightscape CCD camera produces high-quality deep-sky images with a minimum of effort. It is also ideal for a wide range of telescopes, including short-focus instruments. The camera is pictured here attached to the f/4 Newtonian focus of the author's 12½-inch classical Cassegrain with a Baader coma corrector threaded to the front of the camera's 2-inch nosepiece.

Celestron Nightscape

U.S. price: $1,499 including camera-control and image-processing software, USB cable, and 2-inch nosepiece
Celestron (and its worldwide dealers)
Phone: 310-328-9560: www.celestron.com

THE PRICE PER PIXEL in astronomical CCD cameras has been plummeting in recent years, but nothing drove that point home to me more than testing Celestron's new Nightscape CCD camera. In 1997 I reviewed Celestron's Pixcel 255 CCD camera, which was manufactured in collaboration with Santa Barbara Instrument Group. It offered 77,000 pixels in an array measuring 2.4 mm by 3.2 mm, and it cost $1,499. You could only do color imaging by shooting through individual red, green, and blue filters, and Celestron's optional filter wheel cost another $395.

Fast forward 15 years. I'm in my backyard observatory mounting another Celestron CCD camera — the Nightscape — on the same telescope I used in 1997. This camera, however, has a one-shot color Kodak KAI-10100 CCD with 10.7 million pixels in an array measuring 13.5 mm by 17.9 mm. That's 139 times more pixels packed into an imaging area 31 times larger than what was available with the Pixcel 255. The cost of Nightscape? Still $1,499.

Celestron's new camera has a distinctive appearance, differing markedly from the box-like or hockey-puck look of most other astronomical cameras. The 4-inch (100-mm) diameter, 2-pound (0.9-kg) camera looks almost mushroom-like with its 2-inch nosepiece attached. True to Celestron's longtime color scheme, the camera is black with handsome orange trim. Its circular head-on profile is designed to work with minimal obstruction on Celestron's Fastar-compatible telescopes.

A small, three-speed fan dissipates heat from the camera's thermoelectric cooling (TEC) system. There is a cluster of three jacks on one side of the camera. One accepts the included 10-foot (3-meter) USB 2.0 computer cable, and another is for the 12-VDC power input (a 10-foot power cord with a cigarette-lighter plug is included). The third jack is a modular phone connector that the manual says will be used for future features.

The Nightscape has a mechanical shutter, making it easy to acquire dark frames for image processing without having to cover the telescope's aperture. An infrared-blocking filter is mounted ahead of the CCD chip but behind the shutter. More details about the camera's physical construction appear in the 16-page Nightscape manual, which can be downloaded for free from the Support section of Celestron's website.

Because Nightscape's TEC system, which cools the CCD chip to as much as 20°C below ambient air temperature, is regulated, you can make a library of stored dark frames for various temperatures. Doing this during twilight or cloudy nights will avoid wasting valuable observing time shooting dark frames when the sky is clear. The TEC's user-selectable temperature set point is visible on the computer monitor throughout the imaging process, and I found the temperature regulation very precise, varying by no more than 0.03°C on a typical night. The software lets you know when the selected temperature has stabilized so you can begin to make exposures. This took up to 20 minutes depending on the ambient air temperature.

Nightscape's CCD array is made up of square 4¾-micron pixels, and a full-resolution image measures 3,760 by 2,840 pixels. Binning the pixels 2×2 or 4×4 while shooting, which increases the camera's sensitivity and speeds the readout of images (at the expense of lower resolution), produces images measuring 1,880 by 1,420 pixels and 940 by 710 pixels, respectively. There's also a subframe setting that allows imaging at full resolution, but using only the central half or the central quarter of the array. The binning and subframe options allow optimal imaging over a wide range of focal lengths. The small pixels work well with fast, short-focus telescopes, while binning is great for long-focus instruments with slower f/ratios.

WHAT WE LIKE:

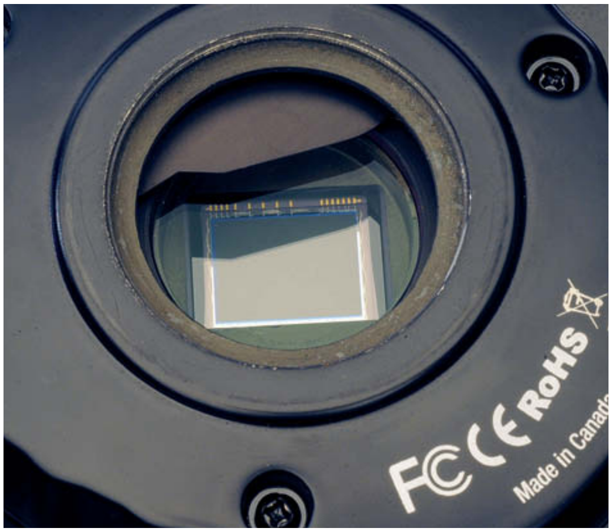
Large, one-shot color CCD

Regulated cooling

Easy-to-use software

WHAT WE DON'T LIKE:

Camera body lacks tripod socket



Nightscape's one-shot color CCD has 10.7 million pixels in an array measuring 13.5 by 17.9 millimeters. The camera's mechanical shutter and the optical window in front of the CCD are also visible in this picture.

The camera's small, 4¾-micron pixels work well with short focal lengths, and the author had excellent results shooting with a 300-mm f/2.8 Nikon telephoto lens. He used a stock lens adapter sold by Orion Telescopes and Binoculars to couple the Nightscape to the lens.

I tested Nightscape at the f/4 Newtonian focus of my vintage 12½-inch classical Cassegrain reflector, using a Baader MPCC coma corrector to improve star images at the edges of the field covered by Nightscape's large chip. I also tested the camera on my 11-inch Celestron Schmidt-Cassegrain telescope and a 300-mm f/2.8 Nikon lens, using a Nikon lens adapter available from Orion Telescopes and Binoculars. The lens performed very well with the Nightscape's small pixels, and fortunately the tripod socket on the lens permitted me to easily attach the imaging setup to a tracking platform. A tripod socket or optional tripod adapter for Nightscape would be welcomed by astrophotographers looking to use shorter-focal-length lenses that lack tripod sockets.

Nightscape's CCD is located 55 mm back from the T threads on the front of the 2-inch nosepiece, which is very convenient if you use the camera with accessories designed for conventional 35-mm camera bodies. With the nosepiece removed, the setback distance to the CCD is 26 mm from the front mounting surface of the camera body, which also has female T threads.

AstroFX Software

One of the most attractive features of Nightscape, especially for those relatively new to processing astronomical images, is the included *AstroFX* software. It transforms the work of making exposures and, more importantly, the tedious aspects of processing images, to a few mouse clicks.

I ran the software on a recent-model Dell desktop machine with an AMD Athlon II 2X processor, 4 gigabytes of RAM, and Windows 7. It installed with no problems and the software acquired the Nightscape camera the first time I started the program. Launching *AstroFX* brings up an unconventional-looking screen for those who are familiar with many camera-control and image-processing programs. The screen does, however, remind you that it's a Celestron product with an orange-on-black color scheme.

As explained in the accompanying text, one of Nightscape's biggest strengths is the supplied *AstroFX* software for controlling the camera and processing its images. All the software's functions are operated from a small dialog box that can be placed anywhere on your computer screen. A Nightscape raw image before color correction with the Stretch function is shown in this view.

This stack of 25 five-minute exposures of NGC 1977, informally known as the Running Man Nebula, north of the Orion Nebula, was made with the 12½-inch f/4 reflector and the Nightscape's pixels binned 2x2.

Most *AstroFX* functions are located in a small rectangular window that you can move to any place on your computer monitor. There are pull-down menus for making focus, bias, flat, and dark frames, as well as your normal exposures. The whole sequence of shooting and processing images is organized into seven steps. Exposing an image is done with functions under the Snap tab, and the subsequent processing steps of Stack, Stretch, Smooth, Sharpen, Saturate, and Share are listed on tabs to its right. Each step has user adjustable sliders in addition to an "Auto" button (more about this in a minute).

Rather than a monochrome "raw" image that some one-shot color cameras display after an exposure, *AstroFX* shows a color image, but the initial colors are far from accurate. Most showed a greenish sky background. Applying the Stretch function turns the colors to a more accurate hue.

Acquiring and composing a celestial target is best done using the camera's quarter-resolution setting because readout and display of the image happens in about 3 seconds. The binned pixels also have greater sensitivity, showing the general shape and extent of brighter deep-sky objects in exposures 1 to 10 seconds long.

Once you've composed an image, *AstroFX* helps you quickly achieve sharp focus. You do this by drawing a mouse-selectable subframe around a single star — the smaller the subframe, the faster the readout of the focus images. Large digits display the star's diameter measured in pixels at the so-called full-width half-maximum (FWHM) part of its intensity profile. Sharpest focus occurs when this value is the smallest you can make it while adjusting the focus of the telescope.

During an imaging session, a folder is created on your computer's hard drive that holds all the light, dark, bias, and flat frames made for a given object. You designate each type of frame using a pull-down menu before the exposure is started. This makes processing the images extremely easy. The Stack command begins by automatically creating master flat and dark frames from the appropriate exposures in the folder. It then proceeds to calibrate the light images with these masters.

The next step is to align and stack the individual calibrated images by either letting the program automatically select stars for aligning or by manually selecting a single star that you identify in each image. When working with about two dozen calibrated images, the processing time needed to display a stacked image took about 2 minutes on my late-model computer.

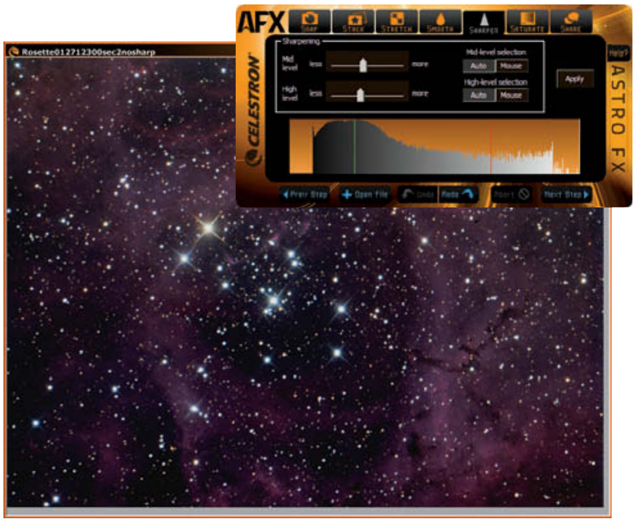
You then proceed to the Stretch step followed by Smooth, Sharpen, Saturate, and Share. Each step has user-settable sliders that control the amount of processing done to the image, but there's also the Auto mode for each step, which produces really first-class results with just a single click of the mouse. I used this setting for processing all the images accompanying this review. I can see the Auto feature being a huge boon to people new to the esoteric art of processing astronomical images.

The Share tab would be more aptly named "Save," because it simply lets you save the processed image in a variety of file formats, including 16-bit FITS (a standard for astronomical images). You can also save them as 16- or 8-bit TIFF files as well as JPEG format with three different levels of file compression.

The camera is supplied with standard ASCOM drivers for people who want to control the image-capture process with other brands of imaging software. I successfully tested it with *Nebulosity* (available from **www.stark-labs.com**) and *Images Plus* (**www.mlunsold.com**). Regardless of which astronomical program I used to capture and process exposures in the past, I usually opened the "finished" images in *Adobe Photoshop* for final tweaking. With *AstroFX,* however, this wasn't necessary — the software did an excellent job by itself. I'm impressed.

If Celestron was trying to create a high-quality, one-shot color CCD camera with regulated cooling and easy-to-use software, they've certainly done it with Nightscape. Astrophotographers who have used DSLRs or small-chip cameras for deep-sky imaging and are looking to upgrade to a high-megapixel, dedicated astronomical camera should strongly consider Nightscape. And if you're a beginner when it comes to astronomical image processing, *AstroFX* can be your step-by-step guide to rewarding, high-resolution deep-sky images. ✦

This view of the California Nebula next to brilliant Menkib (Xi Persei) is a stack of 21 five-minute exposures with the Nightscape attached to the author's Nikon 300-mm f/2.8 lens set to f/4.0.



The Stretch function renders deep-sky objects with more accurate colors. All of *AstroFX*'s image-processing steps have an Auto button that eliminates guesswork and produces excellent results.

Fayetteville, N.C., newspaper photo editor ***Johnny Horne*** *wonders how much camera $1,499 will buy 15 years from now.*

New Product Showcase

▸ EDGE-HD REDUCER

Celestron introduces a line of focal reducers for its popular EdgeHD telescopes. The EdgeHD 0.7x Reducer ($599) incorporates a 5-element design to increase your imaging field while maintaining the field correction of the EdgeHD telescope. The reducer screws directly to the 3¼-inch threads on the rear cell of the 11- and 14-inch EdgeHD telescopes, and provides generous back focus to accommodate a wide range of additional accessories, such as off-axis guiders, filter wheels, or other accessories. Each EdgeHD telescope requires its specific reducer; see the manufacturer's website to choose the appropriate model for your telescope.

CELESTRON

Celestron
2835 Columbia St., Torrance, CA 90503
310-328-9560; www.celestron.com

▾ BELOVED GUIDEBOOK UPDATE

One of the most popular astronomy guides of all time, *Turn Left at Orion* by Guy Consolmagno and Dan M. Davis, has undergone a major update for the 4th edition. The new spiral-bound book is easier to handle outdoors at the telescope, and is specifically updated to accommodate today's Dobsonian owners. Drawings depicting the views with small telescopes are contrasted side by side with drawings showing the same objects appearing in larger Dobsonian telescopes. Many Southern Hemisphere objects have expanded entries with star-hopping directions and tables of updated astronomical information. A night-by-night Moon section is also included along with many more new additions.

Cambridge University Press,
256 pages, ISBN 978-0-521-15397-3.
www.cambridge.org

S&T: SEAN WALKER

iOptron
6F Gill St., Woburn, MA 01801
781-569-0200; www.ioptron.com

◂ SOLAR GRAB-'N'-GO iOptron's latest observing package takes advantage of increasing solar activity. The new iOptron Solar 60 ($399) is a portable solar telescope and Go To mount that fits in a convenient backpack. This 60-mm f/6 achromatic refractor includes a full-aperture, thread-on, white-light solar filter and a 1¼-inch rack-and-pinion focuser. The included Cube Go To mount and SmartStar hand controller isn't limited to solar observing; its internal database has more than 5,000 astronomical objects, including the planets, Messier objects, and much more. Additionally, the outfit has an iE1300 electronic eyepiece with USB cable, allowing you to share the view on your computer. The Solar 60 also comes with a lightweight aluminum tripod, a 25-mm 1¼-inch Plössl eyepiece, and AC power adapter.

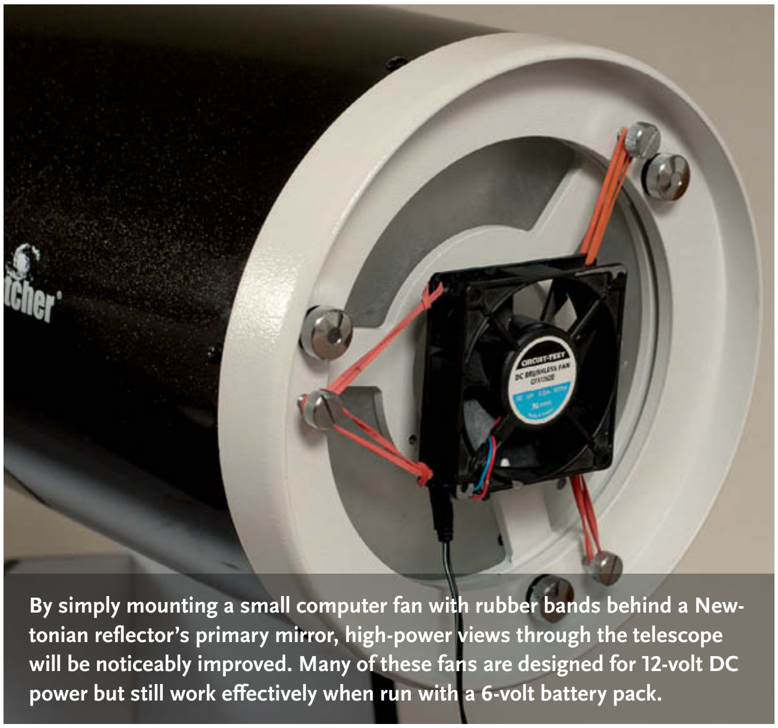
New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information, contact the manufacturer or distributor. Announcements should be sent to nps@SkyandTelescope.com. Not all announcements can be listed.

Thermal Basics

Beating the heat will get you the sharpest views from your Newtonian.

NEXT TO COLLIMATION, the biggest barrier to optimum optical performance with a Newtonian reflector is poor thermal management. And like collimation, thermal management is a topic that invites debate and confusion. Some even suspect the whole issue is merely the product of hyper-obsessive perfectionism on the part of some telescope junkies. In reality, however, neither the problem nor its solutions are terrifically complex. As long as you focus on a few basics, the results of even minimal effort can pay big dividends.

The first thing to understand is that a Newtonian's primary mirror is the root of all thermal evils. Forget about tube currents, forget about the spider and the secondary — that big hunk of glass sitting at the back of your scope is where you need to direct your attention. That's because the primary mirror has considerable heat-storage capacity — heat that it happily (and with agonizing slowness) radiates whenever the air inside your scope is cooler than the mirror itself.



By simply mounting a small computer fan with rubber bands behind a Newtonian reflector's primary mirror, high-power views through the telescope will be noticeably improved. Many of these fans are designed for 12-volt DC power but still work effectively when run with a 6-volt battery pack.

GARY SERONIK

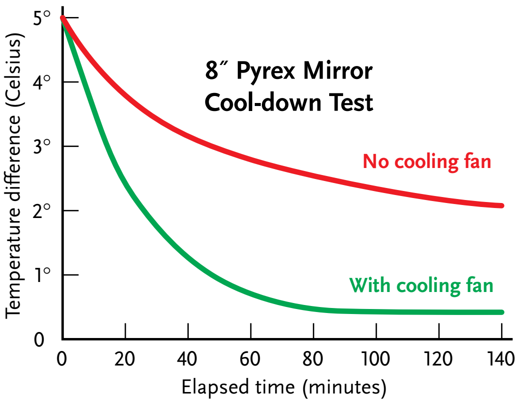
But why is this a problem? Simply because air masses of different temperatures have different densities. On its journey from a star or planet through zones where warm and cool air mix (typically directly in front of the primary mirror), light wiggles and bends, producing an effect that looks a lot like bad atmospheric seeing. Some telescope users who despair that they observe from locations where the seeing is *always* bad may be fighting telescope thermals more often than bad seeing. The big difference is that you can do something about a warm mirror!

Another basic consideration is that the amount of problem heat that your primary mirror stores is related mainly to its thickness. In other words, the type of glass and the mirror's diameter don't make as much difference as its thickness. Thick is bad, thin is good. As Bryan Greer's careful work (detailed in the May and June 2004 issues) demonstrates, any mirror thicker than about ½ inch is unlikely to cool quickly enough on its own for satisfactory high-resolution viewing.

Third on the list of basic issues is that it's the temperature *difference* that matters. In other words, if you bring your scope out of a garage on a mild summer's evening and the primary is sitting at 75°F (24°C) while the ambient air is at 68°, the thermal consequences are just as severe as in the winter when your mirror is at 39° and the air surrounding it is at 32°. Some observers think they don't have to worry about thermals when it's warm outside, but mild climate or not, it's a rare location where the night temperature doesn't drop a few degrees per hour when the sky is clear.

What if you leave your scope outside all the time? It helps, but it's not usually enough by itself. The trouble is your mirror dumps its heat more slowly than the rate at which the night air cools. Even if your primary is at the same temperature as the ambient air at the beginning of an observing session, it's unlikely to remain so for long.

So what can you do? Simple. Install a small fan to blow air at the rear surface of your telescope's primary mirror. That is the easiest and most effective solution, and a small DC-powered computer fan is ideal. The only "gotcha" is that you have to mount the fan in such a way that its vibrations (and *all* fans vibrate to some degree) aren't transferred to the telescope — there's no point in making



A fan greatly helps minimize the difference between a primary mirror's surface temperature and that of the surrounding air. The data graphed here was gathered by Ohio ATM Bryan Greer using his own telescope and a sensitive thermometer on a night when the ambient air temperature was falling 2°C per hour, a rate typical of many clear-sky locations.

the cure worse than the disease. Suspending the fan with elastic bands, as shown in the picture here, is a great way to do this.

As Bryan's tests convincingly demonstrate, any fan is better than none at all — even a little airflow makes a big difference. That being the case, wouldn't a lot of airflow be even better? Yes, but only up to a point. All a fan can do is blow away air warmed by the surface of the glass, but heat within the glass has to get to the surface first. The limiting factor is the rate at which heat is conducted from inside the glass, and a more powerful fan does very little to accelerate that process. A bigger fan also has a potential of producing more image-blurring vibrations.

One final point. If you mostly observe deep-sky objects and rarely push your telescope to its magnification and resolution limits, a warm mirror might not affect your observing very much. But if you like to take in views of the Moon and planets regularly, a little thermal management will go a long way toward improving what you see in the eyepiece. There is much more to this subject, but it's the basics that matter most. In summary, install a fan, don't worry, observe happy. ✦

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*Contributing editor **Gary Seronik** is a longtime ATM who strives to keep his scopes calm, cool, and collimated. Some of his efforts are featured on his website, **www.garyseronik.com**.*

Planetary Imaging
with Your DSLR Camera

JERRY LODRIGUSS

Digital single-lens reflex cameras (DSLRs) today are amazingly versatile. Using the latest models, you can shoot long-exposure deep-sky images, create time-lapse movies from a set of still images, or record high-definition video with a quality that exceeds footage recorded by some dedicated video cameras. And, of course, DSLRs can be used to snap daytime photos of any kind. But few users realize that the video modes available on DSLR cameras are great for recording high-resolution planetary images.

To capture the best planetary images these days, the preferred technique is known as "lucky imaging." This method records thousands of frames in a high-speed video stream, which you can later sort for the best frames to stack into a final high-resolution image. This is where two video modes on your DSLR camera, Live View and high-definition video, come into play.

Live View Versus HD Video

The trick to capturing the highest-resolution details on the planets with a DSLR is to use a mode that allows you to record the image off the camera's sensor at its native pixel resolution. Cameras with Live View offer the easiest route, using the zoom preview mode to get to a 1:1 crop of the central portion of the camera's detector. Although you can use normal high-definition 1080p or 720p video modes for lunar and solar imaging with great results, you generally don't want to use this mode for planetary work because it resamples the image recorded by the camera's detector, and you will lose fine detail.

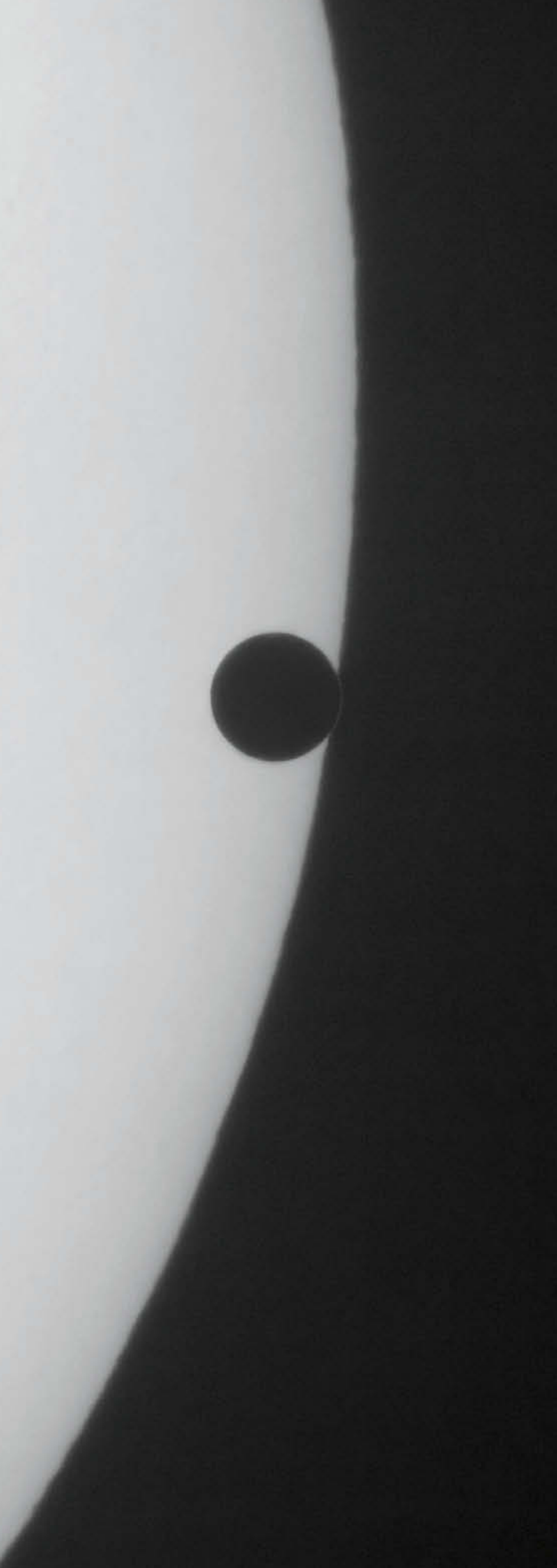
For example, the sensor in the Canon EOS Rebel T3i (also called the 600D) has an array of 5,184 by 3,456 pixels. In 1080p high-definition video mode, the camera records an image that is only 1,920 pixels wide by 1,080 pixels

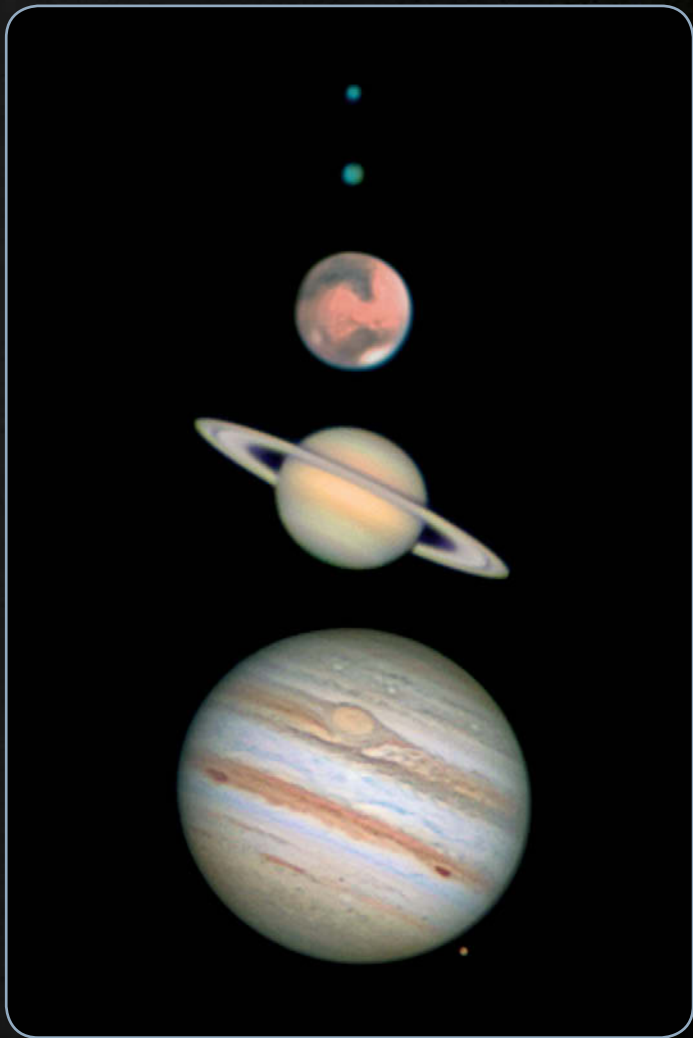
Chances are you already own a great planetary camera, but didn't know it.

Right: **Although this photo of the 2004 transit of Venus was recorded before video was available in consumer DSLR cameras, the upcoming transit on June 5–6 will offer a perfect opportunity to hone your planetary video imaging skills.**

Left: **Jerry Lodriguss with his Celestron C11 EdgeHD and Canon DSLR camera.**

ALL IMAGES ARE COURTESY OF THE AUTHOR.

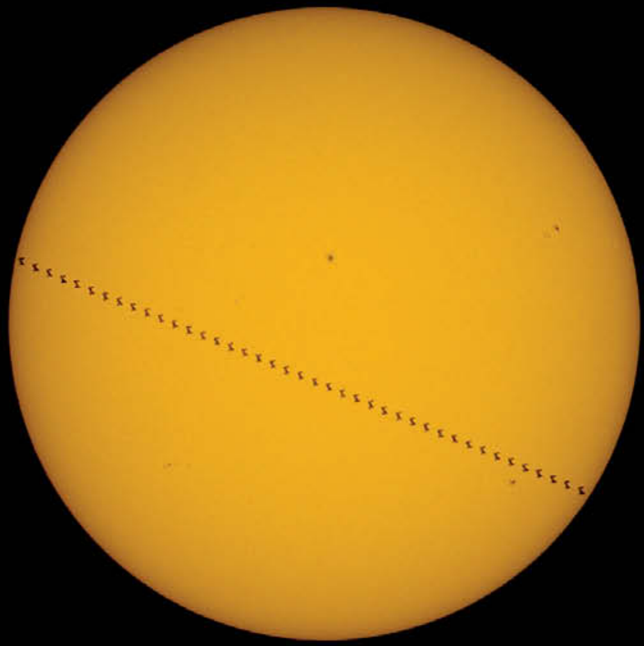


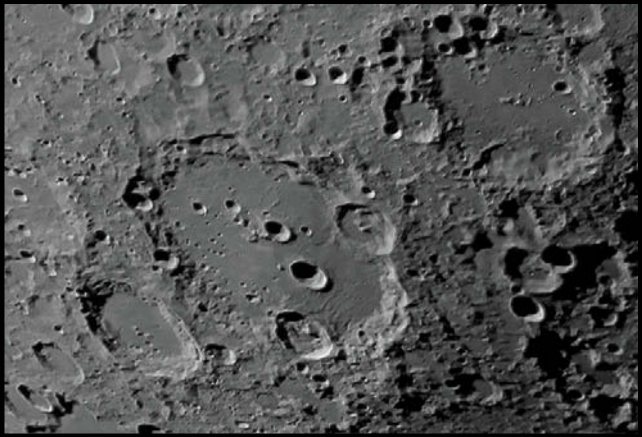


It's surprising what DSLR cameras are capable of these days. It's not uncommon to see deep photographs of nebulae and galaxies taken with a stock DSLR, or the Milky Way captured over a picturesque landscape. But you can also use your DSLR as a high-speed video camera to take great high-resolution images of the Sun, Moon, and planets like the fine examples above of Neptune, Uranus, Mars, Saturn, and Jupiter. The author captured each of these images using a Celestron C11 EdgeHD operating at f/29 and a Canon EOS Rebel T2i in Live View mode.

COLLIMATE YOUR OPTICS

Newtonian reflectors, Schmidt-Cassegrains, and other mirror-based telescopes need to be precisely collimated to perform at their best. Use a star near your target to collimate your scope just before you shoot to ensure your best collimation.





Although it's easy to capture the entire Moon in a single exposure through most amateur telescopes using a DSLR camera, sharp close-ups of lunar craters, such as this detailed portrait of Clavius *(above)*, or a solar transit of the International Space Station *(left)*, require high-speed videos to record the best moments of steady seeing conditions. The author used a Canon EOS Rebel T2i to record both images.

high. This down-samples every frame, reducing the resolution of the image.

There are two ways to record planetary videos with a DSLR at a 1:1 pixel ratio. The first is to capture the Live View video feed with a computer using a USB connection. The other is to record a cropped video with the camera itself, if your camera model has this feature. Not all cameras have the latter option, but most cameras that include Live View can be used with the first method. Live View displays the video image from the sensor to either the screen on the back of the camera or to a computer monitor. You will, however, need additional software to record the Live View video feed on your computer.

Although Canon cameras come with *EOS Utility* software that allows remote control of the camera, the program will only record video onto the memory card in the camera using its standard video modes, not Live View. The framing rate you get with video shot in the camera is usually 24 or 30 frame per second, and it won't drop frames because all of the processing is handled by the camera's internal processor.

Software programs including *EOS Movie Recorder, Images Plus, Backyard EOS,* and *Astro Photography Tool* allow you to capture the Canon Live View video signal on your computer, even if the camera doesn't shoot video. When recording planetary videos with your DSLR, use the camera's exposure-simulation mode if available. Adjust the shutter speed and ISO to control the exposure. If you underexpose, your stacked result will be noisy, and might not be salvageable. Use the daylight white-balance setting. *Images Plus* will also capture the Live View signal from Nikon DSLRs. One word about Nikon — its Live View only allows limited manual adjustment of the exposure, so it may require more experimentation to use it for planetary imaging.

The frame rate you can capture will depend largely on the write speed of your computer and operating system. *EOS Movie Recorder* and *Backyard EOS* will record AVI files that can be directly opened in the planetary image-stacking program *RegiStax*. *Images Plus* records uncompressed data from Canon and some Nikon cameras in a custom SID format that can then be converted into individual bitmap images to be stacked in your preferred program. *Astro Photography Tool* records high-quality JPEG images from Live View that can also be stacked in *RegiStax*.

To access 1:1 pixel data, depending on the camera, use either the 5× or 10× zoom-in software while recording Live View. Some software also gives you the ability to zoom in 200%, but this is just the preview being magnified, and it provides no real gain in resolution. The Live

INCREASING YOUR FOCAL LENGTH

Due to a planet's small apparent size, you'll need to magnify the image so that it's sufficiently sampled by the pixels in your camera. The amount of magnification should be based on the camera's pixel size. Use a high-quality Barlow or eyepiece projection to increase your effective focal length. A simple rule of thumb for high-resolution work is to shoot at about f/20. If you have a night of superb seeing, you can push the magnification up to about f/30. On nights of mediocre seeing, you can use less magnification and get a wider field, but expect to record less detail.

BEATING THE SEEING

High-resolution planetary photography is all about the seeing. Seeing describes how much the image of a celestial object is blurred by turbulence in Earth's atmosphere. With good seeing, an image can be sharp and steady, revealing fine details. Although nothing will compensate for very poor seeing, high-speed videos combined with advanced stacking software will increase your chances of a sharp image by throwing away the blurriest frames and stacking only the sharpest ones.

View SID files recorded using *Images Plus* are uncompressed, but the frames per second (fps) is subject to the speed of your computer.

Movie Crop Mode

Some cameras, such as the Canon EOS Digital Rebel T2i and 60D, for example, offer a special 640 × 480 "Movie Crop Mode" under the video movie recording menu option. This function records only the pixels in the center of the sensor, giving us the 1:1 pixel data that we need. Additionally, this mode will also record 60 fps. The Canon EOS Digital Rebel T3i offers a slight variation on Movie Crop Mode where you can select 1080p high-definition video mode and use 3× digital zoom to get 1:1 pixel data at 30 fps, which is particularly useful on wider fields of view such as the Moon and Sun.

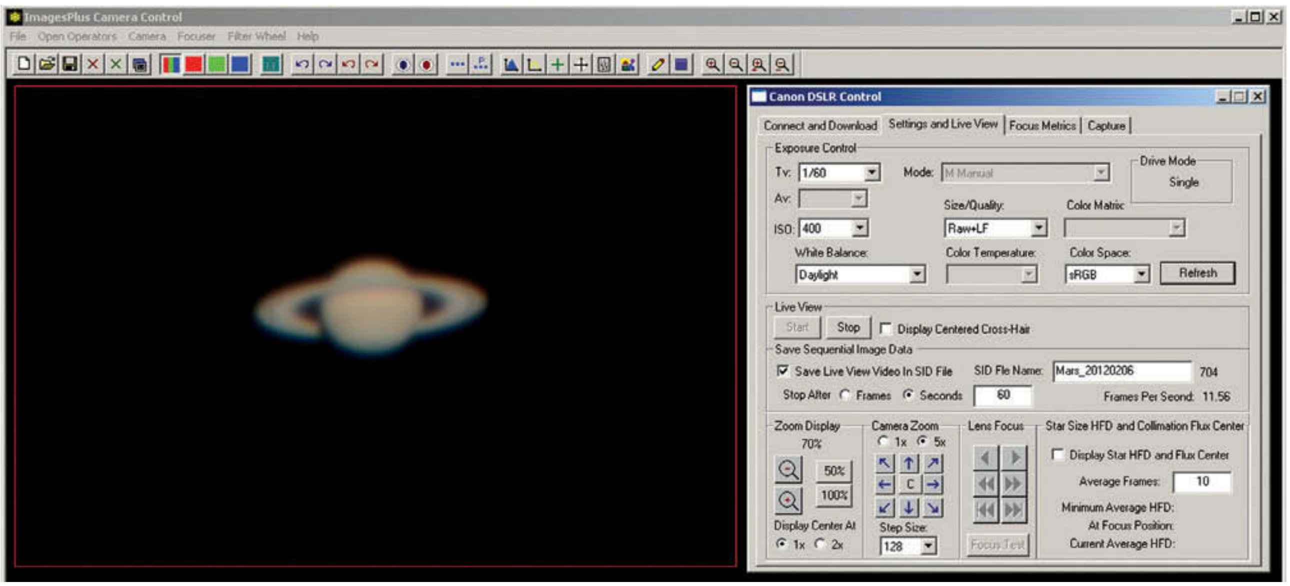
Using Movie Crop Mode, the video is recorded directly to the camera's memory card and doesn't require an additional computer at the scope. The high 60-fps rate in Movie Crop Mode allows you to take lots of frames in a short period of time before your target planet rotates enough to blur detail. This gives you more frames to pick from, and thus more of a chance to get really sharp results.

Most DSLR cameras record high-definition video using H.264 video compression in MOV format to maximize the length of video that can be recorded to the media card. Unfortunately, popular stacking programs such as *RegiStax* and *AutoStakkert! 2* can't open these MOV files directly. I use a program called *SUPER* (**www.erightsoft.com/SUPER.html**) to convert these files to an uncompressed AVI format that my stacking program can then open. Be warned though: uncompressed AVI files can be gigantic compared to the compressed MOV files out of the camera.

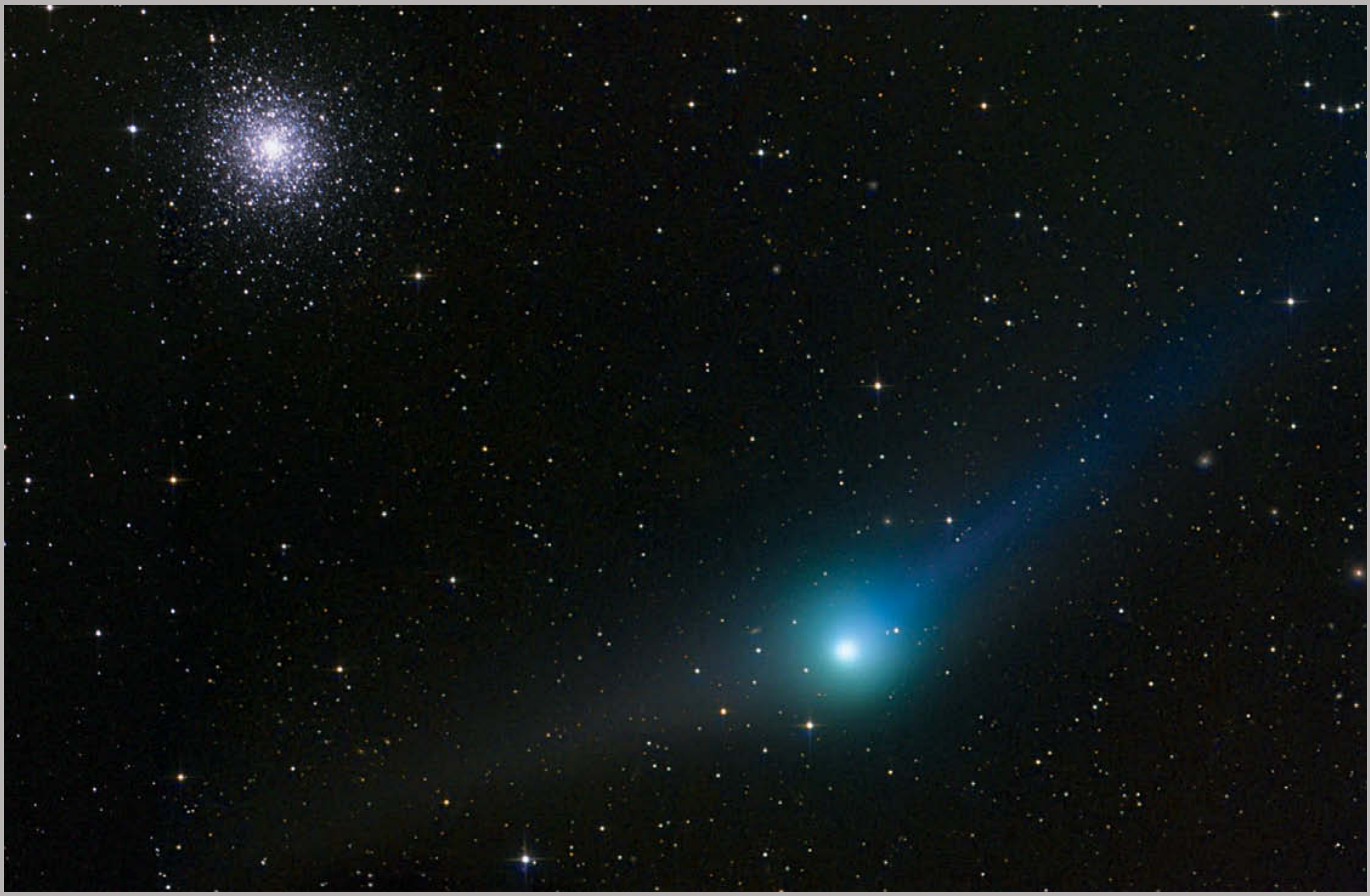
The newest DSLRs utilize the latest technology to produce low-noise images with smaller pixels at higher ISOs, such as the Canon T2i, T3i, 60D, and 7D. This allows you to shoot at a shorter focal length while still achieving optimum pixel sampling. After you've succeeded in recording hi-resolution planetary videos, processing them is relatively easy. A selection of current planetary stacking programs is listed in the May 2011 issue, page 50.

If you normally shoot long-exposure, deep-sky images with your DSLR, it can be a lot of fun to try some really short exposures on some relatively bright objects for a change of pace. With Live View and the video capabilities of today's DSLR cameras, you can take some great planetary images! ✦

***Jerry Lodriguss** is a DSLR aficionado whose latest book,* A Guide to DSLR Planetary Photography, *will be available next fall. See more of his pictures at **www.astropix.com**.*

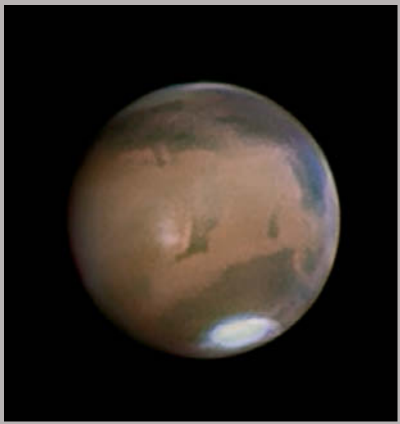


Many DSLR cameras offer video modes, but most down sample the recorded frames to fit the popular high-definition television formats. Additional software may be required to capture the native resolution video stream from your camera. *Images Plus* (www.mlunsold.com) allows your computer to record the Live View video preview of Canon DSLR cameras to a PC at 24 to 30 frames per second while retaining important control functions such as exposure, ISO, and white balance.



▲ **GLOBULAR HOUSE CALL**
Gerald Rhemann
Comet Garradd (C/2009 P1) sports a faint anti-tail as it passed by globular cluster M92 in Hercules on the evening of February 3rd.
Details: *ASA 12-inch f/3.6 astrograph with FLI ML8300 CCD camera. Total exposure was 35 minutes through color filters.*

► **DUSTY SISTERS**
Dean Salman
The Pleiades' stars in Taurus are rewarding targets for observers and imagers alike. Any telescopic view will reveal dozens of members in this nearby cluster, while long exposures highlight the bluish reflection nebulosity surrounding the stars.
Details: *Intes-Micro MN84 Maksutov-Newtonian telescope with QSI 583wsg CCD camera. Total exposure was 6½ hours through Astrodon color filters.*



▲ **MARS APPROACHES**
Robert English
As Mars neared Earth early this year, observers were treated to views of the rapidly shrinking North Polar Cap (bottom) and the familiar "blue cloud" often seen over Syrtis Major at right in this detailed image.
Details: *20-inch Newtonian reflector with Point Grey Research Flea3 video camera. Stack of multiple video frames recorded through color filters.*

▶ **AURORAL ARC**
Allen Hwang
With solar activity on the rise, observers at far-northern latitudes have reported brilliant auroral displays on many nights last winter. This impressive view was captured in the dark skies over Abisko, Sweden, on January 24th.
Details: *Nikon D700 digital SLR camera with 14-mm lens at f/2.8. Total exposure was 30 seconds at ISO 1600.*

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◂ **REFLECTIONS IN M78**

Lynn Hilborn

Visible in small telescopes, Messier 78 is a large complex of dust and gas concealing a cluster containing dozens of embryonic stars.

Details: *TEC APO 140 refractor with FLI ML8300 CCD camera. Total exposure was 16 hours through Astrodon filters.*

▾ **AIRGLOW OVER TÜBITAK**

Raşid Tuğral

Greenish airglow is captured in the exceedingly dark skies over the TÜBITAK National Observatory in Turkey. Orion appears to hover above the mountains at center.

Details: *Canon EOS 450D DSLR camera with 8-mm fisheye lens. Mosaic assembled from multiple images, each exposed for a total of 90 seconds.*

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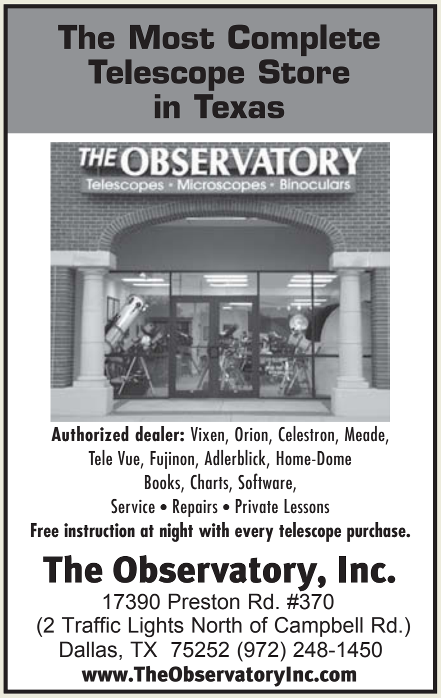

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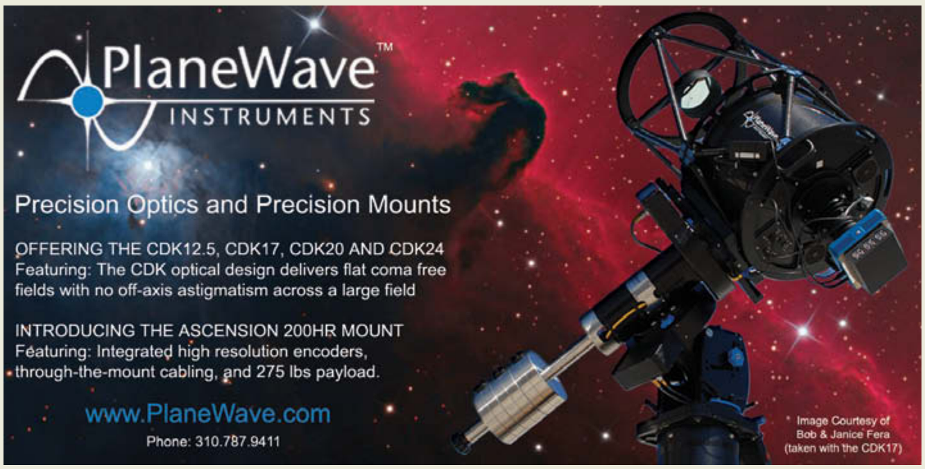

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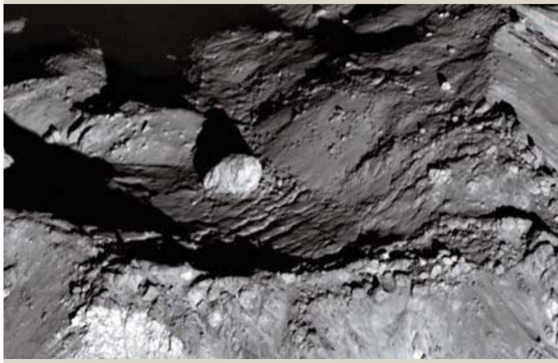

NASA's New Moon

The Lunar Reconnaissance Orbiter has returned spectacular science and images from Earth's nearest neighbor.

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In the first major international scientific effort, astronomers traveled around the world to observe 1761's transit of Venus.

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With My Own Eyes

Visual observing is still worthwhile even if it doesn't contribute to science.

I'm sometimes asked why I spend time observing things that professional astronomers have studied for so many years. The first instance occurred not long after the Apollo 11 landing. My father came outside to see what I was up to, puzzled that I would still be so interested in looking at the Moon with my 60-mm refractor. After all, hadn't I seen all the pictures sent back to Earth? I have no recollection of how I responded; I can only hope I had the answer for him then that I give now.

Why bother? After all, these celestial objects have long been cataloged, many not long after the telescope was still a new and paradigm-shattering invention. Years of patient study have since revealed the truth behind much of what the first telescope users saw. Why go to the trouble in this day and age to peer into the night with a relatively small telescope at these thoroughly characterized (if not quite fully understood) celestial objects? Surely the days in which amateurs equipped with such instruments could make a contribution to science must be long gone.

Of course, this is not true, and pro-am astronomy projects are alive and well. Dedicated and well-equipped amateurs continually make contributions to science (for example, see the March issue articles about Epsilon Aurigae). Some writers refer to this as making "meaningful" observations. But most of us will explore the night sky and never add a single data point to any scientific endeavor.

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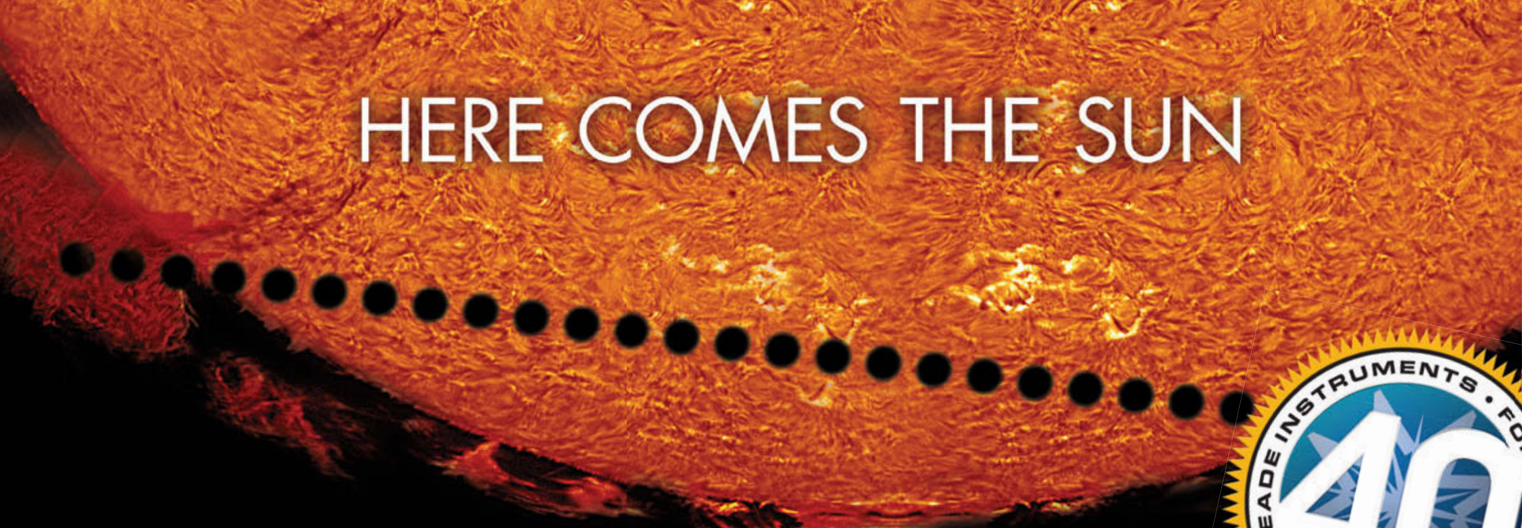
My observations don't lack meaning simply because they don't advance the cause of science; such was never my intent. I bought a telescope because I've discovered that seeing these things for myself is deeply satisfying. It's like taking a trip to the Grand Canyon. Would anyone seriously support the notion that such a wonder isn't worth a visit simply because it's so well known?

The same thing holds true for viewing the Orion Nebula (M42) in the eyepiece. Countless people have observed, studied, and recorded it using every technique and in every wavelength available. But I still study it myself each winter. It doesn't matter that others have seen it before. The best picture postcard of the Grand Canyon will never replace standing on the rim and gazing into it with your own eyes. Nor does it matter that the nature of the Orion Nebula has already been determined, any more than the Grand Canyon can be said to have lost its wonder because we know what those layers of rock tell us about the depths of time.

I need to see these things for myself. That was true when I studied the Moon in my youth, and that need has grown stronger as I've grown older. All the photos, sketches, and images cannot replace the feeling of seeing for myself shadows cast by lunar mountains, or the diamond-dust glitter of a globular cluster. The depth and beauty of the universe gain a new level of meaning when you take the time to see things for yourself. For me, that's reason enough to spend time at the eyepiece. ✦

Thomas Watson is a freelance writer, naturalist, and amateur astronomer living in Tucson, Arizona, right next door to some very dark and often clear skies.



(AND VENUS)

ON JUNE 5th, VENUS TRANSITS THE SUN FOR THE LAST TIME THIS CENTURY. YOU DON'T REALLY WANT TO MISS THAT, DO YOU?

One of the rarest solar system events (only seven have happened since Galileo's time), Venus' transit of the Sun is something no one wants to miss. And if you don't catch it this June, there's not going to be another for another 105 years. Make sure you're prepared when it happens with a Coronado solar telescope. 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 Hα 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.

The transit lasts only six hours, but it's a memory you'll cherish for a lifetime. And with solar maximum still ahead of us there are plenty of other amazing views to come. Be sure you're ready for them with a Meade Coronado solar telescope.

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