View December's Total Lunar Eclipse p. 58

THE ESSENTIAL MAGAZINE OF ASTRONOMY

SKY & TELESCOPE

DECEMBER 2011

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SKY & TELESCOPE

December 2011

VOL. 122, NO. 6

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On the cover: Illustrator Casey Reed depicts Curiosity being lowered to the surface of Mars as its mother ship hovers with retrorockets.

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S&T TEST REPORT

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PETER & DEBRA CERAVOLO

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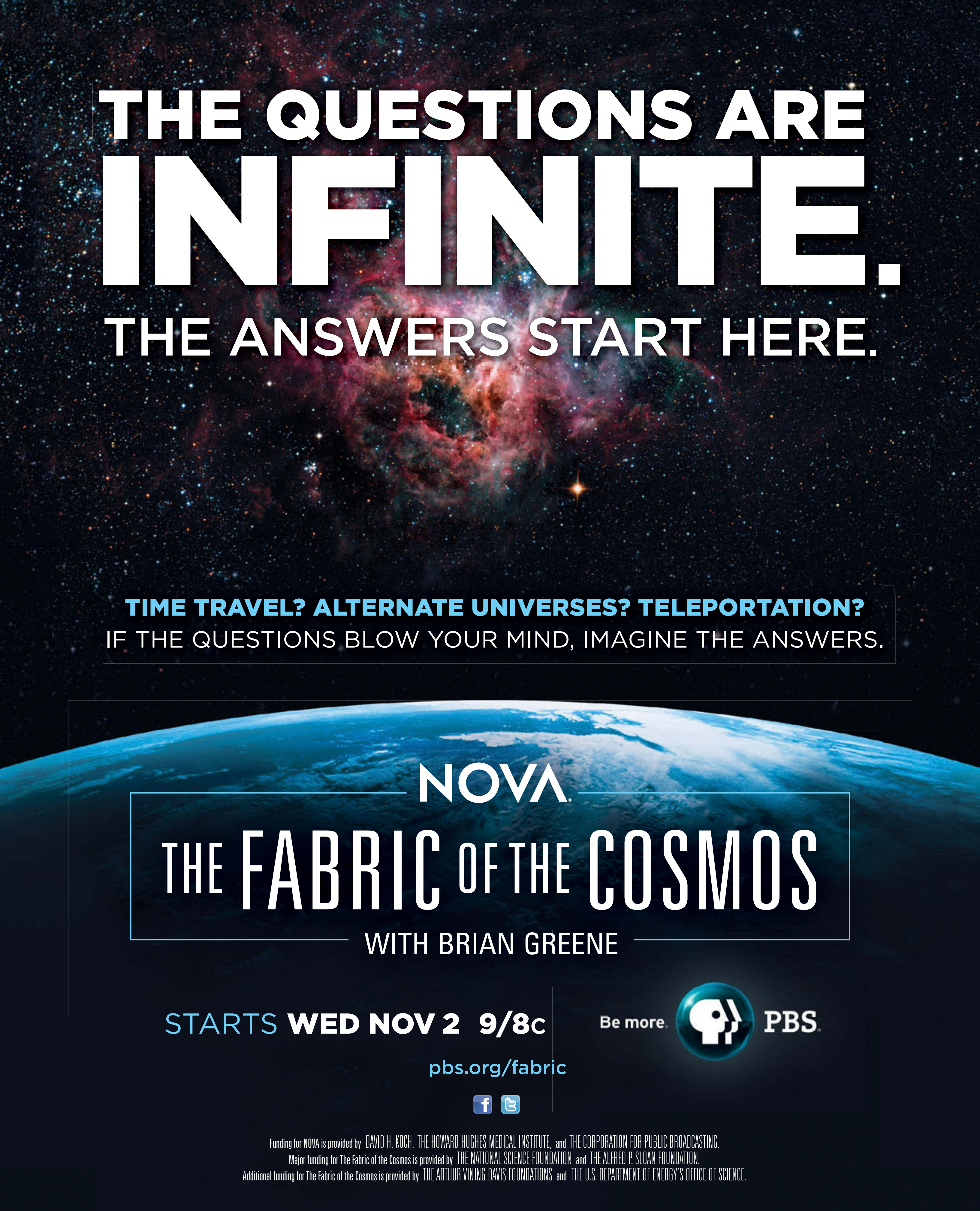
Vol. 122, No. 6. *SKY & TELESCOPE* (ISSN 0037-6604) is published monthly by Sky & Telescope Media, LLC, 90 Sherman St., Cambridge, MA 02140, USA. Phone: 800-253-0245 (customer service/subscriptions), 888-253-0230 (product orders), 617-864-7360 (all other calls). Fax: 617-864-6117. Our website: SkyandTelescope.com. © 2011 Sky & Telescope Media, LLC. All rights reserved. Periodicals postage paid at Boston, Massachusetts, and at additional mailing offices. Canada Post Publications Mail sales agreement #40029823. Canadian return address: 2744 Edna St., Windsor, ON, Canada N8Y 1V2. Canadian GST Reg. #R128921855. POSTMASTER: Send address changes to *Sky & Telescope*, PO Box 171, Winterset, IA 50273. Printed in the USA.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Additional funding for The Fabric of the Cosmos is provided by THE ARTHUR VINING DAVIS FOUNDATIONS and THE U.S. DEPARTMENT OF ENERGY'S OFFICE OF SCIENCE.

Robert Naeye
Spectrum

Astro Nerve Center

TWELVE YEARS AGO the Cincinnati Observatory invited me to give a public lecture at a fund-raising event to help renovate this historic facility. I remember the two beautiful buildings and large refractors, and extremely friendly people. But I also remember empty rooms and the feeling that the restoration project was very much a work in progress.

Fast forward to September 2011. Observatory Outreach Astronomer Dean Regas invited me to come speak again for the annual Scope Out festivities. Having edited Dean's feature article about the Cincinnati Observatory in our August 2009 issue, I knew before boarding the airplane that I would see big changes. Yet even this foreknowledge didn't completely prepare me for the magnitude of the transformation. I was delighted to see fully equipped offices and conference rooms, museum-like displays, and a gift shop. The observatory is now accommodating more than 10,000 visitors per year.

Dean, observatory director Craig Niemi, and dozens of volunteers have done an amazing job turning the facility into a nerve center for astronomy outreach and education. I saw this on full display the evening prior to Scope Out, when Dean handed out awards to 20 Galileo teams, who last year were given free 8-inch Dobs in exchange for promises to conduct public star parties and other outreach events. With all the negativity in the world, it was heartwarming to see that the positive activities of a small group of staffers and fund-raisers are bearing fruit on a local level.

DEAN REGAS

I also want to bid a fond farewell to our editorial assistant Katie Curtis, who is moving back to her native Michigan to attend to several ill relatives. Katie has performed a wide range of duties, from copy editing to answering phone calls, and her cheery disposition has contributed to our pleasant work environment ever since she joined our staff in 2005. We're going to miss her *a lot*. We're excited that former *S&T* editorial intern Camille Carlisle is coming onboard as an assistant editor following a stint at *Science News* magazine. Besides performing some of Katie's duties, Camille will write articles for the magazine and website, and she'll produce multimedia content. You might recall her January 2009 cover story about the search for Earth-like exoplanets.

Our staff also feels a sense of relief that former illustrator Casey Reed has returned safely after a year-long deployment in Afghanistan (*S&T:* October 2010, page 6). Casey has decided to take a job closer to his home, but he will create illustrations for *S&T* on a freelance basis — starting with this issue's cover art. We're pleased that Leah Tiscione will stay on as our staff illustrator.

Robert Naeye
Editor in Chief

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The Essential Magazine of Astronomy

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

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

Customer Service: Magazine customer service and change-of-address notices: custserv@SkyandTelescope.com
Phone toll free U.S. and Canada: 800-253-0245.
Outside the U.S. and Canada: 515-462-9286.
Product customer service: skyprodservice@SkyandTelescope.com
Phone toll free: 888-253-0230.

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

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

Unsung Virtue

I already had a smile on my face before I read the opening line of Gary Seronik's Telescope Workshop describing Jerry Oltion's handiwork (September issue, page 64). Even those who have never seriously thought about building a telescope can tell from the picture that Oltion must have had a lot of fun making his giant Astroscan lookalike.

I'm pleased that the magazine has never stopped its coverage of telescope-making projects. As teenagers many years ago, my buddies and I eagerly looked forward to each issue and Bob Cox's Gleanings for ATMs column, hoping to find ideas for our own projects. We started building telescopes back then because we couldn't afford to buy them. That's not the case now since there are many quality commercial telescopes that are within reach of amateurs with limited budgets. But as enjoyable as it is to view the heavens with any telescope, it's unbelievably rewarding to do it with an instrument you've had a hand in building. It's one of the unsung virtues of telescope-making.

B. Heath
New York, New York

S&T: DENNIS DI CICCO AND SEAN WALKER

TELESCOPE-MAKING MECCA Stars circle above the observing field during last August's Stellafane convention in Springfield, Vermont. Considered the birthplace of the amateur telescope-making movement in North America during the 1920s, Stellafane continues to be a source of inspiration for the hobby, and in recent years has greatly expanded its hands-on demonstrations of mirror-making.

How Far "North" is North?

It was with surprise and delight that I found David A. Rodger's article, "In Praise of the Great Dark North," in the September 2011 issue (page 66). David was one of the truly great creative forces in the history of Canadian planetariums, being the first director of the H. R. MacMillan Planetarium in Vancouver, British Columbia. The International Planetarium Society had a very nice meeting there, hosted by David and his staff, in July 1982. I was then living in northern Virginia (latitude +38° 50′), had grown up in Rochester, New York (latitude +43° 10′), but I even have *that* beaten now by living in the suburbs of Stockholm, Sweden (latitude +59° 25′). After reading David's article on the delights of the circumpolar sky, I am going to spend some telescope time this autumn reacquainting myself with that part of the sky.

Tom Callen
Vaxholm, Sweden

Stella Spectra from Years Past

I read with great interest Tom Field's article on amateur stellar spectra ("Spectroscopy for Everyone," August issue, page 68). Excellent article! The author, however, states that "until recently" this activity was costly and too complicated for amateurs, and I wish to direct him to the May 1967 issue of *Sky & Telescope*. There, he will discover an article I co-wrote with Roger McPherson on this subject 44 years ago.

We obtained many spectra at reasonable cost using a large 45° prism taken from a surplus World War II tank. The prism was placed in front of the lens of an ordinary fully-manual SLR camera. Our home-built clock drive used surplus gears and various spare parts. We bought Tri-X film in 100-foot rolls to save money, and of course had no computers.

I don't remember how much we spent, but it wasn't much!

Bob Waber
Boulder, Colorado

A Matter of Mass

Jim Bell's marvelous article about the asteroid Vesta (November issue, page 32) has an unfortunate error in celestial mechanics. He writes, "Astronomers estimated Vesta's mass by the way Mars, Jupiter, and other asteroids perturb its orbital motion." But it is the perturbing body, not the perturbed body, whose mass can be determined. In principle Vesta's mass could be estimated from the way it affects the orbits of Mars and Jupiter, but these perturbations are too small to measure. On the other hand, the mass of Vesta was previously estimated by the way it affects the orbits of other asteroids.

Doug Robertson
University of Colorado
Boulder, Colorado

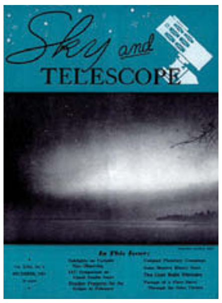
Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send e-mail to letters@SkyandTelescope.com. Please limit your comments to 250 words. Published letters may be edited for clarity and brevity. Due to the volume of mail, not all letters can receive personal responses.

75, 50 & 25 Years Ago

Roger W. Sinnott

December 1936
Invisible Stars "What is possibly the coldest star yet discovered has recently been found in this way. The new observational method will be continued in an effort to find more infra-red stars. . . . A first step in the proof of the existence of low temperature stars even down to black dwarfs is believed to have been taken."

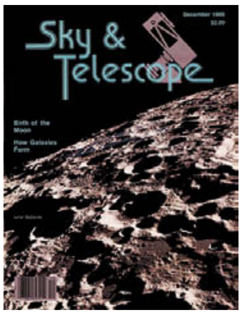
Yerkes Observatory astronomer C. W. Hetzler was recounting his own pioneering work, a few months earlier, with infrared-sensitive photographic plates.



December 1961
Project West Ford "On October 21st about 13:53 UT, the experimental launch-detecting satellite Midas IV was sent aloft by the U. S. Air Force. It carried a package of test 'needles' for Project West Ford, a proposed system of long-range communication. The plan calls for a belt of tiny orbiting wires, which would scatter microwaves from a ground radio transmitter, allowing the signals to be picked up by a distant receiver. . . .

"Many astronomers have feared that optical and radio observations may be hindered by the orbiting needles of Project West Ford, and space scientists have wondered about collisions of the fast-moving wires with manned spacecraft. . . . The first test was made with assurances that its results would be studied thoroughly before any more wires were put into orbit."

To the relief of astronomers and future astronauts, the controversial project was soon scrapped in favor of dedicated communications satellites.



December 1986
Dark Matter "Everywhere that astronomers are able to measure galaxy [rotational] velocities, and thereby probe the force field controlling their motion, we learn that there is insufficient luminous matter to provide the inferred gravitational field. It falls short by about a factor of 10 over scales that range from the 300,000 light-year diameters of galaxy halos to the 30 million light-year spans of superclusters. . . .

"What is this mysterious form of matter that apparently dominates the universe?"

In his overview of galaxy formation, Joseph Silk focused on the feature that was — and still is — the most perplexing.

PICTURE PE

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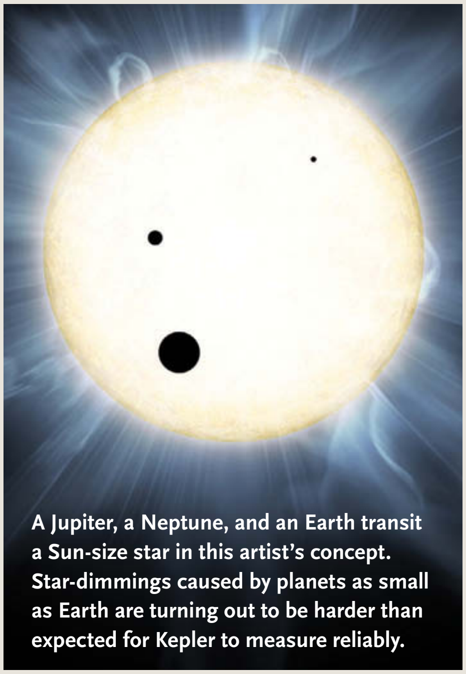
Exoplanet Hunters Almost Losing Count

"It's just amazing," remarked exoplanet pioneer Michel Mayor, looking around in a free moment during the Extreme Solar Systems II conference in Wyoming last September 12–16. "Fifteen years ago, there were just a handful of people working in this field. Now there are well over a thousand."

The number of extrasolar planets has risen even faster, if you count both the confirmed and likely ones. The canonical Extrasolar Planets Encyclopedia listed 687 confirmed as of the end of September. Then there's NASA's Kepler mission. Last February the Kepler team announced 1,235 planet "candidates" transiting the faces of stars in the spacecraft's field of view. Team members expect 90% to 95% of these to prove real. At the September conference, Natalie Batalha of the Kepler team announced more than 500 additional exoplanet candidates as part of Kepler's latest data release, bringing the new total to 1,781. (Of these, about 200 of all types lie within their stars' habitable zones.) And, she said, "There are many more in the pipeline. At the end of the mission, we may easily have found over 3,000 candidates."

Kepler represents the big-science end of the world's exoplanet searches. Elsewhere at the conference, Coel Hellier of Keele University, U.K., was presenting 23 new giant planets found by the WASP-South transit survey. This South Africa-based project watches star fields across wide areas of the sky using off-the-shelf telephoto camera lenses.

Most exciting among the Kepler finds are the so-called "multis" — stars with two, three, four, five, or six candidate planets crossing their faces, each at its own clockwork pace. "I just love these systems," said Darin Ragozzine (Harvard-Smithsonian Center for Astrophysics). "We've hit at an amazing treasure trove here." Kepler announced 170 multi systems last February. At the Wyoming conference, Jason Rowe (NASA/Ames Research Center) added 158 more. And, he said, "there are many more on the horizon."



A Jupiter, a Neptune, and an Earth transit a Sun-size star in this artist's concept. Star-dimmings caused by planets as small as Earth are turning out to be harder than expected for Kepler to measure reliably.

S&T: LEAH TISCIONE

One reason why the multis are considered so exciting is that they're almost certainly all real planets, not just candidates, explained theorist Jack Lissauer (NASA/Ames). It's virtually impossible that spurious signals could team up to produce the observed patterns — especially when transit timing variations (TTVs) reveal the planets' mutual gravitational tugs *on one another,* providing their masses in the process. "This is an extremely high-fidelity sample of candidates," Lissauer said.

The Quest for Terra II

A running theme throughout the conference was the quest for a holy-grail number: what fraction of main-sequence stars host Earth-like worlds? Determining this number is the Kepler mission's main goal.

At a lively panel discussion, the prevailing conclusion was that we don't know the number yet, despite the widely publicized conclusion by Wesley A. Traub (JPL/Caltech) a few days later that, extrapolating from Kepler statistics, 20% to 50% of Sun-like stars (*F, G,* and *K* dwarfs) have at least one terrestrial planet in their habitable zones. Panelists pointed out that 80% to 90% of exoplanet systems seem to have gone through a period of early orbital chaos, leaving orbits a mess. Theorist Alessandro Morbidelli (Observatoire de la Côte d'Azur, France) said this uncertain dynamical history suggests that we can't be sure whether the so-called super-Earths now being confirmed — planets between 2 and 10 times Earth's mass — are rocky terrestrials or gassy mini-giants.

Explained planet hunter Geoff Marcy (University of California, Berkeley), "We can't just extrapolate from the Jupiters and the mini-Neptunes down to the real, rocky Earths."

NASA will decide this spring whether it can afford $20 million per year to extend the Kepler mission for 4 years beyond its planned 3.5 years. An extended mission will be necessary if Kepler is to obtain good data on planets that are as small and far from their stars as Earth is. The problem is that most stars are turning out to show more microvariability than expected, adding noise to transit light curves (October issue, page 12). Batalha is worried about the outcome. "We live in difficult times," she said, "when scientific progress is not limited by technology, but by economics."

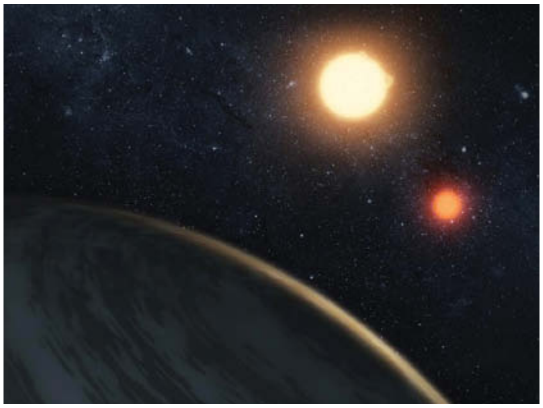
Asked whether the Kepler team has thought about private funding for a mission extension, she replied that the thought had crossed the team's mind. "We're talking about at most $20 million per year," she said. "When I mentioned this while lecturing to a group of entrepreneurs, they just laughed — it's really not that much. On the other hand, we really feel the government should do this."

— *Govert Schilling*

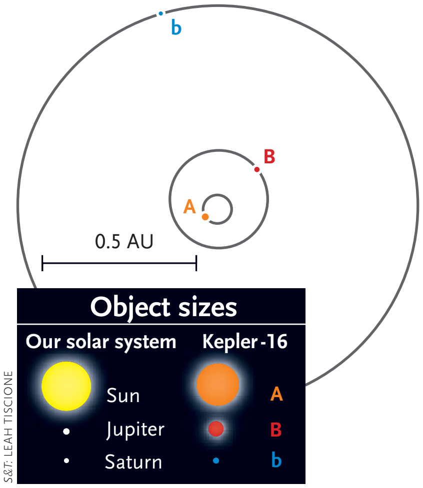
Planets that Orbit Two Suns

In September the media were filled with news and illustrations of the "Tatooine planet," Kepler-16b, which orbits not a single star but a close binary pair. (It was nicknamed for Luke Skywalker's home world in *Star Wars*.) Circumbinary planets have been strongly suspected before, but this was a solid confirmation.

Meanwhile, out of the media limelight at the Wyoming exoplanet conference, Bill Welsh (San Diego State University) was presenting convincing evidence for at least *three* and possibly a dozen other circumbinary planets in Kepler's field of view. "I would still call these 'candidates'," Welsh said, "but I would be extremely surprised if they weren't real. We will know for sure within just a few months."



NASA / JPL-CALTECH / T. PYLE



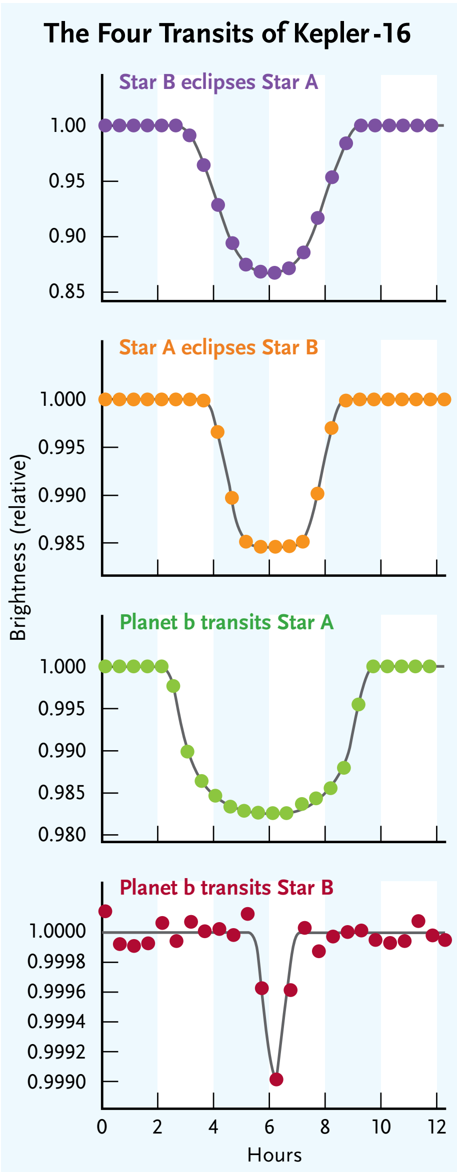
S&T: LEAH TISCIONE

Above: **An artist's concept of Kepler-16b orbiting Kepler-16AB, an orange dwarf and a red dwarf.** ***Top right:*** **The orbits of the system are shown to scale.** ***Bottom right:*** **The stars and planet shown to scale with more familiar objects.**

Kepler-16AB, the "Tatooine" host, is an unresolved, 12th-magnitude speck 200 light-years away in Cygnus. Its A and B components are orange and red dwarfs with 0.69 and 0.20 times the mass of the Sun. Their size ratio is also about 3 to 1. The pair eclipse each other every 41 days as they revolve around their center of mass in a mildly eccentric orbit.

In addition, Kepler found that the system's light also dips by 1.7% and by 0.1% in a complex timing pattern due to a small third body crossing *both* stars about every 229 days. Its slight gravitational tugs on the stars show that it has nearly Saturn's mass. The size of its silhouette reveals that it's a bit smaller in diameter than Saturn and thus should be 1.4 times denser, suggesting that it's richer in heavy elements.

Such a system is especially valuable because it enables very accurate determinations of the sizes and masses of all the bodies involved. It may also help unlock mysteries of planet formation. The three eclipsing objects orbit within 0.5° of the same plane. This indicates that they formed at the same time, from the same protoplanetary disk, and haven't been much disturbed since.



S&T: LEAH TISCIONE, DATA: KEPLER SCIENCE TEAM.

Left: **Light curves of the four kinds of transits observed in the Kepler-16 system. The two stars eclipse each other, producing the primary and secondary eclipses. The planet crosses the face of each star, causing the tertiary and quaternary eclipses.**

That's not to say things here aren't changing. Gravitational interactions in this three-body system are warping the planet's orbital plane around in a precession cycle. The planet is now just grazing the dim star from our viewpoint, but should start missing it altogether in 2014. The planet will also miss the brighter star beginning around 2018. Not until about 2042 will the transits start up again.

The planet orbits only three times farther out than the separation of its two suns; they can appear up to 20° apart in its sky. Astronomers didn't expect such a system to be stable enough to exist long-term. However, orbital simulations indicate that Kepler-16's particular intimate arrangement is stable on timescales of at least a few million years.

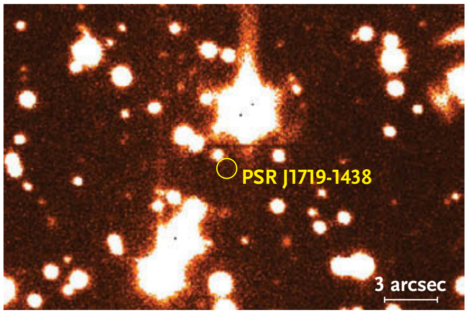
About That Diamond Planet...

Another exoplanet that was recently all over the news is "the diamond planet" orbiting a pulsar 4,000 light-years away in Serpens. This object, say Matthew Bailes (Swinburne University of Technology, Australia) and colleagues, must have formed by the pulsar stripping a companion white-dwarf star of practically all its material, leaving behind just a bit of its carbon core.

The pulsar (PSR 1719-1438) is an extra-fast "millisecond" pulsar: a neutron star spun up to rotate hundreds of times per second by accreting matter from a companion star. Its radio pulses periodically come a little early and late, in a pattern indicating the gravitational tug of a companion slightly more massive than

Jupiter whirling around it in just 2 hours 10 minutes. If you assign the pulsar its expected mass, the companion's orbit comes out to be only about 370,000 miles (600,000 km) in radius, half again the distance from Earth to the Moon and less than the radius of the Sun.

That allowed the group to estimate how densely the companion must be packed in order to keep it from overflowing its Roche limit and being tidally torn apart by the pulsar's gravity. Assuming the orbit is not highly inclined from our line of sight, the body can be only a little larger than Uranus despite its high mass. Its average density comes out to 23 grams per cubic centimeter, compared to 11 g/cc for lead.



MATTHEW BAILES / KECK OBSERVATORY

In this Keck Telescope image, PSR 1719-1438 and its companion are invisibly faint. However, if the biggest white blobs on either side of it aren't random star images, they could be signs of pulsar winds jetting from it.

If it's the last remains of a carbon-core white dwarf, carbon that has adjusted itself to be at that density should be in crystalline form — a type of diamond, at least in the interior. The object may well have collected a crust and atmosphere of other stuff, so news cartoons of space miners hauling trucks of gem-quality diamonds across a sparkly landscape are probably way off the mark. (And those miners better get good pay; the surface gravity of 17 *g* would squash a human flat.)

Should such a thing be called a planet at all? "Technically it is a stellar remnant," says Bailes. But, he adds, "All the rocky planets are composed of elements that were once in stars."

One Image, Five Moons

NASA's Cassini orbiter has been on the job at Saturn for more than seven years, but it keeps sending back new science-fiction vistas. Beyond the need to maximize Cassini's science return, Carolyn Porco (Space Science Institute), who heads the mission's imaging team, has shown a keen eye for capturing the beauty of this mini-planetary system. "Since the first days of this mission," she explains, "I had this vision that the imaging team would be serving as the nature photographers of the Saturn system — visually recording, whenever possible, all the phenomena there are to see around Saturn."

A tourist pic from a scenic overlook near Saturn's ring plane.

CASSINI IMAGING TEAM

Cassini took the shot above on July 29th. It shows (with depth compressed by the camera's telescopic lens) the sunlit outer edge of Saturn's main rings, the filamentary F ring beyond, and big, icy Rhea, half the size of our Moon, in the foreground at far right. Left from there are Mimas, snow-white Enceladus, little Pandora (which orbits just inside the F ring), and Janus (discovered telescopically in 1966).

This monochrome image was taken in green light. As Porco notes, "Some of these multiple-body photos are useful for refining orbits of the moons — and especially for working out how moons perturb one another."

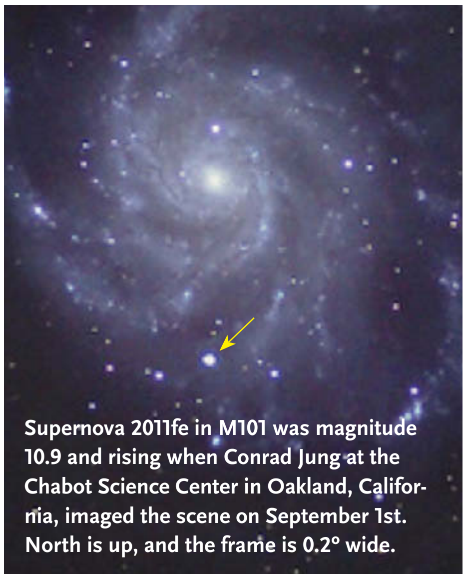
The Supernova by the Dipper

One of the brightest supernovae ever recorded delighted small-telescope users in late summer and early fall. For observers under all but the darkest skies, Supernova 2011fe became easier to see than its host galaxy, M101 in Ursa Major. The last significantly brighter supernova was SN 1987A in the Large Magellanic Cloud.

The Palomar Transient Factory sky-patrol project discovered the stellar explosion on August 24th when it was still only magnitude 17.2. That was within a day of the star's actual outburst; nothing was present there in an image the previous night. It quickly proved to be a Type Ia explosion, the kind that results from an overloaded carbon-oxygen white dwarf undergoing a complete thermonuclear detonation and fusing most of its material to heavier elements in a matter of seconds. Given M101's distance of 23 million light-years, the supernova was predicted to peak at about magnitude 9.9, and that's exactly what it did — remaining about that bright for 10 days in mid-September. You could see it in large, well-mounted binoculars.

Type Ia supernovae are crucial standard candles for telling distances far across the cosmos, so observatories worldwide and in space grabbed the opportunity to study one so near and bright. Expect lots of research results in coming months.

This was the brightest Type Ia since Supernova 1972E reached magnitude 8.5,



Supernova 2011fe in M101 was magnitude 10.9 and rising when Conrad Jung at the Chabot Science Center in Oakland, California, imaged the scene on September 1st. North is up, and the frame is 0.2° wide.

at a time when cutting-edge research instruments were less capable than they are now. It should take months to fade; its continuing brightness is powered by radioactive decay of freshly created isotopes, especially nickel-56. By late October M101 will be very low right after dusk unless you're at a high northern latitude. For updates and a current light curve, check **SkyandTelescope.com/sn2011fe**.

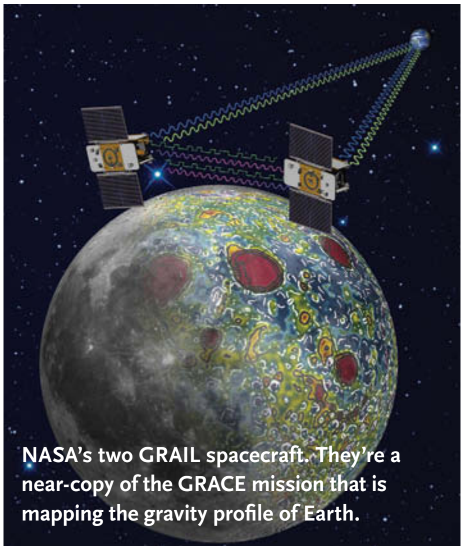
The Newly Uncertain Age of the Moon

The 12 Apollo astronauts collected 842 pounds (382 kg) of rocks and dust during their six lunar landings from 1969 to 1972. Three robotic Luna missions netted Soviet scientists another 10½ ounces (0.3 kg). Since then hundreds, if not thousands of analyses on these precious samples have proved without doubt that, geologically speaking, the Moon is very old and very dead.

But a single pea-size nugget of anorthosite, collected during Apollo 16, now has lunar geochemists in a tizzy. A team led by Lars Borg (Lawrence Livermore National Laboratory) used the best modern techniques to date it, independently by three means, to an accuracy of better than one part in a thousand. The group concludes from it that the Moon has been fibbing about its age of its crust. Instead of being at least 4.43 billion years old, as earlier assays had shown, the group found an age of 4.360 billion years, give or take just 3 million.

A change in the Moon's age of 70 million years — less than 2% — might not seem like a big deal. But it makes a huge difference in the context of the fast-evolving early solar system.

Nearly every lunar researcher now accepts that the Moon formed after a Mars-size protoplanet plowed into the newly formed Earth, splashing white-hot debris into orbit that rapidly coalesced into a sizable satellite. Borg and his team assert that either this happened late, long after the rest of the inner solar system's major chaotic collisions had quieted down (contrary to the dating of many other lunar samples) — or that the mystery rock represents some kind of large-scale remake of lunar crust that remelted and recrystallized later. A second satellite of Earth doing a late splat into Moon (see last month's issue, page 16) might play into this story.



NASA's two GRAIL spacecraft. They're a near-copy of the GRACE mission that is mapping the gravity profile of Earth.

NASA / JPL-CALTECH

There's another way out: force the Moon's original magma ocean to cool very slowly. Last year, MIT researchers Jennifer Meyer, Linda Elkins-Tanton, and Jack Wisdom proposed that the infant Moon, being much closer to Earth than it is now, would have experienced tidal flexing strong enough to keep it hot and molten.

Bottom line: the Moon's birth story may be quite complicated.

With luck, NASA's twin GRAIL spacecraft (Gravity Recovery and Interior Laboratory), launched on September 10th, will succeed in mapping the gravitational structure of the lunar interior finely enough to sort out the correct sequence of events. The GRAIL craft will orbit the Moon in formation from 40 to 140 miles apart, continuously monitoring the distance between them to a precision of 0.2 micron, nearly one part in a trillion. This data will reveal gravitational irregularities that should improve the quality of the Moon's density maps by a factor of 100 to 1,000 from crust to core, laying bare the Moon's interior structure.

SETI Projects Hit by Recession

The global recession has been tough on a lot of things, including searches for intelligent life in the universe.

• SETI@home was astronomy's first big citizen-science project on the internet. Starting in 1999 and running more powerfully now, it uses the downtime on a worldwide armada of volunteers' computers to sift through cosmic radio hiss collected at Puerto Rico's giant Arecibo Observatory. While you sleep, your computer looks for weak artificial signals of various forms that might have been emitted by alien transmitters among the stars.

But much of SETI@home's funding comes from corporate and individual donations, and both have shrunk. "Individual donations have dropped to below half of where they were before the recession," says Eric Korpela, SETI@home's project scientist. "And corporate donations have been very hard to get since before the recession." As a result, SETI@home has laid off one of its four staff members and has delayed its data-analysis plans. Chief scientist Dan Wertheimer is philosophical: "Money has always been tight for SETI. This is a high-risk, high-reward endeavor, and therefore does not attract donations easily."

• A different SETI project, the Allen Telescope Array (ATA) built by the SETI Institute in California, faces bigger troubles. The ATA is a radio interferometer with 42 six-meter dishes tightly linked. It has scanned a piece of the Milky Way's midline for narrowband signals across a wide frequency range, and it can examine individual stars in greater depth. It does conventional radio astronomy as well.

In April the ATA shut down for lack of funds. A public internet appeal raised $228,000, enabling it to resume work at least temporarily. But the ATA's long-term future remains shaky. It needs $5 million to fully fund the next two years of operations (renting its services to the Air Force for orbital-debris tracking could bring in some of this). It would need $50 million to expand to the 350 dishes originally intended. Developing the ATA to its current level has cost $50 million over the last decade or so, including $25 million from the Paul G. Allen Family Foundation.

For an overview of all the world's SETI projects, what they do, how they work, and the different strategies they have chosen, see **SkyandTelescope.com/seti**. ✦

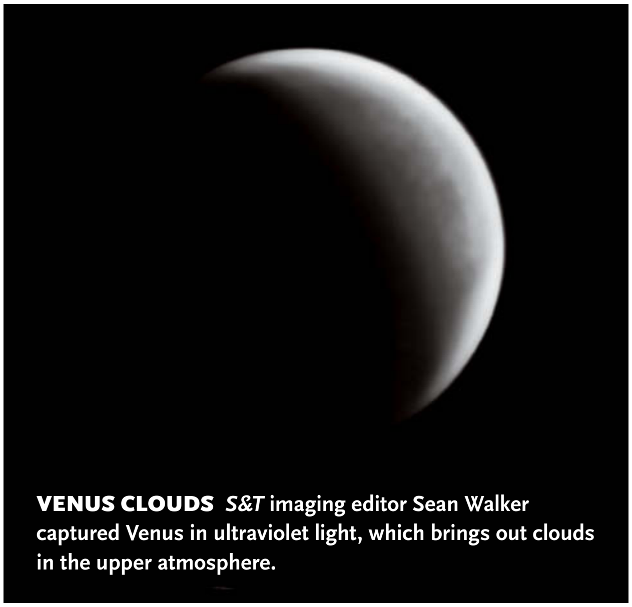
Losing Venus

By neglecting Venus, we could lose valuable knowledge about Earth.

EVEN WHILE human spaceflight goes through a period of uncertainty, robotic interplanetary missions persevere. NASA has spacecraft at Saturn, Mars, Mercury, and Vesta, and others are en route to Jupiter and Pluto. And yet there is something missing. NASA has no spacecraft at Venus, and there's little chance of a new U.S. mission to Earth's sister planet for at least a decade.

At some point Venus apparently suffered a runaway greenhouse, when solar heating triggered irreversible ocean evaporation. Nobody knows exactly when this happened and how this relates to changes in Earth's climate. New missions could go a long way toward filling in the gaps by revealing how sunlight is converted into heat and motion and solving the mystery of if, how, when, and why our sister planet went through its ancient transformation from more mild conditions.

Without such missions, we're losing vital knowledge of how climate works on an Earthlike planet. I fear this loss may be irretrievable. NASA research support goes where the missions go. Support for basic research about the geology and climate of Venus has declined, which results in fewer grad students pursuing Venus science. Consequently, the community within NASA advocating for new Venus missions has been shrinking, which makes it harder for new missions to compete against those with larger constituencies. In general, I think NASA does a good job at selecting missions. But this feedback loop works against new missions to a planet that has not been recently visited.



VENUS CLOUDS *S&T* imaging editor Sean Walker captured Venus in ultraviolet light, which brings out clouds in the upper atmosphere.

S&T: SEAN WALKER

NASA, which hasn't launched a Venus mission since 1989, just selected its new round of missions for preliminary funding, and of seven serious Venus proposals, none made the cut. Venus research is in serious danger of a death spiral. Some of us have been advocating new Venus missions for decades only to get repeatedly shot down. Now we have to face the prospect of no missions to Venus within our careers. Perseverance can be admirable, but doing the same thing repeatedly and expecting different results is, well, you know.

The international community is aware of this gap, but nobody else has NASA's resources and experience. The European Space Agency's Venus Express mission, launched in 2005 and still in orbit, is humanity's one remaining climate-monitoring spacecraft at Venus, but even the best-case scenarios show it dying before any other spacecraft joins it. Japan launched Akatsuki in May 2010 but a malfunction caused the spacecraft to miss Venus and it remains unclear whether mission controllers can steer it back into Venus orbit (April issue, page 20).

There is no anti-Venus conspiracy at work within NASA — all the recently selected missions are worthy and there is not enough money to fund all of the good ones. But the worsening prospects for Venus research are unfortunate when considering the lessons that Venus has to offer about climate and the origin, survival, and loss of life-supporting conditions on Earthlike planets.

One small ray of hope is that in NASA's recent Decadal Survey, an ambitious orbiter, the Venus Climate Mission, is recommended for consideration if more expensive plans fall through. As a Venus guy I would love to participate in such a mission, but I also think it would be good for our country and the world. ✦

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*Noted book author **David Grinspoon** is Curator of Astrobiology at the Denver Museum of Nature & Science. His website is www.funkyscience.net.*


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OrionTelescopes.com

Face to Face

NASA's new rover Curiosity will take Mars exploration to an entirely new level.

Emily Lakdawalla

I can only see the eyes of the engineer who hands me booties to cover my shoes, and a paper face mask and hair net for my head. Next comes a white coverall and a second set of cloth boots. After donning a hood and vinyl gloves, I'm covered from head to foot in sterile white cloth, with only my eyes visible. All of this gear is not to protect me, it's to protect Mars, and a spacecraft that's being sent to explore it.

Next I'm guided into an airlock where a hundred little blowers blast me with air, whisking away any dust that may have stuck to my coverall. I leave the airlock and walk through tall double doors into a giant clean room at NASA's Jet Propulsion Laboratory. There it is: Curiosity, NASA's next Mars rover, attended by more white-suited engineers. My first thought — really, everyone's reaction when they first lay eyes on it — is "Wow, this thing is *huge!*"

MAT KAPLAN

HUGE ROVER Author Emily Lakdawalla poses in front of Curiosity during her visit to the Jet Propulsion Laboratory on April 4, 2011. Like everyone who sees the rover for the first time, she was immediately struck by its large size. Her "bunny suit" protects delicate spacecraft components from dust and other earthly contaminants.

with a Giant

CURIOSITY ON MARS NASA's new rover will usher in a new phase of Mars exploration. Spirit and Opportunity proved that liquid water once flowed on the planet's surface; Curiosity will take the next step by investigating whether those wet environments were hospitable for life as we know it.

NASA / JPL-CALTECH


NASA / JPL-CALTECH


NASA / JPL-CALTECH

***Left:* This photo shows from left to right, full-scale models of Spirit (or Opportunity), Sojourner, and Curiosity. Amazingly, the instrument package at the end of Curiosity's robotic arm is almost as large as Sojourner, which rolled across Ares Valles for 83 Mars days (sols) in 1997. *Right*: Clara Ma, a 12-year-old from Lenexa, Kansas, submitted the winning name "Curiosity" in a contest that inspired more than 9,000 entries from students aged 5 to 18. Clara is seen here visiting JPL's Mars Yard on June 8, 2009.**

Curiosity's body plan is similar to its predecessors Spirit and Opportunity, but whereas those two were golf-cart scale, Curiosity is an automobile. The six enormous wheels connect to the body through a suspension system made of black pipes as thick as my arm. That body is a fat white box, its metal skin held on with rows of rivets like those on an aircraft. I'm barely tall enough to see over the rover's back, and I have to crane my neck to look up at the top of its camera mast.

Curiosity won't win any beauty contests. But seeing it looming so large before me gives me newfound respect; this pile of parts has come together into a businesslike machine, constructed for heavy duty. It's nearly ready to trek up dusty red hills, take spectacular images, and drill into Martian rocks. Its mission is to move our study of Mars beyond the search for water, toward the search for life.

Piecing Together Mars's Story

Curiosity will cap a tremendously successful program of Mars exploration that has unfolded over the past 15 years. Every orbiter and rover launched since 1996 has been sent to answer the same basic questions, and each successful mission has contributed a piece to the puzzle. How long ago was liquid water present on Mars's surface? How much was there, and how long did it last? Where did it come from, and where did it go? And did it persist long enough for life to develop?

In 1997 NASA's Mars Global Surveyor mapped the global mineral patterns for the first time. This orbiter didn't find the carbonates that geologists had hoped would be the telltale signs of ancient oceans, but it spotted an unusual concentration of gray, crystalline hematite in Meridiani Planum. On Earth, gray hematite usually forms near hot springs, where volcanic activity heats groundwater. Four years later, Mars Odyssey peered beneath Mars's dust, discovering abundant hydrogen all over Mars, in vast deposits of ice lurking just below the surface. Mars's missing water was everywhere, just hidden from optical cameras.

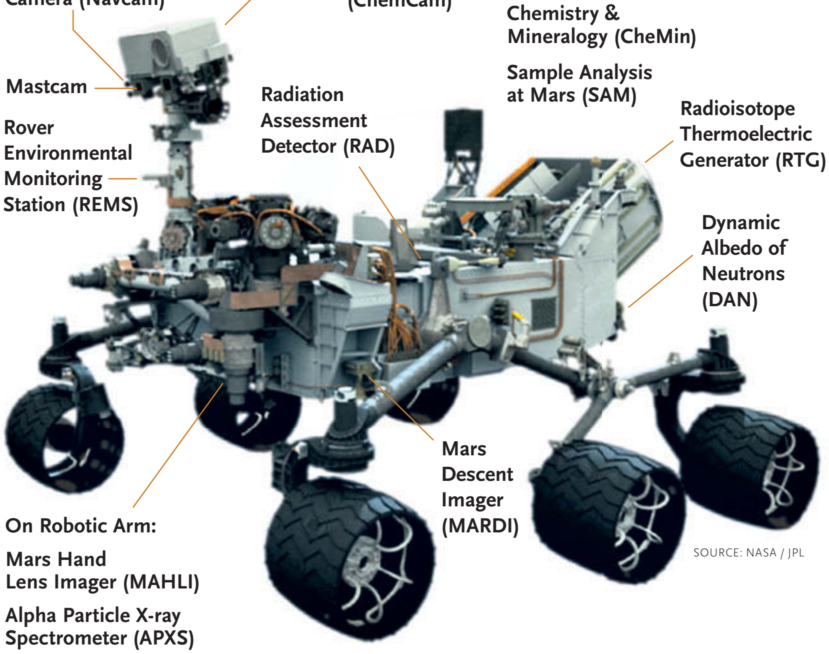
Then NASA sent two rovers to "ground truth" the orbital finds. Spirit landed in Gusev Crater, which must have been a lake, at least briefly, when water gushed through a deep channel that emptied into the crater floor. Opportunity landed in the middle of Meridiani Planum to investigate the hematite signal. The rovers succeeded beyond everyone's hopes, proving that liquid water once played an important role on Mars. Opportunity found sandstones and evaporites that had been saturated by very salty, highly acidic water. Spirit found a fossil fumarole, where silica-rich water percolated near a volcanically heated vent, and it discovered sulfate salts that may have been deposited much more recently.

On May 25, 2008, Phoenix landed in Mars's frozen north. This stationary lander ground-truthed the Odyssey evidence for near-surface ice, finding a hidden water-ice table just centimeters below the surface (*S&T:* October 2008, page 22).

Over the past several years, spectral data from the European Space Agency's Mars Express orbiter and NASA's Mars Reconnaissance Orbiter (MRO) have revealed from space, at last, tiny exposures of rock containing minerals that must have formed in water: clays, carbonates, sulfates, and salts, among others (*S&T:* July 2009, page 22). These deposits are ancient and very deeply buried; they are only revealed through rare, small windows where the overlying volcanic rock and windblown sediments have been eroded away.

The combined work of four orbiters, two rovers, and a polar lander has given scientists a new understanding of Mars's geologic history, and the role that water played in it. A long time ago, while it still retained its infant heat, Mars was quite wet, at least underground. This early, wet era can be read from clays found at the bases of deeply incised canyon walls, such as those of Mawrth Vallis. Then the internal heat from Mars's formation waned and produced a last, violent burst of volcanic activity. Volcanoes spewed out gas as well as rock, water vapor, and more noxious gases that combined in the atmosphere to create acid rain. Mars's global chemistry changed. It no longer made clays; instead, sulfate minerals precipitated out of acid waters, forming deposits such as those at Meridiani.

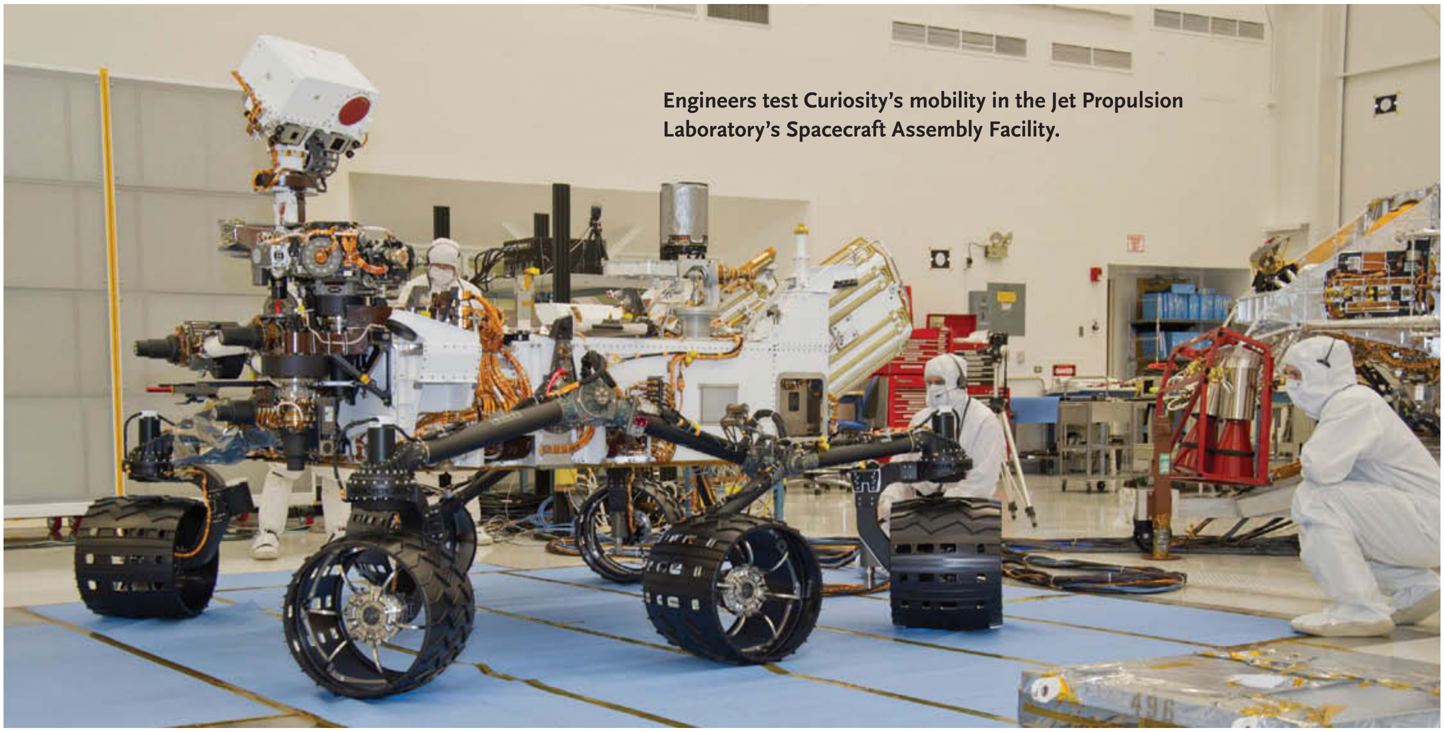
Last came the longest, quietest era of Mars's history, the cold, mostly dry, oxidizing environment we see today. Periodically, as the orientation of Mars's spin axis varies from perfectly upright to nearly sideways, summers may get warm enough to allow thin films of water to coat soil grains and facilitate reactions with atmospheric molecules to form new minerals, sulfates, and oxides. Though it's possible that Martian microbes exist in tiny underground refugia, the watery environments of the sulfate or clay eras offered better prospects for life. Curiosity will take the logical next step in the Mars program by going up to sulfate- and clay-rich rocks and figuring out whether Mars was a habitable place when they formed.



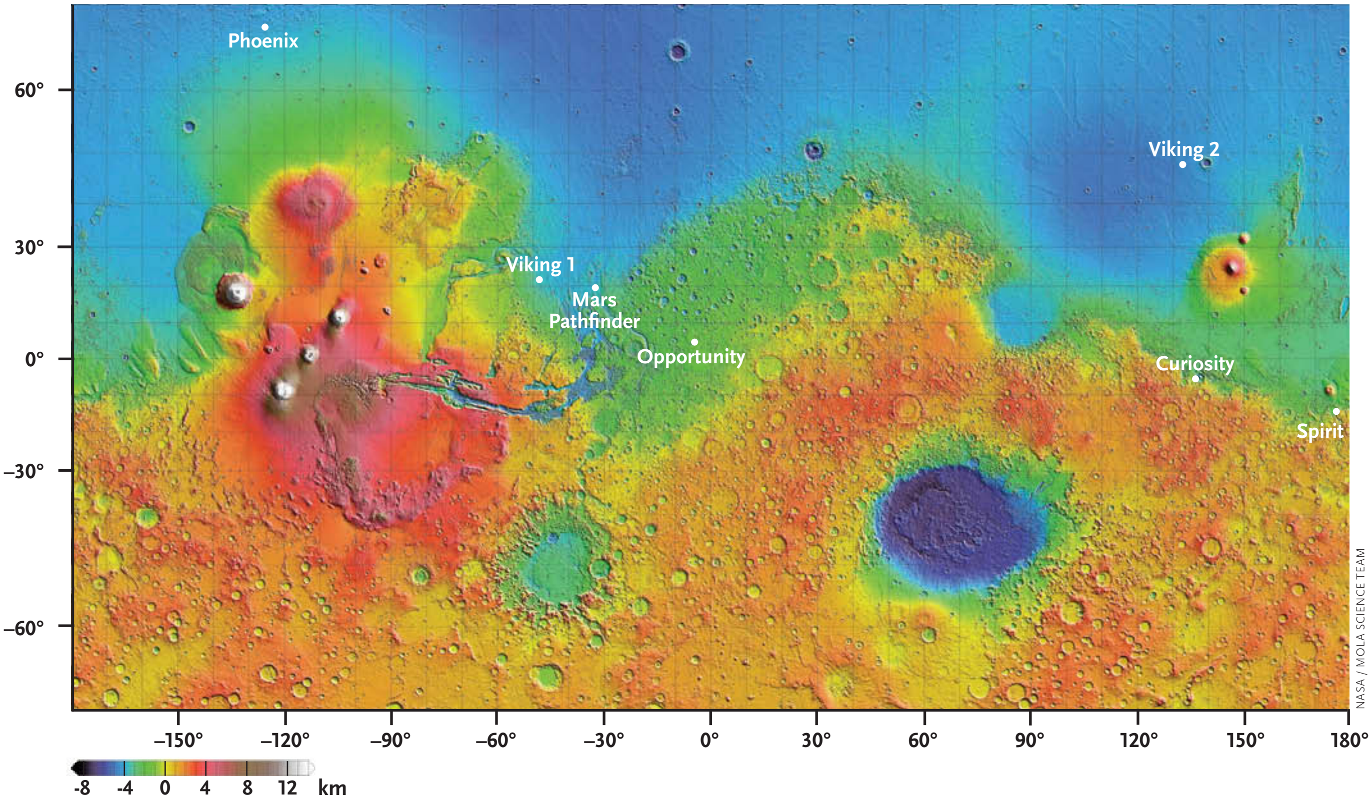
SOURCE: NASA / JPL

Habitable, Not Inhabited

Curiosity isn't designed to detect life, living or dead. Finding fossils even in Earth's 3-billion-year-old rocks is like looking for a needle in a haystack. Looking for life and not finding it on Mars, which is what happened with the


Engineers test Curiosity's mobility in the Jet Propulsion Laboratory's Spacecraft Assembly Facility.

NASA / JPL-CALTECH



THE TARGET Curiosity will land in Gale Crater, located just 4.6° south of the equator and right on the boundary between Mars's flat, low-lying northern hemisphere and heavily cratered southern highlands. The laser altimeter aboard NASA's Mars Global Surveyor orbiter provided the data for this topographical map.

Viking landers, won't tell you for certain whether or not Mars ever harbored life. Instead, Curiosity is designed to study ancient rocks in order to determine what the environment was like when they formed, and whether the ingredients for life — water, a source of energy, and organic materials — were present, and for how long.

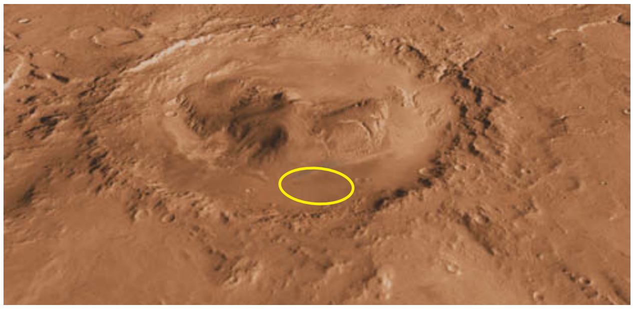
Thanks to the thorough orbital mapping, Curiosity is guaranteed to find rocks that formed in the presence of water. Finding and measuring organic materials will be harder. The problem is that water, a necessary ingredient for life as we know it, is also a powerful agent for destroying evidence of life's existence. If an organism is entombed in water-rich sediment, its complex organic compounds of carbon, oxygen, hydrogen, and sulfur are destroyed, oxidized to inorganic chemicals such as carbon dioxide. These substances may, in turn, be incorporated into the rock as a carbonate mineral, leaving no sign of its former chemical richness. That's why fossils are so rare on Earth.

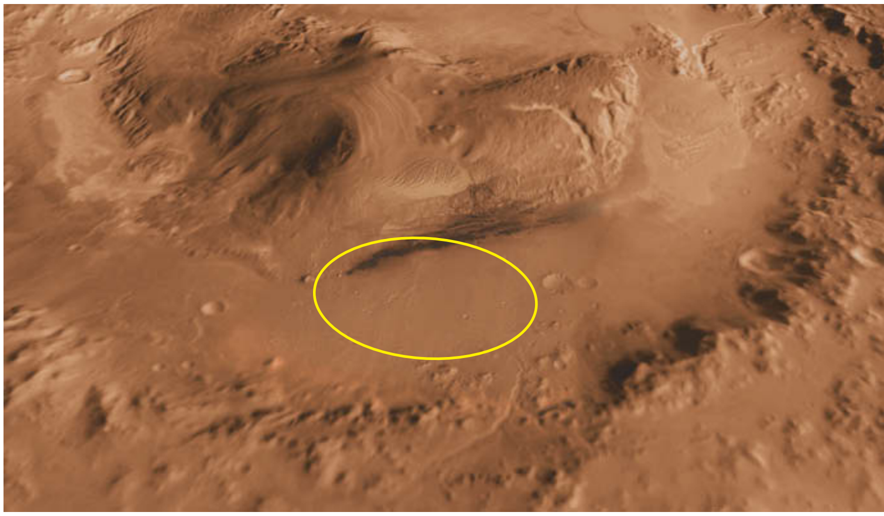
Organic compounds in meteoroids are falling to Mars's surface even now, riding within carbonaceous chondrites. They are possibly providing the raw materials for current life (if it exists), but these organics may not last long. One of Phoenix's startling discoveries was the potent oxidizer *perchlorate* in the Martian soil. To search for organics, Viking had to bake the sample; if there was perchlorate in the Martian soil, the heat could have split apart any organics into tiny inorganic compounds.

Curiosity can look for organics without wetting its samples. So in order to understand a place and time on Mars where life had any chance of starting, Curiosity will be sent to explore Gale Crater — a landing site that was carefully selected to contain ancient, water-lain sediments that formed in the unusual sort of environment where organic materials have a chance of being preserved. The 154-kilometer-wide (96 miles) crater is near Mars's equator and on the "dichotomy boundary" that separates the northern lowlands from the southern highlands. Gale has long intrigued Mars scientists because of its central mound, a 5-km-high stack of intricately layered rocks. Mars Express and MRO have found signs of both sulfates and clays at different levels within this mound.

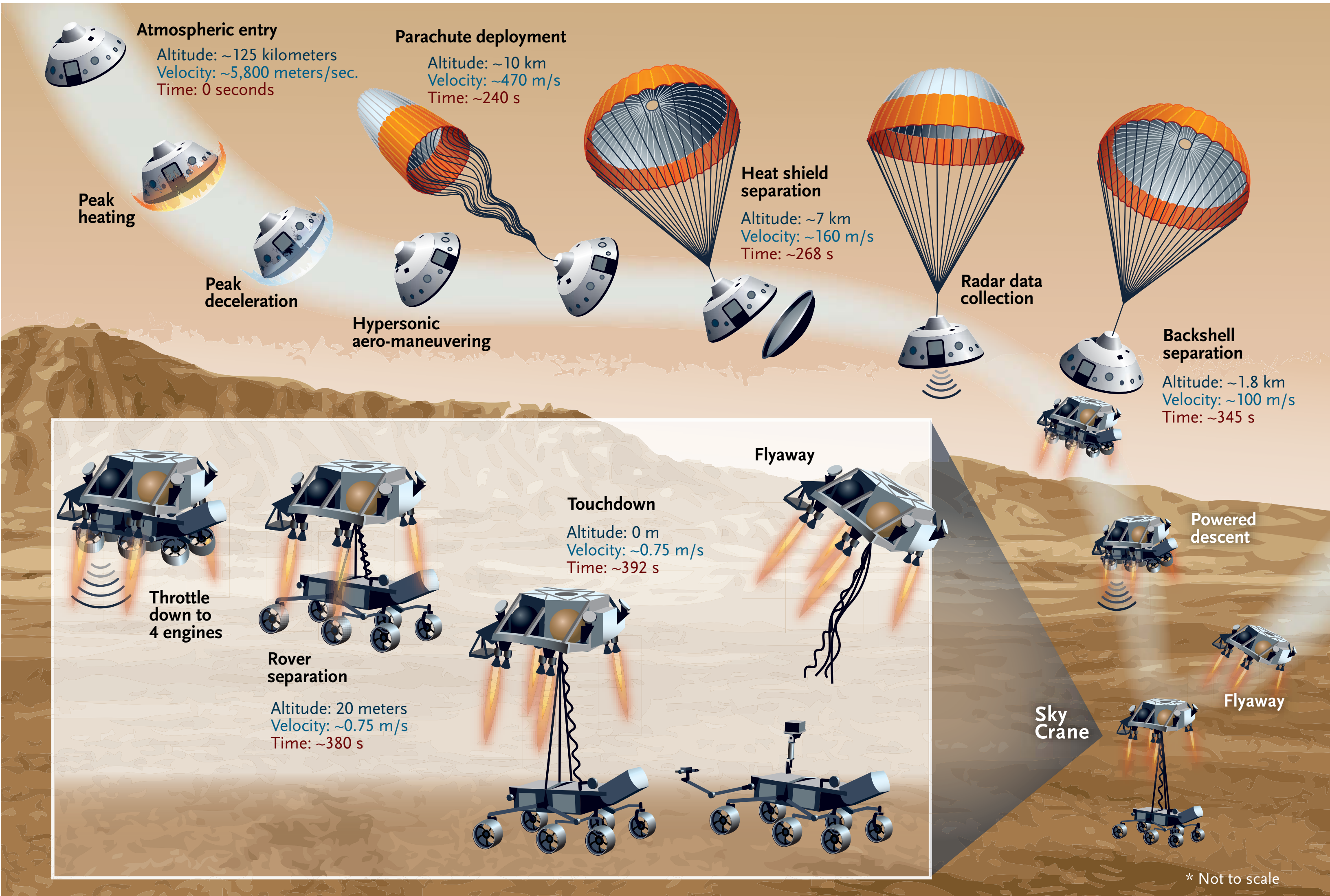
Delays and Overruns

Mars Science Laboratory, as Curiosity was originally called, was selected for flight in 2004. Transforming Curiosity from blueprint to reality required numerous revisions to both software and hardware. Development of the avionics proved to be extremely difficult for such a complex vehicle with so many redundant systems, and the original 2009 launch schedule left insufficient time for testing. The new sample-acquisition and handling systems were also redesigned several times. Originally planned as a rock corer and crusher, the acquisition system had to be changed to a rock-powdering drill. In fact,





GALE CRATER After years of discussion, NASA selected a small target region inside the Connecticut-sized Gale Crater. Orbital observations of the base of the 5-km-high central mound revealed layers of sulfates and clays that likely required water to form. Powered by heat from the radioactive decay of 4.8 kg of plutonium dioxide, Curiosity has a good chance of surviving long enough to venture outside its 20×25-km landing ellipse. North is at bottom.



HOLD YOUR BREATH! Due to its 900-kg (2,000-pound) weight, Curiosity is too heavy to land on Mars using prior methods. Engineers devised Sky Crane, an entirely new way to put a heavy science package on the surface of Mars. If successful, it could pave the way for more ambitious future missions. Sky Crane has been exhaustively tested, and engineers are confident it will work. Watch an animation of the landing sequence at http://youtu.be/E37Ss9Tm36c.

S&T: LEAH TISCIONE / SOURCE: NASA / JPL-CALTECH

Selected Mars Rovers and Landers Compared

Mars landers	Mass (kg)	Number of science instruments*	Average energy used per sol	Mission goal	Mission duration
Viking lander	576	8	1,600 watt-hours (RTG)	Conduct a detailed scientific investigation of Mars, including a search for life.	Lander 1: 2,245 sols Lander 2: 1,281 sols
Sojourner	10.6	1	100 w-hr (solar array)	Demonstrate technology, and determine the elemental abundances in surface rocks.	83 sols / 104-meter traverse
Spirit/Opportunity	185	5	900 w-hr (solar array)	Determine the history of climate and water at sites where conditions may once have been favorable to life.	Spirit: 2,210 sols / 7,730-meter traverse, Opportunity: 2,700+ sols and 33,500+ meter traverse and counting
Curiosity	900	10	2,400 w-hr (RTG)	Explore and quantitatively assess Mars as a potential habitat for life, past or present.	Nominal: 687 sols / 20,000-meter traverse (and possibly longer)

*Instrument totals do not include cameras used for engineering purposes such as hazard avoidance, nor do they include instrument positioning tools such as camera masts, robotic arms, or sampling equipment.

modifications to the sample-handling systems were still being made as the rover was undergoing final testing in early 2011, in response to the experiences of Mars Phoenix.

Phoenix showed that experts had failed to accurately predict how Martian soil would behave. The stuff clumped and clogged the hoppers and sieves that were supposed to funnel samples to Phoenix's analytical instruments. Curiosity's sample-handling mechanisms have been tested for Phoenix-like clumpy soil, so they'll be ready to deal with it on Mars.

But it was a different problem that finally broke the 2009 launch schedule. The mission team had planned to develop a new technology of dry-lubricated motors with titanium parts that would enable the rover to drive at low temperatures, without spending precious power to heat the motors first, permitting more activity in colder weather. Those efforts failed, and they had to go back to the tried-and-true wet-lubricated steel motors. This change occurred so late in Curiosity's development — just a year before the intended launch — that there was insufficient time to build and test the performance of all of the 32 motors necessary to operate Curiosity's arm and wheels (and the duplicates needed for the test rover on Earth). It didn't make the October 2009 launch opportunity. And when you miss the bus to Mars, you have to wait 26 months for the next one. The upcoming launch window runs from November 25th to December 18th.

The challenges, redesigns, and delays cost a lot of money. A brief NASA interest in belt-tightening in 2007 removed some of the rover's science capabilities, including a zoom function on its main cameras, but it failed to deflate the ballooning price. Originally estimated to cost around $1 billion, the mission may wind up costing taxpayers as much as $2.5 billion.

Sky Crane

Pathfinder, Spirit, and Opportunity all bounced down within folded landers that were enveloped by a cocoon of airbags. But with a weight more than twice that of Spirit and Opportunity combined, Curiosity is far too heavy for that approach. There is no way to launch Curiosity to Mars inside a lander big enough to protect it; and even the most durable airbags would shred under the force of its impact. Instead, Curiosity needs to decelerate under the power of retrorockets, but somehow end up separate from its rocket stage, ready to roll, without the benefit of a protective lander.

JPL engineers devised a solution termed "sky crane." A heat shield and parachute will slow Curiosity's descent. It will jettison its heat shield, and then, at an altitude of 1,500 meters (4,900 feet), it will separate from its parachute, leaving the rover attached to the bottom of a descent stage that will fire eight rockets to bring the rover to a hover. Then comes sky crane: the descent stage will deploy cables to lower the rover gently toward the ground as its wheels and legs deploy, until the wheels rest safely on the surface. Curiosity will cut the tethers to its

SKY CRANE The mother ship will use retrorockets to hover like a helicopter about 20 meters above the surface. It will gently lower Curiosity to the ground on cables.
NASA / JPL-CALTECH

A Mission Worth the Price

The general shape of Curiosity's traverse from landing site to steeper terrain will be mapped out far in advance, thanks to MRO's complete coverage of the Gale Crater landing site with aerial photos and topographic maps. Scientists can identify rock targets of interest from space, if they're more than half a meter or so across.

From the moment of the landing between August 6 and August 20, 2012, Gale's central mountain will dominate Curiosity's southern horizon. As it approaches the mound's toe, it will encounter the most ancient rocks, which contain the clays. As Curiosity climbs, it will also be traveling forward through Martian time, into sulfate minerals. Thus the mission's scientists will be reading Mars's watery history in the order in which it happened. Curiosity will examine its environment with an unprecedentedly powerful (not to mention large) assemblage of instruments and tools.

As the rover drives, it will image its surroundings with its color Mastcams and also remotely analyze rock compositions with ChemCam. Once the team has identified an interesting rock from orbit or with Curiosity's remote sensors, the rover will be commanded to approach it, placing it within reach of its robotic arm. If imaging with its MAHLI microscopic imager and elemental analysis with its APXS spectrometer indicate that the rock is worth sampling, the rover will bore into it with its percussive powdering drill.

Transferring a sample from inside a rock to inside the rover will be an arduous, tedious ordeal, especially in the mission's early days, before operators have built confidence in their methods through experience. Pulverized rock powder must be augured up the drill and transferred through a tube into a set of chambers and sieves called CHIMRA. Gravity will guide the rock powder through and out of CHIMRA's mazelike chambers, as the rover performs a series of moves to reorient the turret that its engineers refer to jokingly as "rover tai chi." These maneuvers will parcel out the drilled material into samples of the desired volume, with the preferred grain size, to deliver to two inlet ports on the rover's body that lead to its analytical instruments.

NASA / JPL-CALTECH

PARACHUTE TEST In April 2009 engineers tested the rover's parachute in the world's largest wind tunnel, at NASA's Ames Research Center. The parachute is nearly 16 meters (52 feet) across. Most of the fabric is nylon.

Curiosity's huge size is a product mostly of the requirement that it haul around CheMin and SAM, two complex instruments of a type that are commonly used in geological laboratories on Earth but that have never before been sent to another planet. CheMin will yield the first definitive identifications of the mineral and elemental abundances of sampled rocks and soils. Mineralogy can only be inferred from Spirit and Opportunity's measurements; CheMin can measure mineral composition directly.

SAM focuses on the molecular and elemental chemistry of elements such as carbon, oxygen, nitrogen, sulfur, and hydrogen that are present in Mars's atmosphere and within the planet's rocks and soil. If Curiosity finds organic materials, SAM will make that discovery. SAM can also sniff the atmosphere for methane (CH_4) to see if concentrations and isotopic ratios change over time. Curiosity scientists have no expectation for finding evidence of

Listen to a BONUS AUDIO INTERVIEW

To listen to an audio interview with Curiosity Deputy Project Scientist Joy Crisp, visit SkyandTelescope.com/Curiosity.

mother ship, and the descent stage will pitch at an angle and fly away from the rover as far as its remaining fuel will take it, crashing hundreds of meters away.

This Rube-Goldberg-like autonomous sequence frightens many people, but its development gave engineers relatively few headaches. The landing technology was essentially ready for action for the originally planned October 2009 launch.

With its guided descent, the spacecraft can steer as it passes through the atmosphere to stay closer to its planned trajectory. That produces significantly less uncertainty about where it will touch down. Navigators define a "landing ellipse" as an area within which the craft is about 99% likely to touch down. Spirit and Opportunity had landing ellipses of about 80×20 km, mostly due to uncertainty in the variable density of Mars's atmosphere on landing day. That uncertainty sharply limited the options for those rovers' landing sites to very flat regions. But Curiosity's landing ellipse is only 20×25 km, and that might be narrowed further during flight. The ellipse fits comfortably inside a flat area on the northern floor of Gale Crater, between the crater wall and the central 5-km-high mound. Curiosity is designed to drive far enough to exit its landing ellipse. So once Curiosity has landed safely and completed its commissioning, it will drive southward, making tracks for the enticing layered mound.

life on Mars, but if SAM finds methane gas, the team will be very interested to compare concentration and isotopic measurements with those on Earth, where most atmospheric methane has a biological origin.

The mission has established flexible targets of between 15 and 50 samples over 8 to 20 km of driving during the primary mission, planned to last one Mars year (687 Earth days). Less driving would leave time for more samples, and vice versa. If the rover survives the primary mission in good health, there will be plenty more Martian history to explore.

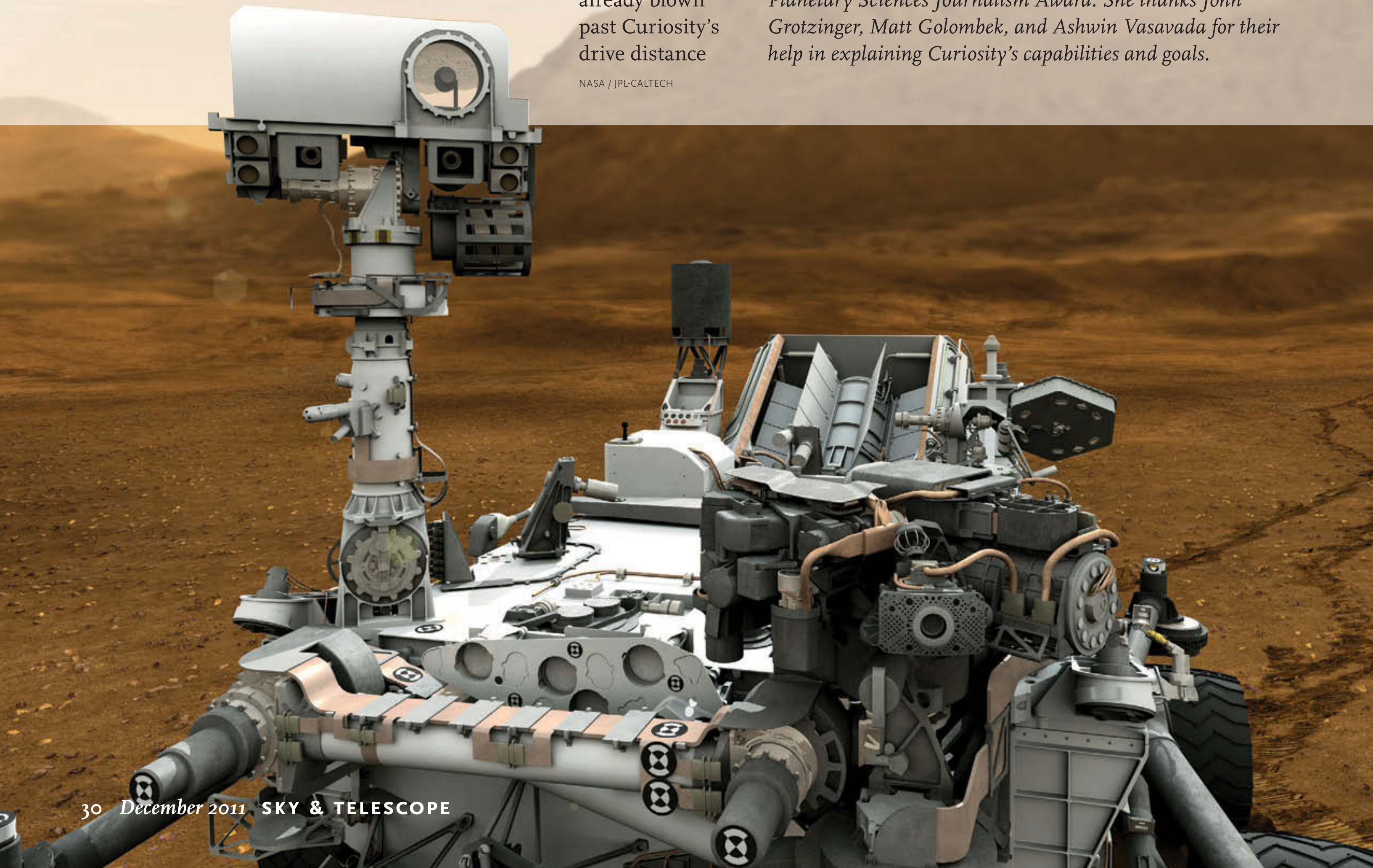
Spirit and Opportunity's bat-wing solar panels give them grace and symmetry. But Curiosity is nuclear powered. The housing for its radioisotope thermoelectric generator (RTG) protrudes awkwardly from the rover's posterior, where it can safely radiate surplus heat. The RTG can theoretically provide sufficient power to operate the rover for at least 14 Earth years, although the decay of its plutonium will decrease its performance over time. Both SAM and CheMin have reusable sample chambers designed for more than 70 analyses, so an extended mission will be highly productive.

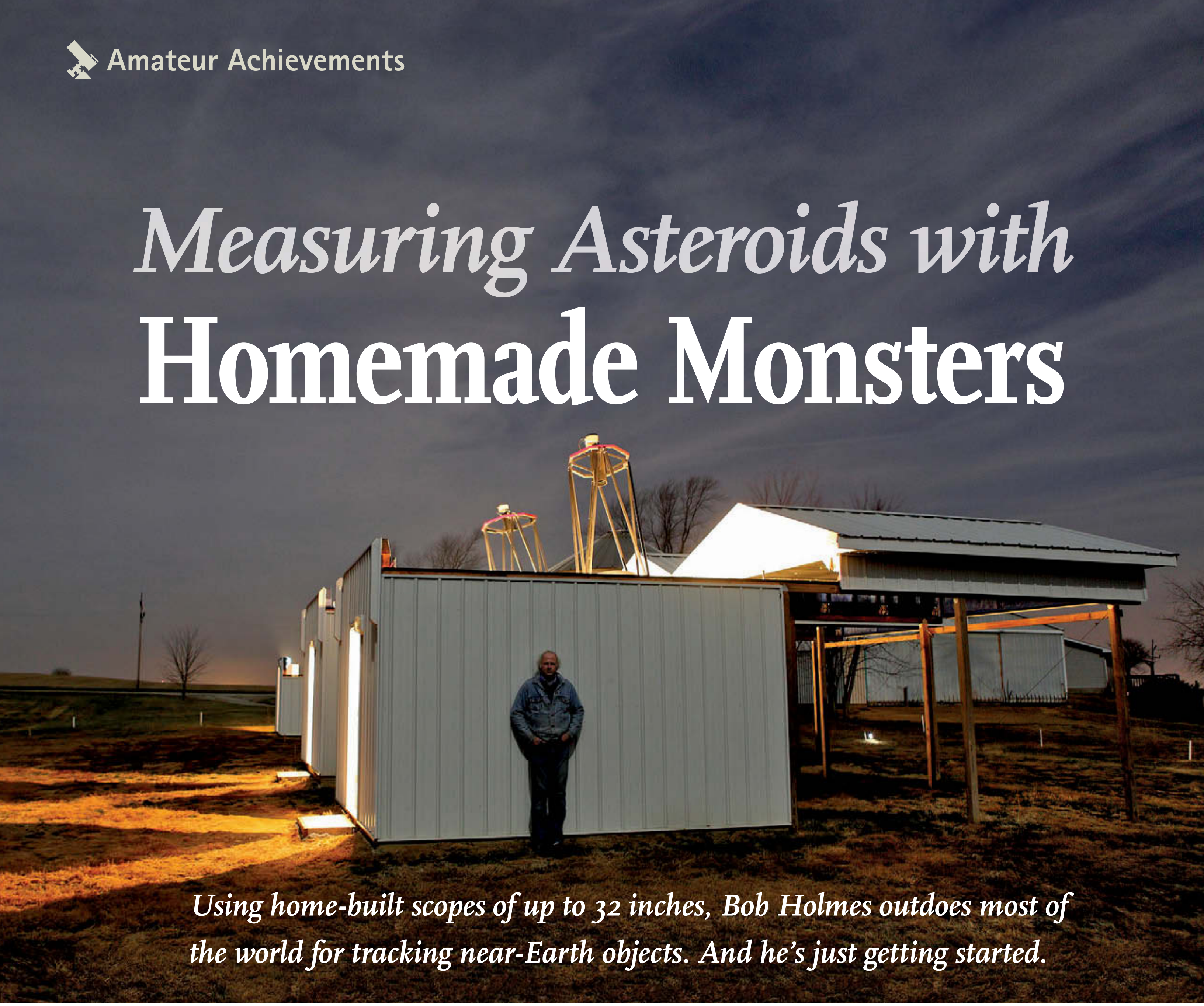
Despite its ambitious goals, Curiosity has a tough act to follow in Spirit and Opportunity. With an odometer reading of 33.5 km at press time, Opportunity has already blown past Curiosity's drive distance goal. And Opportunity may even reach those elusive clay minerals as it explores Endeavour Crater, perhaps even before Curiosity lands on Mars. Beating Curiosity to clays is not an official goal for Opportunity, but its close-knit team of scientists and engineers has imbued that rover with a plucky personality and are rooting for its success. Spirit inspired similar love but also exasperation, surviving tortuous struggles to climb mountains, only to suffer mechanical breakdowns at the most dramatic possible moments.

Will the ungainly Curiosity rover inspire the same kind of devotion? It's unclear yet what its personality will be. After I'd listened to one of the engineers proudly describe Curiosity's capabilities for awhile, I asked whether his peers referred to Curiosity as "it," or as "she." He answered that not many colleagues anthropomorphize the rover or refer to it as female (as is traditional for spacecraft). But he predicted that the situation would begin to change now that the rover is being readied for launch. As it's tested and flown, operators will find Curiosity to have its own unique set of quirks. "It doesn't have a soul yet," he said. "But it will." ✦

S&T *contributing editor and Planetary Society blogger* ***Emily Lakdawalla*** *is the 2011 recipient of the Jonathan Eberhart Planetary Sciences Journalism Award. She thanks John Grotzinger, Matt Golombek, and Ashwin Vasavada for their help in explaining Curiosity's capabilities and goals.*

NASA / JPL-CALTECH





Measuring Asteroids with Homemade Monsters

Using home-built scopes of up to 32 inches, Bob Holmes outdoes most of the world for tracking near-Earth objects. And he's just getting started.

ALL PHOTOS COURTESY OF MIKE LOCKWOOD UNLESS OTHERWISE CREDITED

MIKE LOCKWOOD

It's a still summer night at 2 a.m. Insects chirp and drone. Frogs sing. The air is heavy with dew and the smell of cut grass. An occasional breeze rustles the surrounding cornstalks and soybeans and the branches on a few sentinel trees. Farther out across the flat farmland, insecurity lights dot the horizon, some blessedly obscured by the growing crops.

The sky is clear, so Robert E. Holmes, Jr., and his big instruments are busily working.

Dim light glows from a basement window of the nearby house, betraying Bob's lone vigil. Linked to his desk by network cables, a 24-inch f/4.6 and a 32-inch f/4 telescope follow electronic marching orders in their observatory buildings. CCD cameras at the telescopes' prime foci count photons pixel by pixel. The soothing chords of astronomical work — the whirring of drive motors and the clicking of CCD camera shutters — are sometimes audible over nature's chorus.

Only occasionally does a car drive down the country road in front of Bob's office, headlights briefly illuminating the trees and shrubs. Neither the telescopes nor their operator are distracted.

Bob and his wife Jackie used to live near the glow of Charleston, Illinois, close to an over-lit Walmart. In 2009 they moved 12 miles to this new, much darker location — the outcome of an intense, 10-year astronomical saga.

"Twenty years ago," explains Bob, "I left my astronomy hobby for a career as a commercial magazine photographer. I sold my home-built 14-inch Newtonian to finance this venture. It turned out to be an excellent investment — I've had over 4,600 photographs published in magazines in more than 50 countries worldwide."

But in 1999, after picking up an issue of *Sky & Telescope* in a store, he went to a meeting of the Champaign-Urbana Astronomical Society and then attended a talk by Robert Kirshner at the University of Illinois at Urbana-Champaign. These events rekindled Bob's interest in amateur astronomical research. A commercial 16-inch telescope soon provided his first images and data.

He made two supernova discoveries by repeatedly imaging distant galaxies, and these motivated him to continue farther down the path of imaging for scientific purposes. In 2002 Bob created the not-for-profit Astronomical Research Institute (ARI) to ease the financial burden of running his own observatory, to allow him to apply more easily for grants and donations, and to facilitate outreach to schools, colleges, and students. As he describes it: "The ARI mission was to bring real science directly to the classroom, and provide students with a rewarding hands-on research project that would demonstrate in a small way the opportunities that are possible by continuing with higher education." He named the 16-inch scope's building the Astronomical Research Observatory (ARO).

By then Bob's main interest had turned from the relatively unproductive task of taking hundreds of images looking for rare supernovae, to the more immediate task of imaging and reporting the positions of asteroids and the occasional comet, especially near-Earth objects (NEOs). The Minor Planet Center in Cambridge, Massachusetts, receives his data; Bob joined hundreds of observatories, amateur and professional, that contribute positions to determine the precise orbits of these objects. The better an orbit is known, the clearer it becomes whether an object poses an impact threat to Earth, the Moon, or another planet.

In particular, the MPC posts a "wish list" of objects needing more position measurements. These include objects that were lost and have to be recovered, objects needing more accurate orbits, and newly discovered objects that need immediate confirmation and tracking.

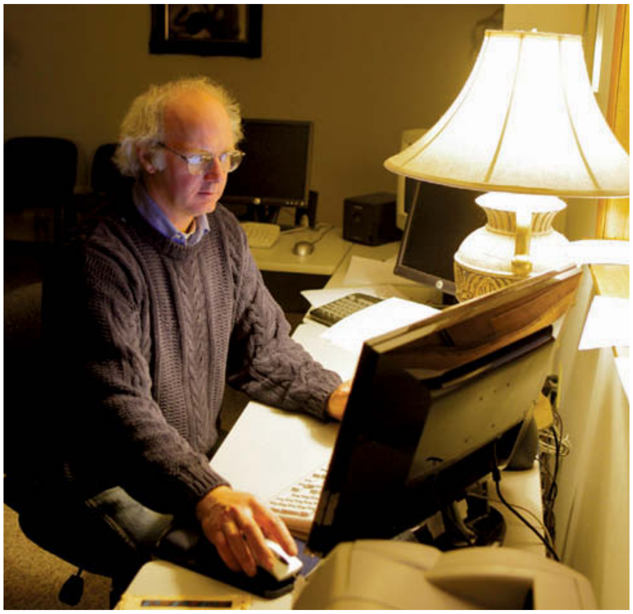
Bob is particularly dedicated to educational outreach. He shared images and data with other researchers and eager students early on. A pilot program involving a high-school teacher and students in North Carolina in 2006 produced several dozen new asteroids and a few supernovae. But this pushed the 16-inch telescope to its limits. Its relatively long (f/10) focal length meant that, even with a focal reducer, the telescope's field of view was narrow, so it was easy for him to miss his target if the object's position was not precisely known. And 16 inches just wasn't very big. "Making discoveries using the 16-inch reflector became increasingly difficult for students," Bob recalls, "as undiscovered objects became fewer and fainter." Bob decided that a larger instrument was in order.

WORKHORSE **Bob Holmes with his fork-mounted 32-inch telescope. All of his scopes have large CCD cameras permanently mounted at the focus; there's no place for an eyepiece.**

Building a Bigger Scope

By 2003 he was drawing up the plans for a 32-inch f/4 fork-mounted, truss-tube Newtonian with a CCD camera permanently installed at its prime focus. Such an instrument could image objects fainter than 23rd magnitude, a realm few other amateurs could reach. Small, faint asteroids are far more numerous than larger ones and thus pose a greater impact risk to Earth. Yet even with twice the aperture the new telescope was designed to have a larger imaging field of view, covering more sky in each image. All Bob had to do was build it.

On a shoestring budget, Bob designed and built his 32-inch professional-quality instrument himself, and then



THE CONTROL ROOM Most of the time, Holmes runs his telescope farm in indoor comfort.

later a 24-inch. Luckily, Bob had friends who were up to the task of doing the optical work and machining critical drive components. In his garage shop he used a hand grinder to cut steel plate into telescope parts. He wore out several grinders in the process. He welded the parts for the 32-inch, including its massive fork mount, in the same modest shop, using an engine hoist to move heavy steel assemblies.

He completed the telescope body in 2005. "Installation in the observatory proceeded very smoothly," he says, "and the major telescope components were assembled in just over two hours." But it still lacked a primary mirror. The optical company he paid to do the work proved incapable of it and shipped the mirror back to Bob, at his expense, in a crate that was literally falling apart. The mirror was scratched and badly astigmatic with surface roughness; in other words, unusable.

Another company finished the mirror, and in June 2006 the 32-inch was finally complete. After debugging problems with collimation, the mirror cell, and the coma corrector, the telescope began producing a river of quality data that rivaled larger professional instruments. To this day, Bob regularly hears that his 32-inch scope in a cornfield produces NEO data that rivals or beats that from much larger professional instruments on mountaintops.

SMALL SCOPES? Holmes's 24-inch Newtonian is the smallest on his telescope farm. It took the image on the facing page. *Right:* A donated 30-inch Ritchey-Chrétien is used by high-school and college students, who run it from remote locations.

Settling In

Although the temperature, sounds, and environment change with the seasons, Bob's routine became steady after the completion of the 32-inch. Every clear night he began observing at the end of twilight and went to sleep only with the arrival of clouds or dawn. For a year Bob kept this demanding schedule while working days as a photographer. He made his astronomical images available for download by interested high-school and college classes so that students could search for and share in the discovery of new asteroids.

Most objects that Bob images are moving, often rapidly, so accurate pointing and short exposures are necessary. This is what his scopes were built for. An image that successfully captures an elusive object yields valuable position and brightness data. Images are analyzed with software, and the resulting data goes by email to the Minor Planet Center.

In 2007 a NASA grant changed Bob's role from sleep-deprived volunteer to paid, professional data gatherer and observatory operator. He had impressed NASA with the quality, quantity, and reliability of his data to the point that they began to fund it. Bob closed his photography studio to devote himself fully to astronomy.

Not the type to be bored, he filled his free daylight hours building a new, lightweight 24-inch Newtonian, again with a camera permanently at its prime focus. At his former location, he added a second observatory and installed the 24-inch inside it on a Paramount equatorial mount.

Bob now focuses (pun intended) solely on his telescope duties and maintenance, writing grant proposals for new equipment, spending time with his understanding and supportive wife Jackie — and now building a 50-inch telescope to expand his imaging capabilities. Occasionally he sleeps.

If you get to know an unusual and capable person, you often find more that's unusual. Bob used to build model airplanes and rockets capable of reaching hundreds of miles per hour. With some construction background, Bob

GOT ONE! **The near-Earth object NEO 2009 XR2 (arrowed) was moving past the Horsehead Nebula in Orion when Bob Holmes imaged it with the 24-inch scope on January 6, 2010.**

built all of his observatory buildings himself from the ground up, fast and cheap. At his current location he built the three observatory buildings pictured on the next page and recently completed a larger fourth for the 50-inch.

In 2008, Bob's old observatory near the lights of town produced 11,593 observations of asteroids and NEOs accepted by the Minor Planet Center (MPC). This was more than any other individual or professional observatory (most of which had larger instruments) in the world that year. In 2009 he produced 7,893 observations while also working to move to his new location.

Bob explains: "One advantage of the Midwestern location are the observations we make during the summer months, when the Southwestern observatories are closed due to the monsoon season. In the summer of 2011, ARO worked 66 out of 75 nights, producing more than 2,200 NEO measures and confirming hundreds of potentially new NEO discoveries made by PanSTARRS," one of the next generation of giant professional sky surveys. "During the same time period all other observatories in the entire U.S. made just over 1,250 measures — including PanSTARRS."

He made nearly all his early observations from an altitude of 721 feet less than a mile from a badly overlit apartment complex and a Walmart parking lot striving for permanent daylight. In one direction down the street, a neighbor had bright lights that would occasionally interfere with scientific work. In the other direction, every night an inconsiderate church shone a parking lot spotlight directly at Bob's house, casting shadows on his property from a distance of a quarter mile, despite Bob's repeated requests for it to be re-aimed or replaced.

Under these conditions Bob produced data accepted by the MPC for objects as faint as magnitude 23.7, and he imaged stars fainter than that. The telescope was carefully baffled against stray light, and the interior of the observatory was painted a dark color.

Bob and Jackie's new 40-acre tract, all their own, has meant not only more room for observatories but a larger buffer zone between them and neighbors' lights.

The property already had a house. The relatively lightweight 24-inch telescope was easily disassembled and moved. The 32-inch required a crane to lift parts out of the old observatory and onto trucks. After everything was reassembled, realigned, and rewired, in November 2009 Bob resumed observations under a new MPC observatory code: H21. Only after the telescopes came back to life did the couple complete the move of their household!

Even prior to the move, however, Bob had begun an ambitious new project: a 50-inch scope, to increase

For more information, see the Astronomy Research Institute site, www.astro-research.org.

ONE PROJECT, THREE OBSERVATORIES Bob Holmes stands in the doorway of his 32-inch automated telescope. The 30-inch is at left; the 24-inch at right. On the empty ground between them, construction is now nearing completion for his new 50-inch scope. All the scopes run at once, controlled remotely.

productivity. Next to the other two new observatories he staked out a site for its building. But first came a third, smaller observatory. This one houses a donated 30-inch instrument that is mostly run by students via the internet. Modernizing and debugging the drive system took more time and work than expected, but the 30-inch came online in 2010.

Bob then devoted his "spare" time to the 50-inch project. A huge fork mount rose from a pile of metal in his shop. The base of the mount was next. As of this writing, most of the telescope is complete except for the primary mirror itself.

Position Measures of Faint Near-Earth Objects in 2010

Observatory	Max. aperture	Measurements
Magdalena Obs.	2.4m	2,907
David Tholen team	2.2m	621
Mark Trueblood	2.1m	292
Spacewatch II	1.8m	5,406
PanSTARRS	1.8m	779
Mt. Lemmon	1.5m	7,109
Spacewatch I	0.9m	1,510
Tenagra II	0.81m	2,187
Robert Holmes / ARO	**0.81m**	**11,492**
WISE Space Telescope	0.41m	10,360

Only the Start

"From the very beginning education and public outreach has been an important element of our research." Holmes insists. "Putting current data in the hands of teachers and students directly in the classroom continues to be a major focus. Each night we work, about 3 gigabytes of images are uploaded to our FTP site for student researchers less than 12 hours after acquisition. Through our work in NASA education and public outreach programs, we reach about 300 schools in 40 countries each year."

He continues: "I think what sets ARO apart from most other observatories is our passion for the science. When we were told that the telescopes we were using were simply not large enough for NEO observations, we built our own from scratch. When the site was no longer dark enough for faint observations, we moved all our instrumentation and built new observatories to produce the best observations that we possibly can in the Midwest."

Based on past experience, Bob won't stop until the new 50-inch is performing superbly, and then he will start planning some new instrument or endeavor, which will cost him even more sleep... and so goes the life astronomic on the Holmes telescope farm. ✦

*Professional optician **Mike Lockwood** manufactures large telescope optics and made the mirrors for Holmes's big scopes.*

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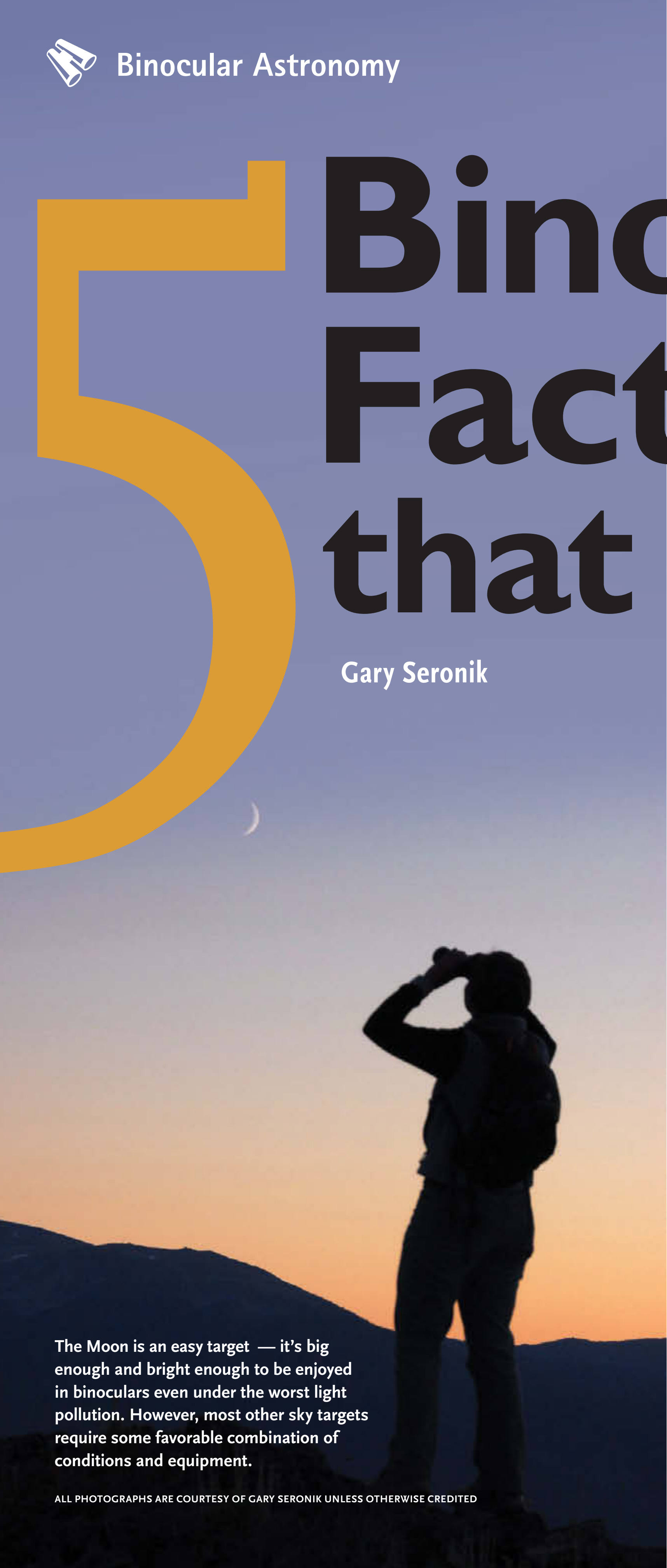
5 Binocular Factors that Matter

To see, or not to see — that is the question.

Gary Seronik



The Moon is an easy target — it's big enough and bright enough to be enjoyed in binoculars even under the worst light pollution. However, most other sky targets require some favorable combination of conditions and equipment.

ALL PHOTOGRAPHS ARE COURTESY OF GARY SERONIK UNLESS OTHERWISE CREDITED

Binocular stargazing is full of surprises. Sometimes you stumble across a pretty cluster and wonder how you'd previously missed it. Other times, you hunt and hunt for a galaxy listed at 8th magnitude, only to come up empty handed. It's enough to make you wonder — what makes one object a binocular standout and another a difficult challenge? Compiled here are the five most important factors that determine whether a deep-sky wonder will turn out to be binocular trash or treasure.

5 Aperture Rules

You've heard the mantra many times: aperture wins — and wins big. Certainly when it comes to telescopes, the diameter of the objective lens or mirror trumps just about every other consideration. And aperture is also very important in the binocular universe. All other things being equal, the more light-gathering power your binos have, the fainter you're going to be able to see, and the more likely you'll be able to detect elusive deep-sky objects. But all things are rarely equal.

For example, not all 10×50s are created equal — some models have better optical quality and more effective coatings than others. But one aspect that isn't often considered is the fact that many binos don't make full use of their objective lenses. Indeed, one pair of cheapo 10×50s I own are functionally 10×40s. Similarly, my low-cost 15×70s are really 15×66s. What's going on? In both cases, the internal construction and optics are choking off some of the light.

You can check to see if your binoculars are living up to

An easy way to measure the effective aperture of your binoculars is to shine a light into one of the eyepieces and measure the diameter of the emerging beam of light.

specs by employing a fairly simple test. All you need do is shine a flashlight into one of the eyepieces and measure the diameter of the beam of light emerging from the objective lens, as shown in the picture above. A flashlight with a narrow, well-defined beam, such as an LED light, works best. Position the flashlight an inch or two behind the eyepiece so that you get a sharply defined disk of light projected onto a card or nearby wall. Measure the disk's diameter and you'll know within a couple of millimeters what the effective aperture of your binoculars really is. You might be surprised by what you find.

4 Steady as She Goes

How steady you hold your binoculars has a huge impact on how much you can see — and I mean *huge*! Of all the factors that go into plumbing the depths of the binocular sky, image steadiness is probably the one that's least appreciated. Try this experiment yourself: Look at a field of stars and note the magnitude of the faintest ones you can see (planetarium software or charts from the AAVSO are particularly good for this task). Now mount your binos on a tripod and look again. You'll likely find that you've just gained a full magnitude, or perhaps even more.

Steady views are the reason so many experienced observers are fans of image-stabilized binoculars. These opto-mechanical wonders yield wonderfully steady views, but without the awkward posturing, neck strain, and added encumbrance that comes with using a tripod. The downside is that image-stabilized optics cost and weigh quite a bit more than conventional binoculars and need batteries to operate.

You can also buy or build a dedicated binocular mount that will work far better than a camera tripod. We have run many articles in this magazine over the decades that detail how to make suitable supports, most recently in the August 2010 issue, page 68.

3 Magnification Adds Up

I have 30-mm binos that outperform a 50-mm pair. It's true. My 10×30 image-stabilized binoculars actually go deeper than my budget 7×50s. Image stabilization and better optics are part of the equation, but an even bigger factor is the greater magnification of the 10×30s. For observers accustomed to telescope magnifications, it might be hard to imagine that 3× can make much of difference, but in the binocular universe, every 1× is a significant jump.

To understand why, consider what magnification does to the view. First and most obviously, it makes things appear larger. That's important, because as more of your field of vision is occupied by a deep-sky target, the likelier it is you're going to detect it — especially if it's on the threshold of visibility. But at the very low magnifications found in standard binoculars, extra power plays an even more important role. Upping the power really helps distinguish small deep-sky targets from field stars. Many globular star clusters and most planetary nebulae are easy to overlook simply because they're so tiny. Countless galaxies also fall

Left: Image-stabilized binoculars such as these are a boon to stargazers. They provide the stability of tripod-mounted binos, but retain the instrument's quick-look, easy use appeal. The 10×30s (left) are stellar performers, while the 15×45s provide the extra magnification and aperture needed to locate difficult objects. *Right*: A simple yet effective binocular mount can be made with just a few readily available camera-store items and a little ingenuity. Details on how to build this particular rig ran in the August 2010 issue.

These photos of the Andromeda Galaxy simulate the effects of increased magnification. In the 10×50 view, the galaxy is larger and the background sky appreciably darker. The 7×50s, however, provide a more expansive field of view.

into this category. The difference between 7× and 10× is often enough to enable you to positively identify a deep-sky object that you would have otherwise overlooked.

A second, less obvious benefit of raising the magnification is that, for a given aperture, doing so darkens the background sky, which helps make faint objects easier to see. But note the proviso, "for a given aperture." It may be counterintuitive, but the background sky in 10×50s will be darker than in 7×50s even though both have 50-mm objective lenses.

What really determines the background sky's brightness is the diameter of a binocular's exit pupil — the round disks that appear to float in the eyepieces when you hold the binoculars at arm's length. Generally, the smaller the exit pupil, the darker the background. Exit-pupil size is calculated by dividing the diameter of the objective lens by the magnification. For example, 10×50s will have 50 ÷ 10 = 5-mm exit pupils. So it follows that you should choose the model with the highest magnification to get the smallest exit pupil in a given binocular size. The main downside to more power is that the field of view shrinks as the magnification goes up. That's why I prefer 15× binos for general observing to those featuring 18× or 20×.

Sky & Telescope **senior editor Dennis di Cicco shot the same section of the Milky Way from a rural location (*left*) and his suburban backyard. Light pollution degrades the binocular view of the Andromeda Galaxy just as much.**

2 Bright-Sky Blues

Being able to see a particular deep-sky object depends on a complex relationship between three things: your observing skill, your binoculars, and your skies. And of these factors, the latter is usually the most crucial. Sadly, for most of us, dark skies are a rare treat enjoyed only on occasional weekend getaways or at summer star parties. And that's too bad. Observing under pristine conditions makes binocular targets so much easier to see, even if your equipment isn't the best of the best. That said, there are steps you can take to get the most of out of your backyard sky.

First, make sure that you're sheltered from direct light sources. You might not be able to do much about the dull orange light dome overhead, but a dark-colored T-shirt pulled over your head to block out a neighbor's porch lights can really make a big difference. Alternatively, if you only have to contend with lighting from one direction, a well-placed tarp hung from a line or fence can work wonders.

Another strategy is to plan your observing sessions with a little care. If possible, make use of the pre-dawn hours when light pollution is at its minimum. When I lived in suburban Boston, I did the majority of my observing for my *Binocular Highlight* column early in the morning. I was amazed how much better conditions were then compared with just a few hours earlier. You can also improve matters by utilizing the first clear nights after a weather system has moved through your region. Under these conditions you normally will experience very transparent skies — and the better the transparency, the less troublesome light pollution is.

1 Magnitude Matters

Without doubt, the most important visibility factor is how bright a deep-sky object actually is. Really bright targets can be seen under light-polluted skies with modest equipment, while faint ones demand darker conditions and better gear. But there's more to this than meets the eye.

Although you can look up the brightness of any deep-sky object, you have to be a little careful about treating that number as a definitive indicator of an object's visibility. The listed magnitudes for large, extended objects often give only a ballpark indication of visibility. Take the galaxy Messier 33, in Triangulum, for example (page 45). Most sources list it around magnitude 5.8, which should make it a piece of cake in binoculars even under suburban skies. But here's the rub — the galaxy's brightness is spread out over a 71′ × 42′ oval — more than three times the area of the full Moon. That gives it a low *surface brightness* (intensity) and makes it a tricky object under bright skies.

Some sources show surface brightness as well as overall brightness. M33's surface brightness is listed around magnitude 14.4 per square arcminute. Messier 81, in Ursa Major, shines at magnitude 7.3 — just a quarter as bright as M33 — but it's much smaller. That gives it a surface brightness of magnitude 13.6 per square arcminute, twice as intense as M33. And in fact, M81 is much easier to spot.

What Doesn't Matter

The five factors outlined above are the most important, but there are obviously others to consider. For example, some equipment junkies obsess over the quality of the lens coatings. Typical binoculars have about 10 air-to-glass surfaces. If the binoculars had no coatings at all, each surface would reject about 4% of the incoming light, and only ⅔ of it would reach your eyes. But as bad as this sounds, it's less than a ½-magnitude brightness drop. Almost all modern binoculars have some kind of coatings, so it's hardly ever that bad in practice. Coatings do matter, but they're rarely a make-or-break factor.

Many aspects of binocular construction amount largely to personal preference — for instance, focuser style. Most binoculars use a convenient center-focus control that moves both eyepieces back and forth to achieve focus. Another scheme requires adjusting each eyepiece individually. In theory, individual focus is more robust and should help keep the optics in good alignment. In my experience though, even budget-model binos with center-focus adjustments work reasonably well.

Prism design is another topic of frequent debate. Porro-prism models are more common than the roof-prism binos, but excellent binoculars are made utilizing both arrangements. Granted, budget-priced roof-prism binoculars lacking "phase coatings" can be noticeably inferior to similarly priced porro-prism models. But for high-quality binoculars, the deciding factor might be simply which one feels more comfortable in your hands.

I also see a good deal of fretting (and confusion) over exit-pupil size. Some boldly state that binoculars must have 7-mm exit pupils to be useful for astronomy. As the previous discussion about magnification explains, this claim is nonsense. Others argue that binoculars with exit pupils of 3 mm produce views that are too dim for nighttime use. Again, this doesn't bear close scrutiny. My advice when it comes to selecting binoculars for astronomy is to not worry about exit pupil size at all. You'll do fine if you choose on the basis of magnification and aperture.

Putting It All Together

Every binocular observer's dream is to utilize the finest equipment under pristine, dark skies, but that's simply not the reality for many of us. We use the gear we have, and usually from the location that's most convenient. And though failure can be disappointing, it's important to remember that every time an object eludes your grasp, you have the chance to learn something about your equipment, skills, and observing conditions.

Over many years of viewing the night sky, I've come to realize that most of the time when I fail to locate an object, it's because I'm either not looking in exactly the right place, or my expectations are out of whack with reality. And the latter is by far more common when it comes to binocular observing. Before getting out the binoculars, check out the size and magnitude of your target, then take a moment to imagine how it should look in your binos under your sky conditions. Sometimes the answer is "very small, and very faint" — and knowing that beforehand can be the key to actually finding an elusive deep-sky wonder. ✦

*Contributing editor **Gary Seronik** views the night sky with an armada of equipment that includes several binoculars and a collection of home-built telescopes. He can be contacted through his website: www.garyseronik.com.*

Fred Schaaf

The Longest Nights

In the eastern sky, a tall tower of dazzling stars heralds the advent of winter.

'Tis the year's midnight, and it is the day's:
Lucy's, who scarce seven hours herself unmasks.
The sun is spent, and now his flasks
Send forth light squibs, no constant rays;
The whole world's sap is sunk . . .

— John Donne, *A Nocturnal upon St. Lucy's Day, Being the Shortest Day*

ST. LUCY'S DAY is December 13th, but it was once considered to be the shortest day of the year. The name Lucy means "light," and in parts of Scandinavia girls still don a headpiece decked with candles to bring light to the world at its time of deepest darkness.

Many cultures around the world hold festivals of light to symbolize cheer and hope in this season of the shortest days. Astronomers have their own headpiece of lights to put on at this time of year. It's the tower of bright constellations dominating the east on these December evenings.

Tower of brilliance. What are the components of this tower? Look at the all-sky map in the center of this issue and turn it around so its "Facing East" horizon is at the bottom, right-side up. Just above that horizon is bright Orion. Betelgeuse and Rigel, his shoulder and knee (or foot) stars, outshine even his irresistible three-star Belt, now nearly vertical. Left of Orion, low in the east-northeast, is Gemini, dominated by Pollux and Castor.

CLAUDIA GRÜNDER / WIKIMEDIA COMMONS

A Swedish girl wears a headpiece of candles for St. Lucy's Day.

But Orion and Gemini are just the base of the tower, which reaches all the way to the zenith.

The zenith is held by the bright constellation Andromeda, the chained maiden of Greek mythology. Andromeda contains three 2nd-magnitude stars in a long, gentle arc. The western end of the arc is Alpheratz, the star that Andromeda loans to help form the Great Square of Pegasus. Alpheratz is already a little past the zenith.

Cassiopeia, the constellation of Andromeda's mother, stands to her left as you face east and crane your head up to look overhead.

Turning elsewhere for a moment, the mythological Andromeda was chained to await a sea monster represented by Cetus, the Whale. Cetus is in the trailing (eastern) edge of a vast region of sky dimness: the Water or Great Celestial Sea, lower in the southeast to southwest.

Just as Andromeda needed to be rescued from the sea monster, we're now being rescued from too long an expanse of this dim sky. In the myth, her rescuer was the hero Perseus. In the sky, Perseus floats just below Andromeda and her bright zigzag of a mother.

Perseus is brighter overall than Andromeda but has only two 2nd-magnitude stars, and one of them isn't always 2nd magnitude. I'm talking about Beta Persei, the bright eclipsing binary Algol, which dips from magnitude 2.1 to 3.4 for a few hours every 2.867 days.

To the right of Perseus (again facing east and craning our necks) is little Aries. It's not much as constellations go but adds a couple of stars to the overall tower of light.

There's one more story of brightness in our tall tower, below Perseus and Aries but above Orion and Gemini. This consists of Auriga the Charioteer on the left, with blazing Capella, and Taurus the Bull on the right, featuring Aldebaran, the Pleiades, and the Hyades.

Night festival. Astronomers actually like long nights — as long as those nights are clear and full of their special bright lights. So we can celebrate with Lucy:

Let me prepare towards her, and let me call
This hour her vigil, and her eve; since this
Both the year's and the day's deep midnight is. ✦

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

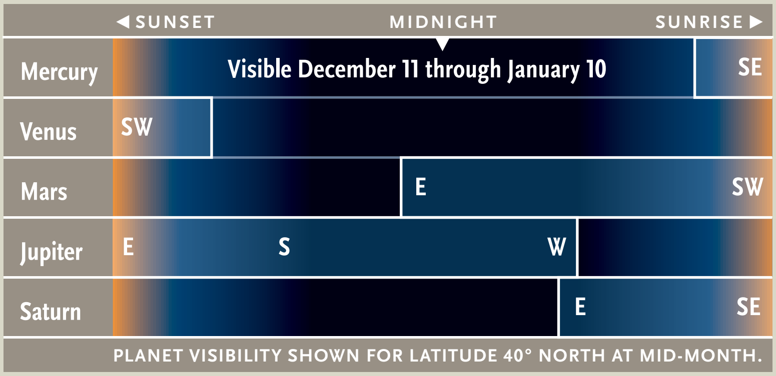
Sky at a Glance

SKY & TELESCOPE

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

PLANET VISIBILITY



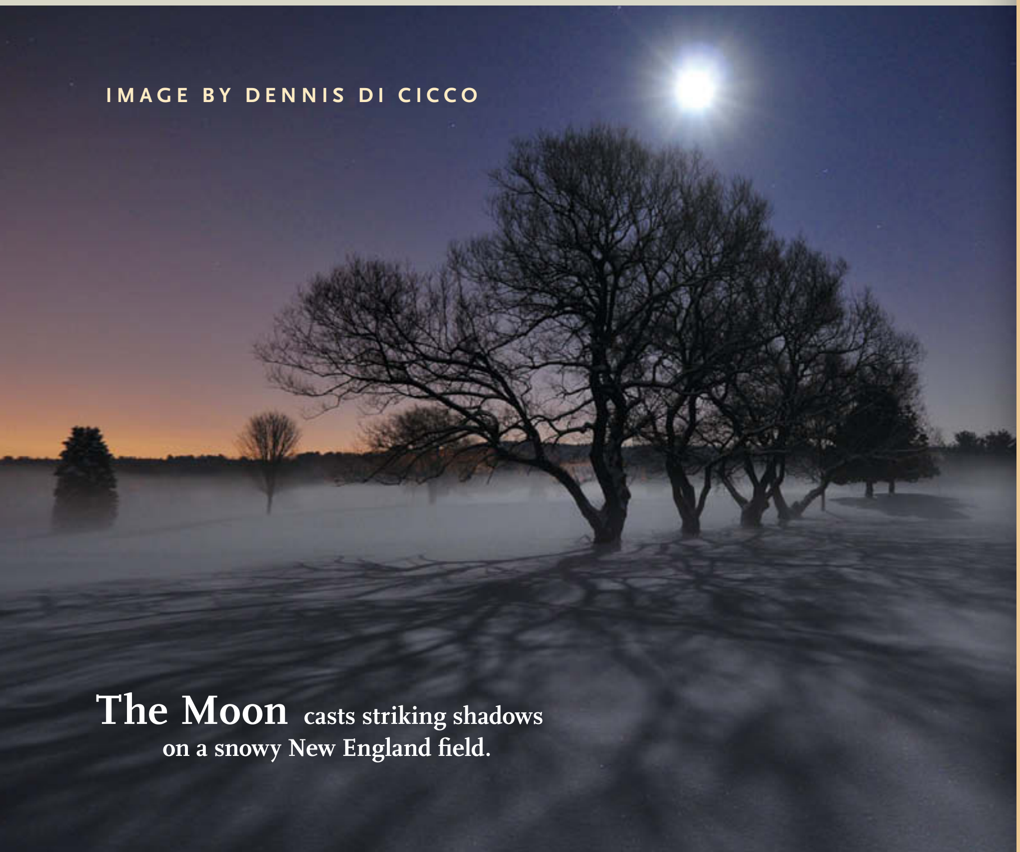


IMAGE BY DENNIS DI CICCO

The Moon casts striking shadows on a snowy New England field.

December 2011

2 FIRST-QUARTER MOON (4:52 a.m. EST).

6 EVENING: Jupiter shines right or lower right of the waxing gibbous Moon (for North America), as shown on page 48.

7 EVENING OR NIGHT: Algol is at minimum brightness for roughly 2 hours centered on 8:56 p.m. PST (11:56 p.m. EST); see page 59.

10 FULL MOON (9:36 a.m. EST).

PREDAWN AND DAWN: A total lunar eclipse is visible in western North America. See page 58 for details of the eclipse's visibility there and across the Pacific, Asia, and parts of Europe.

13, 14 NIGHT: The Geminid meteor shower is due to peak around 1 p.m. EST on the 14th, so it's best observed from North America on both the preceding and following nights. However, the fat gibbous Moon will hide all but the brightest meteors.

14–28 DAWN: Mercury is bright and relatively high in the southeast, 8° to 10° above the horizon 45 minutes before sunrise (at latitude 40° north).

17 LAST-QUARTER MOON (7:48 p.m. EST).

19, 20 DAWN: The waning crescent Moon is upper right of Saturn and Spica on the 19th and below them on the 20th.

21–22 THE LONGEST NIGHT of the year in the Northern Hemisphere. Winter starts at the solstice, 9:30 p.m. PST or 12:30 a.m. EST.

22 DAWN: The thin crescent Moon is upper right of Mercury low in the southeast 45 minutes before sunrise.

23 DAWN: The very thin crescent Moon is well below Mercury and a little to its left.

24 NEW MOON (1:06 p.m. EST).

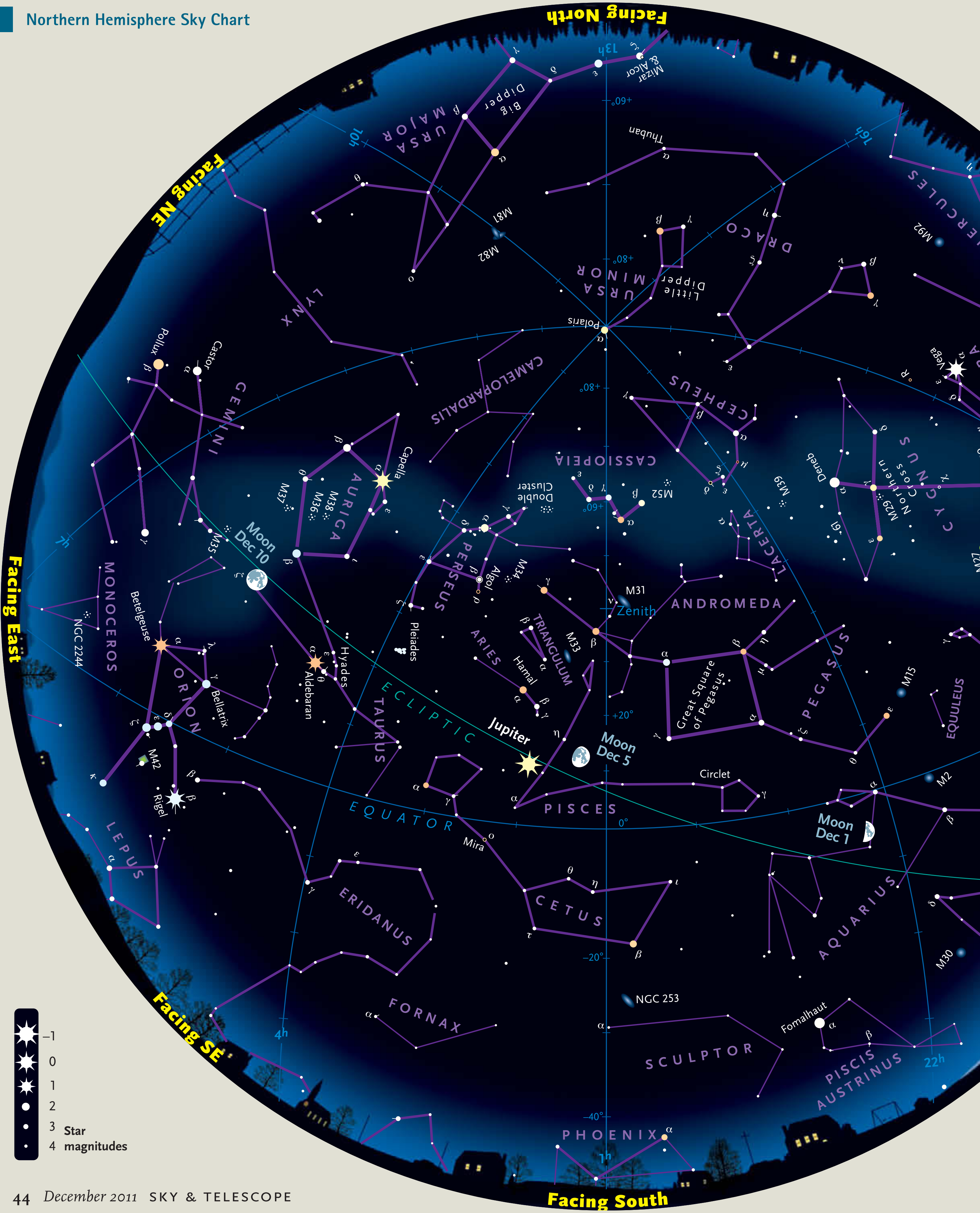
25 DUSK: The very thin crescent Moon is visible low in the west-southwest 30 to 60 minutes after sunset.

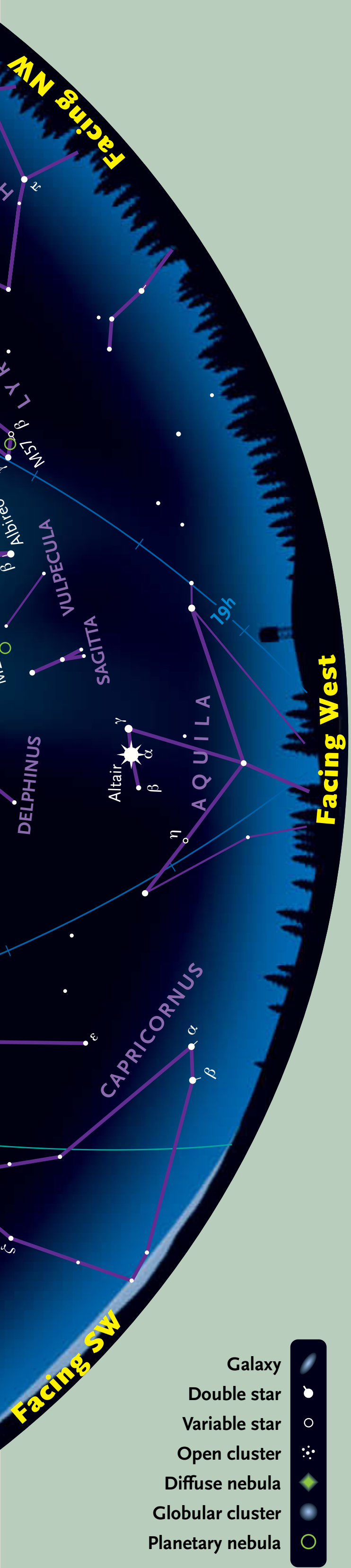
26 DUSK: Venus shines left of the thin crescent Moon, a lovely sight; see page 49.

27–28 NIGHT: Algol is at minimum brightness for roughly 2 hours centered on 10:41 p.m. PST (1:41 a.m. EST).

30 EVENING: Algol is at minimum brightness for roughly 2 hours centered on 10:30 p.m. EST (7:30 p.m. PST).

See SkyandTelescope.com/ataglance for details on each week's celestial events.


Facing North
Facing NE
Facing East
Facing SE
Facing South
URSA MAJOR
Big Dipper
Mizar & Alcor
Thuban
M81
M82
LYNX
DRACO
URSA MINOR
Little Dipper
Polaris
M92
HERCULES
Vega
CAMELOPARDALIS
CEPHEUS
CASSIOPEIA
Double Cluster
M52
M39
Deneb
Northern Cross
M29
CYGNUS
LACERTA
Pollux
Castor
GEMINI
Capella
AURIGA
M37
M36
M38
M35
Moon Dec 10
MONOCEROS
NGC 2244
Betelgeuse
Bellatrix
ORION
M42
Rigel
LEPUS
PERSEUS
Algol
M34
Pleiades
Hyades
Aldebaran
TAURUS
ARIES
Hamal
TRIANGULUM
M33
M31
Zenith
ANDROMEDA
Great Square of Pegasus
PEGASUS
M15
EQUULEUS
Jupiter
ECLIPTIC
Moon Dec 5
PISCES
Circlet
M2
Moon Dec 1
EQUATOR
Mira
ERIDANUS
CETUS
AQUARIUS
M30
FORNAX
NGC 253
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
13h
10h
16h
7h
4h
1h
22h
+60°
+80°
+20°
0°
–20°
–40°
Star magnitudes
–1
0
1
2
3
4



Using the Map

WHEN

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

*Daylight-saving time.

HOW

Go outside within an hour or so of a time listed above. Hold the map out in front of you and turn it around so the yellow label for the direction you're facing (such as west or southeast) is at the bottom, right-side up. The curved edge is the horizon, and the stars above it on the map now match the stars in front of you in the sky. The map's center is the zenith, the point overhead. Ignore all parts of the map over horizons you're not facing.

Example: Rotate the map so that "Facing NE" is right-side up. About halfway from there to the map's center is the bright yellowish star Capella. Go out, face northeast, and look halfway up the sky. There's Capella!

Note: The map is plotted for 40° north (the latitude of Denver, New York, and Madrid). If you're far south of there, stars in the southern part of the sky will be higher and stars in the north lower. Far north of 40° the reverse is true. Jupiter is positioned for mid-December.

You can generate a sky chart that's customized for any location and any time at SkyandTelescope.com/skychart.

Watch a SPECIAL VIDEO

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

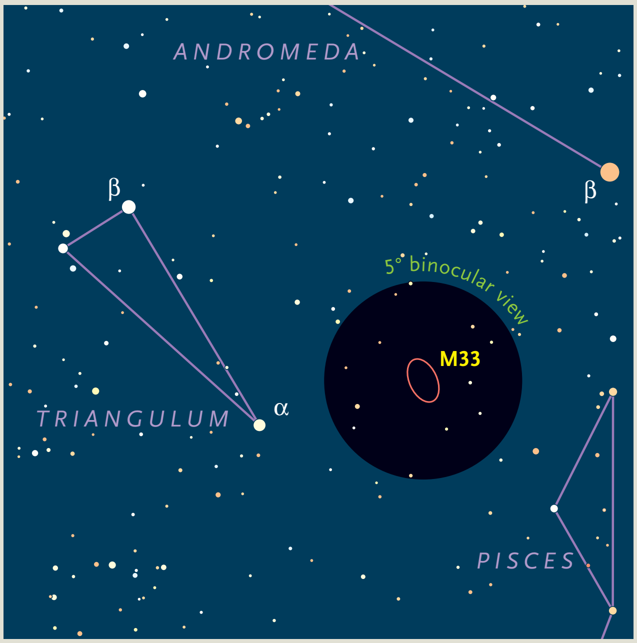
Binocular Highlight: Triangulum's Treasure

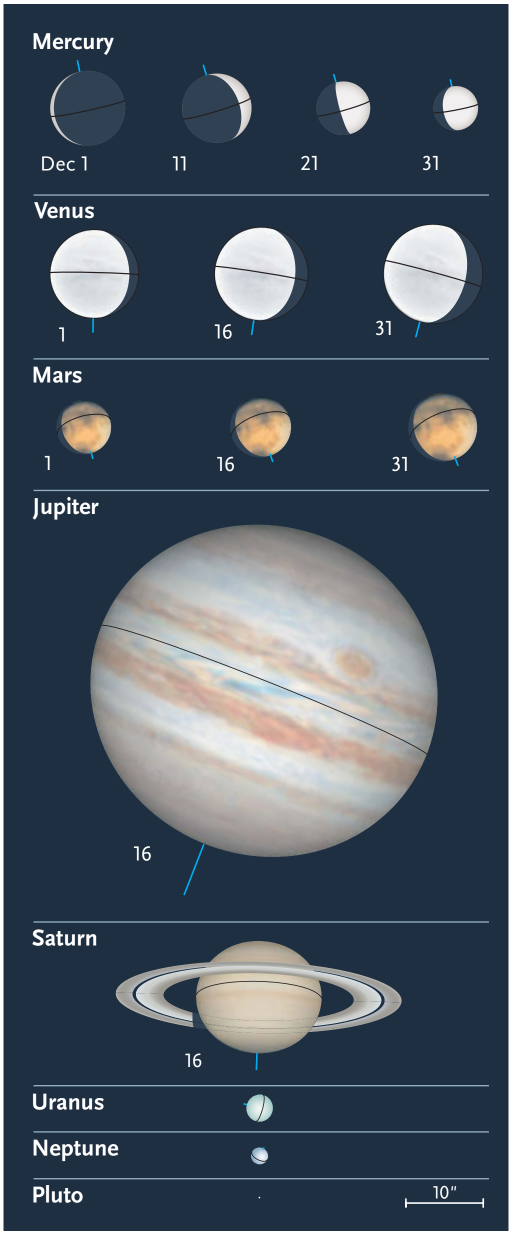
Rewarding binocular galaxies are few and far between. Indeed, of the 39 specimens in the Messier catalog, only two are much more than tiny blurs in ordinary binos. The Andromeda Galaxy, M31, is the best by far. But situated nearby in little Triangulum resides the other good one, **M33**.

Finding M33's location is a snap — it shares a binocular field with 3.4-magnitude Alpha (α) Trianguli. However, the galaxy has a reputation for being a difficult target. Looking at its stats, you might wonder why. M33 is big, spanning 73′ × 45′, and is listed at magnitude 5.7 — bright enough to be seen with the naked eye under dark skies. But experienced observers know that when it comes to deep-sky objects, it's often the *surface brightness* that matters most. And that's the problem in this case. If you spread M33's total brightness out over its considerable area, you end up with something dim enough to vanish in moonlight or even modest light pollution.

From my semi-rural backyard though, picking up M33 in 10×30 image-stabilized binoculars is a piece of cake. The galaxy looks like a small, hazy, dim football. Boosting the magnification by switching to my 15×45s doesn't change the galaxy's overall appearance, but it does become easier to see. What's striking about M33 is that it doesn't have an especially dramatic brightness profile. Although the galaxy does brighten gradually toward its center, it's more evenly illuminated than most deep-sky objects. Compare M33 with M31 and you'll see what I mean. Unlike M33, the Andromeda Galaxy has a bright, nearly stellar nucleus. That's one reason why it's so much easier to see under bright skies than M33. ✦

— *Gary Seronik*





Sun and Planets, December 2011

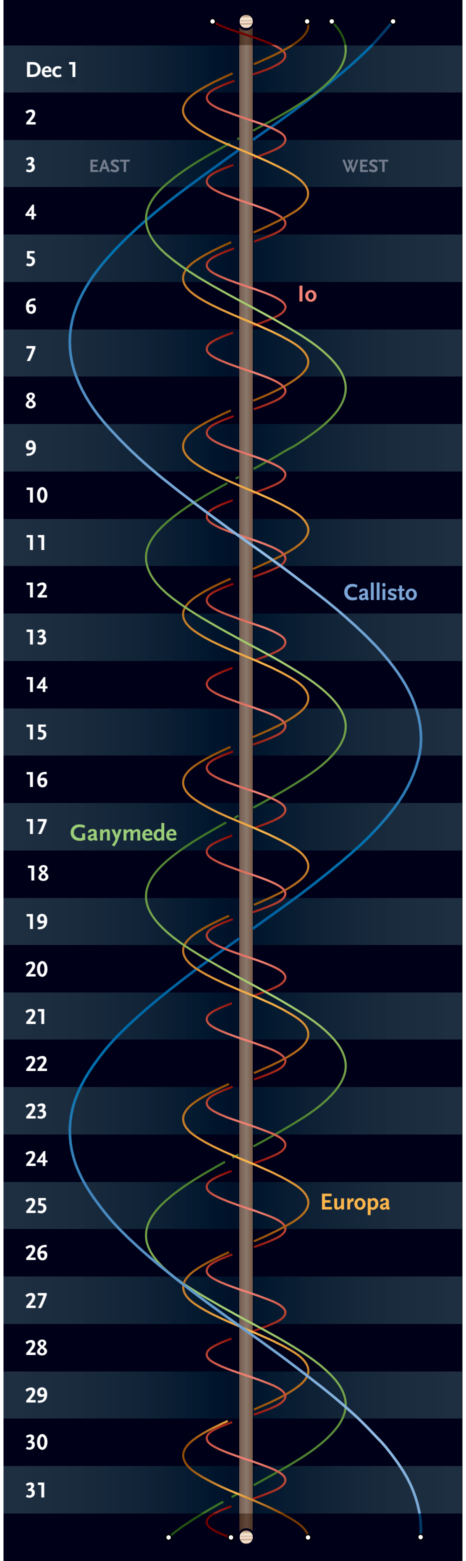
	December	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	16^h 26.1^m	–21° 41′	—	–26.8	32′ 26″	—	0.986
	31	18^h 38.2^m	–23° 09′	—	–26.8	32′ 32″	—	0.983
Mercury	1	16^h 59.5^m	–22° 34′	8° Ev	+3.3	9.7″	5%	0.694
	11	16^h 12.3^m	–18° 24′	14° Mo	+1.2	9.0″	17%	0.747
	21	16^h 22.4^m	–19° 09′	22° Mo	–0.4	6.9″	57%	0.969
	31	17^h 09.7^m	–21° 52′	20° Mo	–0.4	5.8″	79%	1.166
Venus	1	18^h 23.7^m	–24° 45′	27° Ev	–3.9	11.5″	89%	1.450
	11	19^h 18.0^m	–23° 56′	29° Ev	–3.9	11.9″	87%	1.402
	21	20^h 10.9^m	–21° 54′	32° Ev	–3.9	12.3″	85%	1.351
	31	21^h 01.7^m	–18° 50′	34° Ev	–3.9	12.9″	83%	1.298
Mars	1	10^h 46.3^m	+10° 10′	89° Mo	+0.8	7.1″	90%	1.322
	16	11^h 09.1^m	+8° 12′	98° Mo	+0.5	7.9″	90%	1.185
	31	11^h 26.7^m	+6° 46′	109° Mo	+0.2	8.9″	91%	1.049
Jupiter	1	1^h 58.4^m	+10° 37′	143° Ev	–2.8	47.6″	100%	4.145
	31	1^h 54.3^m	+10° 24′	111° Ev	–2.6	43.5″	99%	4.528
Saturn	1	13^h 38.1^m	–7° 43′	43° Mo	+0.8	16.0″	100%	10.384
	31	13^h 47.7^m	–8° 31′	71° Mo	+0.7	16.7″	100%	9.972
Uranus	16	0^h 02.9^m	–0° 29′	97° Ev	+5.8	3.5″	100%	19.933
Neptune	16	22^h 02.8^m	–12° 34′	65° Ev	+7.9	2.2″	100%	30.408
Pluto	16	18^h 27.9^m	–19° 20′	14° Ev	+14.1	0.1″	100%	33.101

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

Jupiter's Moons



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

A Great Month for Planets

All of the bright planets are on good display in December.

A TOTAL LUNAR eclipse awaits observers in western North America, the Pacific, and Asia on December 10th (see page 58). And all of us can enjoy a rich variety of planetary sights this month.

The nightly planet parade begins at dusk with Venus, which appears ever higher and more prominent in the southwest as the month progresses. Jupiter rules the southeast and south these evenings. Mars brightens impressively all month, rising in late evening and shining high in the south at dawn. Saturn trails Mars by three or four hours and glows in the southeast at dawn. Last but not least, Mercury springs up far to Saturn's lower left to put in a fine dawn showing in the second half of December.

DUSK

Venus, blazing at magnitude –3.9, appears higher in the southwest after sunset each week, on its way to the peak of a superb apparition in 2012. Skywatchers at mid-northern latitudes see Venus about 9° above the southwest horizon 45 minutes after sunset on December 1st and about 18° high at the corresponding time on December 31st. Telescopes show its 12″- or 13″-wide disk as only slightly out of round — decreasing from 89% to 83% lit over the course of the month.

EVENING

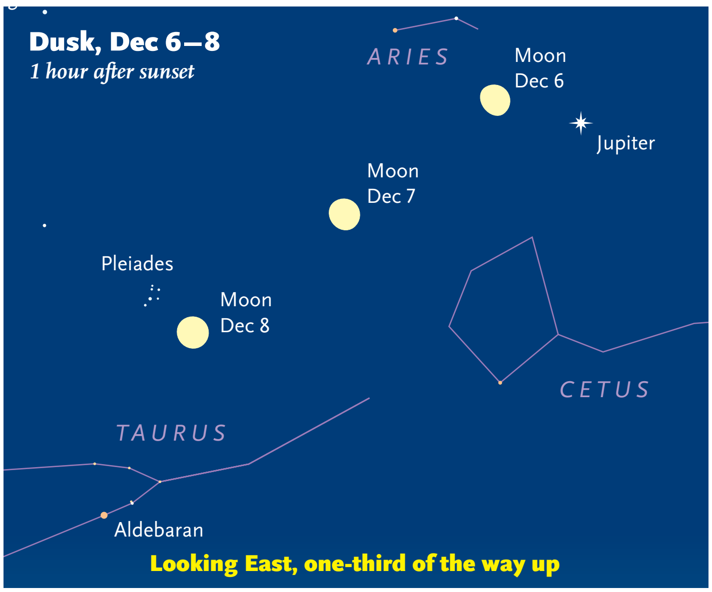
Jupiter comes into view almost halfway up the southeastern sky at dusk. During December, Jupiter remains impressive but dims a little, from magnitude –2.8 to –2.6, and shrinks a little in telescopes, from 47½″ to 43½″ wide. It hangs at the border of Aries and Pisces, shining highest in the south around 8 p.m. and setting in the early hours of the morning. Jupiter retrogrades westward against the stars for most the month, barely inching from Aries into Pisces on the 4th. On December 26th the planet halts and resumes direct motion (eastward relative to the stars).

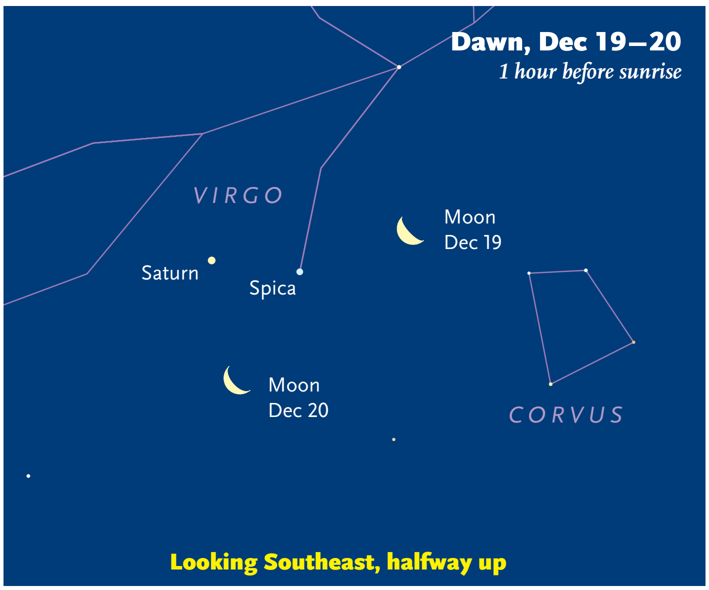
Uranus, in western Pisces, and **Neptune**, in Aquarius, are still well-placed for observation right after dark. For finder charts, see page 53 of the September issue or **SkyandTelescope.com/uranusneptune**.

NIGHT AND PREDAWN

Mars rises above the eastern horizon around 11:30 p.m. at the beginning of December and more than an hour earlier by December 31st. Mars brightens dramatically in December, from magnitude +0.8 to +0.2, plainly showing its striking orange-yellow hue to the naked eye. It moves from south-central to southeastern Leo, and its motion slows. That's an indication that it will begin retrograde motion in early 2012 as it heads towards its March 3rd opposition to the Sun.

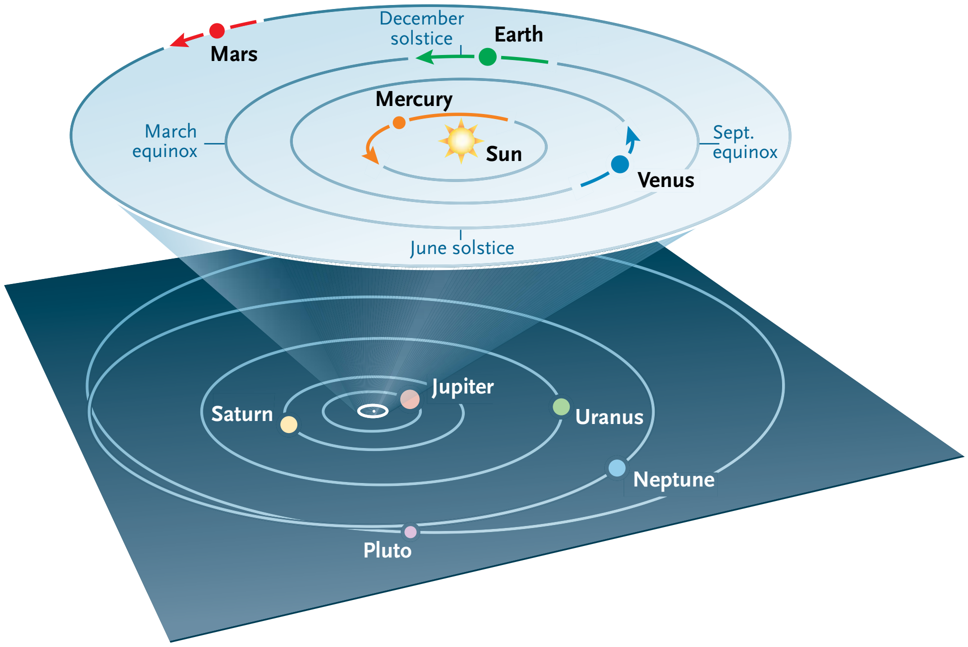
This month, however, Mars is only going through quadrature, 90° west of the Sun on December 2nd. It reaches the





ORBITS OF THE PLANETS

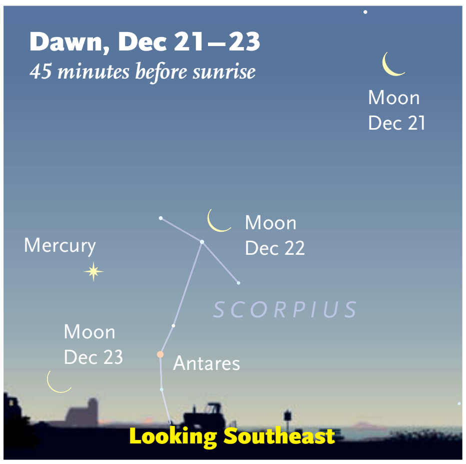
The curved arrows show each planet's movement during December. The outer planets don't change position enough in a month to notice at this scale.



meridian (shining highest in the south) during or before the first light of dawn.

Mars finally appears large enough in amateur telescopes that you're likely to see a few surface features on good nights. The rusty desert world grows from 7.1″ to 8.9″ wide in December, with its shrinking north polar cap and dissipating north polar hood of clouds tilting towards us.

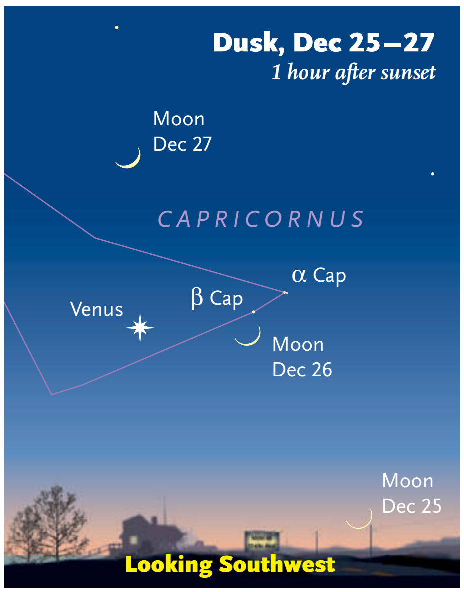
Saturn rises with Spica to its right a few hours after midnight in December, the steady planet slightly outshining the twinkly star. Their separation grows from 4.7° to 6.1° during the month. They're about halfway up the southeast sky as morning twilight comes on, and if you fail to see any surface features on Mars these December dawns, just turn your telescope on Saturn. The tilt of the rings increases from 14° to almost 15° from edgewise this month — the most open view of the rings we've had since 2006. Saturn's globe is currently less than 17″ wide at its equator, but the rings span almost 38″ by month's end.



These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west). For clarity, the Moon is shown three times its actual apparent size.

DAWN

Mercury is the night's final planetary attraction, emerging low in the growing light of dawn. The swift planet goes through inferior conjunction with the Sun on December 4th but climbs, rapidly brightening, into the southeast dawn sky in the next few weeks. Mercury glows at magnitude –0.4 when it reaches greatest elongation from the Sun on December 23rd, and telescopes show its disk to be 6.6″ wide and 63% illuminated. Around this date Mercury rises in a fully dark sky more than 1½ hours before the Sun.



MOON AND SUN

The gibbous **Moon** shines near Jupiter on the evenings of December 5th and 6th. The full Moon experiences a total eclipse on December 10th — visible from the American West across the Pacific, Australia, and Asia (see page 58). At dawn on December 19th, the thick waning lunar crescent forms a lovely arc with Spica and Saturn; the next morning it's below them. A slimmer crescent makes triangles with Mercury and Antares (use binoculars for the latter) 45 minutes before sunrise on the mornings of December 22nd and 23rd. At nightfall on December 26th a slender waxing crescent moon shines to the right of Venus — always a lovely sight.

The **Sun** reaches the December solstice at 12:30 a.m. EST on December 22nd (9:30 p.m. PST on the 21st). This is the moment when the Sun is farthest south for the year and begins its six-month return northward, marking the start of winter in the Northern Hemisphere and summer in the Southern Hemisphere. ✦

Giant Lunar Shield Volcanos?

They were strangely missing — until now. Spacecraft altimetry suggests that the Moon has low, broad structures similar to the Hawaiian Islands.

BACKYARD MOONWATCHERS and lunar scientists tend to have different interests. The scientists are most interested in how and why things happened: in ages, compositions, and processes. Observers tend to be most interested in lunar geography: identifying features and perhaps searching for challenging craterlets or rilles.

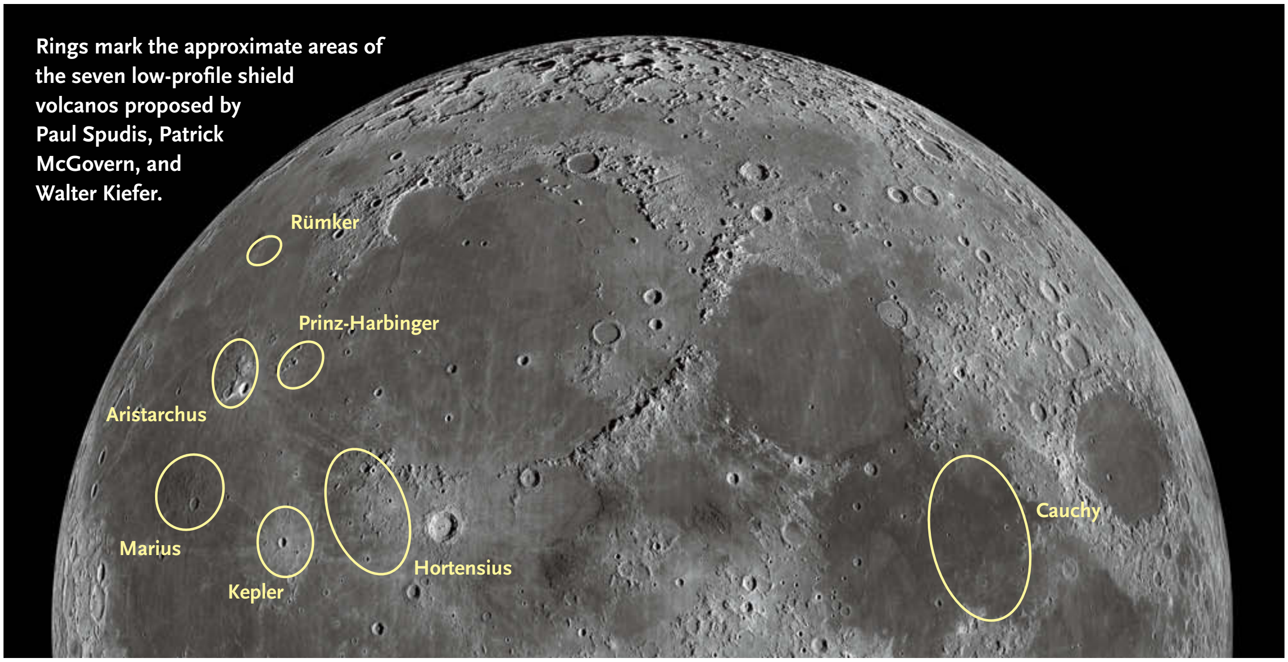
But often, amateurs have a chance to look in on lunar research discoveries for themselves. Such is the case with recent claims of seven big lunar shield volcanos.

"Shields" are wide volcanic mountains built by long tongues of very fluid lava. Over time (up to a few million years for large shields on Earth, such as Hawaii's Mauna Loa), lava flows will run in all directions away from a vent, building up a massive, roughly circular mound. The biggest one in the solar system is Olympus Mons on Mars, 600 km wide and almost 22 km high. Because runny lavas flow far from their vents, shields do not build steep cones (think Mount Fuji) but rather form broad, very gentle slopes, often with a collapse caldera at the top.

Although large shields are common on Earth, Mars and Venus, geologists long ago noted that there are none on the Moon. The Moon did experience plentiful volcanism between about 3.8 and 2.5 billion years ago, but most of it formed the flat lava plains we see as the maria, sporting only low wrinkle ridges. The Moon also has some small-scale volcanic features — sinuous rilles, dark halo craters, and domes (July issue, page 20).

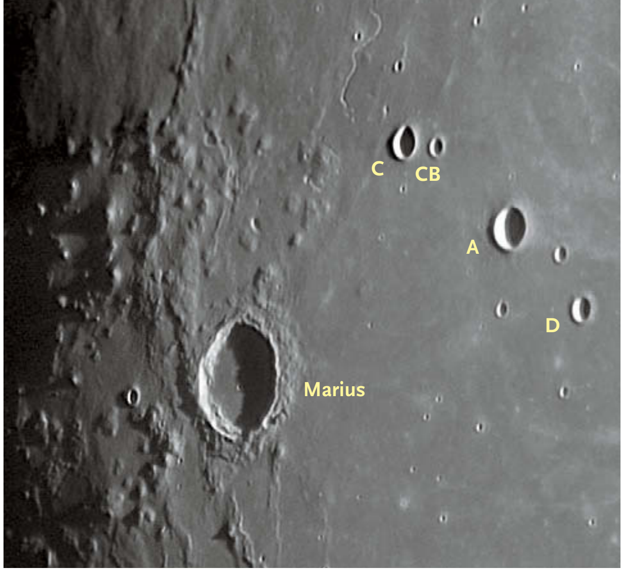
Enter the Lunar Orbiter Laser Altimeter, or LOLA, one of the instruments on NASA's Lunar Reconnaissance Orbiter going around the Moon. LOLA can measure elevation differences of only 1 meter, so scientists are now discovering undulations of the lunar surface that were previously unknown.

Three lunar scientists at the Lunar and Planetary Institute in Houston have used LOLA-created maps to identify giant shield volcanos — giant in diameter, but low in height. Paul Spudis, Patrick McGovern, and Walter Kiefer have described seven possible large shields, some of which

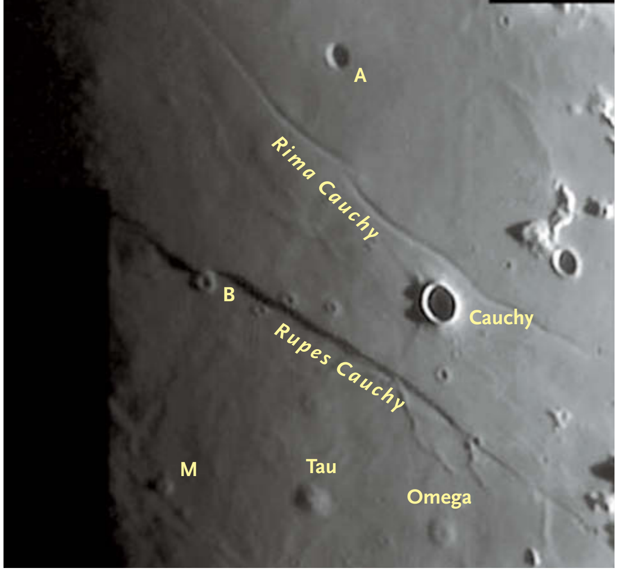


Rings mark the approximate areas of the seven low-profile shield volcanos proposed by Paul Spudis, Patrick McGovern, and Walter Kiefer.

NASA / GSFC / ARIZONA STATE UNIVERSITY



JÉRÔME GRENIER



PAOLO LAZZAROTTI

***Left*: The abundant domes of the Marius Hills, visible in backyard telescopes, are famous leftovers from ancient lunar volcanism. Do they stand on an enormous, low shield volcano only recently revealed? *Right*: Cinder-cone domes topped by central pits dot the mare floor around Cauchy and its famous fault and rille.**

were already known to have unusual volcanic structures.

The most convincing one underlies the swarm of about 300 small cones and domes known as the Marius Hills (above). These were probably the vents for numerous lava flows that combined to build a shield that LOLA shows to be about 330 km wide and 3.2 km high. If you observe when the illumination is low at the Marius Hills, you may notice the relatively abrupt edge of the Hills' northern flank. That marks the front of repeated lava flows.

Spudis and his colleagues propose that the Aristarchus Plateau and the nearby Prinz region, well known to backyard observers, are also shields. These areas are elevated about 1.6 to 2 km above the surrounding mare surface. Each has sinuous rilles (including the largest on the Moon, Schröter's Valley), as you can observe with even a small scope. But these may not be true volcanic shields; they look more like uplifted blocks of crust. Fractures in them may have allowed magma to pour onto the surface.

The two largest of the possible shields lie near the small crater Cauchy, in eastern Mare Tranquillitatis, and west of Copernicus in the domeland near Hortensius and Tobias Mayer. The Cauchy area is famous for a fault and rille on either side of the crater and for many small volcanic domes in and around the region. The six domes near Hortensius and a larger one at T. Mayer are classic dome examples. Careful observing at times of grazing illumination will reveal these small features. Telescopic views do not indicate the subtle rise in elevation: about 2 km spread over 300 to 400 km, a slope of less than 1°.

The proposed giant shields have the merit of explaining something that was previously a mystery: why are swarms of small volcanic features concentrated in the places they are? Similar minor volcanos are often seen dotting large terrestrial shields. And the Spudis group points out that the seven proposed shields are located near basin rims, where modeling suggests the lunar crust may be deeply fractured, providing conduits for magma to rise preferentially.

The next time the lighting is good, see what you can spot at these locations. ✦

For a daily Moon fix, visit ***Charles Wood's*** *Lunar Photo of the Day: lpod.wikispaces.com.*

The Moon • December 2011

Phases

First quarter	December 2, 9:52 UT
Full Moon	December 10, 14:36 UT
Last quarter	December 18, 0:48 UT
New Moon	December 24, 18:06 UT

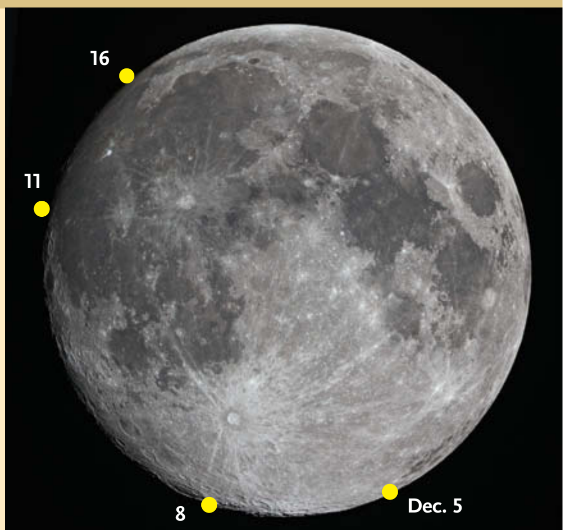
Distances

Apogee 248,701 miles	December 6, 1ʰ UT diam. 29′ 52″
Perigee 230,086 miles	December 22, 3ʰ UT diam. 32′ 16″

Librations

Boussingault (crater)	December 5
Bailly (crater)	December 8
Vasco da Gama (crater)	December 11
Xenophanes (crater)	December 16

S&T: DENNIS DI CICCO



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

 Dennis di Cicco

A New 4-inch Refractor from Astro Telescopes

S&T: DENNIS DI CICCO

MY FIRST REACTION upon unpacking the refractor on loan from Hands on Optics for this review was a simple one; I thought we received the wrong model telescope. Even though we've become accustomed to optical bargains coming out of Asia, surely no 4-inch refractor with this one's outward appearance of quality cost only $499 — unless, maybe, the objective was sold as an option. But I was wrong. It was indeed the AT102F11 telescope we asked for. And while the $499 price is only for the optical tube assembly, it does include a set of high-quality tube rings and a Vixen-style dovetail mounting bar.

With its tube painted high-gloss pearl and all the

Handsome on the outside, with top-notch optics and mechanical construction on the inside, the new Astro Telescopes 4-inch f/11 refractor available exclusively from Hands on Optics, carries a price tag that makes it one of the best values ever for a refractor in this aperture class.

The AT102F11 (4-inch f/11) Refractor

U.S. price: $499

Hands on Optics, 26437 Ridge Rd., Damascus, MD 20872

www.handsonoptics.com; 301-482-0000

fittings glossy-black anodized, the refractor is strikingly attractive. And the quality runs more than just skin deep. The dual-speed, 2-inch Crayford-style focuser with 85 millimeters (3.3 inches) of travel is of much better quality than those I've seen on refractors costing considerably more. Large knobs provide smooth control of the coarse focus, and the fine-focus knob offers an 11:1 reduction. The focuser rotates 360°, with locking thumbscrews for both the rotation and the drawtube travel. The drawtube, which has a nicely engraved millimeter scale, has a brass compression ring and three locking thumbscrews spaced at 120° intervals. These ensure that eyepieces, cameras, and accessories are securely held in place. Very nice!

The retractable dew cap, which is threaded to accept the scope's rugged metal lens cap, extends 8 inches, giving the scope an overall length of more than 4 feet (1.3 meters). There are three baffles within the tube positioned to keep any stray light reflected off the interior tube walls from reaching the scope's focal plane.

All these niceties, however, would be for naught if the scope was an optical dud. But that wasn't the case. The refractor's optics proved to be every bit as good as its mechanics. Although I didn't have the benefit of doing a side-by-side comparison, I couldn't recall another refractor in this aperture class with a doublet objective providing significantly better performance. There was no astigmatism, barely a hint of spherical aberration, and the weak blue halo visible at high magnification around the brilliant star Vega was subtle enough to easily be ignored.

Much of the credit for this fine color performance is due to the scope's f/11 focal ratio. Modern optical glasses and sophisticated three-element objectives have given rise to today's rich assortment of short-focus refractors offering premium color performance. But it's equally true that a long-focus doublet objective made with modern glass can run circles around the color performance of yesteryear's two-element achromatic refractors.

And there's another benefit of long-focus telescopes; they work very well with all eyepiece designs. I did the bulk of my observing with a selection of Tele Vue eyepieces ranging from a 24-mm Panoptic (yielding a magnification of 46× and a true field of 1.4°) to a 3-mm Radian (367×). One evening I easily split both stellar pairs of Lyra's famous Double-Double with the Radian.

I had some of my best views of sunspots in the current solar cycle using the scope with a Baader Herschel Safety Wedge. In early July I glimpsed the 12th-magnitude supernova in M51 (see page 14) at 122× with about the same ease as I was able to see it with a 6-inch Maksutov. And while I'm accustomed to observing deep-sky objects with larger telescopes, it's worth remembering that renowned deep-sky authors John Mallas, Walter Scott Houston, Stephen James O'Meara, and Sue French have based much of their writing on observations made with 4-inch refractors.

WHAT WE LIKE:

Top-notch optics

Excellent construction

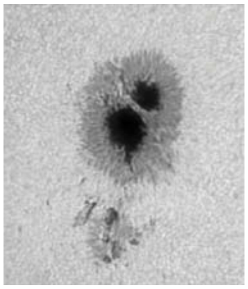
Amazing price

WHAT WE DON'T LIKE:

No finder

S&T: DENNIS DI CICCO

Described in the accompanying text, the focuser has features and an overall quality befitting a scope that costs considerably more than the AT102F11.



S&T: SEAN WALKER

When fitted with a Baader Herschel Safety Wedge (which reduces the Sun's brightness to safe viewing levels), the refractor became a powerful instrument for viewing and photographing the Sun. *S&T*'s imaging editor, Sean Walker, used it to capture this richly detailed sunspot group last September 10th with an Imaging Source DMK 21AU618 video camera.

I really found little to criticize about the AT102F11, but there are two caveats. One is that there is no provision for mounting a finder on the telescope tube. There are, however, multiple threaded holes on the tube rings, though these would place a finder unusually far from the scope's eyepiece. The other caveat is that this scope is big. While some may find its "classic" length a plus, it also means that the scope places more demands on its mounting. It certainly wasn't overkill to use the scope with my Vixen Great Polaris DX mount even though it's rated for twice the scope's 12 pound (5.4 kg) weight.

Although price isn't the first question on the application form, I suspect most refractor enthusiasts will balk at even considering a $499 scope for membership in the club of elite refractors. But that's okay. People who purchase the AT102F11 can still enjoy first-class views through the eyepiece and also have more than enough money left over to smugly sip daily lattes at Starbucks for the next year or two.

Because he struggles with the lingo, senior editor ***Dennis di Cicco*** *usually asks others to order his coffee at Starbucks.*

Joe Heafner

Southern Stars' *SkySafari 3*

This app for Apple's mobile devices literally puts access to the night sky at your fingertips.

SkySafari 3

U.S. price: basic version, $2.99; Plus, $14.99; and Pro, $59.99.
Southern Stars, 123 Tenth St.
San Francisco, CA 94103
415-671-6251
www.southernstars.com

Sky Safari 3 literally places the wonders of the night sky at your fingertips. The program packs the power of planetarium software once reserved for desktop computers into an app that runs on Apple's iPad, iPhone, and iPod Touch devices. With it you can locate and identify stars, planets, asteroids, comets, and deep-sky objects. And, with an optional Wi-Fi module, you can control a wide variety of Go To telescopes. This screen capture shows *Sky Safari 3 Pro* as displayed on the author's iPad 2.

System Requirements

All *SkySafari 3* versions are universal apps for Apple's iPhone, iPad, and iPod Touch running iOS 4 or higher.

MOST WOULD AGREE that the digital revolution in amateur astronomy began quietly in the 1980s with the growing adoption of personal computers. The revolution took a leap forward in the 1990s with the introduction of astronomical CCD cameras and Go To telescopes. A decade later digital photography was reshaping the hobby. Now another decade has passed and another revolution has arrived. Today many amateurs use one device for personal communication, accessing the Internet, and enjoying astronomy. I speak of smartphones and tablet computers, of course.

Apple's iPhone, iPad, and iPod Touch have become mature computing platforms and there are now lots of excellent astronomy apps. Many of these programs behave similarly and have comparable features, but Southern Stars' *SkySafari 3* stands out for its pedigree. The program is a rewrite of Carina Software's venerable *Sky Voyager,* which traces it's roots way back to the 1980s (*S&T:* July 2008, page 32).

WHAT WE LIKE:

The power of desktop planetarium software in an app for Apple's mobile devices

WHAT WE DON'T LIKE:

Minor issues with night-vision mode displaying things with white light

SkySafari 3 comes in three versions: basic, Plus, and Pro. The basic version is aimed at beginners and casual naked-eye observers. Its database includes about 120,000 stars to 8th magnitude, all the objects in the Messier and Caldwell catalogs, many deep-sky images, and about 500 object descriptions.

The Plus version of the program ups this to about 2½ million stars to 12th magnitude, 30,000 deep-sky objects (including the entire NGC and IC catalogs), about 300 images from the Digitized Sky Survey, and roughly 1,000 object descriptions. The Plus version also includes Go To telescope control (which requires optional hardware). And, for good measure, you get precise sky charting, asteroid/comet/satellite databases, and observation planning and logging capabilities.

In addition to the Plus version's features, *SkySafari 3 Pro* ups the ante to about 15 million stars to 15th magnitude, about 740,000 deep-sky objects to 18th magnitude, and every cataloged object in our solar system. This is the version I tested.

I prefer running *SkySafari 3* on the larger screen of my iPad 2 (with 64 gigabytes of memory) rather than my iPhone 4, but everything works the same way on both devices. You can manually set your location or use the iPad's internal location capability. Multiple locations can be saved, and all the typical settings for date and time are easily accessed from the tool bar.

There are buttons for toggling the tablet's built-in compass and gyroscope, as well as a night-vision mode (which is especially nice to have readily accessible rather than buried in a menu). The compass and gyroscope let you move the iPad or iPhone (the iPod Touch lacks a compass) around while the screen continually shows a simulated view of the sky in the direction the device is pointed.

There's also a tool bar button to access *Sky & Telescope's* SkyWeek, a selection of current events along with appropriate sky simulations. Of course you can always use your fingertip to scroll around the sky and zoom in or out. Once you learn the basics of *SkySafari 3's* touch interface, it quickly becomes intuitive.

I really enjoy the extreme portability of tablet-based planetarium programs. Imagine, for example, hosting a public star party with several telescopes set up to view different objects. With *SkySafari 3* on an iPad or iPhone, I can circulate among the attendees and quickly answer all sorts of questions. Some guy points to a star and asks its name. I simply point the iPad in the appropriate direction and let him see the star's name himself. Touching the star on the screen brings up literally everything *SkySafari 3* knows about that star.

A lady asks if there's more to the globular cluster M13 than the fuzzy view she's seeing through the telescope. I oblige by zooming *SkySafari 3's* star chart in until it displays a photograph, and touching the image followed by the Info button brings up all kinds of information about this magnificent cluster. A boy at another telescope wants to know which of the "dots" around Saturn are satellites and which are stars. Zooming the iPad display shows Saturn with its satellites and rings correctly oriented and labeled for easy identification.

Two girls spot a point of light moving silently across the sky and ask if it's an artificial satellite or an airplane. I swing the iPad (with *SkySafari 3* running in real-time mode) to that part of the sky and show them a bright green dot moving among the plotted stars, and a touch of the dot reveals that it's an Earth-orbiting satellite. (Note that the basic edition of *SkySafari 3* does not include comet, asteroid, and satellite data and thus is unsuitable for satellite chasing.)

In the past, answering questions like these meant carrying around observing guides and a red flashlight or running inside to consult a computer. Now, I can simply carry around an iPad or iPhone with *SkySafari 3* and have all this information literally at my fingertips.

I found a few minor annoyances in the initial release of the program, mostly involving the display. For example, in night-vision mode some text labels appear in white rather than red, and touching the buttons on the tool bar create a momentary flash of white light. A similar but more-substantial flash occurs when tapping to enter text into the search bar.

In future updates, a feature for predicting Iridium flares would be a welcome addition, as would an ability for creating animations similar to those in the program's distant relative, *Voyager*. The developers of *SkySafari* are extremely responsive to bug reports and requests for additional features. They also maintain an online discussion group for feedback purposes.

As with other aspects of the digital revolution, smartphone- and tablet-based planetarium programs are game changers. The Pro version of *Sky Safari 3* has completely replaced my desktop planetarium program. Before now, we could only watch the sky on computer screens. With *SkySafari 3* we can touch the sky, and that's revolutionary. ✦

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*College instructor **Joe Heafner** lives in North Carolina and is currently writing an introductory astronomy textbook.*

New Product Showcase

PACIFIC ASTRONOMY PATS AND TELESCOPE SHOW

Several interesting new products made their debut at the Pacific Astronomy and Telescope Show (PATS) last September in Pasadena, California.

▸ **A NEW ETHOS** Tele Vue's optical designer Paul Dellechiaie has once again pushed his skills and created another eyepiece for the company's groundbreaking Ethos line. The new 4.7-millimeter Ethos-SX ($625 street price) delivers razor-sharp views across its 110° field with the same contrast, color-rendition, and distortion correction of its 3.7-mm sibling. Weighing 20.8 ounces (590 grams), the eyepiece fits 1¼-inch focusers and is parfocal with a wide range of other 1¼-inch Tele Vue eyepieces. A custom 1¼- to 2-inch adapter is included with purchase.

S&T: TONY FLANDERS

Tele Vue 32 Elkay Dr., Chester, NY 10918, 1-845-469-4551; www.televue.com

MEADE INSTRUMENTS

◂ **SELF-AUTOGUIDING SYSTEM** Meade unveiled a host of new products at PATS. The most revolutionary of the lot is the LX800 German Equatorial Mount with StarLock ($5,999) designed from the ground up for hassle-free astrophotography. Machined from aircraft-grade aluminum and stainless steel, the LX800 features 5.8-inch-diameter worm gears on each axis driven by beefy 0.68-inch-diameter precision brass worms. The mount is rated for 90 pounds (41 kg) of equipment not including the two supplied 18-pound counterweights. The LX800's unique feature is its automatic StarLock full-time guiding system built around a 25-mm f/1 lens and an 80-mm f/5 refractor each fitted with a permanently focused ½-inch-format CMOS detector. The system finds your target, locks onto a guide star, and automatically begins autoguiding the mount each time you move to a different target. In addition, the StarLock system assists with drift alignment of the mount without the need for a separate computer. The LX800 is also available paired with Meade's new 10-, 12-, and 14-inch f/8 Advanced-Coma Free optical tube assemblies featuring zero image-shift internal Crayford-style focusers. See Meade's website for many additional details.

Meade Instruments 27 Hubble, Irvine, CA 92618; 800-626-3233; www.meade.com

▸ **VIDEO TRACKER** Another intriguing new product introduced at PATS is *Optic Tracker*. This software program works with your video camera and Go To telescope to lock-on, track, and record moving targets such as satellites, airplanes, and rocket launches. Recording high-resolution views of the International Space Station has never been so easy! Starting at $29.95 for a basic package, the downloadable *Optic Tracker* software features digital image-stabilization technologies, allowing you to zoom directly into your target even when it's bouncing around in the field of view. *Optic Tracker* is compatible with two-line elements of satellite orbit data available online, and it can report the exact time your chosen target will pass overhead. The program currently supports Celestron's SE and Meade LX200 Go To telescopes. See the website for additional details.

OPTIC TRACKER

S&T: TONY FLANDERS

Optic Tracker www.optictracker.com

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

A Dawn Eclipse of the Moon

For many of us, the Moon will become totally eclipsed before sunrise December 10th.

MARK YOUR CALENDAR to get up early on Saturday, December 10th, if you're anywhere in central or western North America. That morning the full Moon goes through its last total eclipse until 2014.

The map and diagram here tell the story. In North America, the farther west you are the better. In the Pacific time zone you can watch the Moon slip into Earth's shadow completely, while the Moon is sinking low in the west-northwest. In the Northwest you can even see the Moon start to emerge from Earth's shadow before moonset and sunrise end the show.

From roughly Arizona to the Dakotas, the Moon sets while still totally eclipsed. Horizon obstructions and the brightening dawn may end your view somewhat before moonset. In the Central time zone, the Moon sets while still only partially eclipsed. The East misses out completely.

Observers in the Pacific, Australia, and eastern Asia have it better. Seen from there, the whole eclipse happens high in a dark sky from start to finish. For Europe and Africa, the eclipsed Moon will be lower in the east during or after dusk on the evening of the 10th.

When the Moon is totally eclipsed, it glows eerily orange, red, or dark bloody brown. Although the Moon is completely inside Earth's shadow at that time, it's still dimly lit by sunlight that skims the edge of Earth and is refracted into Earth's shadow by the atmosphere. What you're seeing on the Moon's face is light from all the world's sunsets and sunrises at the

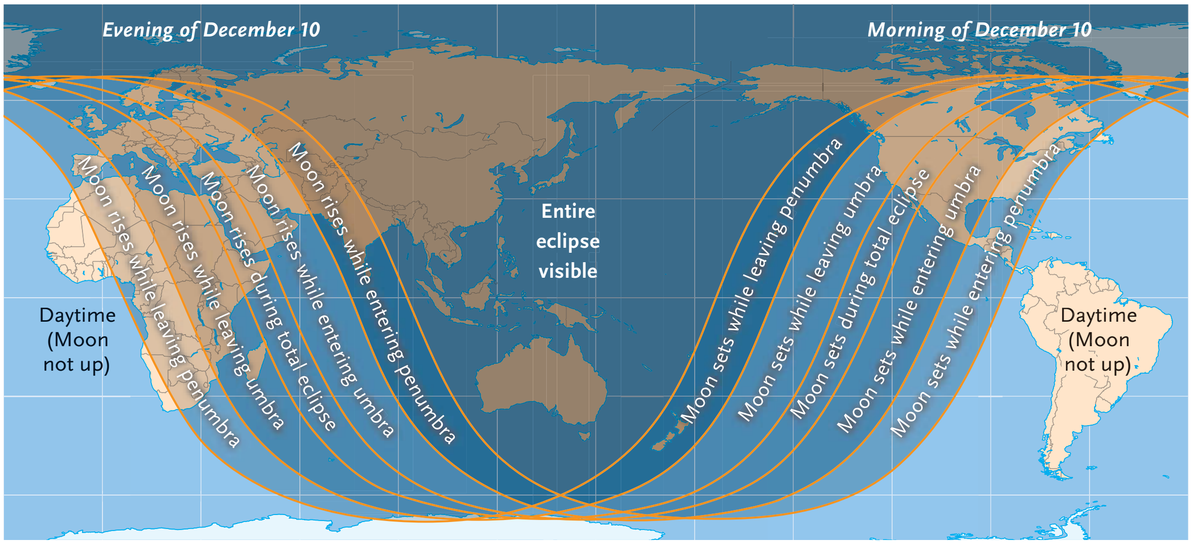
BRIAN KIMBALL

When the Moon was totally eclipsed on December 21st last year, the parts of it deep in the umbra became very dark red.

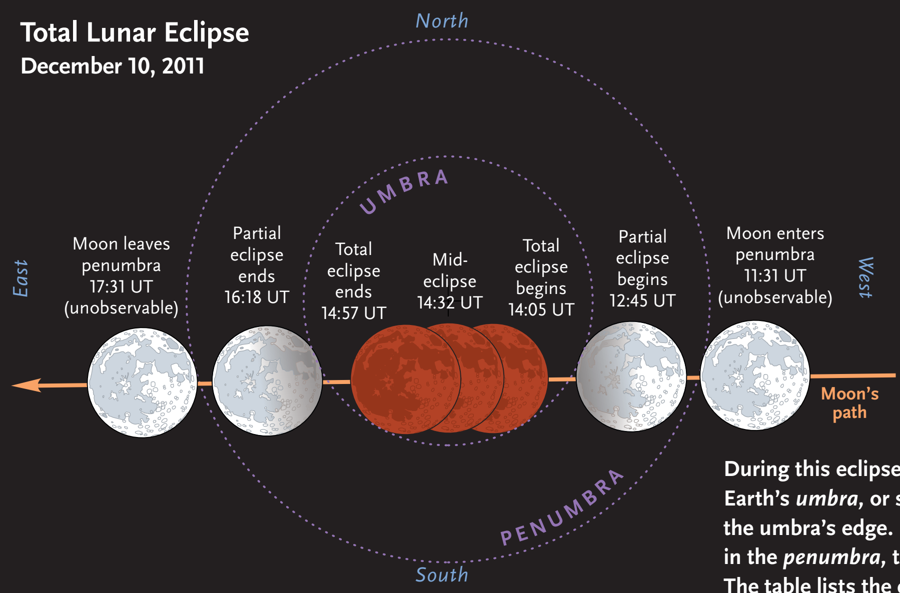
TWO OBSERVING PROJECTS

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

• John Westfall seeks naked-eye timings of the eclipse *contacts:* when the partial phase begins and ends before and after totality, to help calibrate the historical timings made by mariners and others when this was one of the few ways to determine longitude at sea. Go to www.alpo-astronomy.org/eclipse/TLE10DEC11.html.



Find your location to see whether the Moon will rise or set during any stage of the eclipse for you. Because an eclipsed Moon is always full, the Sun sets or rises at almost the same time on the opposite horizon. This means that moonrise or moonset will happen in a bright sky.



Total Eclipse of the Moon

Eclipse event	CST	MST	PST
Penumbra first visible?	6:05 am	5:05 am	4:05 am
Partial eclipse begins	6:45 am	5:45 am	4:45 am
Total eclipse begins	—	7:05 am	6:05 am
Mid-eclipse	—	7:32 am	6:32 am
Total eclipse ends	—	7:57 am	6:57 am

During this eclipse the Moon (in Taurus) skims just inside the southern edge of Earth's *umbra,* or shadow core. The eclipse is partial while the Moon is moving across the umbra's edge. Less noticeable are the first and last stages, when the Moon is only in the *penumbra,* the shadow's pale outer fringe. The diagram gives Universal Times. The table lists the corresponding Central, Mountain, and Pacific Standard Times.

time that you're looking. How bright or dark the eclipsed Moon will appear depends on the cloudiness along Earth's sunrise-sunset rim and, especially, on the amount of dust high in the upper air globally.

For this eclipse the Moon barely skims inside the southern edge of Earth's umbra, as shown above. So we can expect the Moon's southern rim to remain brighter than the rest — creating a lovely 3-D effect and drama for photographers. To get a good image scale, use a wide-field telescope or a long telephoto lens.

If it's cloudy, the next eclipse of the Moon will be a partial one before and during dawn next June 4th, visible from most of North America except the Northeast.

The next *total* lunar eclipse doesn't come until the night of April 14–15, 2014. But then the Moon will be high in a dark sky all across the Americas.

Geminids in the Moonlight

As dedicated skywatchers know, the two best annual meteor showers, the Perseids in mid-August and the Geminids in mid-December, share similar Moon circumstances. Each year the Geminid peak comes just four days later in the lunar cycle than the peak of the Perseids. So if the sky is dark and moonless for one shower, it's usually that way for the other.

Amir Abolfath caught a bright Geminid plunging over the Zagros Mountains in Iran on the morning of December 14, 2009.

Or the reverse. This year the Perseids were largely wiped out by the light of the full Moon. So a waning gibbous Moon will also compromise the Geminid shower on the nights of December 13–14 and 14–15. The Moon rises in early to mid-evening on those nights, before the shower's radiant rises high and meteor activity picks up. The Moon blazes bright for the rest of the night.

Even so, you may see still some bright Geminids through the skyglow. If you see a shooting star, trace its path backward across the sky. If is was a Geminid, this line, extended far enough, will pass Castor and Pollux in Gemini — well up in the eastern sky by mid- to late evening and high overhead around 2 a.m.

Minima of Algol

Nov.	UT	Dec.	UT
3	19:08	2	11:18
6	15:57	5	8:07
9	12:46	8	4:56
12	9:35	11	1:46
15	6:24	13	22:35
18	3:13	16	19:24
21	0:02	19	16:13
23	20:51	22	13:02
26	17:40	25	9:52
29	14:29	28	6:41
		31	3:30

These geocentric predictions are from the heliocentric elements Min. = JD 2,452,253.567 + 2.867321*E*, where *E* is any integer. Derived by Marvin Baldwin (AAVSO), they are based on 17 timings collected from 1999 to 2003 and on the star's average period during the previous 35 years. For more about this star, visit SkyandTelescope.com/algol.

Action at Jupiter

Io was crossing Jupiter's Great Red Spot when Christopher Go caught this image on September 15th. South is up.

December finds Jupiter high and bright during convenient evening hours, and still a big 47 to 44 arcseconds wide.

Even the smallest scope shows Jupiter's four big Galilean moons. Binoculars usually show at least two or three. You can identify them with the diagram on page 47. Listed below are all their interactions with Jupiter's disk and shadow during December, events fascinating to watch with a small scope.

On Jupiter itself, the North Equatorial Belt was still dark red-brown as of September, the South Equatorial Belt (SEB) was broader, and the Great Red Spot, in the south edge of the SEB, was still surrounded by an unusually dark rim.

Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates (also in UT) are in bold. Eastern Standard Time is UT minus 5 hours. The Red Spot appears closer to the planet's central meridian than to the limb (edge) for 50 minutes before and after these times:

December 1, 6:09, 16:05; **2,** 2:00, 11:56, 21:52; **3,** 7:47, 17:43; **4,** 3:39, 13:34, 23:30; **5,** 9:26, 19:21; **6,** 5:17, 15:13; **7,** 1:08, 11:04, 21:00; **8,** 6:55, 16:51; **9,** 2:47, 12:42, 22:38; **10,** 8:34, 18:29; **11,** 4:25, 14:21; **12,** 0:16, 10:12, 20:08; **13,** 6:04, 15:59; **14,** 1:55, 11:51, 21:46; **15,** 7:42, 17:38; **16,** 3:33, 13:29, 23:25; **17,** 9:20, 19:16; **18,** 5:12, 15:08; **19,** 1:03, 10:59, 20:55; **20,** 6:50, 16:46; **21,** 2:42, 12:38, 22:33; **22,** 8:29, 18:25; **23,** 4:20, 14:16; **24,** 0:12, 10:08, 20:03; **25,** 5:59, 15:55; **26,** 1:51, 11:46, 21:42; **27,** 7:38, 17:33; **28,** 3:29, 13:25, 23:21; **29,** 9:16, 19:12; **30,** 5:08, 15:04; **31,** 0:59, 10:55, 20:51.

These times assume that the spot is centered at System II longitude 173°. ✦

Phenomena of Jupiter's Moons, December 2011

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

The Sculptor's Workshop

This small, faint constellation is rich in deep-sky objects.

. . . A sculptor wields
The chisel, and the stricken marble grows
To beauty . . .
— William Cullen Bryant, *The Flood of Years, 1876*

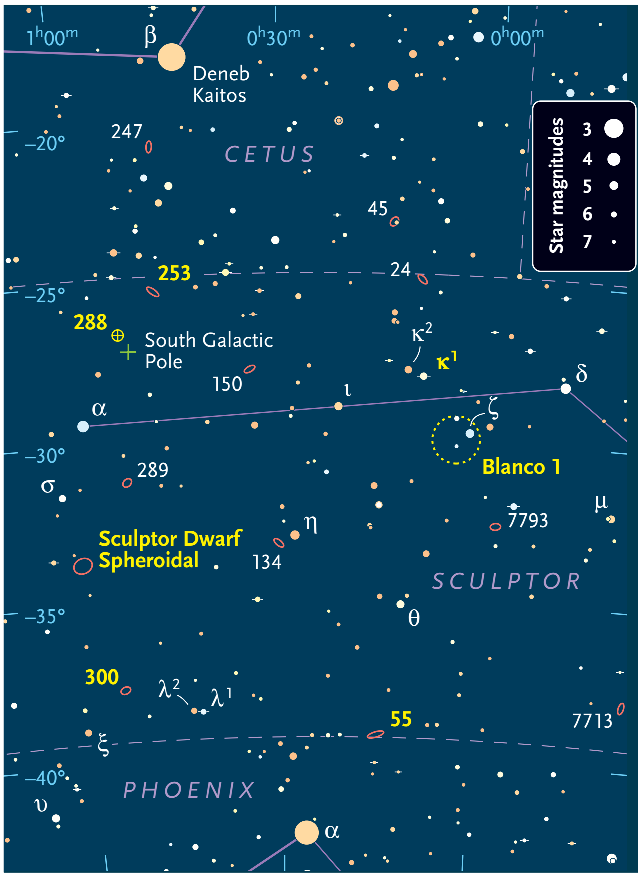
Two hundred sixty years ago, the French astronomer and mathematician Nicolas Louis de Lacaille arrived at Africa's Cape of Good Hope. There he set up his instruments near Table Mountain, where he made positional observations of 9,766 southern stars in 10 months. Lacaille created 14 new constellations to house some of these stars. Mensa commemorates Table Mountain, and the rest memorialize instruments of the arts and sciences. These constellations were presented to the French Royal Academy of Sciences in 1754 on a painted planisphere 76 inches across, but none were named on this introductory map.

The Lacaille constellation that we'll pursue is Sculptor. It was l'Atelier du Sculptor (Sculptor's Workshop) when first labeled on a 1756 planisphere and Apparatus Sculptoris on Lacaille's posthumous 1763 planisphere. The name survives today simply as Sculptor.

Sculptor contains no star brighter than 4th magnitude, but it does possess some impressive deep-sky wonders. The brightest is the open cluster **Blanco 1**, also called the Zeta Sculptoris Cluster even though Zeta (ζ) is no longer thought to be a member of the group.

ESO

NGC 253 is one of the brightest galaxies in the entire sky. It's sometimes called the Silver Coin Galaxy, Silver Dollar Galaxy, or simply the Sculptor Galaxy.



DAVID A. KODAMA

NGC 253 forms a fine wide-field pair with the globular cluster NGC 288 (at lower left). The red streak in this medium-format film photo is due to an airplane, and north is slightly right of up.

Covering a generous 1.5°, Blanco 1 is best observed through a small telescope at low power. My 130-mm (5.1-inch) refractor at 23× shows a spray of 40 bright to faint stars starting at an 8th- and 9th-magnitude pair and widely fanning northwest. The brighter star of the pair appears yellow, and blue-white Zeta adorns the wide end of the fan.

When stargazing, we find most open clusters in or near the band of the Milky Way. Blanco 1 appears farther away from the plane of the Milky Way than any true open cluster except Melotte 111 (Coma Berenices). The cluster probably formed in or near the galactic plane about 100 million years ago with a high relative velocity that has carried it to its present position. Blanco 1 is thought to be roughly 800 light-years away and near its maximum separation from the plane as it pursues its galactic orbit.

You'll find the pretty double star **Kappa^1 (κ^1) Sculptoris** just 2.3° northeast of Zeta. Its nicely matched 6th-magnitude suns are 1.3″ apart and aligned nearly east-west. In my 130-mm scope, these pale yellow stars show a hairline split at 117× and a more comfortable one at 164×.

The second-brightest deep-sky wonder in Sculptor is beautiful **NGC 253**, sometimes called the Silver Coin or Silver Dollar Galaxy. Knowing my interest in the origin of these names, Australian amateur Mike Kerr told me that David Bergamini's book *The Universe* has a photo caption that reads "SILVERY COIN of the flat Sc spiral NGC 253." This quote is from the 1964 Time-Life International edition published in the Netherlands. I obtained the original 1962 edition published in New York, which instead reads "SILVERY DOLLAR . . ." indicating that this work may be the source of both nicknames. Does anyone know an earlier reference?

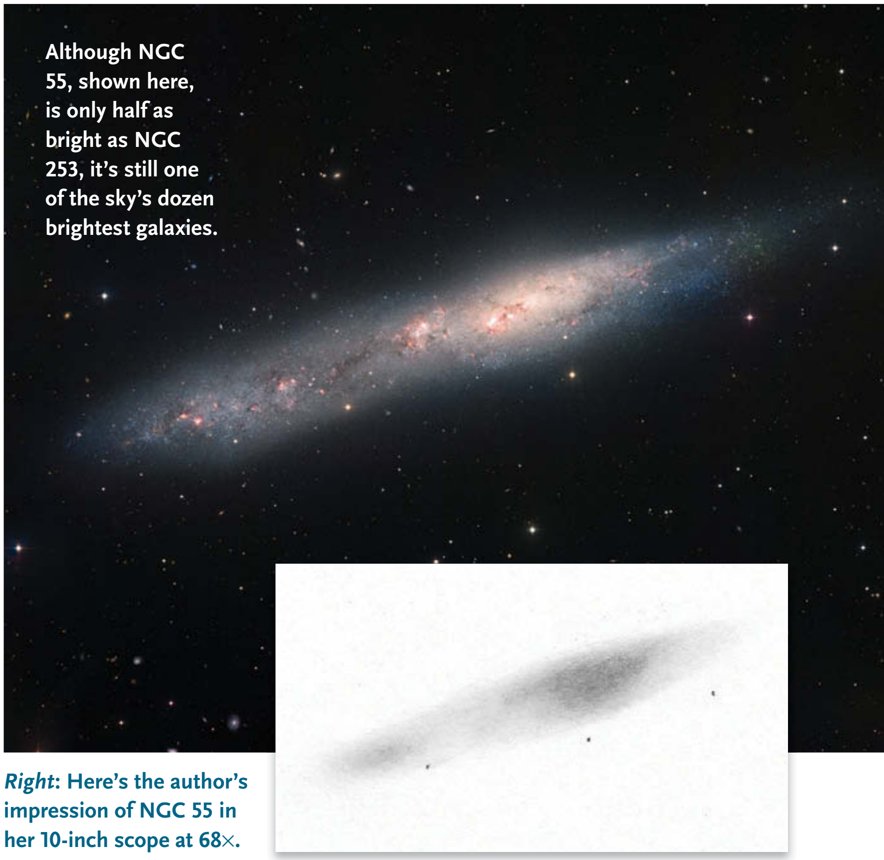
NGC 253 is a sizable, easily visible glow that's elongated northeast-southwest through my 130-mm refractor at 23×. At 63× the galaxy covers about 26′ × 6′ and grows brighter toward the center, sporting an elongated core and nucleus. At 102× the Silver Coin is very, very pretty. It looks slightly woolly, and its core is a bit offset toward the galaxy's southeastern flank.

NGC 253 is the most luminous galaxy in the Sculptor Group and lies approximately 10 million light-years away.

The globular cluster **NGC 288** sits just 1.7° southeast of the Silver Coin. The two share a field of view through my 130-mm scope at 23×, with NGC 288 manifesting itself as a softly glowing ball of light with granular edges. At 117× this lovely cluster is freckled with stars all across its face and shows little concentration toward the center. At 164× a fainter 8¾′ halo appears around the 4½′ core, and I can resolve many stars having a fairly large brightness range. The cluster is gorgeous through my astronomy club's 18-inch scope, looking much like a rich open cluster with intricate lines of the brightest stars crisscrossing a well-resolved background.

NGC 288 is 29,000 light-years distant and contains about 40,000 stars. It orbits our galaxy in a direction opposite that of most other stars. In combination with other astrophysical clues, this retrograde motion suggests that NGC 288 may have been pilfered from a dwarf galaxy that our Milky Way absorbed.

Another Sculptor Group galaxy, **NGC 55**, hugs the southern boundary of Sculptor, with its fringe intruding into Phoenix. In my 130-mm refractor at 37×, it spreads an impressive 26′ east-southeast to west-northwest and



Although NGC 55, shown here, is only half as bright as NGC 253, it's still one of the sky's dozen brightest galaxies.

ESO

***Right*: Here's the author's impression of NGC 55 in her 10-inch scope at 68×.**

is 4′ wide across the center. A very large bright patch dominates the western half of the galaxy. At 63× a weaker brightening is revealed at the eastern end, while the western one appears broadly brighter toward the galaxy's long axis. Three faint stars cradle the southern flank of this magnificent congregation of distant suns.

NGC 55 is about 6 million light-years away from us, as is our next Sculptor Group member, **NGC 300**. While NGC 55 is easily swept up in a small scope, NGC 300 has low surface brightness and is more of a challenge to spot. Look for it 1.8° northwest of Xi (ξ) Sculptoris. It sits in the point of a 1.3° skinny V of 7th- to 9th-magnitude stars pointing north-northeast. At 63× it's a faint, 10′ × 7′ glow with a slightly brighter core perhaps 1½′ across. Vague traces of spiral arms are discernible. One starts on the galaxy's eastern side and wraps north, and another starts on the opposite side and wraps south.

I made the observations of the Sculptor Group galaxies with my 130-mm scope at the Peach State Star Gaze in Georgia, where the galaxies crest nearly 10° higher than they do in my sky. At my home (latitude 43° north), I usually need my 10-inch reflector to see as much detail.


ESO / POSS-II / CALTECH / PALOMAR OBSERVATORY

European Southern Observatory staff members created this 1°-wide image of the Sculptor Dwarf Spheroidal Galaxy from Digitized Sky Survey plates.

Our final target is the **Sculptor Dwarf Spheroidal Galaxy** (ESO 351-30) only 280,000 light-years distant. It's not a Sculptor Group galaxy, but rather a member of our Local Group and a satellite of the Milky Way Galaxy.

Although Sculptor dSph is only a few percent as big across as the Milky Way, it's close enough to appear as large as the Full Moon in our sky. However, the relatively star-poor dwarf's feeble light gives it a very low surface brightness. The galaxy sits 2.2° south and a tad west of Sigma (σ) Sculptoris, and it makes a squat isosceles triangle with Sigma and Alpha (α) that fits within a finderscope field.

From my semi-rural home in upstate New York, I saw only the central part of Sculptor dSph through my 10-inch scope at 43×. That portion lies just west of an 8½′-tall triangle formed by three stars, magnitudes 10.1 to 10.7. The ashen apparition spans about 13′ and is best noticed when slowly sweeping the telescope across the galaxy. The starry triangle is actually superposed on a dimmer part of the dwarf. The overall size of the Sculptor Dwarf Spheroidal galaxy is 40′ × 31′, stretching east-southeast to west-northwest. How much of this ghostly neighbor can you glimpse?

An astronomer wields the telescope, and the sky's hidden treasures grow to beauty. ✦

Splendors of Sculptor

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Blanco 1	Open cluster	4.5	89′	00^h 04.2^m	–29° 56′
κ^1 Scl	Double star	6.1, 6.2	1.3″	00^h 09.3^m	–27° 59′
NGC 253	Galaxy	7.2	22.7′ × 6.7′	00^h 47.6^m	–25° 17′
NGC 288	Globular Cluster	8.1	13.0′	00^h 52.8^m	–26° 35′
NGC 55	Galaxy	7.9	32.3′ × 5.6′	00^h 15.1^m	–39° 13′
NGC 300	Galaxy	8.1	22.1′ × 16.6′	00^h 54.9^m	–37° 41′
Scl dSph	Galaxy	9.7	39.8′ × 30.8′	01^h 00.2^m	–33° 43′

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

Sue French *welcomes your comments at scfrench@nycap.rr.com. Her new book* Deep-Sky Wonders *is now available for purchase.*

 Alan MacRobert

The editors of Sky & Telescope *answer your astronomy questions.*

Ideal Lube for Telescope Mounts

When I try to center something in my telescope eyepiece at high power, the mount sticks and jerks so much that it's almost impossible. I oiled the mount and that made it worse. What's wrong?
— William Turley, Chicago, Illinois

Take the mount apart, clean the oil off the bearings, and replace it with ChapStick or some other soft wax.

Oils and greases are generally the wrong lubricants here. They're meant for reducing moving friction and wear, like in your car engine. A telescope mount is not a car. What the mount needs is smoothness and controllability of *very tiny motions*.

More precisely: a telescope mount needs the minimum possible *difference* between *moving friction* and *static friction* (what amateur telescope makers call "stiction").

Waxes are good for this. An old standby is to rub candle wax on a mount's metal bearings. But candle wax can be pretty stiff. ChapStick is a softer mix of wax and oils. Vaseline is even softer. Experiment and see what works best; situations differ.

S&T: DENNIS DI CICCO

WAX IS THE WAY **The motions of this beefy altazimuth mount were greatly improved by cleaning the factory grease off the bearings and applying waxy lip balm instead.**

Also, make sure the telescope is nicely balanced on both axes. An off-balance load makes any mount stickier and jerkier. To keep both axes balanced at all orientations, you may need to rig an off-center counterweight on one side of a telescope tube to counterbalance the focuser and finderscope on the tube's other side. An optical tube assembly's center of gravity needs to be close to the tube's centerline.

Dobsonian mounts, whose bearings have broad, wide motions, need a different strategy. The accepted wisdom is that Dobsonian bearing pads should be Teflon or, better, Teflon's relative PFA (perfluoroalkoxy fluorocarbon). See the definitive article in the October 2003 *S&T,* page 122.

The weight on a Dobsonian's azimuth pads often needs to be lightened a bit by adding rings of thin plastic, such as you can cut from plastic milk jugs, around the center bolt to carry some of the load. The usual advice is don't lubricate Teflon or PFA, but there's no harm experimenting. You can always clean it off. ✦

Peculiar Velocities

If the universe is expanding and galaxies are moving away from each other, why do galaxies collide?
— Norm Pascal, Lethbridge, Alberta, Canada

When galaxies are fairly close together, their mutual gravitational pull overpowers the relatively weak expansion of space. Only on very large scales — basically, larger than galaxy clusters — does the cosmic expansion add up enough to make everything move away from everything else. So, for instance, it has no effect on the space right around us on Earth, or in the solar system, or in the Milky Way.

Think of expanding space like an ocean that is expanding due to water welling up everywhere from below. Galaxies are ships on the ocean. You're on a ship. The farther you look, the faster you'll see distant ships moving away from you — even if each one is sitting dead in the water around it.

In fact the ships, or galaxies, are not quite dead in the water; they have their own individual motions, which are called *peculiar velocities*. For "ships" nearby, these motions dominate (partly because the ships attract each other). Only on larger scales does the expansion of the ocean predominate over everything else.

Send questions to QandA@SkyandTelescope.com for consideration. Due to the volume of mail, not all questions can receive personal replies.

The Dob Buster

Customization is the key to making a telescope that is truly your own.

ZHENG XIANG

THERE ARE TWO KINDS of telescope builders — those who adhere to well-established designs, and those who view such designs as mere starting points when they set out to build a new instrument. One look at the pictures here should make it clear that San Diego, California, telescope maker Norman Butler is definitely in the latter group.

His 10-inch f/4 "Dob Buster" is a veritable buffet of twists on familiar themes. The scope's Dobsonian DNA is apparent in its bearings and general functionality, but Norman's specific needs and preferences play out in the details of the instrument's construction.

The conspicuous bowling-ball counterweight is one example. "Conventional short-focus Dobs tend to wear out my 6-foot frame after a few hours of observing," Norman explains. "So I decided to build a user-friendly Newtonian with a comfortable eyepiece height." To achieve this, he had to position the scope's primary mirror near the mount's altitude bearings, which made the instrument very front heavy. The 16-pound bowling ball mounted on pipe fittings at the rear of the mirror box serves as a removable counterweight that balances things out.

Another feature is the scope's collimation setup. Located at the front corners of the mirror box are four brass knobs — three to adjust the collimation by changing the tilt of the primary mirror and a fourth to lock down the mirror once the collimation is set. The knobs turn ¼-inch-diameter, 12-inch-long shafts that engage pairs of pulleys linked with rubber O-ring "belts." Seen in the lower photograph on the facing page, the large pulley on three of the pairs rotates a collimation bolt, while the forth controls the locking bolt. Thanks to this arrangement, Norman can align the optics of his scope while looking into the focuser — a huge plus as anyone who as spent time trying to collimate a large Newtonian surely knows.

Convenience is also a hallmark of the Dob Buster's

Dubbed the "Dob Buster," Norman Butler's unconventional 10-inch f/4 Newtonian has a primary mirror that he ground and polished himself, as well as a host of custom features that make the telescope a joy to use. Among the more obvious is the bowling-ball counterweight that helps place the eyepiece at a comfortable observing height.

NORMAN BUTLER

One of the Dob Buster's unusual features is the mirror-fed, right-angle finder, which attaches to the telescope tube with magnets. Another is the low-profile sled focuser. Both are described in the accompanying text.

periscope-style finder, which attaches magnetically to the main telescope tube. It is a conventional right-angle model with a 30-mm objective lens that is fed by a front-surface mirror tilted at 45°. The finder is aligned by simply adjusting the tilt of the feed mirror, and its eyepiece position is conveniently located near the scope's eyepiece, so no awkward neck craning is needed. Because the feed mirror adds a second reflection to the system, the finder's image is only inverted, not reversed left-to-right as it is with right-angle finders that have just a single reflection.

Perhaps the most interesting feature of Norman's scope is its "sled" focuser. Seldom seen today in amateur scopes, the design has some interesting advantages over conventional rack-and-pinion models. Norman notes that the focuser provides a smooth-moving platform capable of handling just about any 2-inch eyepiece, regardless of its weight or focus position. It also has an inherently low-profile, which allows the scope to have a smaller secondary mirror.

The focusing mechanism consists of an inner slide captured within a wooden frame. The slide moves up and down the tube, parallel to the primary mirror's optical axis, and it carries the eyepiece (in a 2-inch PVC-pipe fitting). The scope's secondary mirror is also carried by the slide and is attached to it with a single, rigid stalk. The slide's focusing motion is precisely controlled by a fine-pitch ¼-28 lead screw made of stainless steel, and a pair of spring-loaded ball bearings that push the slide against the top of its housing. "There is no slop whatsoever and no dead play even when you reverse focusing direction," Norman reports. He kept friction to a minimum by sanding the slide with fine sandpaper, and coating it with smooth, clear epoxy.

All of these features add up to a scope that is as pleasurable to use as it is convenient. "It's as user-friendly as I'd hoped it would be," Norman notes, "but when I go to star parties and show the scope to other observers, well, that's when the real fun begins!"

Readers wanting to know learn more about the Dob Buster can contact Norman at p.namron@yahoo.com. ✦

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*Contributing editor **Gary Seronik** has made some odd-looking telescopes, but nothing quite like the Dob Buster. Some of his scopes are featured at his website, www.garyseronik.com.*

ZHENG XIANG

The back of the mirror box conceals the pulley system (operated by knobs at the front of the box) that turns the collimation bolts. The central pulley engages a bolt that bears against the back of the mirror cell for locking down the collimation. Also visible is the pipe fittings for attaching the bowling ball counterweight.

Deep-Sky Imaging

Natural Color *with* Six Filters

PETER & DEBRA CERAVOLO

Try this alternative technique to enhance your color images made with broadband and narrowband filters.

DEBRA CERAVOLO

Astrophotographers striving to produce natural-appearing color images of deep-sky targets often enhance conventional tri-color images with narrowband data to better reveal the structure and extent of faint nebulosity. Author Debra Ceravolo used Hα, S II, and O III imagery to enhance this view of M8 using her new technique to spectrally map the narrowband images into a conventional RGB photo, thus revealing subtle hues in their proper spectral wavelengths.

ALL IMAGES ARE COURTESY OF DEBRA CERAVOLO UNLESS OTHERWISE CREDITED.

Narrowband imaging has become a popular method of showcasing nebula photographs in interesting and new ways. This technique got its start from the famous "Pillars of Creation" image of M16 taken with the Hubble Space Telescope back in 1995. This one image greatly influenced the world of amateur astronomical imaging. Today, it's common to see images of nebulae displayed in a variety of vibrant colors, so much so that many non-astronomers have come to accept this as reality. Often they're surprised to learn that this isn't how the universe really looks.

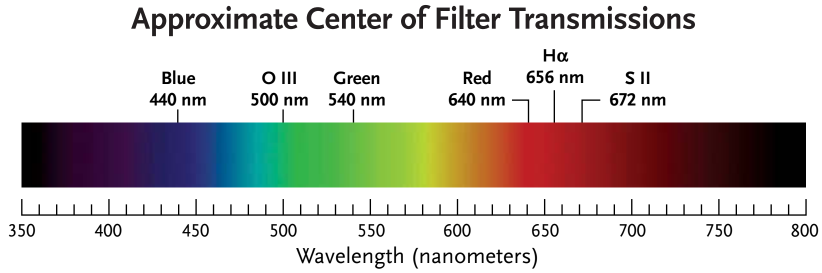
Amateur astrophotographers have embraced narrowband imaging mostly because the filters block many of the strongest sources of light pollution and allow one to shoot deep-sky objects from less-than-perfect observing sites. These filters have a very narrow passband, often just 3 to 10 nanometers (nm) of the visible spectrum, where specific ionized gases fluoresce. Images taken with these filters and combined into a color image tell us the predominant gas in a nebulous region, and highlight subtle structures within these glowing clouds. In contrast, traditional broadband red, green, and blue filters pass approximately 100 nm of the visible spectrum each. These filters originated as a way to create natural-looking color images of daylight scenes.

Astrophotographers who strive for natural-appearing celestial images often augment their RGB images with narrowband data that is blended into the RGB exposures. Generally, Hα and S II are blended into the red exposure. Because O III lies at the crossover between the blue and green filters, it's equally blended into both respective exposures. The original red, green, and blue image is thereby enhanced with narrowband detail while preserving the original color appearance.

The shortcoming of this blending technique is that it forces both the Hα and S II images to be the same color as the broadband red image. O III is forced to have the same color as the broadband green image, as well as the blue. The narrowband images aren't highlighted in their proper color assignment; they are only contributing to the overall structural detail in the object.

Understanding Color

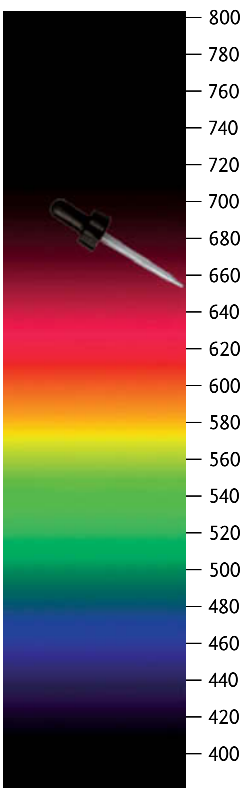
As Andrew Young of San Diego State University pointed out in his article "What Color is the Solar System?" in the May 1985 issue of *Sky & Telescope*, color can be defined by three parameters: hue, saturation, and brightness. Hue is the dominant wavelength of a particular color, though in imaging we tend to use red, green, and blue filters to mimic our eyes' response to light. Saturation refers to the purity of the color (spectral colors are 100% saturated), and brightness means how dark or light the color is. Changing any one of these parameters changes the color perceived by our eyes. A good example of this is an orange peel and a chunk of chocolate. They look distinctly different but both are the same hue and saturation. They differ only in brightness. Similarly, Mars is not really the reddish orange often shown in photographs. Images of Mars that we have become accustomed to were lightened to better reveal detail. Mars reflects only 10% of the Sun's light, so when the brightness levels have been properly adjusted, like the orange peel and chocolate example, the planet really appears dark brown. In summary, when you change an object's brightness, you also change its apparent color.



The visible spectrum covers the span from 400 nanometers (nm) to 700 nm, as shown above. Red, green, and blue filters used for tri-color astrophotography typically pass 100 nm each, which presents a problem when enhancing images with narrowband data: the oxygen III (O III) emission line resides almost directly on the crossover between blue and green. Both hydrogen alpha (Hα) and sulfur II (S II) are located within the red filter's bandpass. Simple channel-blending methods commonly used by astrophotographers often fail to assign each narrowband wavelength its proper color hue.

Color Mapping

In conventional RGB astrophotography, filtered images are monochrome until we designate each a particular color. Red, green, and blue images are assigned their colors according to their positions on a color wheel. Red is given a hue value of 0 or 360°, green 120°, and blue 240°. When assigning these images to the color channels in *Adobe Photoshop*, the program automatically makes their saturation 100% and assigns a medium brightness value of 50. These values are the software's default settings and not necessarily calibrated to the specific filters used. Once the color images are combined,



You can use this spectrum from Andrew T. Young (http://mintaka.sdsu.edu/GF/explain/optics/rendering.html) as a reference to establish the approximate color of filtered images using the eyedropper tool in *Adobe Photoshop*.

there are several methods of balancing the color ratios to show natural color. The most common method used by astrophotographers is to select a spectral class G2V star in the image as a reference for white balance. G2V stars are similar to our Sun, and appear white to our eye.

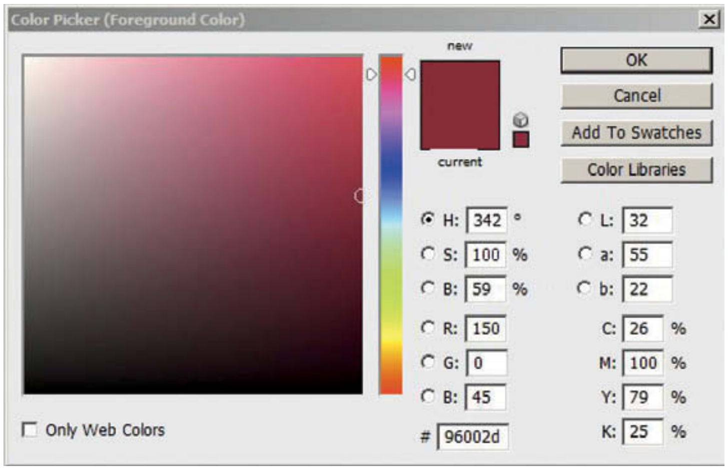
Using my spectral color mapping technique, all six images are placed in separate layers and assigned their own unique color using a Gradient Map adjustment layer. We can then assign the proper hue, saturation, and brightness values to each layer.

Matching the Visible Spectrum

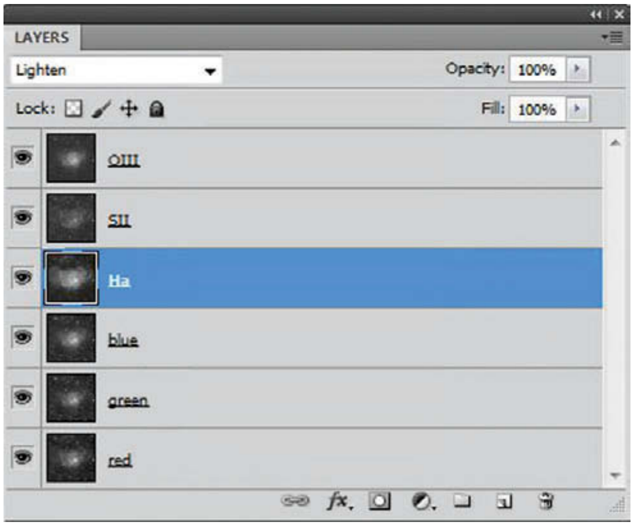
Ideally, the RGB and narrowband image layers should have assigned colors that closely represent their natural wavelengths. Red's central wavelength is 640 nm, green 540 nm, and blue 440 nm. Additionally, Hα is centered at 656 nm, SII 672 nm, and OIII lies at 500 nm. To create a natural color image using all six filters, the problem becomes one of converting each image's central wavelength to the appropriate hue, saturation, and brightness values.

Andrew Young developed a technique to render spectra for realistic display on RGB monitors (**http://mintaka.sdsu.edu/GF/explain/optics/rendering.html**). His work allows us to determine the proper values of hue, saturation, and brightness for any wavelength in the visible spectrum. By measuring these values in Young's spectrum in *Photoshop*, we can create naturally colored images of any celestial object by properly representing the color of each narrowband image.

To do this in *Photoshop*, open the image of Young's spectrum and using the Eyedropper Tool, click on an



Once you've clicked on a region of Young's spectrum that corresponds to the central wavelength of a filter's passband, click on the Foreground Color tool at the bottom of the tool palette in *Photoshop*. The color picker window opens, showing the color measurements of your selection. Write down the readings for hue (H), saturation (S), and brightness (B) to use later when assigning your broadband and narrowband color layers.



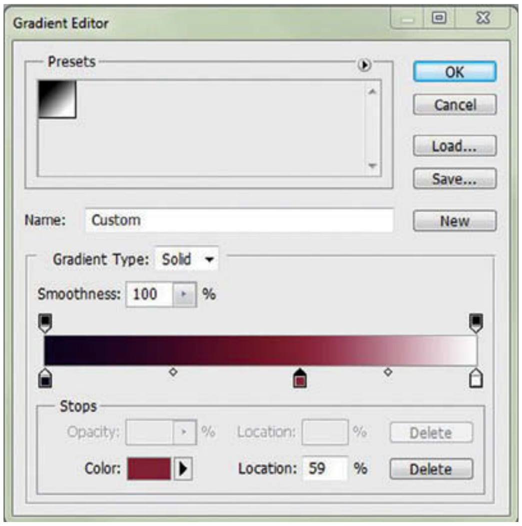
To combine all of our images, first open the red-filtered image and convert its color space from grayscale to RGB color (it will still appear grayscale). Next, copy and paste each of the other images on top of the red photo. Change the layer-blending mode at top-left from "Normal" to "Lighten" for every layer except the red. Begin assigning each layer its specific color by first selecting a layer, and then clicking the "create new adjustment or fill layer" at the bottom of the layer palette (black-and-white circle), and choose the Gradient Map option.

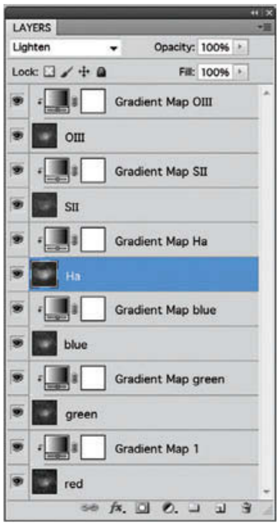
area of the spectrum corresponding to the filter's central wavelength. The Foreground Color Box at the bottom of the Tools palette now contains all the values of the selected color. By double-clicking on the Foreground Color box, the Color Picker window appears and displays the three important values of hue (H), saturation (S), and brightness (B).

Spectral Color Mapping

Before combining color and narrowband exposures, each image should be properly calibrated, registered, stacked, and stretched using your favorite CCD processing software. All six images, which are 16-bit monochrome TIFF images at this point, are then layered together in *Photoshop*. Start by using the red image as the base and convert its color profile from grayscale to RGB color (Image/Mode/RGB Color) and then copy the green image on top of the red and set the blending mode to "Lighten." Next, copy the blue and paste it over the green layer, and continue doing the same with the Hα, S II, and O III images until all six layers are in one image. Each layer should have the blending mode set to "Lighten" except for the red layer on the bottom. Name all the layers accordingly.

Next, select an image layer, click on the adjustment layer icon, and choose the Gradient Map adjustment tool. A Gradient Map window will appear and clicking on the gradient shown will open the Gradient Editor. Click anywhere along or below the gradient in this window





***Far Left*: To use a Gradient Map to assign color, click on the gradient that appears when the Gradient Map adjustment layer is selected. When the Gradient Editor window opens, click on or below the gradient to create a color stop within the gradient. Next, double-click the Color Stop icon you just created to open the Select Stop Color window. Here you want to change the H, S, and B setting to match the values measured earlier for the filter used to create this image layer. *Left*: To apply your Gradient Map to each respective image layer, click on a Gradient Map layer and select the additional options in the layer palette at the top right (below the red X button). Choose the Create Clipping Mask option, and your Gradient Map will apply only to the layer directly beneath it.**

and a Color Stop icon appears. Double-click on the Color Stop icon and the Select Stop Color window opens. Here we enter the three important values of hue, saturation, and brightness we obtained for the filter using the color picker and Young's spectrum. Lastly, enter the brightness percentage in the location window of the Gradient Editor. We have now colorized the image with the spectral color that corresponds to the wavelength of that filtered image. Do this for each layer. To make sure each Gradient Map is affecting the correct layer, right click on the Gradient Map layer and create a clipping mask. A downward facing arrow will appear and the Gradient Map adjustment layer is now directly associated with the image layer below it.

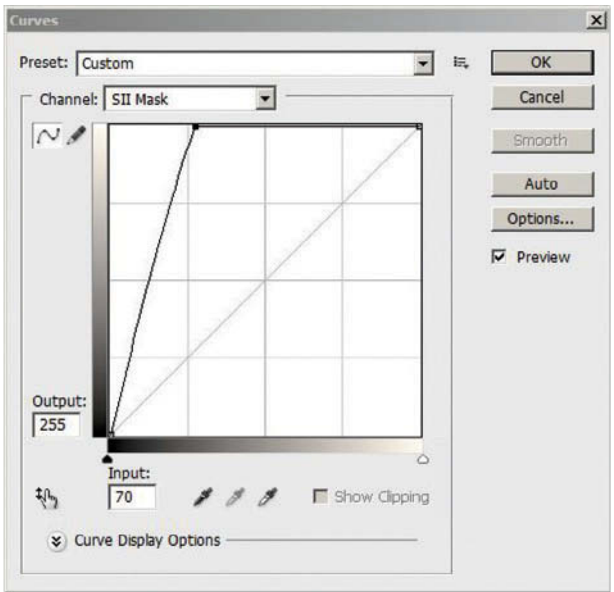
Final Color Balance

The introduction of narrowband images to your RGB layers often causes the sky background and star colors to shift. One remedy for this is to erase the sky background in the narrowband images using layer masks to allow only the nebulae in these image layers to contribute to the overall final image.

One way to do this is to highlight one of the narrowband image layers and create a layer mask. Use the dropdown menu and select Layer/Layer Mask. Select and copy the Hα layer; we'll use Hα because most nebulae are dominated by hydrogen alpha emission, making it the best layer for masking. Next, hold down the ALT key and click on the Layer Mask to make the window active. The image will appear white because you are now viewing the Layer Mask instead of the main image. Paste the Hα image into the layer mask, and apply a strong Gaussian Blur (a value of about 20 depending on size of image). Then open the Curves window and adjust the curve to look like it is clipping out the faintest and brightest areas of the mask.

To see the image layer again, simply click on the main image to the left of the layer mask. Do this for all of the narrowband layers to only allow the nebulae in the narrowband images to contribute to the overall image, while preserving the sky background and star colors.

This new technique brings out more narrowband structure than the channel-blending method, as well as displaying the natural colors of the emissions intrinsic to the nebula. It should be mentioned that colors are not



To ensure your narrowband image layers only enhance the nebulae within your image without disturbing the color balance of the background sky, create a custom clipping mask for each narrowband-image layer. Simply copy the targeted image, and alt-click the clipping-mask box to the right of the Gradient Map. Paste your image here, and adjust it by applying a strong blur filter, then use the Curves function as shown here.

Gradient mapping to better target your image's color balance can be performed on any type of astronomical photo, though its results are most pronounced in photos of nebulosity. Peter Ceravolo recorded this brilliant image of M42 through six filters. Author Debra Ceravolo processed it using her 6-color gradient-mapping technique.

portable, in other words, an image can be balanced and finessed on one monitor and yet appear slightly skewed on others. Monitor calibration is important, but still problems can arise with variation between color management programs, browsers, and projectors. Printing your image is another matter entirely; color saturation on a monitor exceeds what is possible in printed material. If your end goal is to print your images, you'll need to calibrate your monitor to match your printer's results.

Still, this technique is a big step toward many astrophotographers' goal of accurately portraying the vibrant beauty of the universe. ✦

__Debra Ceravolo__ and her husband Peter work together as an imaging team. Peter records long exposures of deep-sky objects that Debra processes into stunning celestial portraits.

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Statement of Ownership, Management, and Circulation

1. Publication Title SKY & TELESCOPE	2. Publication Number 0037-6604	3. Filing Date 10/1/11
4. Issue Frequency MONTHLY	5. Number of Issues Published Annually 12	6. Annual Subscription Price $42.95
7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and ZIP+4) 90 SHERMAN STREET CAMBRIDGE, MA 02140		Contact Person Nicole McGuire Telephone 617-758-0242

8. Complete Mailing Address of Headquarters or General Business Office of Publisher *(Not printer)*
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PS Form 3526 (Facsimile), October 1999

13. Publication Title	14. Issue Date for Circulation Data Below
SKY & TELESCOPE	OCT 11

15. Extent and Nature of Circulation		Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a.	Total Number of Copies *(Net press run)*	115,449	111,017
b. Paid and/or Requested Circulation	(1) Paid/Requested Outside-County Mail Subscriptions Stated on Form 3541. *(Include advertiser's proof and exchange copies)*	64,530	63,679
	(2) Paid In-County Subscriptions Stated on Form 3541 *(Include advertiser's proof and exchange copies)*	0	0
	(3) Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Non-USPS Paid Distribution	11,627	13,550
	(4) Other Classes Mailed Through the USPS	0	0
c.	Total Paid and/or Requested Circulation *[Sum of 15b. (1), (2), (3), and (4)]*	76,157	77,229
d. Free Distribution by Mail *(Samples, complimentary, and other free)*	(1) Outside-County as Stated on Form 3541	421	432
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f.	Total Free Distribution *(Sum of 15d. And 15e.)*	421	432
g.	Total Distribution *(Sum of 15c. And 15f.)*	76,578	77,661
h.	Copies not Distributed	38,872	33,356
I.	Total *(Sum of 15g. And 15h.)*	115,450	111,017
j.	Percent Paid and/or Requested Circulation *(15c. Divided by 15g. times 100)*	99.5%	99.4%

16. Publication of Statement of Ownership
Publication required. Will be printed in the DEC 11 issue of this publication. Publication not required.

17. Signature and Title of Editor, Publisher, Business Manager, or Owner
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◄◄ **COMETARY PHOTO-OP**
Rolando Ligustri
Comet Garradd (C/2009 P1) passes the bright stellar asterism in Vulpecula popularly known as the Coathanger Cluster.
Details: *Takahashi FSQ-106N refractor with SBIG ST-8300C CCD camera. Total exposure was 5 minutes.*

◄ **STREAKING LYRID**
Larry Andreasen
While the Lyrids aren't a particularly active meteor shower, Larry Andreasen managed to catch this bright streaker over the Painted Hills in Oregon.
Details: *Nikon D3 digital SLR camera with 14-24-mm zoom lens. Total exposure time was 30 seconds at ISO 4000.*

▼ **GALACTIC PANORAMA**
Manuel Jung
This deep mosaic of the Milky Way features dozens of pinkish hydrogen-alpha nebulae and thick lanes of dust obscuring the stars beyond.
Details: *SBIG STL-11000M CCD camera with Canon EF 35-mm lens at f/4. Five-frame mosaic with 11 hours of total exposure through Baader color filters.*

▲ **DARK COLUMNS WITHIN IC 5067**

Mel Helm

IC 5067, the Pelican Nebula in Cygnus, reveals towers of thick gas that are slowly being evaporated by the ionizing light of hot, young stars just beyond the top of this image. **Details:** *Dream Telescopes 16-inch Corrected Newtonian astrograph with QSI 583wsg CCD camera. Total exposure was 11 hours through Astrodon color and hydrogen-alpha filters.*

► **THE WILD DUCK CLUSTER**

Anthony Ayiomamitis

This deep image highlights red and blue stars in the bright cluster M11 in Scutum, which is also known as the Wild Duck Cluster.

Details: *Astro-Physics 160 mm f7.5 StarFire EDF refractor with SBIG ST-10XME CCD camera. Total exposure was 2 hours through Astrodon color filters.* ✦

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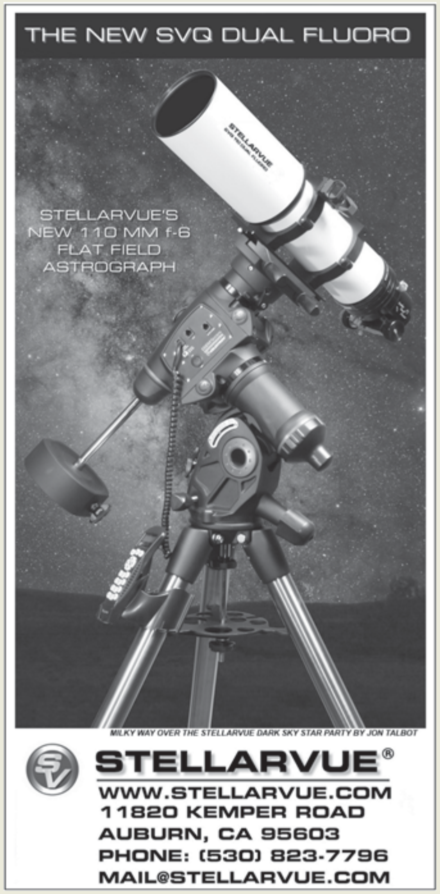

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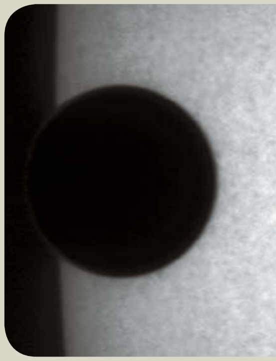

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Why We Should Build Webb

By pushing beyond Hubble's limits, Webb will inspire a new generation.

I'M A HUBBLE HUGGER. It started when I led the Hubble team that watched Comet Shoemaker-Levy 9 plow into Jupiter in 1994. The detailed images of black smudges on Jupiter cemented Hubble's reputation as the finest telescope ever crafted. Yet over the next 4 to 6 years, Hubble's complex machinery will inevitably succumb to the harsh environment of space, and no servicing missions remain.

To fill the looming void, NASA is developing the James Webb Space Telescope. Hubble could almost reach the very first galaxies; Webb will see those galaxies, and maybe even the first stars. Hubble spotted planets orbiting nearby stars; Webb can detect water in the atmospheres of planets just a few times larger than Earth. Like Hubble, Webb will return remarkable images, from our solar system to the edge of the visible universe. But Webb's machinery will be complex: multi-segmented adaptable optics will operate at cryogenic temperatures at the L_2 point, more than a million miles from Earth.

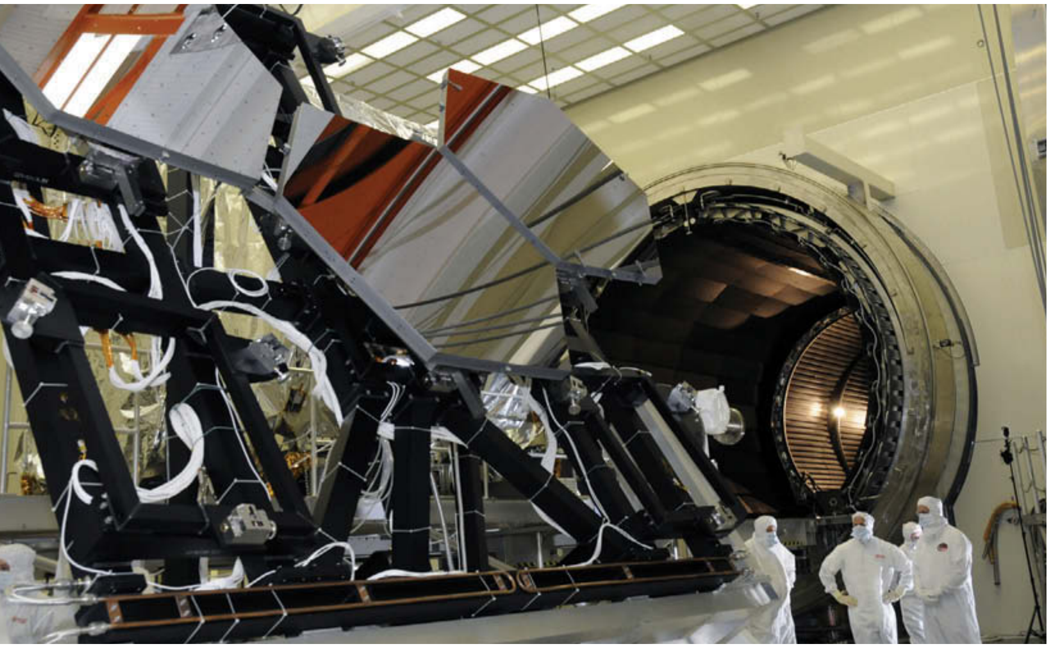
Building something this innovative doesn't come cheap. The last official total cost in 2008 was $5.1 billion. After a Congressional Review in 2010 indicated this was not enough, NASA re-evaluated Webb's full cost: it may be closer to $8.7 billion for a 2018 launch with at least five years of operation. To put that in perspective, though, Webb will cost *less* than Hubble (about $13 billion in current dollars) and yet it will be 100 times more powerful. The Review also zinged the project for poor management; NASA responded with substantial management changes and in 2011 Webb has hit all of its milestones.

For Webb, $3.5 billion has already been spent, much of it inventing cutting-edge technology. About 75% of the telescope is complete, in production, or undergoing testing. In addition, the European and Canadian space agencies are providing the launch vehicle, the guidance system, and several of the scientific instruments, for a total investment of $1 billion.

But we still have to put the telescope together, and here's the catch: Webb is so large that there is no facility where it can be assembled and tested all in one piece. A challenging new engineering strategy is required to test the various components separately, and still ensure with high confidence they will work together in space. Innovation costs real money.

Why bother? Because great nations do great things. Webb's new technologies have implications far beyond space science, including national security applications. But for me, the real reason for Webb is deeper. The grandeur of space provides a fundamental shift in human perspective. Just as Hubble images have inspired the world, Webb's images will enable us to rise above our daily interests, sparking the creative thinking needed to solve today's difficult Earth-bound problems.

Completing, launching, and operating Webb will require NASA to reallocate $3.6 billion over the next 12 years. That's roughly $12 per U.S. citizen, or $1 per person per year for the world's most amazing telescope. Surely this is a worthwhile investment of 1/30 of NASA's budget, which itself is less than 0.5% of the federal budget. Given Hubble's inspiration, science, and leadership, the tiny fraction of federal funding for its successor is an investment that Americans should be proud to make. ✦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*Astronomer **Heidi B. Hammel** is the Vice President of the Association of Universities for Research in Astronomy and an Interdisciplinary Scientist for Webb.*

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