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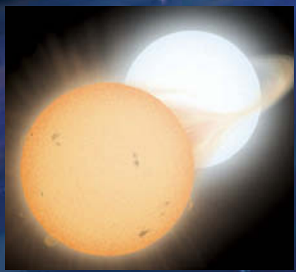

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SKY & TELESCOPE

August 2012

VOL. 124, NO. 2

CASEY REED

On the cover: Artist Casey Reed portrays the imaged giant planet orbiting the young Sun-like star LkCa 15.

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Robert Naeye
Spectrum

Who Will Lead the Way?

MY *S&T* COLLEAGUES and I spend a lot of time thinking and writing about exploration going *up* — into space. But earlier this year the office was abuzz with discussion about exploration going *down* after we read reports that filmmaker James Cameron successfully dove to the Challenger Deep. We were particularly eager to hear news of what kind of life might be able to survive the crushing pressure nearly 11 kilometers (6.8 miles) below sea level. Kudos to Cameron for not only undertaking such a risky venture, but also for spending millions of dollars of his own money for exploration and research.

I wonder if this is the wave of the future for ocean exploration and even space exploration. Inexplicably, the White House submitted a budget to Congress earlier this year that would whack 20% out of NASA's planetary-science budget, with the greatest amount of hurt falling on the Mars program. Even though it looks like Congress will restore most of that funding, the proposed cuts forced NASA to cease cooperation with the European Space Agency on a future Mars rover. And with the overall planetary-science cuts, it's difficult to predict when we might see a new flagship mission to Jupiter or Saturn to explore the potential of their icy moons to support life.

It's baffling that NASA's Mars program is being "punished" for the excesses of the James Webb Space Telescope. Cutting back on Mars exploration right now, just as Curiosity is approaching the Red Planet, represents a giant leap *backward* for American leadership in space. And NASA won't be able to launch humans into space for at least five years. Sure, the U.S. has a $15.8 trillion national debt (slightly greater than its annual GDP), and certain space-science missions have had cost overruns, but this is only part of the problem. NASA seems to be in a state of disarray, not because it lacks brilliant scientists and engineers, but because it's not receiving clear direction from the President or Congress.

With NASA in the doldrums, we're seeing encouraging signs that private business is picking up some of the slack. Besides Cameron, wealthy entrepreneurs such as Richard Branson and Eric Schmidt are funding deep-sea submersibles and space-exploration projects. Just as this issue was going to press in late May, the private company SpaceX launched a cargo vehicle to resupply the International Space Station. Various organizations are vying for the $30 million Google Lunar X Prize to land a privately funded robot on the Moon. And as the news story on page 18 explains, a company financed in part by software executive Charles Simonyi has been formed to mine asteroids for precious metals. We're a long way from such a mission actually flying, but perhaps visionary entrepreneurs such as Cameron, Branson, Schmidt, and Simonyi can help lead the way to an exciting future in space.

Robert Naeye
Editor in Chief

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Revisiting the *Titanic*

Your *Titanic* article in the April issue (page 34) was absolutely fascinating. I was particularly moved by the words of rescued passenger Lawrence Beesley, and was curious to learn if his observations were accurate.

So, I used the freeware program *Stellarium* to set up an observing site at *Titanic*'s approximate collision location (41.75° north, 49.9° west), and set the date to April 14, 1912. It turns out that at 11:40 p.m. (the time of the collision) Mars was just setting, and Jupiter had already risen in the east, along with the Milky Way. By the time of the sinking, three hours later (after the ship's electric lights were extinguished), a glorious Milky Way was clearly visible in the moonless southern sky. This explains Beesley's comment, "in places there seemed almost more dazzling points of light set in the black sky than background of sky itself."

Beesley's description of the Moon is dead-on, for "the thinnest, palest of moons" was indeed rising, right alongside Venus, "with the crescent turned to the north, and the lower horn just touching the horizon." If his latter observation about the Moon's "lower horn" is accurate, then I conclude that Beesley made this observation 40 minutes before sunrise on April 15th.

Thanks to *S&T* and the *Stellarium* software, I almost felt like I was sharing a lifeboat with Lawrence Beesley on that terrible night, 100 years ago. We truly live in a magical age.

Tom Sales
Somerset, New Jersey

The sensationalist article "Did the Moon Sink the Titanic?" in the April issue was extremely disappointing. The article gives the impression that the iceberg and the large field that it belonged to were a singularly extraordinary event. But while the field may have been larger than usual for the time and latitude, 1) it wasn't some once-in-a-millenium-type event, and much more importantly, 2) multiple combined human errors led to the collision, sinking, and loss of life, not least of which was that Captain Smith either wholly neglected to plot or deliberately ignored the multi-mile-wide ice field directly across the ship's path. These are well discussed in Walter Lord's classic book *A Night to Remember*. The perigean tides' effect on the number of icebergs really was incidental.

Had the article been written from the perspective of, "Okay, so a combination of human errors caused the *Titanic* tragedy. What astronomical factors could have helped prevent or ameliorate it had they been different?", it would have been a lot stronger. The lack of moonlight to illuminate the berg would have dominated, but the perigean tides could *then* have been included as one exacerbating event.

Art Samplaski
Ithaca, New York

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.

Between 2007 (right) and 2012 (above), the Horn Antenna in Holmdel, New Jersey, had a makeover: for one, the ladder's rust is gone.

RUSTY: BELL LABS / NATIONAL PARK SERVICE; CLEAN: HELDER JACINTO

Horn Antenna's Makeover

After reading a letter in *S&T* about the sorry state of the Horn Antenna in New Jersey used to discover the cosmic microwave background (*S&T:* October 2010, page 8), I made it a personal goal to check out the antenna myself. I finally made it this past April. Thanks to Google Earth, I easily found the antenna just where the previous letter-writer said it was: atop a steep hill with various other buildings in an Alcatel-Lucent office complex.

I walked up and around and am happy to report that the condition seems pretty good for the instrument's age. There is very little rust, and it looks like parts of the antenna have been repainted. Three plaques detail the antenna's importance in the discovery of the microwave background. Being in the presence of such history was greatly exciting for me. Sadly, few people know its history, and fewer still go see it. Considering how close it is to New York City, more people should try to visit.

Helder Jacinto
via e-mail

Eyepiece Heavyweights

In his April review of the 120° Explore Scientific eyepiece (page 64), Dennis di Cicco noted that the eyepiece is the heaviest and most expensive mass-marketed astronomical eyepiece in existence. However, the Rodenstock 40-mm, Meade Series 5000 30-mm, and Celestron Axiom LX 31-mm are all heavier than the 120° ES eyepiece. In addition, Nikon's NAV-HW 100° eyepieces are more expensive. So, while the ES eyepiece breaks new ground in apparent field, it does not in weight or price.

Don Pensack
Los Angeles, California

Author's Note: *Several readers wrote in to alert us that the mass-marketed Celestron*

and Meade eyepieces mentioned by Mr. Pensack are a few ounces heavier than the Explore Scientific 120° eyepiece. We're glad to see our readers are as sharp-eyed as ever. Regarding the very heavy 40-mm eyepiece made by the German firm Rodenstock, the eyepiece is for military binoculars, but has an after-market retrofit for 2-inch telescope focusers and therefore doesn't fall into the "mass-marketed" category of astronomical eyepieces. Several Nikon 100° telescope eyepieces are available in Japan with street prices around $1,200. While this price exceeds the ES 120°'s current $999.95 cost, ES's list price is $1,499.95, and is therefore still the record-holder — as far as I know.

Comet Colors FYI

There's a growing misconception about comets that I'd like to bring to your readers' attention, namely that their green color is due to cyanogen. Although cyanogen can be in comets, its dominant emission is outside the visible (in the UV below 400 nm); comets' green glow is due primarily to molecular carbon (C_2). Somehow, the fact that many comets are green, and that comets often contain cyanogen, was conflated to "Comets are green because they contain cyanogen." It's unclear how this misconception started, but the internet is spreading it rapidly, with several reputable websites repeating the error.

This serves as a reminder to us all to check our sources and, particularly, *their* sources. Without a direct link to a primary source, preferably a peer-reviewed journal article, the information might be suspect.

Frank Suits
Garrison, New York

75, 50 & 25 Years Ago

Roger W. Sinnott

August 1937

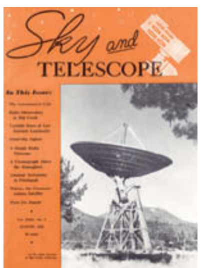
Known Minor Planets "Up to November, 1936, there were 1380 asteroids whose . . . [orbits] were well enough known to [be officially numbered by] the Astronomisches Rechen-Institut. . . .

"[Armin O.] Leuschner of the University of California is one of the world authorities on this subject. . . . Concerning the total number of these spheroids in existence, it is the opinion of Professor Leuschner that there are probably about 50,000 of them! Now this is rather a new idea, even for many astronomers."

Today roughly 330,000 asteroids have accurately known orbits, a tally that increased by 50,000 in the past year alone. No end is in sight.

August 1962

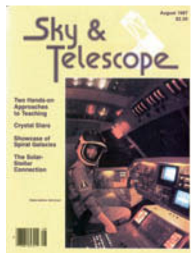
TV via Space "If some day soon you watch on your home television a 'live' program from Bali or some other remote land, you can thank a small pioneer satellite that this summer began circling the earth. Built by Bell Telephone Laboratories, Telstar is essentially a broad-band microwave relay station whose great altitude enables it to transmit over very long distances, whereas its earthbound counterparts are limited by the curvature of the globe. . . . [A] system of similar satellites could provide a world-wide communications system."



Telstar flew in low-Earth orbit, but it was a big step toward realizing Arthur C. Clarke's 1945 vision of a network of communications satellites in higher, geostationary orbits.

August 1987

Other Jupiters? "Canadian astronomers may have detected bodies with masses no more than 8 or 10 times that of Jupiter — planets, perhaps — orbiting seven nearby stars. Bruce Campbell (Dominion Astrophysical Observatory) and colleagues found two 'probable' and five 'possible' candidates among 16 stars they observed from 1981 to 1987. The nearby stars showed variable Doppler shifts that may be due to the gravitational effects of small companions. Epsilon Eridani and Gamma Cephei are the two best candidates."



Jupiter-mass exoplanets were ultimately found around Epsilon Eri and Gamma Cep, although the Campbell team's data were inconclusive.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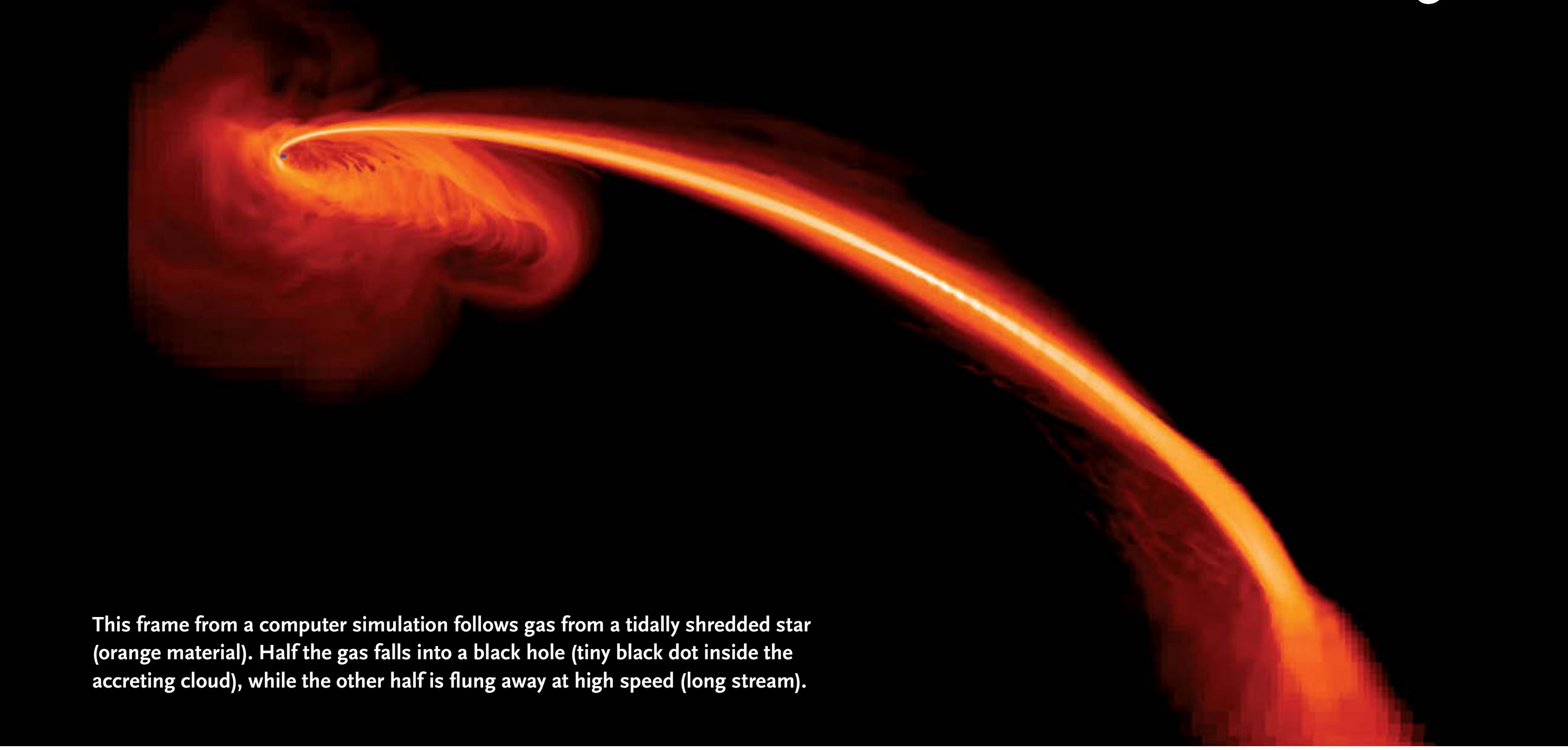
BLACK HOLES | Leviathan Peels Star Before Eating



This frame from a computer simulation follows gas from a tidally shredded star (orange material). Half the gas falls into a black hole (tiny black dot inside the accreting cloud), while the other half is flung away at high speed (long stream).

NASA / S. GEZARI (JHU) / J. GUILLOCHON (UCSC)

A closely-studied flare from a supermassive black hole in a distant galaxy has revealed not only that the beast ate a star but also the type of star it tore apart and swallowed, an international team reported in the May 10th *Nature*.

Astronomers have already seen supermassive black holes devour a few other stars. Two of these events were reported last year, which were found thanks to relativistic jets that shot out as the black holes scarfed down the shredded material. But the new incident is the first to reveal what kind of star met this unpleasant fate.

The team spotted the flare in visible light data recorded in May 2010 by Pan-STARRS 1, a 1.8-meter scope on Mount Haleakala in Hawaii. The project is among the first of the coming generation of fast, deep, wide-field sky-monitoring surveys. A month later, the Galaxy Evolution Explorer (GALEX) satellite (April issue, page 20) discovered the flare independently in ultraviolet light. The flare was so bright that observers had to wait a year for it to fade enough so they could see the host galaxy and measure its redshift and distance (about 2.7 billion light-years), says study coauthor Suvi Gezari (Johns Hopkins University).

The flare was at least as powerful as a supernova, but its behavior didn't jibe with a stellar explosion. Instead, the flare's rise and decay times matched those predicted by models of a black hole consuming a star. Such an event doesn't happen all at once. As the star draws nearer, the black hole's tidal force stretches the star into a banana-like shape. When the star finally comes too close, it's ripped apart. Half of the disrupted star's material is chucked out at high velocity, while the other half gathers into an accretion disk and spirals into the black hole. It's this accreting material that produces the radiation seen as a flare.

Spectroscopic observations of the ejected debris, made with the 6.5-meter MMT in Arizona, showed ionized helium emission but no sign of hydrogen — odd for a star, which is normally mostly hydrogen. But if an aged red giant had been stripped of its hydrogen envelope on an earlier swing-by, reducing it to its helium-rich core, the star's death would match the observations.

Such a two-step scenario is just what theorists expected. A star that dies from being shredded by a supermassive black hole probably makes many earlier, wider loops around the leviathan, edging closer until it's ultimately devoured. A red giant's hydrogen envelope is typically more than a thousand times larger than its tiny, white-dwarf-like helium core, and this fluffy envelope would be more easily stripped off during an earlier pass than a ripe peach is torn off its pit.

■ **CAMILLE M. CARLISLE**

To read astronomy news as it breaks, visit skypub.com/newsblog.

COSMOLOGY | Dark Energy BOSSes Around the Universe

A new detailed map of cosmic structure created from the Baryon Oscillation Spectroscopic Survey (BOSS) is helping astronomers home in on the nature of dark energy with high precision.

"Dark energy" is a generic term for whatever repulsive force is making the expansion of the universe speed up. This mysterious force began to overpower gravity on the largest cosmic scales about 6 billion years ago. At that point, the matter in the expanding universe had thinned out enough that the gravitational pull of everything on everything else became too weak to counteract the unknown repulsive energy making space expand. The universe's expansion stopped slowing down and started to accelerate.

BOSS studies the universe's history by mapping the gigantic, cobwebby structures traced out by hundreds of thousands of galaxies. Way back in the hot, primordial-soup days after the Big Bang, before photons and matter decoupled at a cosmic age of 380,000 years, huge acoustic waves rang through the universe, sloshing matter into higher-density and lower-density regions. As the universe expanded and cooled and the earliest galaxies formed, the imprint of those pressure waves remained, recorded in the galaxies' stringy arrangements. This imprint, as seen at later and later eras of the universe, acts as a sort of standard ruler — a measuring stick with which astronomers can see how the universe had expanded at different ages.

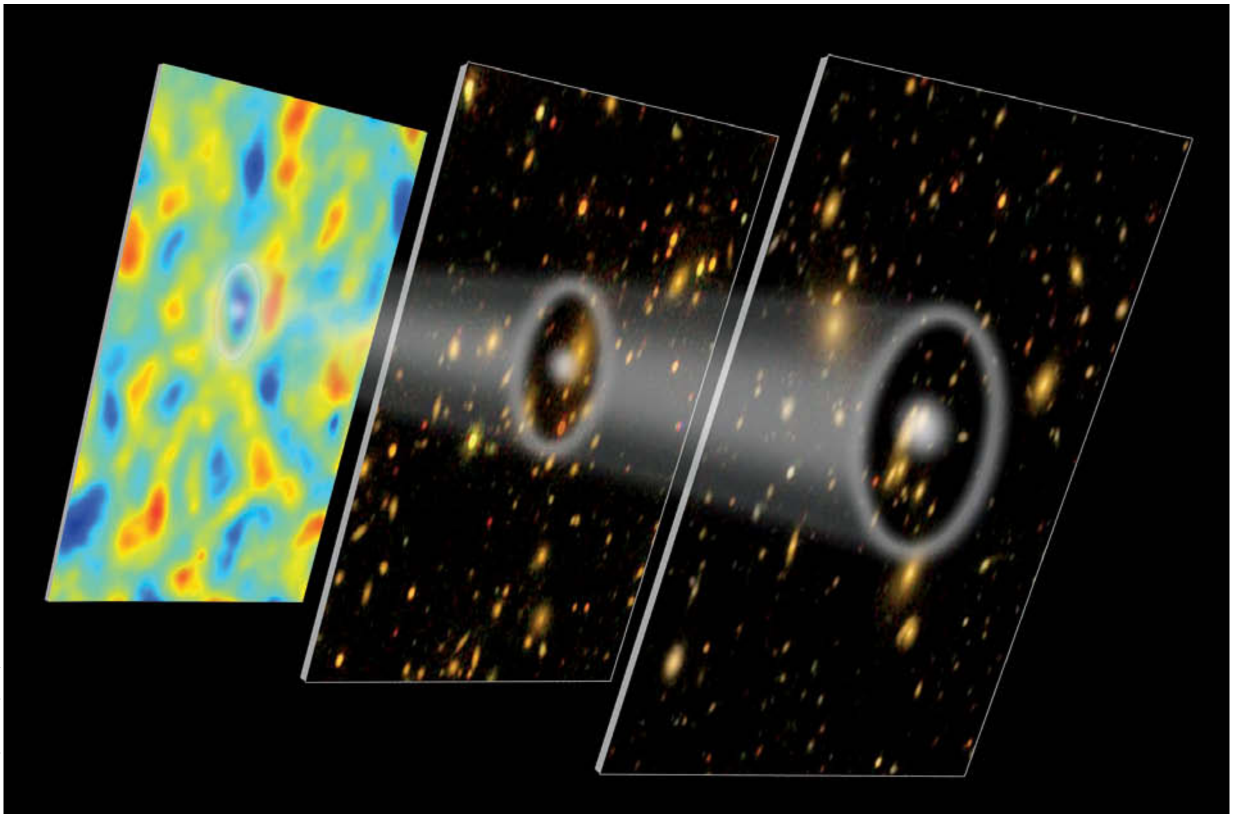
BOSS astronomers presented preliminary high-precision results this spring at the National Astronomy Meeting in Manchester, England. They concluded that dark energy makes up between 70.7 and 73.1% (at a 68% confidence level) of the universe's matter-and-energy tally. This is right in line with previous determinations but adds new precision.

They also confirmed that dark energy appears to be unchanging over time, with a degree of precision (± 7% in dark energy's "equation of state," or *w*, which quantifies its pressure and density) slightly better than previous findings.

The new results argue against throwing dark energy or dark matter out the window in favor of a modified theory of gravity on large scales, Beth Reid (Lawrence Berkeley National Laboratory) and her colleagues showed. Reid's team tested for a breakdown of Einstein's general theory of relativity by examining the growth of large-scale structure patterns in the BOSS survey. Unmodified general relativity predicts how fast galaxies should fall toward one another to create these structures. So the team measured the individual velocities of hundreds of thousands of galaxies and found that they were falling exactly as described by gravity as we know it, even on enormous scales.

It appears that dark matter and dark energy are both here to stay.

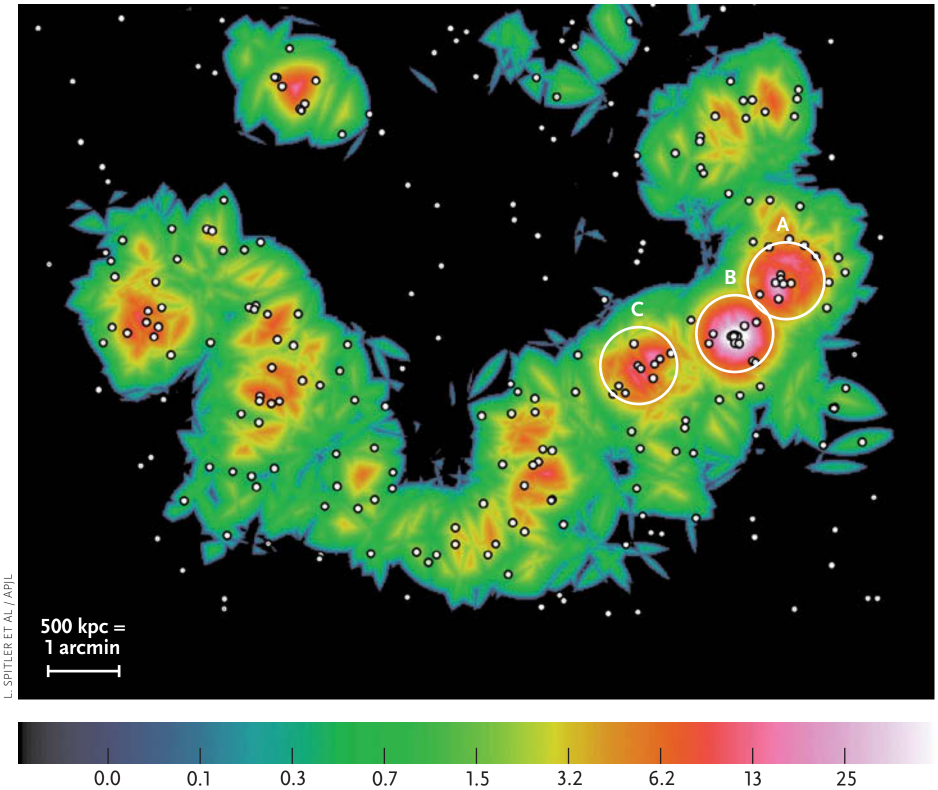
■ **MONICA YOUNG**



E.M. HUFF / SDSS-III / SPT / ZOSIA ROSTOMIAN

This illustration portrays baryon acoustic oscillations (white rings), the sound waves that rippled through the early universe. The signature of these waves remains imprinted on the cobweb-like structure of galaxies that formed much later, shown here at 5.5 billion years ago (center) and 3.8 billion years ago (right). The changing structure at different times tells how fast the universe had been expanding up to those points in cosmic history.

GALAXIES | Colorful Cluster Transformation



This near-infrared map reveals remote concentrations of matter not visible in optical light. Units are standard deviations above the mean density, and individual dots are galaxies. Astronomers suspect the overdensities labeled A and B together mark an early galaxy cluster. The overdensity marked C is less stark compared to its surroundings.

Astronomers have used a powerful infrared imaging camera called FourStar to discover what may be the oldest galaxy cluster observed that is making the transition from lively star formation to a more sedate existence.

These results are the first from the FourStar Galaxy Evolution Survey, an effort using the 6.5-meter Magellan Baade Telescope in Chile to observe galaxies at redshifts greater than 1, from the universe's first 6 billion years. The potential cluster is a set of 29 galaxies in a region 800,000 light-years across, shining from just over 3 billion years after the Big Bang, the team reported in the April 1st *Astrophysical Journal Letters*. Researchers think that rich groups in today's universe, such as the Coma Cluster in Coma Berenices, must have resembled this galactic huddle early on.

The compact grouping not only includes middle-aged "red" galaxies, those glowing with older, redder stars, but it also has a dash of "blue" galaxies still churning out lots of hot, massive stars that burn through their fuel fast.

This blue-red combination suggests the cluster's member galaxies are ending their eras of active star formation. Different clusters hit this transition at different times, probably when their galaxies run out of cool, star-forming gas. Astronomers don't really understand when and why cluster galaxies run out of this material, especially compared to their counterparts in less-dense environments, such as the Milky Way. Finding such an early cluster that is undergoing the transition could help detect what triggers the change.
■ **JESSICA ORWIG**

PARTICLES | Ultra-High-Energy Cosmic Rays Still a Mystery

New results out of Antarctica contradict the idea that the most energetic atomic particles hitting Earth's atmosphere come from gamma-ray bursts. This conclusion, reported in the April 19th *Nature*, perpetuates the mystery of what is to blame for accelerating these impossible-seeming particles.

Cosmic rays are high-speed particles (usually protons) that appear to strike Earth from all directions. The lower-energy ones are probably accelerated within our galaxy, such as by magnetic winds in young star clusters (March issue, page 12). But at the extreme upper end of the scale, "ultra-high-energy cosmic rays" (UHECRs) probably come from outside the Milky Way. These are single atomic particles that can carry as much kinetic energy as a pitched baseball. Active galactic nuclei used to be the prime candidates for their source (*S&T:* March 2008, page 24), but that theory has been weakened by recent data that show the particles come from, on average, no place in particular.

One proposed source has been gamma-ray bursts, or GRBs, flashes of high-energy photons that mark the collapse of a very massive stellar core or the merger of two neutron stars. A GRB might be able to spawn ultra-high-energy particles. If so, some of them should immediately produce a burst of neutrinos also heading our way.

The IceCube neutrino detector in Antarctica has been looking for these neutrinos, but the team reports that it finds no correlation of neutrino detections with the times and directions of 300 known gamma-ray bursts. The team expected to see 8 or 9 such matches over the course of two years if the theory was right.

GRBs were already a doubtful UHECR source: several researchers think it's unlikely that GRBs can produce such super-high-energy particles. But with GRBs and AGNs called into question, the baseball-energy particles remain a mystery.
■ **CAMILLE M. CARLISLE**

SCOPES | New Eye in Store for Russian Heavyweight

Opticians are working to remake a flawed 42-ton slab of glass into a first-rate primary mirror for the 6-meter Bolshoi Teleskop Azimutal'ny (Large Altazimuth Telescope) on Russia's Mount Pastukhov.

From 1975 until the completion of the Keck I telescope in 1993, the BTA was the world's largest optical telescope (*S&T*: June 1992, page 626). The instrument was intended to dethrone Palomar's 200-inch (5-meter) Hale Telescope.

But being biggest never made the BTA best. Poor atmospheric seeing, changeable weather, and bad temperature control hampered the instrument's optical performance. Added to that was the abysmal quality of the telescope's original optics: the first primary blank was unusable, and the second had to have sections blocked out with black cloth. The third primary mirror — installed in 1978 and used since — was good, but its surface has degraded from multiple washings with alkali-based solvents, which were used prior to applying a fresh coating of aluminum.

LYTKARINO OPTICAL GLASS FACTORY

Opticians prepare to remove the topmost 8 mm of glass — and with it a host of imperfections — from the original 6-meter primary mirror for Russia's Bolshoi Teleskop Azimutal'ny.

With budget and observing-schedule constraints, the only option was to refurbish the original mirror. Engineers have pulled it out of storage and used a milling machine to remove 8 mm (0.3 inch) of glass (weighing more than a half ton) from the upper surface, taking the defects with it. Now it's a matter of refiguring and repolishing the mirror to create a clean parabolic surface. The refurbished primary is scheduled to return to the observatory in mid-2013, when it will be coated with aluminum and swapped in for the existing mirror. Perhaps then the "Cyclops of the Caucasus" will take its rightful place among the world's greatest telescopes. ✦

■ **J. KELLY BEATTY**

ASTEROIDS | Mining for Fun and Profit

A recently formed company called Planetary Resources has announced ambitious plans to extract billions of dollars' worth of precious metals, along with water for space travelers, from near-Earth asteroids. The company predicts no financial return in the foreseeable future; the venture is an exploratory one to develop technology for a time when it may become practical.

Asteroid mining isn't a new idea. The first speculations started about a century ago, and in 1996 John S. Lewis, a planetary astronomer at the University of Arizona, made the case for asteroid prospecting in his book *Mining the Sky*. Recently, a team of scientists and engineers unveiled a plan to capture a small near-Earth asteroid and bring it into high lunar orbit for study and exploitation.

Two factors that prior schemes were missing give the Planetary Resources plan credibility: a space-savvy management team and wealthy investors willing to fund it. The team includes planetary scientists, Mars rover engineers, and Lewis himself. One of the investors is software executive and space tourist Charles Simonyi.

"This wouldn't be an appropriate investment for NASA," Simonyi said during the company's press conference. "This is where private enterprise comes in. Private investors can take the risk."

Plans call for a three-phase approach spanning about a decade. First, a series of small orbiting telescopes would find and track thousands of NEOs. Second, clusters of satellite probes would rendezvous with promising targets and assess their resource potential. Third, robotic miners would land and start harvesting the cosmic pay dirt. The first of the orbiting telescopes — dubbed Arkyd 101 — is under construction and should be launched within two years.

■ **J. KELLY BEATTY**

If a bold commercial plan succeeds, about a decade from now a robotic spacecraft could capture a primitive chondritic asteroid and extract its water to fuel future space industries — and travelers.

PLANETARY RESOURCES

Read the plan to capture asteroids and bring them into lunar orbit: http://bit.ly/Jq7CSf.

Pictures of a Baby Solar System

THAYNE M. CURRIE

CAROL A. GRADY

Astronomers have found a young version of the Sun surrounded by a solar system analog in the making.

ILLUSTRATION BY CASEY REED

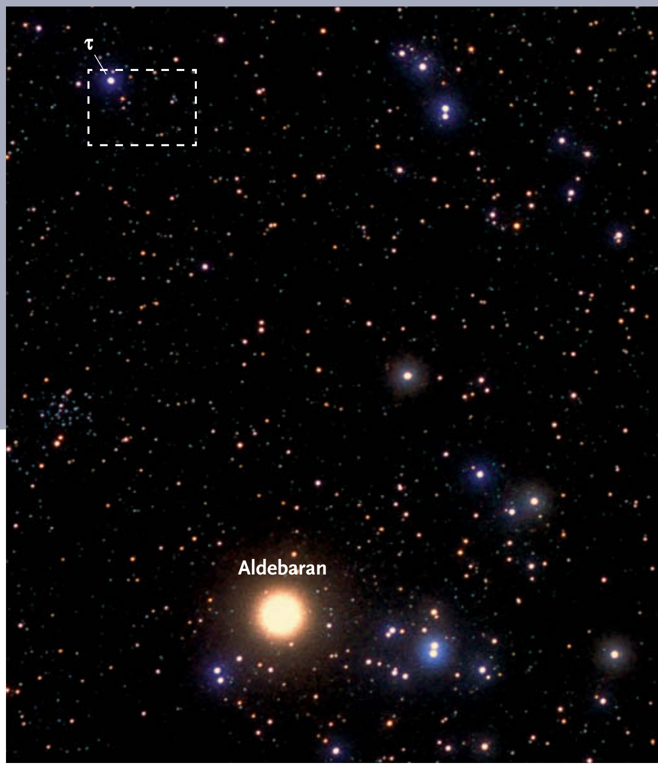
What did our solar system look like in its infancy, ...

. . . when the planets were forming? We cannot travel back in time to take an image of the early solar system, but in principle we can have the next best thing: images of infant planetary systems around Sun-like stars with ages of 1 to 5 million years, the time we think it took for the giant planets to form.

Infant exoplanetary systems are critically important because they can help us understand how our solar system fits within the context of planet formation in general. More than 80% of stars are born with gas- and dust-rich disks, and thus have the potential to form planets. Through many methods we have identified more than 760 planetary systems around middle-aged stars like the Sun, but many of these have architectures that look nothing like our solar system. Young planetary systems are important missing links between various endpoints and may help us understand how and when these differences emerge.

Well-known star-forming regions in Taurus, Scorpius, and Orion contain stars that could have infant planetary systems. But these stars are much more distant than our nearest neighbors such as Alpha Centauri or Sirius, making it extremely challenging to produce clear images of systems that can reveal signs of recent planet formation, let alone reveal the planets themselves.

Recently, a star with the unassuming name LkCa 15 (spoken as "Lick calcium 15") may have given us our first detailed "baby picture" of a young planetary system similar to our solar system. Located about 450 light-years away in the Taurus star-forming region, LkCa 15 has a mass comparable to the Sun (0.97 solar mass) and an age of 1 to 5 million years, comparable to the time at which Saturn and perhaps Jupiter formed. The star is surrounded by a



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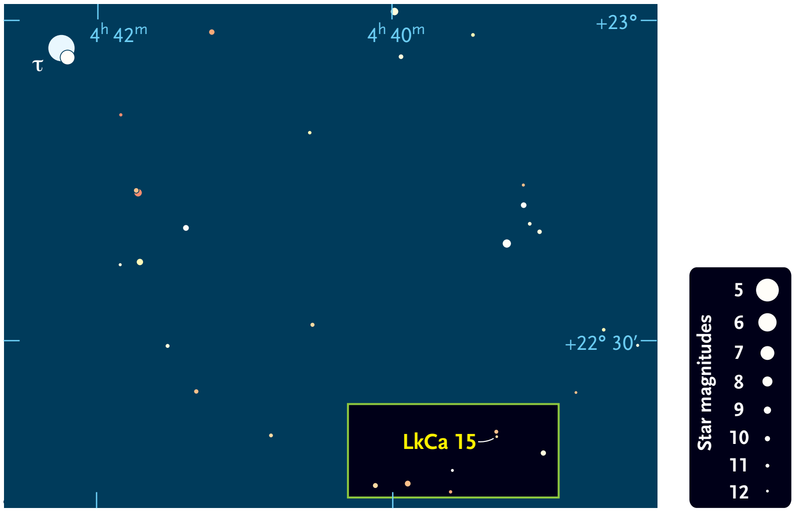
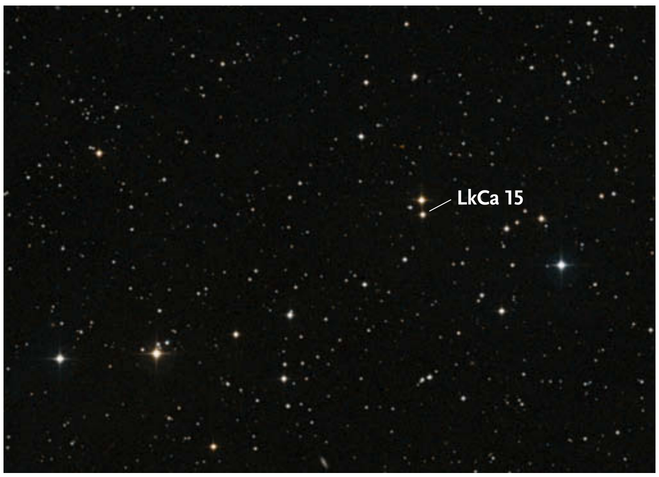




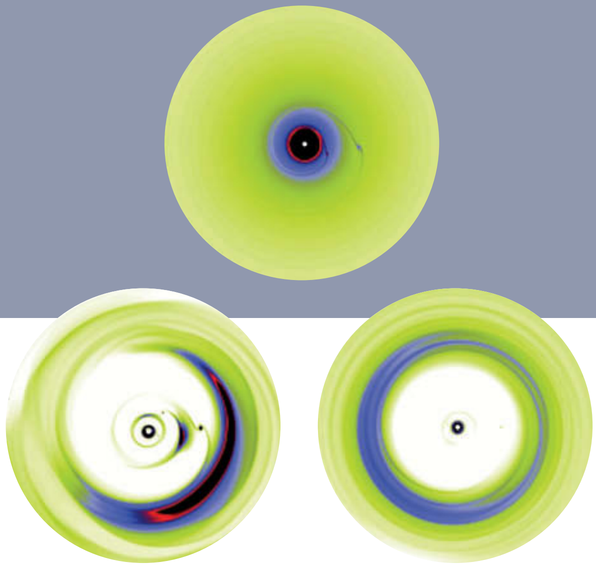
POSS-II / CALTECH / PALOMAR OBSERVATORY

BABY SOLAR SYSTEM *Left:* Artist Casey Reed portrays the LkCa 15 system. The 1- to 5-million-year-old star is nearly identical in mass to the Sun and has at least one planet (foreground) comparable to Jupiter. The disk around the star has sufficient material to produce a planetary system similar to our solar system.

YOUNG SUN *Right:* These pictures show how to find magnitude-12 LkCa 15 in Taurus at R.A. $04^h 39^m 18^s$, declination +22° 21′ 03″. It lies directly south of a magnitude-11 star. The star name comes from a 1980s Lick Observatory calcium-line survey.

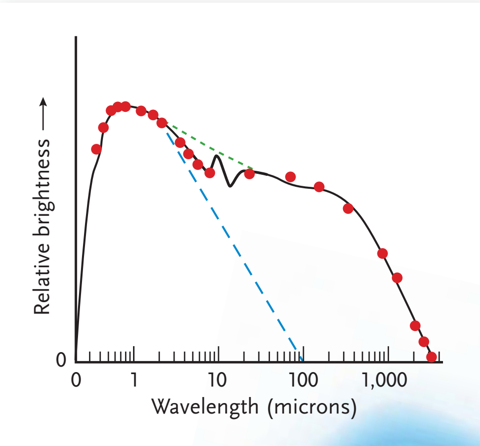
AUTHOR PHOTOS: DAVID FRIEDLANDER / NASA / GSFC

BONUS AUDIO INTERVIEW
To listen to an audio interview with authors Thayne Currie and Carol Grady, visit skypub.com/lkca15.

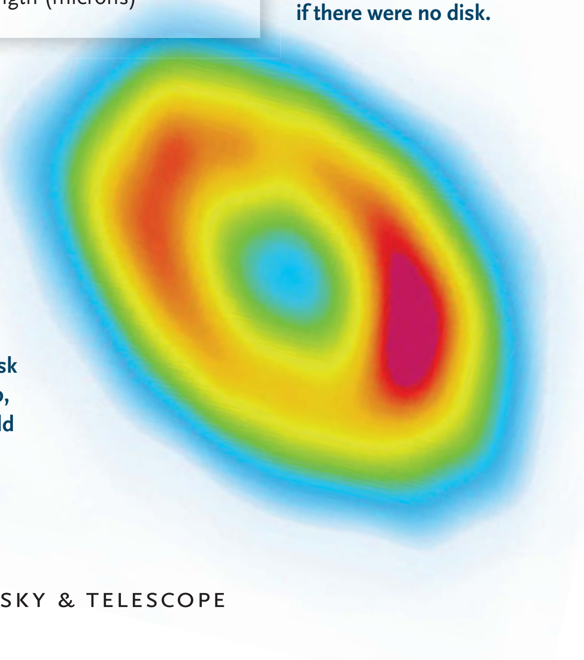


SALLY DODSON-ROBINSON (UNIV. OF TEXAS, AUSTIN) / COLETTE SALYK (NOAO)

CARVING A GAP These frames from a computer simulation show how three planets (with 3 Jupiter masses each) orbiting inside a disk carve out gaps that overlap over a period of 26,667 years, creating a gap with a radius of about 15 a.u. The planets orbit the star at distances of 2.7, 6.3, and 14.3 a.u., respectively.



SPECTRUM This plot shows how LkCa 15's brightness changes from visible (0.5 to 0.8 micron) to infrared (0.8 to 100 microns) to submillimeter wavelengths (100 to 1,000 microns). The dashed green line shows what this plot would look like if the disk didn't have a large gap. The dashed blue line shows what the spectrum would look like if there were no disk.



DISK IMAGED This image from the IRAM Plateau de Bure Interferometer in France clearly resolves the disk around LkCa 15. The bright orangish-red regions are about 50 astronomical units from the star. If the disk didn't have a large gap, the inner regions would also appear bright orangish-red.

SEAN ANDREWS / CFA (2)

gas-rich disk similar in structure to the one that formed the planets in our solar system. With new technologies and observing strategies, we have confirmed suspicions that LkCa 15's disk harbors a young planetary system.

Signs of Planet Formation

Astronomers have identified LkCa 15's disk as belonging to a special subset of circumstellar disks whose members are possibly in transition from a pre-planet-building phase to a post-planet-building system. Compared to typical disks, the one around LkCa 15 (and others like it) have less mid-infrared emission. The thermal (heat) emission from circumstellar disks comes from dust heated by the central star, so the regions lacking this emission appear to be large gaps where solid materials have either been removed from the system or incorporated into larger bodies.

From the dust temperature data, models help us estimate where the dust is (and is not) located. When astronomers do such modeling, we discover that many of these disks either have cleared inner holes or large gaps separating hot material orbiting close to the star from cold material orbiting at much farther distances. In particular, studies from 2007 to 2009 led by Catherine Espaillat (Harvard-Smithsonian Center for Astrophysics) showed that LkCa 15's disk has an inner dust disk from 0.1 a.u. (its outer radius is uncertain), and an outer disk that begins at 50 a.u. — a range that would encompass all of the solar system's planets and the inner Kuiper Belt.

Theorists have predicted that young disks in the process of forming giant planets will have gaps resembling the one in LkCa 15. Massive planets affect disk structure by exerting a tidal torque on the surrounding material. If the planet is more massive than Saturn, the torque is strong enough to open a gap in the disk, which becomes depleted in gas and presumably dust. The more massive the planet, the larger the gap it opens in the disk.

If left undisturbed, disk material will eventually spiral all the way in and accrete onto the star. Because planets less massive than Jupiter open small gaps, they don't affect how disk material accretes onto the star; the disk's inner regions remain well replenished from material spiraling in from the outer disk. As a planet's mass increases

Planet Migration

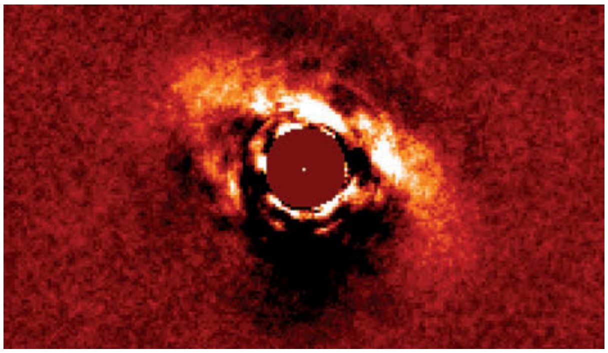
As massive planets such as LkCa 15b carve out gaps in disks, irregularities in the disks exert a gravitational torque on the planets. This process can cause planets to migrate substantial distances inward or outward from where they formed, helping to explain why many exoplanetary systems have Jupiter-mass planets orbiting relatively close to their host stars.

above Jupiter's, the planet intercepts more incoming gas, decoupling the inner disk from the outer disk and thus widening the gap. Objects more massive than 10 Jupiters, comparable to the most massive planets yet discovered, effectively shut off accretion onto the star, leaving a hole in the inner disk instead of a gap. A star with a low accretion rate that is surrounded by a disk with a gap (but not an inner hole) therefore provides the predicted telltale sign of an infant, actively growing Jupiter-mass planet.

Imaging an Emerging System

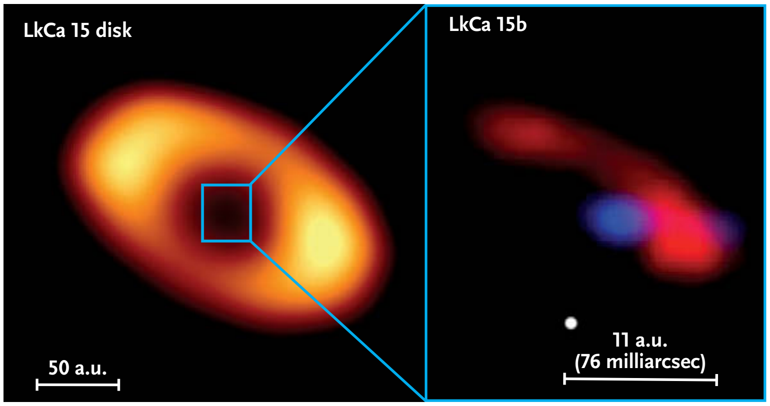
By 2009 it was clear that LkCa 15 exhibited strong circumstantial evidence that it harbored a young planetary system. Submillimeter observations by Vincent Piétu (Institut de Radioastronomie Millimétrique, France) and, more recently, Sean Andrews (Center for Astrophysics) and Andrea Isella (Caltech), resolved the large gap in LkCa 15's disk. In addition, the star accretes gas at a low rate compared to other stars with similar disks.

Despite these encouraging signs, confirming a young planetary system around LkCa 15 required much sharper images of the inner disk (50 a.u. and less) at wavelengths that could identify disk structure caused by unseen planets while directly ruling out stellar or brown dwarf companions. LkCa 15 had to be imaged with ground-based telescopes at near-infrared wavelengths, where the disk is bright, and with an angular resolution and contrast even better than what Hubble could provide.



CHRISTIAN THALMANN / CAROL GRADY, ET AL

TELLTALE SIGNATURE Using adaptive optics, the 8-meter Subaru Telescope in Hawaii acquired this image of the disk around LkCa 15. The star itself has been masked out, but its location is marked with a white dot. The disk has a gap with a sharp edge, which is strong evidence for a planet. The center of the disk is slightly offset from the star, also indicating a planet.



ADAM KRAUS / MICHAEL IRELAND (2)

SMOKING GUN *Left:* The disk around LkCa 15. *Right:* Using the 10-meter Keck II telescope and advanced imaging techniques, Adam Kraus and Michael Ireland resolved a streamer of gas and dust (red) around LkCa 15 swirling toward a massive planet (blue) that's still forming. The planet lies about 10 a.u. from the star.

Two main obstacles stood in the way of revealing LkCa 15's planetary system in detail. First, atmospheric turbulence blurs images, preventing us from distinguishing between a star's light and a planet's light. Second, no telescope has perfect optics: imperfections on mirror surfaces create slowly evolving, bright noise patterns known as *speckles,* which can mask the presence of planets. Fortunately, new adaptive-optics systems correct for atmospheric blurring. And even better, advanced methods of acquiring data and processing images can remove enough speckle noise to see a disk or planet surrounding a star.

The 8.2-meter Subaru Telescope in Hawaii, coupled with a new camera designed to image planets and planet-forming disks, provided even more compelling evidence. A team led by Christian Thalmann (University of Amsterdam, the Netherlands) imaged the planet-forming region of LkCa 15's disk for the first time. The team resolved the inner edge of the disk gap at 50 a.u., finding it to have a sharp edge expected if a planet is sculpting the disk. More importantly, the group found, and Isella and his

Imaging Young Exoplanets

Imaging young planets from ground-based telescopes is challenging because atmospheric turbulence and residual noise sources (due to imperfect telescope optics) impede our ability to separate a star's bright light from a planet's feeble glow. To overcome these obstacles, astronomers use adaptive optics to correct for most of the atmospheric blurring and then advanced observing and image-processing techniques to remove residual noise. Astronomers have incorporated these techniques to image planets around Beta Pictoris and HR 8799, which lie at separations several times the telescope's diffraction limit. Another option, non-redundant masking (NRM) interferometry, allows us to image very young and relatively bright planets at extremely small separations from the star (on the sky), at the telescope's diffraction limit.

In NRM, astronomers place a mask in front of the camera, allowing light from the star (and any planet) to pass only through a series of small holes. Instead of an image, the camera records the interference patterns from light passing through the different holes. If the holes are spaced such that the baseline (the separation from any one hole to any other) never repeats, we can use sophisticated algorithms originally developed for interferometers to reconstruct an image of the system (without having "seen" it) where the spatial resolution of the image approaches the theoretical (diffraction) limit. That's good enough to reveal the planet. In the case of LkCa 15b, Adam Kraus and Michael Ireland also took calibration images of other nearby stars to remove residual effects resulting from imperfect image quality.

Because light can pass through only a small

team have confirmed, that the gap is slightly offset relative to the star, strong evidence for an unseen companion. If a low-mass stellar or brown dwarf companion were responsible for this offset, Thalmann and his collaborators would have detected it, but they didn't.

Last October, Adam Kraus (University of Hawaii) and Michael Ireland (Macquarie University, Australia) reported a direct detection of a planet in the disk gap of LkCa 15. Using the 10-meter Keck II telescope, Kraus and Ireland employed an additional technique known as NRM, short for non-redundant masking (NRM) interferometry (see "Imaging Young Exoplanets," above). NRM provides a way to separate the light from a star and extremely luminous planets at small separations. Kraus and Ireland initially detected the companion in 2009 at a tiny separation of about 75 milliarcseconds (a Saturn-like 10 a.u. at 450 light-years distance) from the star. Observations in 2010 detected the planet at roughly the same location. Because LkCa 15's space motion is known, they compared the companion's position to what it would be if it were an unrelated background object and concluded it's a gravitationally bound object consistent with being a planet.

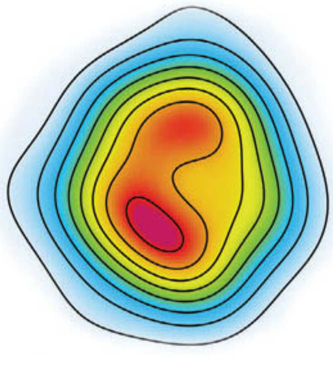
An Infant Planet

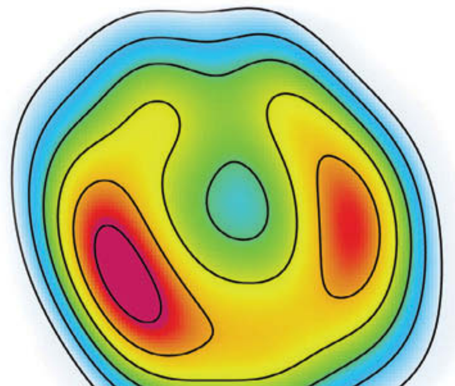
Looking at the image of LkCa 15b, it's a bit hard to see the face of the planet it will become, because the infant planet's appearance stands in stark contrast to those of adolescent planets recently imaged around Beta Pictoris and HR 8799 (12 million years old and 30 million years old, respectively). These planets appear as unresolved point sources, but the emission identifying the planet around LkCa 15 appears as a slightly elongated blob, indicating that it originates from a region far larger than the diameter of a fully formed giant planet. Furthermore, the emission comes not from one structure but two: a centrally located blob clearly detected at 2 microns and a pair of lobes detected at 3.8 microns, located at roughly the same distance from the star as the central source but leading or trailing it in orbit.

LkCa 15b's complex structure requires explanations beyond simply reflected light or thermal emission from a spherical, Jupiter-sized object. Kraus and Ireland interpret the lobes to be material falling along a streamline toward the central source, which presumably marks the planet itself. Thus, in further contrast to imaged planets around Beta Pictoris and HR 8799, we see LkCa 15's infant planet indirectly, since we're actually catching gas and dust heated as it falls toward a shrouded central object (the planet itself).

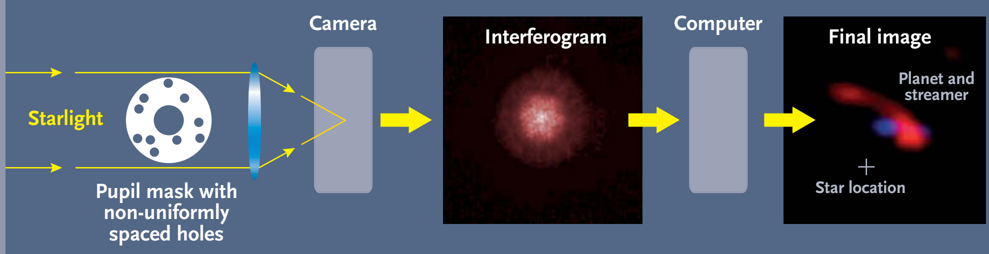
The planet's odd appearance presents additional problems in constraining its physical properties. For example, gas giants contract and cool in a way quantified by detailed planet-evolution models. Thus, the luminosities of planets

MORE DISKS WITH GAPS These three images of planet-forming disks around young stars, taken with the Submillimeter Array interferometer, show clear signatures of large gaps inside the red areas, strong indicators of forming planets. In some cases, we see the disk from the side, which leads to double-peak structures that appear as two reddish regions. SEAN ANDREWS / CFA (3)



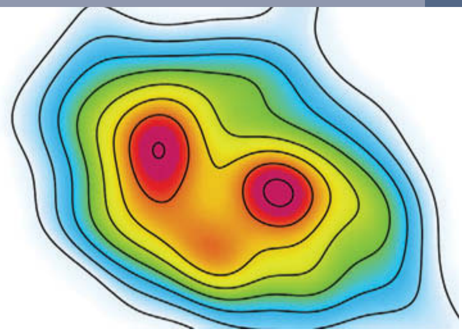


number of holes, the effective light collecting area of a telescope in NRM mode is much less than in normal imaging. Consequently, NRM can right now help us detect only the brightest exoplanets, and it has so far failed to provide images of the previously detected Beta Pic and HR 8799 planets, which are significantly fainter than LkCa 15b. But since planets are brightest when they are newly formed, NRM is well suited for imaging 1- to 5-million-year-old giants such as LkCa 15b.



To image LkCa 15b, Adam Kraus and Michael Ireland employed a relatively new technique known as non-redundant masking (NRM) interferometry. In NRM, astronomers place a mask with holes in front of the camera. Starlight passing through the holes creates an interference pattern, which astronomers can then reconstruct into an image that can resolve a very dim object (such as a planet) very close to a bright star.

S&T: GREGG DINDERMAN / SOURCE: JAMES LLOYD (CORNELL UNIV.)



such as Beta Pictoris b and the four known HR 8799 companions can yield estimates for the objects' masses. Estimating LkCa 15b's mass from its luminosity is trickier, because the infant planet's age uncertainty (1 to 5 million years) translates into a much larger mass uncertainty than for Beta Pic b and the HR 8799 companions because planets cool very rapidly right after their formation.

More importantly, the light identifying the planet likely comes from more than just the planet itself; it probably includes emission from accreting material. So even if we knew LkCa 15's age to high precision, it's very difficult to estimate the planet's luminosity and use this characteristic to estimate the planet's mass. But the total luminosity of the central source and the lobes is significantly less than the luminosity of young 10- to 20-Jupiter-mass objects, so the planet's heft is probably less than 10 Jupiter masses. If the planet is responsible for the gap, which is likely, then disk models predict that its mass should be at least 1 Jupiter. The planet is thus likely comparable in mass to Jupiter or is a slightly scaled-up version of it.

The First of Many Baby Pictures

Although LkCa 15's disk and infant planet provide an important first picture of a baby solar system, we may not have identified all the massive planets in the system. Recent studies by Zhaohuan Zhu (Princeton University) and Sally Dodson-Robinson (University of Texas, Austin) indicate that the LkCa 15 disk gap is too large to be carved by just one giant planet. We have yet to image a second planet in the gap, but such a planet would further cement LkCa 15's status as a young solar system analog, because our own solar system has two gas giants.

Even more encouraging, LkCa 15 is probably not the only newborn Sun-like star that harbors an infant planet that we can image. A number of researchers, including Catherine Espaillat and Kyoung Hee Kim (University of Rochester), have identified many nearby stars that are about the same age as LkCa 15 and that are also surrounded by disks that show signs of having large gaps consistent with forming planets. Submillimeter imaging by Sean Andrews (Center for Astrophysics) and David Wilner (University of Hawaii) shows that some of these disks have gaps extending from 10 to 50 a.u., encompassing the gas- and ice-giant planet regions in our solar system. They also exhibit structures that seem to indicate massive planets.

A team lead by Nuria Huélamo (Centro de Astrobiología, INTA-CSIC, Spain) using the Very Large Telescope in Chile may have already detected a low-mass object in the disk gap of another Sun-like star, T Chamaeleon: perhaps another young solar system analog. These new observations give us confidence that soon our single image of an emerging planetary system will be joined by pictures of many other systems, comprising a nursery of young solar system analogs that will better clarify our own solar system's evolution within the range of planet-formation sequences and outcomes. ✦

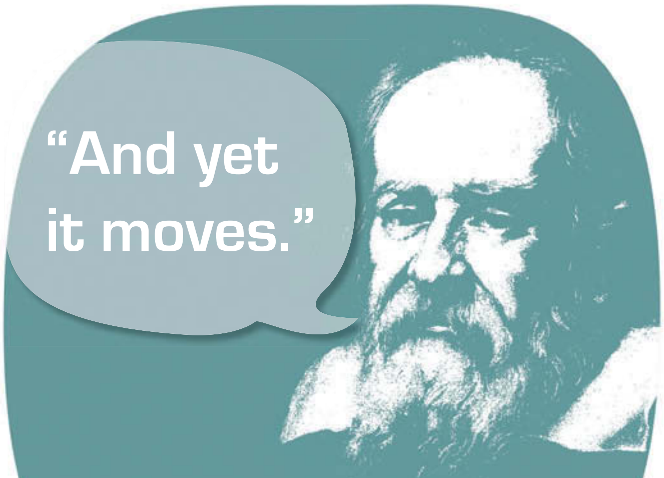
Thayne Currie *is a NASA Postdoctoral Fellow at NASA's Goddard Space Flight Center in Greenbelt, Maryland.* ***Carol Grady*** *is an astronomer working for Eureka Scientific at NASA Goddard. Both specialize in planet formation and circumstellar disks.*

Houston, we have a problem

Dave English

Sometimes the most famous words are those never spoken.

A FEW WORDS can record profound ideas or memorable moments in history. Quotes such as, "Houston, we have a problem" or Carl Sagan's "billions and billions" resonate in our collective memory. But it turns out that our memory isn't always right. Some of history's most well known lines are misremembered, and quotations about astronomy are no exception. From Galileo to the Apollo missions, from *Star Trek* to *Cosmos*, I'll try to set the record straight on some of astronomy's most popular misquotes.



GALILEO GALILEI
The astronomer likely never spoke the words "eppur si move." And yet the myth persists.
WIKIPEDIA / JUSTUS SUSTERMANS

Eppur Si Move

One famously apocryphal story centers on Galileo Galilei, who recanted his heretical heliocentric theory before the inquisition in 1633. In one version, Galileo rises from his knees and mutters under his breath, "... and yet it moves." In Italian, it would have sounded like poetry: *eppur si move*. But there is no definitive evidence that Galileo uttered those dangerous words. The earliest biography of Galileo, written by his disciple Vincenzo Viviani, never mentions the phrase. Although the phrase appears in an approximately contemporary painting showing Galileo, it does not appear in print until over a century later. Only in 1757 did Giuseppe Baretti write in *The Italian Library*, "The moment he was set at liberty, he looked up at the sky and down to ground, and, stamping with his foot, in a contemplative mood, said, *Eppur si move*; that is, *still it moves*, meaning the earth." The story sounds perfect, restoring dignity to a battered old man, but Paolo Galluzzi, the director of the Galileo Museum in Florence, recently dismissed the story as a myth. And yet it persists.

Second Star to the Right...

If you think the source for the phrase "second star to the right, and straight on till morning" is the magical character Peter Pan, you are correct. "That, Peter had told Wendy, was the way to the Neverland; but even birds, carrying maps and consulting them at windy corners, could not have sighted it with these instructions. Peter, you see, just said anything that came into his head."

But when James M. Barrie's *Peter Pan* debuted on the London stage in 1904, he said only, "second to the right, and straight on till morning" — with no mention of astronomical objects. The boy says the same line in the novel, published seven years after the play.

The Walt Disney film added the "star" in 1953. The quote, or parts of it, have since popped up in many places, including the title of a biography of aviatrix Beryl Markham, a Blues Traveler album, and the 1991 movie *Star Trek VI: The Undiscovered Country*. It's there that Chekov asks "Course heading, Captain?" James T. Kirk replies, "Second star to the right, and straight on till morning." Like Peter Pan, the phrase now flies without its shadow.

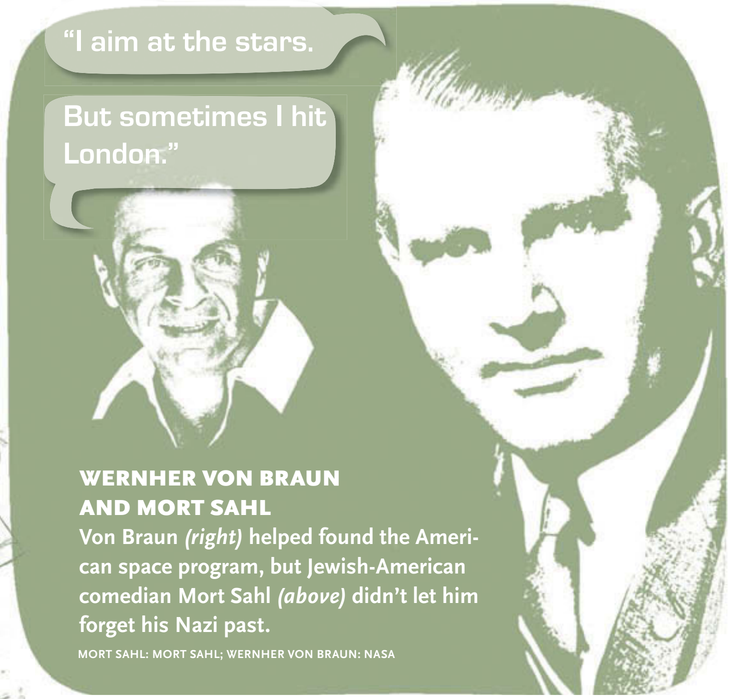
S&T: LEAH TISCIONE

Earth is the Cradle of Humanity...

Konstantin E. Tsiolkovsky, the Russian astronautics pioneer who predicted human space exploration in both science fiction and engineering papers, wrote in a 1911 letter, "Планета есть колыбель разума, но нельзя вечно жить в колыбели." The phrase is almost always incorrectly translated as, "Earth is the cradle of humanity, but one cannot live in a cradle forever." A more accurate rendering would read, "A planet is the cradle of mind, but one cannot live in a cradle forever." The latter translation better illustrates the breadth and universality of Tsiolkovsky's thinking — though he worked largely alone, he considered himself a citizen of the universe.

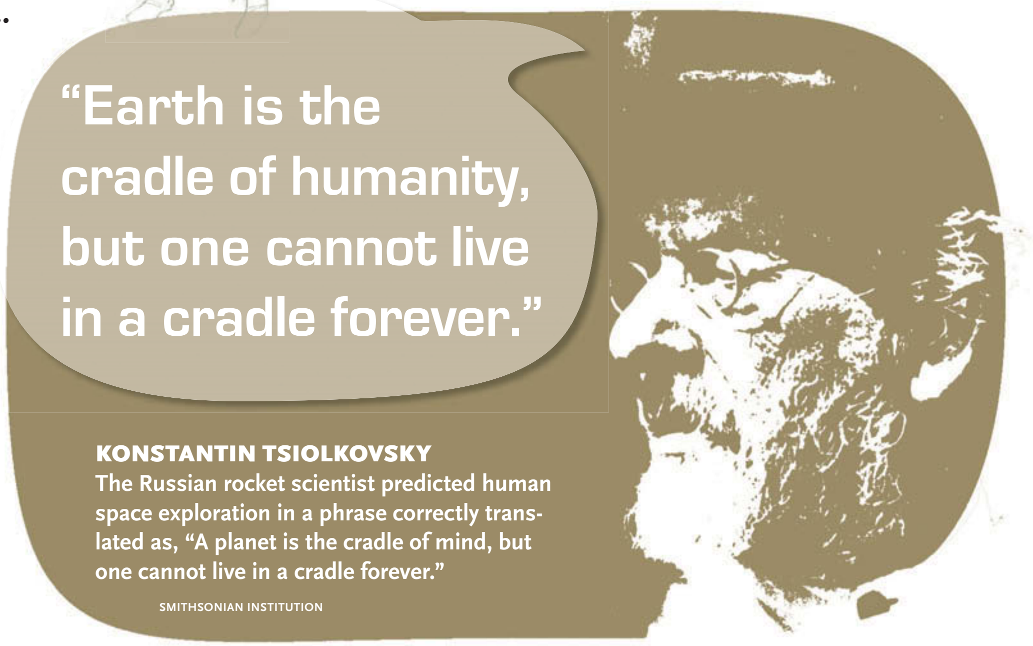
I Aim at the Stars...

"I aim at the stars. But sometimes I hit London." This line is sometimes incorrectly attributed to Wernher von Braun, the principal designer of the Saturn V rocket that launched the Apollo missions. The first part — "I aim at the stars" — was the U.S. title of a 1960 biographical film about the life of von Braun. But it was Jewish-American comedian Mort Sahl who coined the movie's subtitle, a stinging reference to von Braun's World War II work on the V-2 rocket for Nazi Germany.



WERNHER VON BRAUN AND MORT SAHL
Von Braun *(right)* helped found the American space program, but Jewish-American comedian Mort Sahl *(above)* didn't let him forget his Nazi past.

MORT SAHL: MORT SAHL; WERNHER VON BRAUN: NASA



KONSTANTIN TSIOLKOVSKY
The Russian rocket scientist predicted human space exploration in a phrase correctly translated as, "A planet is the cradle of mind, but one cannot live in a cradle forever."

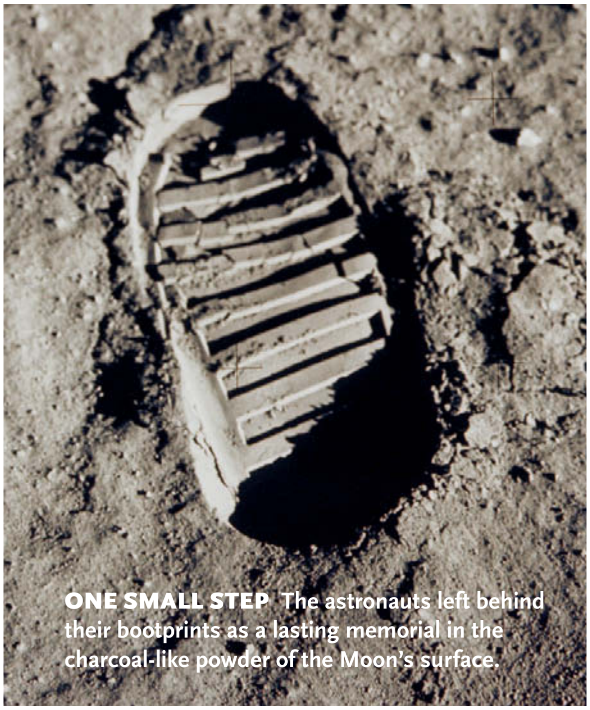
SMITHSONIAN INSTITUTION

That's One Small Step for [a] Man...

On July 20, 1969, at 9:56 p.m. local Houston time, Neil Armstrong stepped off the *Eagle* lunar module and onto the powdery rock of the Moon's Mare Tranquillitatis. He was the first human to walk on another heavenly body. A record-breaking audience of some 600 million people listened as Armstrong spoke slowly and with solemnity the most famous words ever uttered in space: "That's one small step for a man; one giant leap for mankind."

Or at least that's what he meant to say. One particularly short word became surprisingly controversial. The day after the Moon landing, *The New York Times* reported the line several times without the article "a," including on the front page and as the "Quotation of the Day." But Armstrong didn't realize his "a" was not heard until he returned to Earth. In the 1970 book *First On The Moon* (sold as the "exclusive and official account . . . as seen by the men who experienced it"), the quote includes the article, with a footnote explaining, "Tape recorders are fallible." Indeed, lunar surface communications were voice-activated and sometimes subject to interference. *The New York Times* ran a short column about the "a" 11 days after the Moon landing on page 20:

> One small but important word was omitted in the official version of the historic utterance he made when he stepped on the moon 11 days ago. . . . The "a" apparently went unheard and unrecorded in the transmission because of static, a spokesman for the Manned Spacecraft Center in Houston said in a telephone interview. Whatever the reason, inserting the omitted article makes a slight but significant change in the meaning of Mr. Armstrong's words.



ONE SMALL STEP The astronauts left behind their bootprints as a lasting memorial in the charcoal-like powder of the Moon's surface.

NASA (3)

But according to *Chariots for Apollo*, a 1986 book about the making of the lunar module, Armstrong realized his mistake when the builders of the lunar module presented him with a plaque inscribed with 11, not 12, famous words. Upon hearing Armstrong's protest, they listened together to the commemorative MGM 45-rpm record, and the "a" was nowhere to be found. Armstrong reportedly sighed, "Damn, I really did it. I blew the first words on the Moon, didn't I?"

If he didn't say it, no one would blame him. Armstrong was an amazing test pilot and a highly skilled aerospace engineer who had been awake many hours by the time of the moonwalk. He was making history on live TV in the ultimate dangerous environment. He was not an actor used to reciting lines. Armstrong told journalists 30 years after the Moon landing, "The 'a' was intended. I thought I said it. I can't hear it when I listen on the radio reception here on Earth, so I'll be happy if you just put it in parentheses."

That would have been the end of the story, but the debate took another turn when *The Times* of London reported on October 2, 2006, that an Australian computer expert had rediscovered the missing article using high-tech audio analysis. Peter Shann Ford ran the NASA recording through sound-editing software and "clearly picked up an acoustic wave from the word 'a,' finding that Mr. Armstrong spoke it at a rate of 35 milliseconds — ten times too fast for it to be audible." Neil Armstrong issued a statement saying "I find the technology interesting and useful. I also find his conclusion persuasive." But other audio experts have disputed this analysis and it has not

“That’s one small step for a man, one giant leap for mankind.”

NEIL ARMSTRONG
The first man on the Moon grins with giddy excitement after returning to the *Eagle* from the lunar surface, where he spoke his famous words.

been published in a peer-reviewed scientific journal.

What do you think? You can listen to the recording online (**www.skypub.com/misquotes**) to refresh your memory. I think he said the “a,” but the physical exertion, lack of sleep, and importance of the moment combined to rob Armstrong of his normally clear speaking voice. The way he naturally says the phrase makes the “a” soft, which was demonstrated on TV when the late political commentator Tim Russert politely ambushed Armstrong to repeat the phrase 30 years after Apollo 11. Even on that clean, professional recording, the “a,” if it’s there, is just not distinct. So [a] debate continues. And anytime the quote is published without Armstrong’s parentheses, we miss a bit of history.

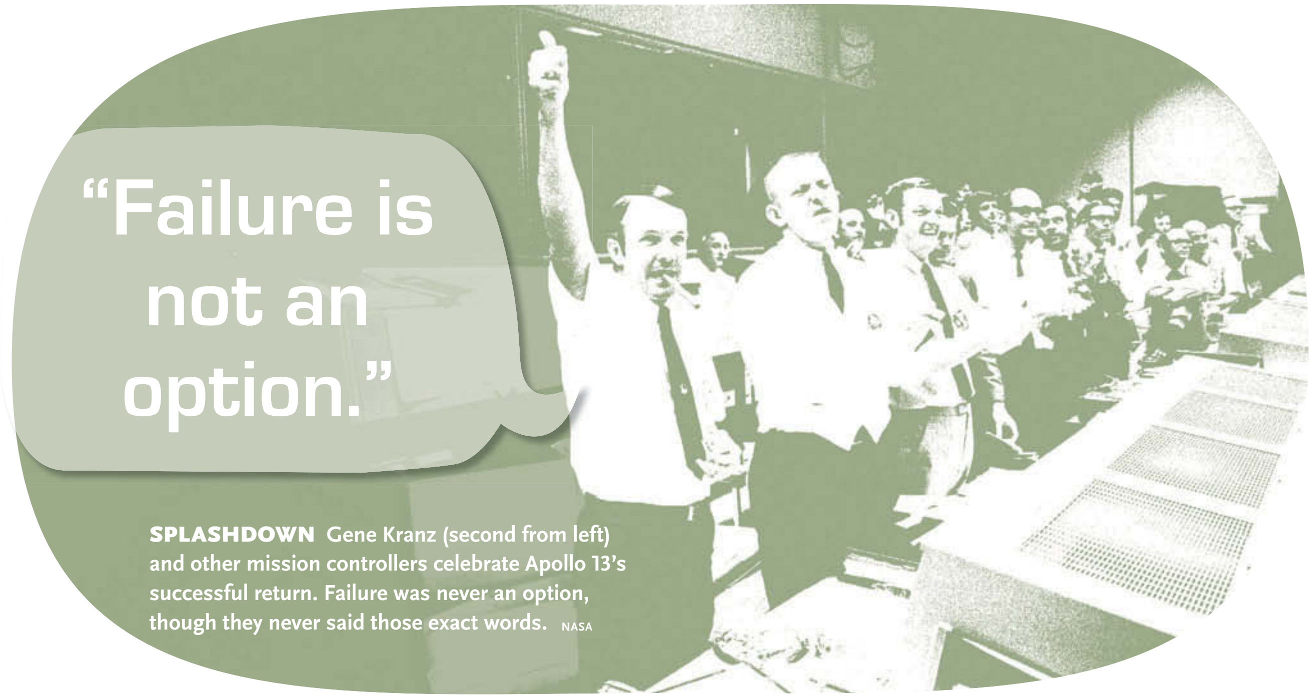
Houston, We Have a Problem

Another mangled quotation from the Apollo era has perfectly clear tape recordings, yet it’s still repeated erroneously: “Houston, we have a problem.” The Apollo 13 crew never said that phrase. At Mission Elapsed Time 55:55:20 (9:07 p.m. local Houston time) on April 13, 1970, Apollo 13 command module pilot John “Jack” Swigert, Jr. heard a large bang and felt a vibration when the No. 2 oxygen tank exploded. He radioed, “Okay, Houston, we’ve had a problem here.” Past tense. Had a problem. Jack Lousma, the on-duty Houston capsule communicator, quite reasonably replied, “This is Houston. Say again, please.” To which mission commander James “Jim” Lovell answered, “Er, Houston, we’ve had a problem. [pause] We’ve had a main B bus undervolt.” Past tense again.

On the recordings it’s clear, yet, as of late May, a Google search for the incorrect “Houston, we have a problem” (in quotes) yields over 1.37 million results, compared to only 177,000 results for the correct version. It certainly doesn’t help that the 1995 movie *Apollo 13* uses the present-tense line, though the movie didn’t invent it. Director Ron Howard aimed for a relatively accurate film, but he wasn’t afraid to take artistic license. According to some sources, he chose the present tense version of the quote to convey the immediacy of the astronauts’ situation.

MISSION CONTROL
“Okay Houston, we’ve had a problem here.” Jack Swigert, Jr.’s words were the beginning of four harrowing days for Apollo 13’s crew, and also for the flight controllers and support personnel on the ground.

"Failure is not an option."



SPLASHDOWN Gene Kranz (second from left) and other mission controllers celebrate Apollo 13's successful return. Failure was never an option, though they never said those exact words. NASA

Failure Is Not an Option

The Apollo 13 movie is also responsible for another misquote: "Failure is not an option." There is no evidence that legendary Flight Director Gene Kranz ever said that line before the movie was released. The words were later used as the title of his 2000 book *Failure Is Not an Option: Mission Control from Mercury to Apollo 13 and Beyond*, where he wrote that this was "a creed that we all lived by . . . Failure does not exist in the lexicon of a flight controller. The universal characteristic of a controller is that he will never give up until he has an answer or another option." Kranz used the phrase several other times in the book, but never directly claims it was his or that it was ever articulated as it's now known.

So how did actor Ed Harris end up saying it in the film? It turns out that the scriptwriters, Al Reinert and William Broyles, Jr., invented the line to quickly condense and capture the overall culture of mission control. They interviewed Jerry Bostick, the Flight Dynamics Officer for Apollo 13, about the atmosphere in mission control. He told them, "When bad things happened, we just calmly laid out all the options, and failure was not one of them. We never panicked, and we never gave up on finding a solution." Months after the interview, Bostick learned that as soon as the scriptwriters got in their car, Broyles yelled, "That's it! That's the tag line for the whole movie, 'Failure is not an option.' Now we just have to figure out who to have say it."

"Beam me up, Scotty."

Listen to APOLLO AUDIO RECORDINGS

Listen to the original NASA recordings from Apollo 11, 12, and 13 and hear what the astronauts really said at www.skypub.com/misquotes.

Beam Me Up, Scotty

A celebrated TV series from the 1960s generated another space-related misquote: "Beam me up, Scotty." The phrase is commonly attributed to *Star Trek*'s Captain Kirk, played by William Shatner, who is presumably asking chief engineer Montgomery "Scotty" Scott for teleportation back to the starship *Enterprise*. But the phrase was never uttered exactly as it is now quoted, even though it can be found everywhere from bumper stickers to T-shirts. Indeed, it's seemingly everywhere except for a single Star Trek screenplay. In the original *Star Trek* TV series "The Gamesters of Triskelion" and "The Savage," Captain Kirk did say "Scotty, beam us up," and other times he said "*Enterprise*, beam us up." In the self-referential movie *Star Trek IV: The Voyage Home*, we come closest with "Scotty, beam me up." The only place the exact phrase is ever spoken is in Shatner's audio adaptation of his novel *Star Trek: The Ashes of Eden*.

Billions and Billions

That's not the only famous line missing from hours and hours of videotape. Consider the final entry in this collection of misquotes: astronomer Carl Sagan's "billions and billions." In his posthumous 1998 book *Billions & Billions: Thoughts on Life and Death at the Brink of the Millennium,* Sagan wrote:

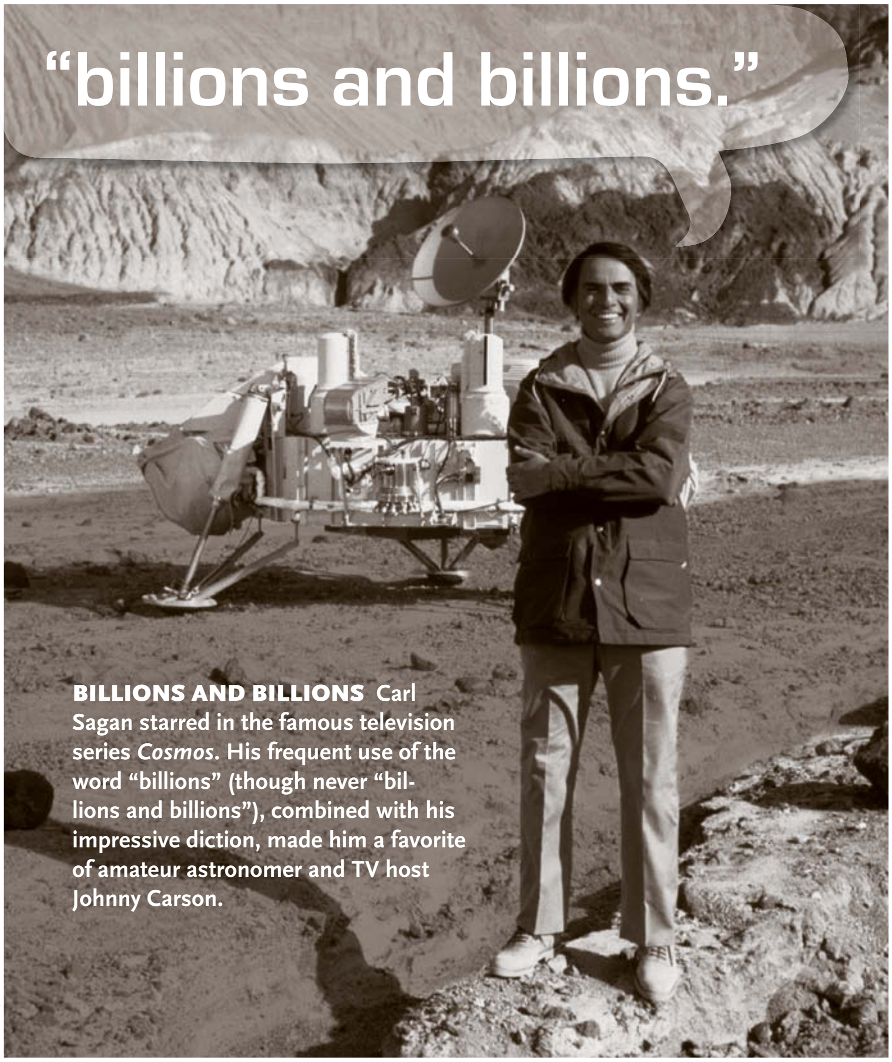
> I never said it. Honest. Oh, I said there are maybe 100 billion galaxies and 10 billion trillion stars. It's hard to talk about the *Cosmos* without using big numbers. I said "billion" many times on the *Cosmos* television series, which was seen by a great many people. But I never said "billions and billions." For one thing, it's too imprecise. How many billions are "billions and billions"? A few billion? Twenty billion? A hundred billion? "Billions and billions" is pretty vague. When we reconfigured and updated the series, I checked — and sure enough, I never said it.

So where did it come from? The answer is found in a comedy skit. Johnny Carson, an amateur astronomer who hosted Sagan almost 30 times on *The Tonight Show,* used the line whenever he impersonated Sagan. "He'd dress up in a corduroy jacket, a turtleneck sweater, and something like a mop for a wig," Sagan said. "Astonishingly, 'billions and billions' stuck. People liked the sound of it." Carson's phrase captured both the vastness of the cosmos and the essence of Sagan's vocal delivery. Although some people thought he emphasized "b" because he had a quirky accent or speech peculiarity, Sagan had carefully considered the problem of verbally differentiating between millions and billions. He felt the alternative — saying "that's billions with a b" — was too cumbersome for popular TV.

The Sagan case illustrates why we often prefer misquotes to the real thing. Johnny Carson's impression of "billions and billions" quickly distilled Sagan's style in an instantly recognizable way. Similarly, good caricatures appear to capture the essence of a person or idea, even though a closer look shows that the simple image distorts reality. A caricature can be more recognizable than a photograph because human brains are better at remembering distinctive features rather than small or fleeting differences. So it is with quotations, astronomy-related or otherwise, with some becoming distorted along the lines of an easy-to-remember caricature. Perhaps Sagan would have appreciated that "his" quote illustrates the curious nature of human perception.

If you've found other astronomy quotes that have been mangled or mashed, send them to **dave@daveenglish.com**. It's interesting to see how history is remembered, but it's also worthwhile to preserve the original lines. I don't know what the next great astronomical quotation will be, but let's hope with modern technology it will be recorded clearly! ✦

Dave English *watches the night sky from his home in Phoenix, Arizona. Visit his website* ***www.SpaceQuotations.com****.*

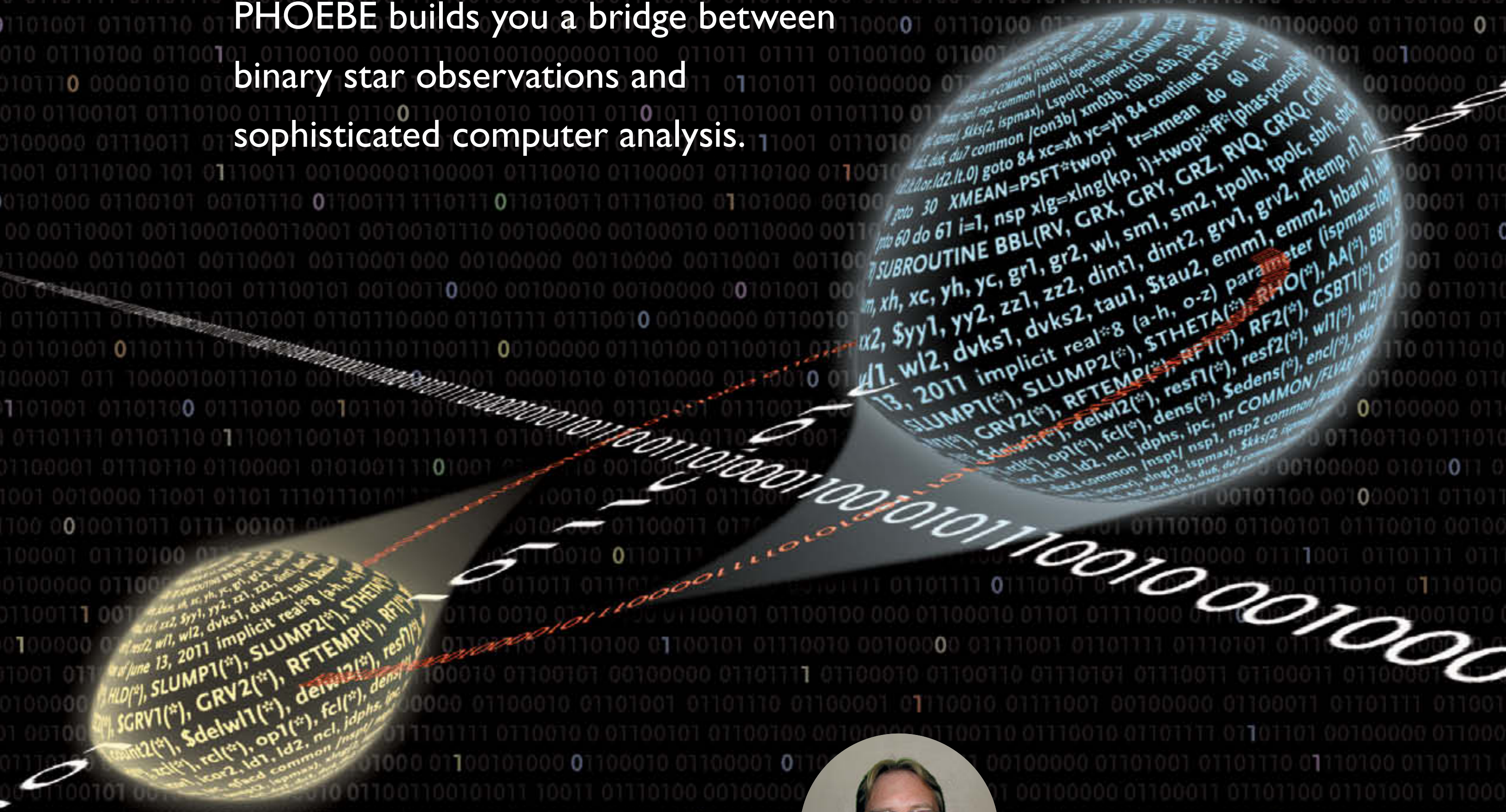


BILLIONS AND BILLIONS Carl Sagan starred in the famous television series *Cosmos*. His frequent use of the word "billions" (though never "billions and billions"), combined with his impressive diction, made him a favorite of amateur astronomer and TV host Johnny Carson.

BILL RAY / DRUYAN-SAGAN ASSOCIATES

Solve Binary Stars Yourself

PHOEBE builds you a bridge between binary star observations and sophisticated computer analysis.



DIRK TERRELL

S&T ILLUSTRATION BY GREGG DINDERMAN

ECLIPSING BINARY stars are rich sources of information on the intrinsic properties of stars. In the past several decades, amateur astronomers have played a crucial role in their study. The amateur contributions have been most visible in the observation of these systems using CCD cameras and modest-sized telescopes, because advances in software and hardware technologies have made it possible to undertake worthwhile observing projects that are impractical for professionals such as myself to pursue at big-time observatories.

For example, John Gross, Walt Cooney, and I recently completed a survey to measure the colors of hundreds of binaries belonging to the W Ursae Majoris class. Projects such as this allow us to advance our understanding of these systems, and of stars in general. But what if you don't have a telescope and CCD camera to do your own photometry? Can you still contribute to research on binary stars without a telescope? Or, have you observed eclipsing binaries and wondered if there was more you could do with the data? Yes, there is a lot more that you can do, whether you're working with your own observations or someone else's. What you need is PHOEBE.

Birth of a Computational Titan

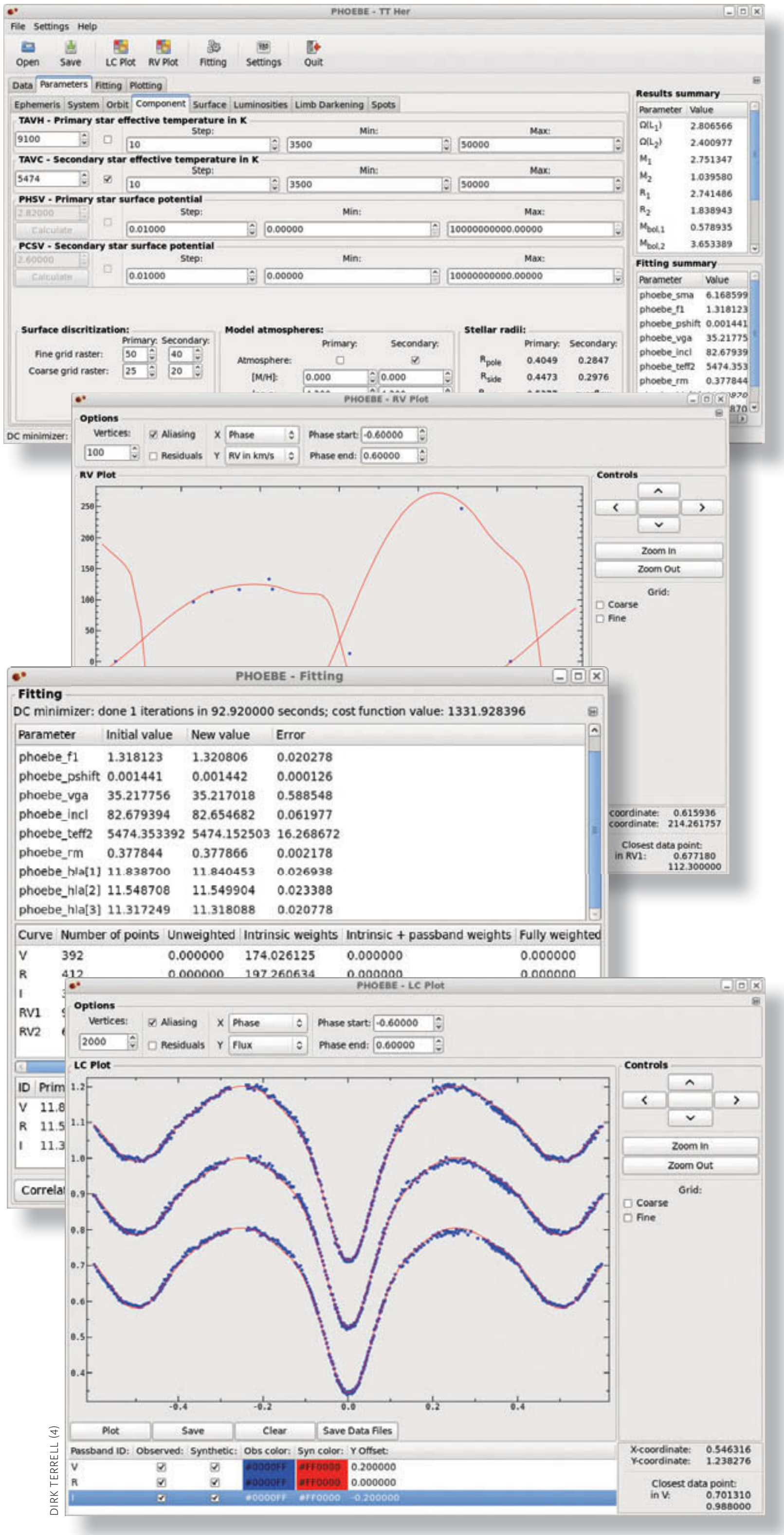
PHOEBE, short for PHysics Of Eclipsing BinariEs, is a tightly integrated collection of software tools used to analyze observations of eclipsing binaries. It's free and available for Linux, Windows, and Macintosh operating systems at **http://phoebe.fiz.uni-lj.si**. The website also has documentation and tutorials, as well as information on the various e-mail lists where you can communicate with the developers and other PHOEBE users.

PHOEBE is built around the widely used Wilson-Devinney program (WD), originally developed in the early 1970s by Bob Wilson and Ed Devinney, then both at the University of South Florida. Continually developed by Wilson (now at the University of Florida) over the years, WD has developed into a sophisticated tool for analyzing light curves and other types of stellar observations such as radial velocities, X-ray-pulse arrival times, and polarization curves.

WD is a powerful analysis tool, but its interface with the user can intimidate those unfamiliar with it: it's a command-line program driven by a text input file, and its output is another text file. Seeing this situation, Andrej Prša — then at the University of Ljubljana in Slovenia and now at Villanova University with Devinney — developed PHOEBE as a set of tools that basically sits on top of WD and makes the user's interaction much more straightforward and efficient.

PHOEBE consists of three parts: the library, the scripter, and the graphical user interface (GUI).

As an end user, you don't have to worry much about the PHOEBE library, just as you don't have to know about the details of an automobile engine to drive a car. The



DIRK TERRELL (4)

PHOEBE has several interface windows (four shown, top to bottom) — the main window, where you do things such as specify your data and tweak parameters; the radial-velocity plot; the parameters window (you can change these yourself or set the program to change them for you); and the light-curve plot, which can include photometry taken in different wavelength bands. Each window gives you a different perspective on how your model fits the data. These data are for TT Herculis.

PHOEBE scripter is for more advanced users wanting to do automated processing of binary star data. The GUI is where most new users will start. But before jumping into the use of PHOEBE, you have to understand how the process of analyzing data works.

Modeling Binary Stars

Observations are at the very core of the scientific process. They allow us to test our ideas about how things work in nature. For eclipsing binary stars, the two major types of observations are photometry, or measurements of the brightness of the binary, and radial velocities, measurements of how fast the binary's stars are moving along our line of sight.

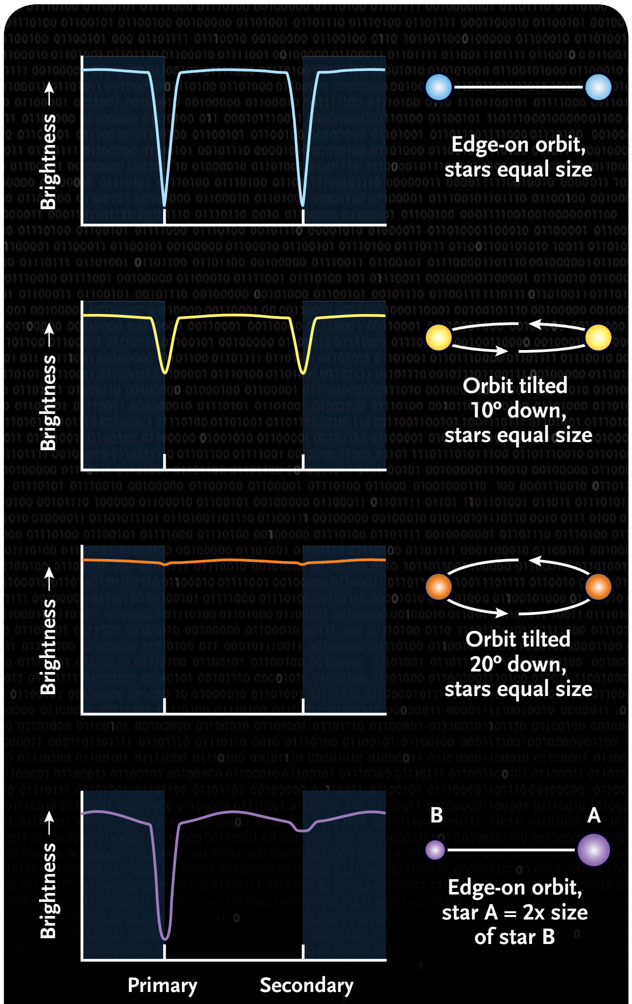
We make various assumptions about a binary system to create a model, and then we test that model's predictions against the observations. For example, a model of a binary system will include some assumptions about the shapes of the stars. A very simple model might assume that the stars are spherical, and in some binaries, that assumption is quite good. In others, it will be terrible. A slightly more complex model might assume that the stars are ellipsoids, making the model applicable to a wider variety of real binaries. A still more complex model would assume that the stars' shapes are based on the physics of gravity and rotation, as is done in the WD program.

A useful model must make predictions that can be tested by observations. A binary star model might predict how the binary's brightness varies with time as the stars orbit each other as seen from Earth, a pattern known as the binary's light curve. It might also predict how fast the stars are moving along our line of sight as they orbit, movements that trace out radial-velocity curves. These predictions, called "observables," can then be compared with the observations to see how well they agree. If they agree, you can have some confidence that the model is a reasonably good approximation of the real binary. This process of fitting a model to observations is precisely what PHOEBE enables you to do.

All models have parameters that can be adjusted to produce changes in the observables. For instance, in the simple model where the two stars are spheres, the individual radii of the stars are parameters. (In more complex models, like WD, the radii are computed from another parameter that is sensitive to distortions in the stars' shapes.) If we are modeling a binary light curve, we can change the values of the radii to make the predicted eclipses longer or shorter.

Another parameter is the inclination of the orbit, the tilt of the binary's orbit with respect to the plane of the sky. When the inclination is 90°, the centers of the stars' disks will pass directly in front of each other, causing total or annular eclipses depending on the stars' sizes. As the inclination decreases the eclipses will become partial, growing shallower with decreasing angle until ultimately they disappear altogether.

In a complex model such as WD, there are dozens of parameters that fully describe a binary model. Part of the art of fitting observations is to understand which parameters are important for binaries of different kinds, and in turn which of those important parameters you should adjust to fit a set of light and/or radial-velocity curves. In



Small parameter tweaks can have big effects. At top is the light curve for a binary with two stars of the same size, seen at an inclination of 90° in the plane of the sky (we see the system edge-on). The next two light curves show the same system seen at 80° and 70° inclination. As you can see, a mere 20° shift in inclination makes the eclipse dips virtually nonexistent. The bottom curve shows an edge-on system where one star is twice as big as the other. The deeper eclipse occurs when the smaller star passes in front of the larger one, because the small one is dimmer.

S&T: LEAH TISCIONE; SOURCE: DIRK TERRELL

Find links to PHOEBE and other binary star projects at skypub.com/PHOEBEcode.

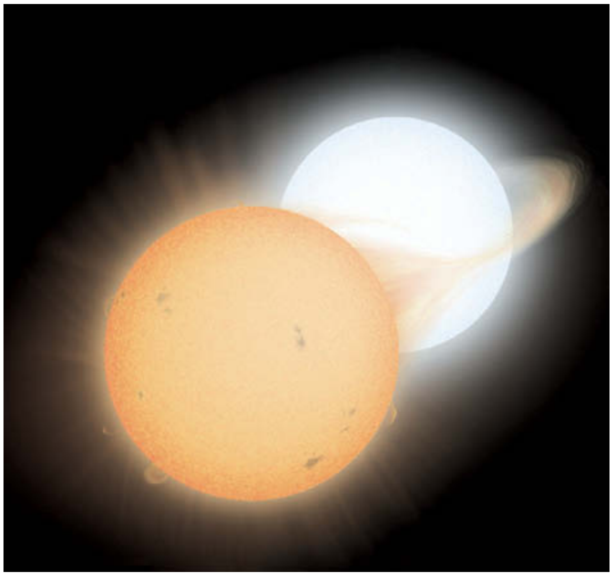
this regard, binary star data analysis is a bit like learning to play chess. There are few rules to learn, but mastering how to put them all together can take a while. That's where PHOEBE can help.

PHOEBE to the Rescue

PHOEBE makes it easy to develop the intuition about how the parameters of a binary affect its observables. You can build a model for an imaginary binary, change a parameter, and then replot the light curve to see what difference it makes. You can steadily decrease the inclination and watch the eclipses get shallower. You can increase the radius of one or both stars and watch the eclipses get wider. You will even come across parameters, such as the semi-major axis of the binary orbit, that have absolutely no effect on the shape of a light curve but a huge effect on a radial-velocity curve. Learning these sorts of things is the first step in learning how to do binary star data analysis.

This intuition will make you see binary observations in a new way. You may observe some eclipsing binary, plot out its light curve, and find yourself wowed by it. It's so beautiful you'll even show it to your non-astronomer friends, who will wonder how a bunch of points on a sheet of paper can get you so excited. But you'll be excited because you know from playing with PHOEBE that from those "boring" points you can figure out all sorts of things about your binary, such as the shapes of the stars, their temperatures, how fast they are spinning, how far apart they are, how they orbit each other, whether they are young or old, and whether material is flowing from one star to the other. Those insights will probably intrigue your friends a bit more. It's fascinating what you can discern about binaries from that beautiful light curve of yours, even about events that happened to the stars millions of years ago.

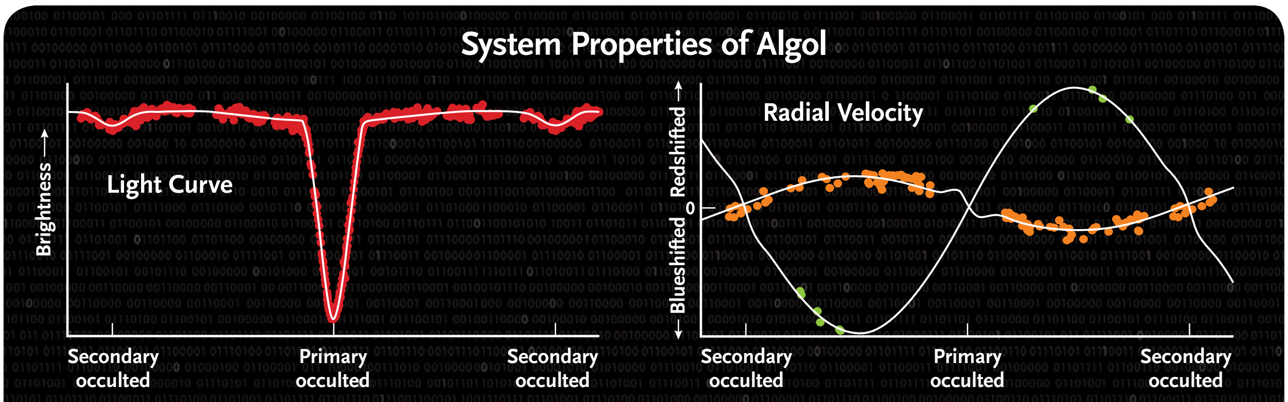
If you find that difficult to believe, just consider Algol (Beta Persei), perhaps the most famous eclipsing binary of them all.



S&T: CASEY REED

Algol (Beta Persei) once presented a distressing puzzle: its lower-mass secondary star (orange) is more evolved, while its higher-mass primary still appears relatively young. Astronomers finally solved the paradox when they realized that the secondary star was once the more massive one and had dumped most of its mass onto the primary when it puffed up in old age, thereby reversing the mass ratio.

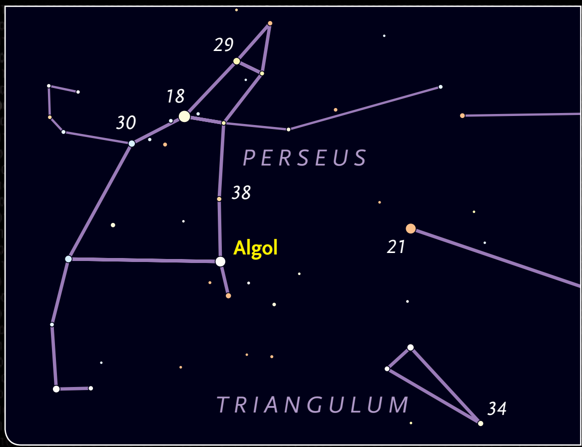
From studies of its light and radial-velocity curves, astronomers discovered that Algol's cooler and lower-mass secondary star is actually an evolved star, while its higher-mass primary star is still a normal, relatively unevolved main-sequence star like the Sun. Since we know that massive stars evolve more quickly than lower-mass stars, this presented quite a conundrum, known as the Algol Paradox. This situation prompted theorists to develop models of the evolutionary history of Algol, revealing that the secondary star was once the more massive one. It expanded millions of years ago and dumped most of its



Using photometric and spectroscopic observations of Algol, you can fit curves to the data to reveal the system's properties. The light curve is sensitive to changes in inclination and stellar radii, whereas the radial-velocity plot is sensitive to mass. As you can see, the more massive primary (orange dots) moves less in the radial-velocity diagram than the secondary (green dots).

S&T: LEAH TISCIONE; SOURCE: DIRK TERRELL

The eclipsing binary star Algol fades every 2.87 days from its usual 2.1 magnitude to 3.4 and back. It stays near minimum light for two hours, and it takes several additional hours to fade and to rebrighten. Shown below are magnitudes of comparison stars (with the decimal points omitted).



Minima of Algol

July	UT	21	17:38	10	19:19
1	15:57	24	14:27	13	16:07
4	12:46	27	11:16	16	12:56
7	9:35	30	8:04	19	9:45
10	6:23	Aug.	UT	22	6:33
13	3:12	2	4:53	25	3:22
16	0:01	5	1:41	28	0:11
18	20:50	7	22:30	30	20:59

These geocentric predictions are from the heliocentric elements Min. = JD 2452253.559 + 2.867362E, where E is any integer. Derived by Gerry Samolyk (AAVSO), they reflect a slight lengthening in the star's period that seems to have occurred in early 2000. Predictions courtesy Marvin Baldwin. For more about this star, visit SkyandTelescope.com/algol.

mass onto the now more-massive primary, reversing the mass ratio. So light and radial-velocity curves, along with some clever thinking, can indeed result in an amazing sleuthing job.

Where the Curves May Lead

In PHOEBE, first you feed the program photometric or spectroscopic observations you or others have made (such as the extremely precise observations made by NASA's Kepler spacecraft or results published in journals) and tell it which filters you used. Then you have some fun setting and adjusting parameters based on what your intuition tells you about your data. You change some parameters and the fit looks better. At some point you might discover that continued changes in the parameters you've selected don't appear to make any difference. Maybe other parameters need to be modified. Maybe the binary is quite different from what you originally imagined. You make changes and the fit looks better. Eventually you get a match to the observations that looks really good. Now what?

The next step is to make sure that your proposed solution makes astrophysical sense. It's tempting to think that just because the computer spits out a solution that looks good, it must be right. This is where collaboration with a professional astronomer who specializes in stellar astrophysics will help. He or she can advise you on whether your solution is reasonable. You might, for example, come up with a great solution for the light curve of Beta Lyrae, only to find out later that it's a system with a very thick disk of material around one of the stars, a situation that even the venerable WD model cannot handle. The parameters you arrive at would be complete nonsense.

How do you establish such a collaboration? Most of the time you just have to ask. Professionals' e-mail addresses are often listed in their research papers. I have worked with amateur astronomers for a couple of decades now and I am always happy to help them do research. We use the website at **http://binaries.boulder.swri.edu** and an e-mail list to communicate. The American Association of Variable Star Observers is also a good place to find opportunities for professional-amateur collaboration.

Once you have arrived at a good, reasonable solution for your data, the next step is to write up a paper describing what you did and what the results were. When first starting out, collaboration with a professional will help allay any anxieties you may have about writing a paper. As you do it more, it will become easier — I have worked with amateur colleagues for years who now write excellent papers with very little input from me. Once you've written the paper, you submit it to an astronomical journal and go through the refereeing process. The referee will assess the work you've done and perhaps suggest changes that would improve the paper. If the journal accepts your paper, it will publish it and your hard work will become a permanent, official contribution to humanity's knowledge of the universe.

And maybe your friends will be a little more impressed with those dots on a piece of paper that you spent all those hours analyzing. ✦

***Dirk Terrell** is an astrophysicist at the Southwest Research Institute in Boulder, Colorado, where he serves as the manager of the Astronomy and Computer Systems section. He is also on the PHOEBE development team.*

NEAF 2012

This astronomical extravaganza in Suffern, New York, is an annual rite of spring for amateur astronomers in the Northeast.

Now entering its third decade, the Northeast Astronomy Forum (NEAF) easily lays claim to being the largest annual gathering of amateur astronomers in North America. Every April several thousand astronomy enthusiasts flock to the two-day event to hear talks, hobnob with fellow amateurs, and, in particular, wander among the equipment displayed by manufacturers and dealers. And several hundred of these participants also arrive a few days early to attend the popular Northeast Astro-Imaging Conference (NEAIC).

Our *Sky & Telescope* colleagues also show up en masse for these events, since NEAF and NEAIC are great opportunities for all of us to interact firsthand with many readers. But as the magazine's resident gear heads, we (Dennis and Sean) also spend as much time as possible looking at the latest telescopes and accessories on display at both events, some of it being shown publicly for the first time.

Each year we see more and more digital technology infiltrating the hobby, much of it aimed at automating the collection of data for astrophotography and scientific research. And at this year's events, held April 26-29, the trend was particularly evident in several new telescope mounts introduced by manufacturers.

When film ruled the world of astrophotography, to be considered premium, an equatorial telescope mount only had to be solid with a smooth-running drive and slow-motion controls, because the long exposures that film required always had to be guided. Digital photography, however, has dramatically shortened the duration of individual exposures. And in response, today's mount manufacturers are turning to sophisticated digital control systems that can flawlessly track the sky without external guiding for the length of these short exposures. It will be fascinating to watch as this trend continues to evolve in the coming years. The pictures here highlight some of the equipment that we found particularly noteworthy this year.

— *Photos and Text by* ***Dennis di Cicco & Sean Walker***

1 www.stellarvue.com • Vic Maris of Stellarvue proved that some of the big things at NEAF are small. He was constantly busy showing off the latest apochromatic refractor in his telescope line. The 50-mm doublet, with an introductory price of $499, has a dual-speed 2-inch focuser, clamshell tube ring, and options that will include a photographic field flattener later this year.

2 www.sbig.com • The unique "differential" autoguiding system from SBIG is unaffected by mechanical flexure. The prototype on display is in the final stages of testing.

3 www.teeterstelescopes.com • Although high-tech gear grabs headlines, NEAF has plenty of the "basics" such as the quality Dobsonians exhibited by Teeter's Telescopes.

4 www.mag1instruments.com
New to its line of highly portable reflectors, the 18-inch f/4.5 Portaball from Mag 1 Instruments attracted a lot of well-deserved attention.

5 **www.telescopengineering.com** • Telescope Engineering Company president Yuri Petrunin (right) explains the Houghton-Terebizh optics of the TEC 300VT to astrophotographer John Boudreau. The 300-mm (11.8-inch) astrograph has an incredible f/1.44 speed and is designed for large-format CCD cameras.

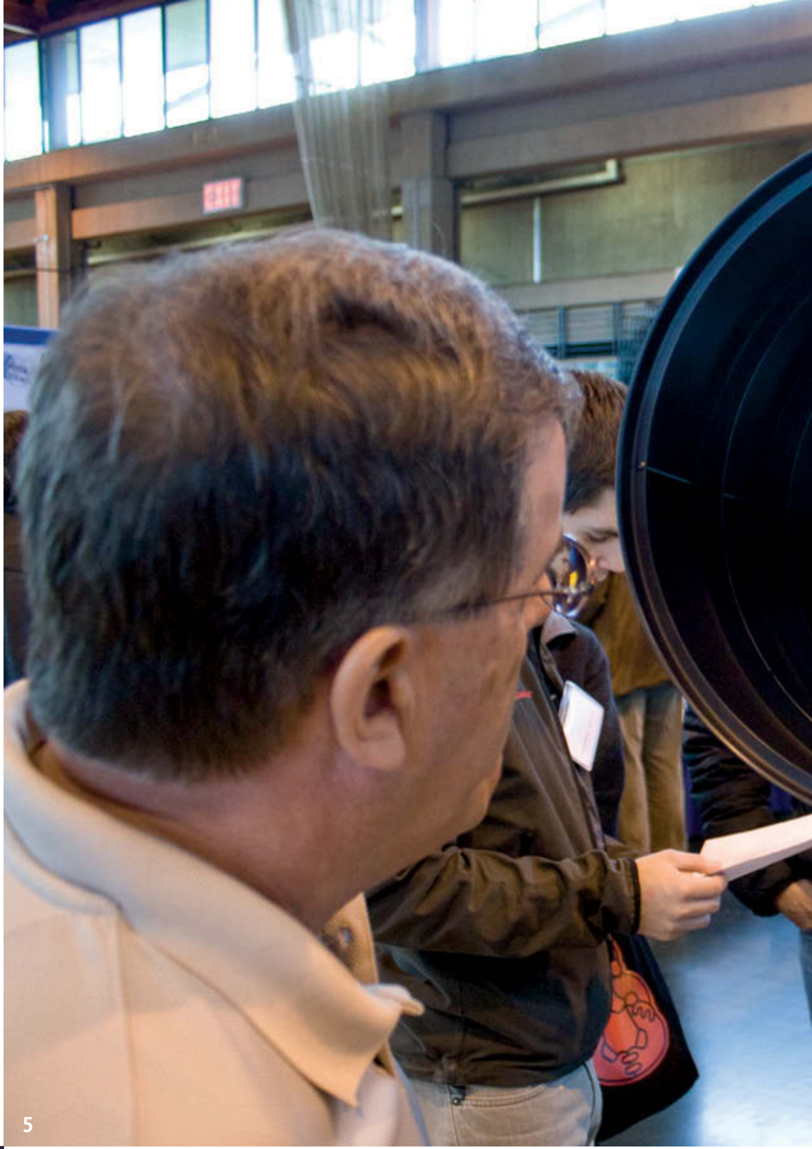
6 **www.meade.com** • The Meade booth drew a constant crowd of amateurs eager to check out the brand new line of LX600 telescopes (the 16-inch is pictured), which combine the company's latest optical and electronic innovations in classic fork-mounted instruments.

7 **www.celestron.com** • The SkyProdigy line from Celestron now includes a 6-inch f/10 Schmidt-Cassegrain telescope, the largest instrument currently available on the company's Go To mounts that align themselves without any input from the user.

8 **www.ioptron.com** • During a public unveiling on Saturday morning, iOptron president and CEO Hua Jiang demonstrated the company's highly portable SmartEQ Go To mount.

9 **www.starlightinstruments.com** • Starlight Instruments displayed a wide variety of high-end focusers, including a wireless system that controls two focusers simultaneously. The company also exhibited its new adjustable observing chair suitable for large telescopes.

10 **www.avalon-instruments.com** • Among the international equipment on display this year were equatorial telescope mounts made by Avalon Instruments of Italy. Using novel belt drives, they are part of today's new breed of mounts designed especially for digital imaging.



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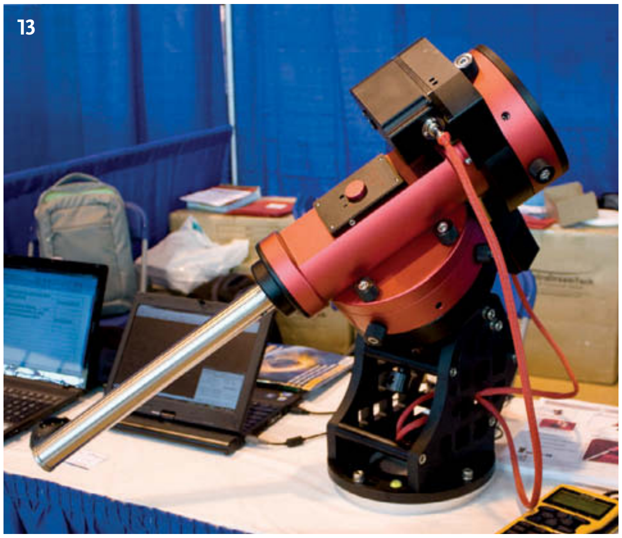
11 **www.televue.com** • Tele Vue had one of the biggest product rollouts this year when it announced five more Delos eyepieces. These highly regarded 1¼-inch eyepieces with 72° apparent fields of view now range from 3.5- to 17.3-mm focal length.

12 **www.sbig.com** • The folks at Santa Barbara Instrument Group (SBIG) also had a noteworthy product rollout, which included the STT and STXL lines of CCD cameras that incorporate state-of-the-art features, many of which were in response to user requests. Also displayed were several new filter wheels.

13 **www.astrodreamtech.com** • NEAF newcomer AstroDream Tech from South Korea displayed several new high-end German equatorial Go To mounts in its Morningcalm line.

14 **www.astro-physics.com** • For fun, the Astro-Physics booth was themed after a 1950s Sweet 16 party for the launch of its new 1600GTO German equatorial mount and 175-mm f/8 StarFire EDF apo refractor. Employees were easy to spot in the crowd thanks to poodle skirts, soda-jerk attire, and the Buddy Holly look of company president Roland Christen (pictured). ✦



In This Section

PHOTOGRAPH: KEN CRAWFORD

The Bubble Nebula is one of the highlights of William Herschel's catalog; see page 60.

AUGUST 2012

11 **DAWN**: The Moon forms a tight triangle with Jupiter and Aldebaran; see page 48.

11–12 **LATE NIGHT**: The Perseid meteor shower peaks after midnight; see page 50.

13 **DAWN**: Venus shines below the thin crescent Moon.

AFTERNOON: The Moon occults (hides) Venus in broad daylight for most of North America, and before dawn in northeastern Asia (where the date is August 14th). See page 51 for details.

13, 14 **DUSK**: Mars threads the narrow gap between Saturn and Spica low in the west-southwest.

14–22 **DAWN**: This is the peak of Mercury's excellent dawn apparition. It's more than 10° above the eastern horizon a half hour before sunrise for observers at latitude 40° north.

16 **DAWN**: Binoculars may help you find the extremely thin waning crescent Moon well below Mercury very low in the east a half hour before sunrise.

21 **DUSK**: The waxing crescent Moon makes a lovely quadrilateral with Mars, Saturn, and Spica low in the west in late twilight; see page 48.

31 **DAWN**: Binoculars show Regulus just 1¾° lower right of brighter Mercury. Look very low in the east-northeast 20 minutes before sunrise.

Planet Visibility

	◀SUNSET	MIDNIGHT	SUNRISE▶
Mercury		Visible August 10 through 31	E
Venus			NE … E
Mars	SW … W		
Jupiter			NE … SE
Saturn	SW … W		

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

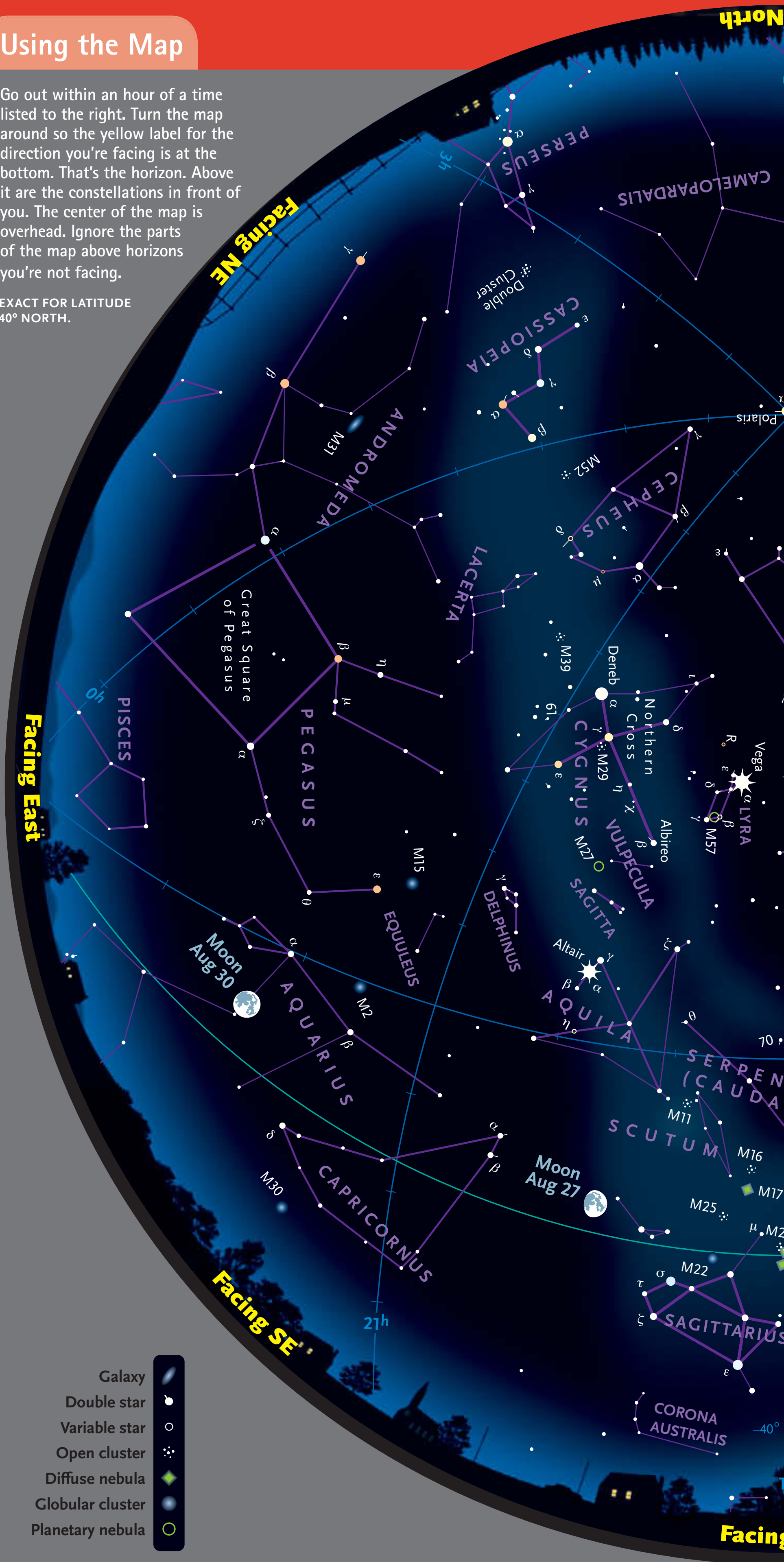
Moon Phases

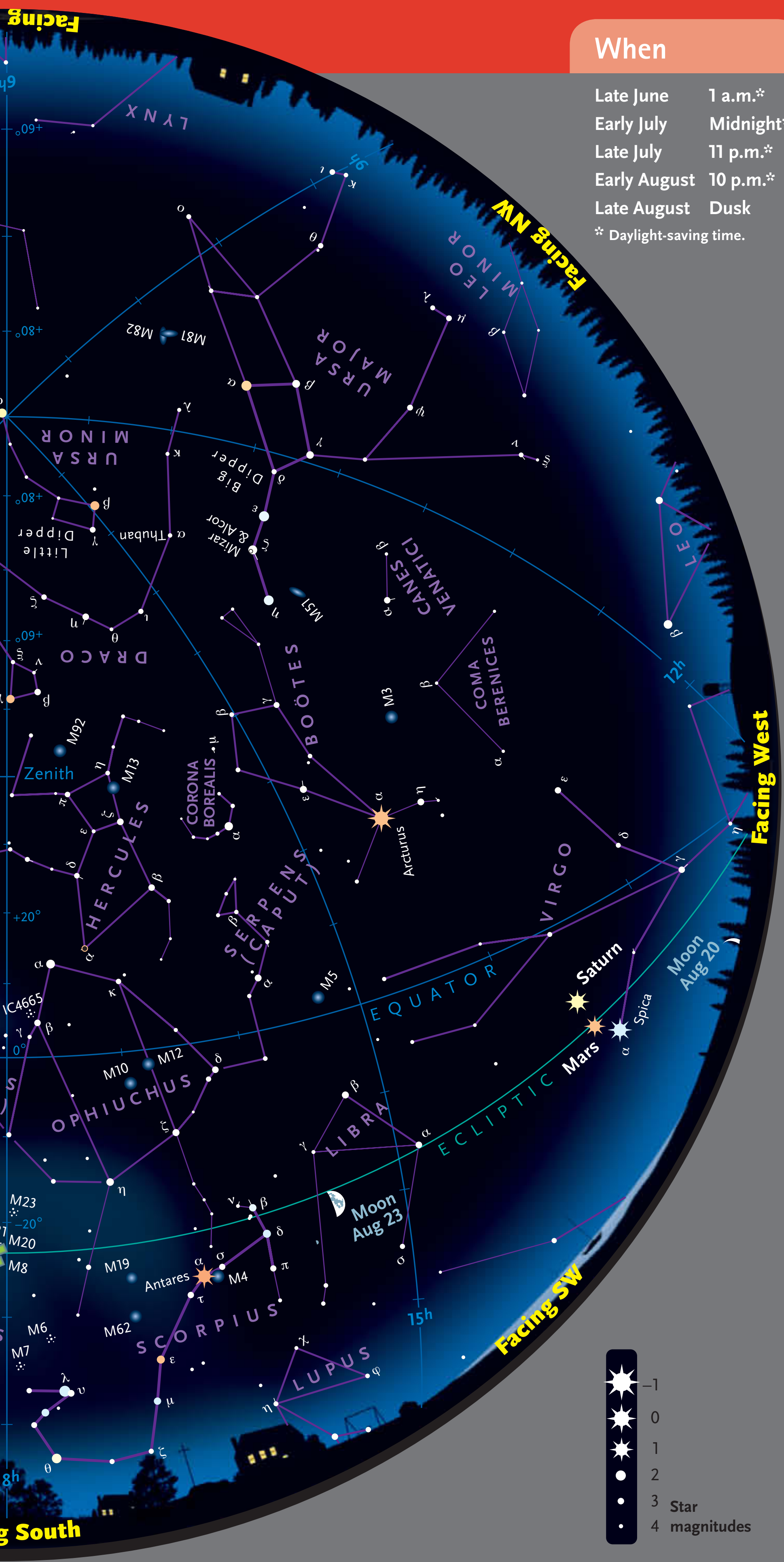
SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.





When

Late June	1 a.m.*
Early July	Midnight*
Late July	11 p.m.*
Early August	10 p.m.*
Late August	Dusk

* Daylight-saving time.

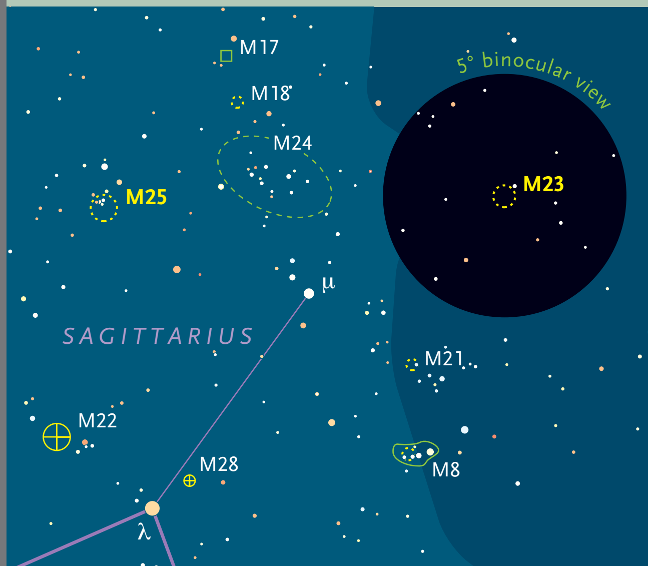
Gary Seronik
Binocular Highlight

Sagittarius Leftovers

Sagittarius is stocked with such an abundance of first-rate binocular sights that even some Messier objects tend to get overlooked. Two of the constellation's underappreciated open clusters are **M23** and **M25**. I suspect they would be viewed far more frequently in a less congested patch of sky.

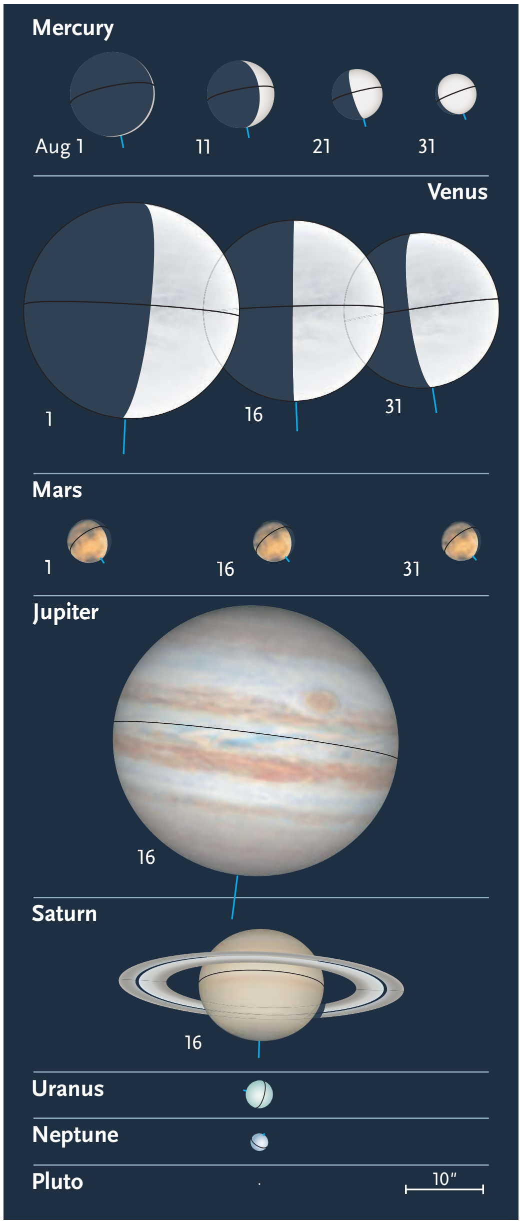
Our jumping-off point for both clusters is Mu (μ) Sagittarii, a 3.8-magnitude star lying one binocular field northwest of the top of the Teapot, Lambda (λ) Sagittarii. To get to M25, place Mu at the 3 o'clock position in your binoculars, and the 4.6-magnitude cluster will enter the field at 10 o'clock. In 10×50s, M25 breaks into about a dozen individual stars, five of which shine at 7th or 8th magnitude among a smattering of fainter ones. The two brightest cluster members are parked on the northern edge, while a close pair marks the central core region. My 15×45 image-stabilized binoculars tease out a few more faint glints, giving the gathering a richer, fuller appearance.

Return to Mu, place it at 8 o'clock, and you'll find 5.5-magnitude M23 situated at the 2 o'clock position, next to a 6.5-magnitude field star. In 10×50s, M23 is a rich shimmer of pale starlight on the verge of resolution. With averted vision (looking slightly to one side of M23), faint cluster stars tantalizingly jump in and out of view. The extra magnification of my 15×45s makes these dim sparkles slightly easier to see. Unlike M25, M23 doesn't have a clutch of prominent members. Its single standout is an 8.2-magnitude star dominating the northeast corner. However, this is simply a foreground object and not a true cluster member. Still, it gives the scene a little extra appeal. ✦



Watch a SPECIAL VIDEO

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

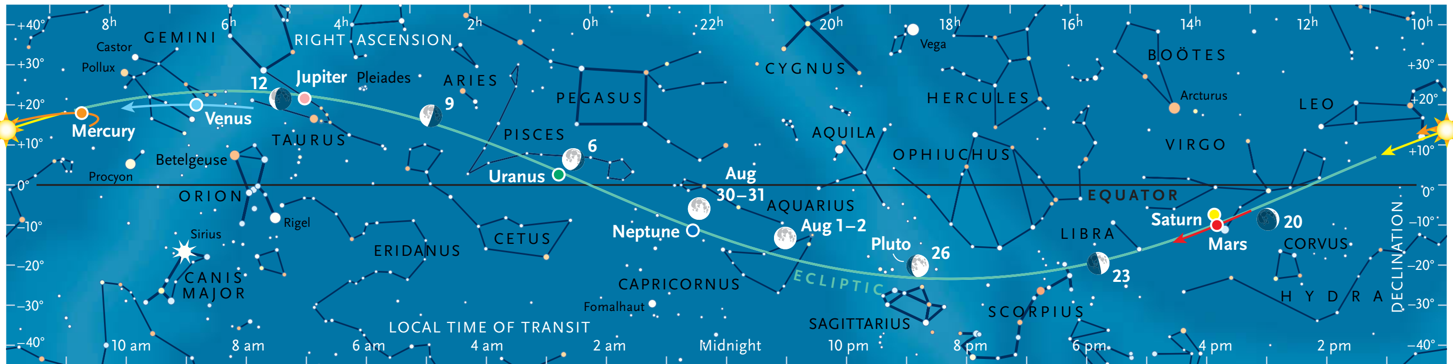


Sun and Planets, August 2012

	August	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$8^h\ 45.7^m$	+18° 01′	—	–26.8	31′ 31″	—	1.015
	31	$10^h\ 38.0^m$	+8° 38′	—	–26.8	31′ 41″	—	1.009
Mercury	1	$8^h\ 19.8^m$	+14° 42′	7° Mo	+4.6	11.0″	2%	0.612
	11	$8^h\ 13.4^m$	+17° 18′	17° Mo	+1.0	8.7″	22%	0.769
	21	$8^h\ 51.9^m$	+17° 43′	18° Mo	–0.7	6.6″	59%	1.023
	31	$10^h\ 01.8^m$	+13° 47′	10° Mo	–1.3	5.4″	91%	1.256
Venus	1	$5^h\ 35.5^m$	+19° 10′	45° Mo	–4.6	28.0″	42%	0.595
	11	$6^h\ 12.4^m$	+19° 50′	46° Mo	–4.5	24.8″	48%	0.673
	21	$6^h\ 53.4^m$	+20° 00′	46° Mo	–4.4	22.2″	53%	0.751
	31	$7^h\ 36.9^m$	+19° 27′	45° Mo	–4.3	20.1″	58%	0.829
Mars	1	$12^h\ 58.2^m$	–6° 20′	67° Ev	+1.1	5.8″	90%	1.627
	16	$13^h\ 32.1^m$	–9° 58′	62° Ev	+1.1	5.5″	91%	1.717
	31	$14^h\ 08.5^m$	–13° 31′	57° Ev	+1.2	5.2″	91%	1.798
Jupiter	1	$4^h\ 34.3^m$	+21° 12′	59° Mo	–2.2	36.1″	99%	5.467
	31	$4^h\ 52.3^m$	+21° 44′	84° Mo	–2.3	39.1″	99%	5.040
Saturn	1	$13^h\ 31.2^m$	–6° 56′	75° Ev	+0.8	16.7″	100%	9.970
	31	$13^h\ 39.7^m$	–7° 52′	48° Ev	+0.8	16.0″	100%	10.404
Uranus	16	$0^h\ 30.3^m$	+2° 27′	135° Mo	+5.8	3.6″	100%	19.331
Neptune	16	$22^h\ 16.1^m$	–11° 25′	172° Mo	+7.8	2.4″	100%	28.993
Pluto	16	$18^h\ 29.8^m$	–19° 31′	134° Ev	+14.0	0.1″	100%	31.576

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.



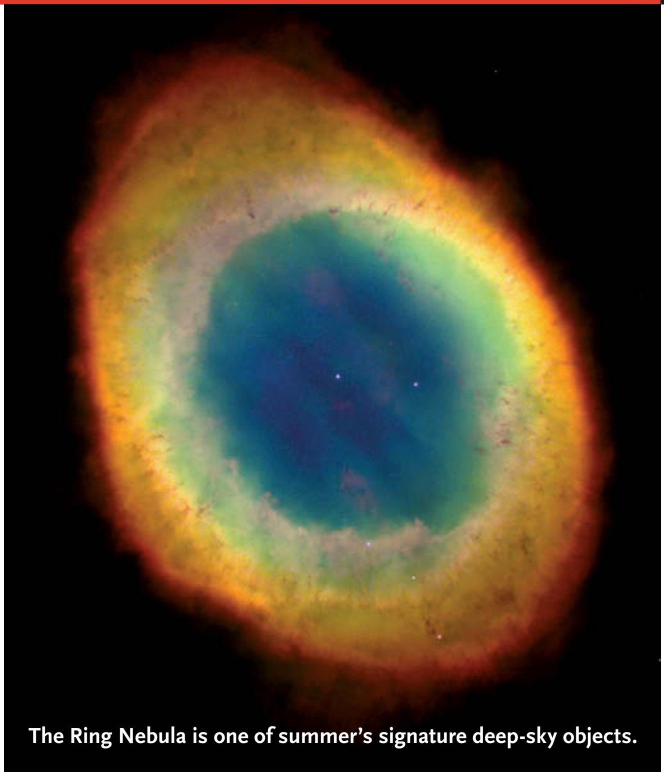
The Sun and planets are positioned for mid-August; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). "Local time of transit" tells when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

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

Fred Schaaf

The Big, the Bright, and the Easy

Summer has it all, from superwide doubles to the greatest galaxy.



The Ring Nebula is one of summer's signature deep-sky objects.

HUBBLE HERITAGE TEAM / AURA / STSCI / NASA

Welcome back to the Summer After-Dusk Sky, which appears in slightly different orientations in the all-sky maps for July, August, and September. Last month I discussed this sky's brightest stars, its renowned asterisms, and its distinctively colored single and double stars. Let's continue our exploration.

Wide double stars. The Summer After-Dusk Sky abounds in very wide double stars. The brightest and widest star pairing — never considered a double because the stars are a full 35′ apart — is 1.6-magnitude Lambda Scorpii (Shaula) and 2.7-magnitude Upsilon Scorpii (Lesath). The pair forms the point of the Stinger of Scorpius, and it's also sometimes called the Cat's Eyes. It's as high as it ever gets at our map time — which is still quite low for observers at mid-northern latitudes.

The naked-eye pairing of Mizar and Alcor (separation 12′) is high in the northwest at the crook of the Big Dipper's handle. Many people need no optical aid to split Alpha Capricorni, now low in the southeast, into two stars 6.3′ apart. And some sharp-eyed observers can split Epsilon Lyrae without optical aid into two similarly bright components 2.5′ apart. But you need a telescope at 100× to split Epsilon's naked-eye components into two tight pairs of similarly bright stars — the renowned "Double Double."

Wide pairs that can be split with binoculars include Alpha Librae and Nu Draconis, the dimmest star of Draco's compact head. But Beta Scorpii (separation 13.6″) needs low-power telescopic magnification.

Glorious globulars. Our map time is the best for observing the full span of great globular star clusters from M3 in the west to M15 and M2 in the east. Choose the globular cluster that impresses you the most. Could it be M3 in Canes Venatici? Or M5 in Serpens? Or the renowned M13 almost overhead in Hercules? Or M22 in Sagittarius? Or perhaps M4 in Scorpius? The only Messier globulars that are not in the sky now are the relatively lackluster M79 in Lepus and M68 in Hydra.

Showcase open clusters. Summer evenings don't offer nearly as many bright open clusters as winter does, but summer's open clusters far outnumber those of spring and autumn — and include some of the best in the heavens. What pair of huge open clusters could be better than M6 and M7 near the Stinger of Scorpius? What open cluster could be richer and more stirring than Scutum's marvelous M11? And the glorious Double Cluster in Perseus is rising low in the northeast.

Brilliant nebulae. M8 (the Lagoon), M20 (the Trifid), M17 (the Omega), and M16 (the Eagle) are among the best of all diffuse nebulae. These luminous clouds of starbirth occupy an amazingly compact span from northwestern Sagittarius to southern Serpens.

Planetaries and a supernova remnant. Early autumn evenings may offer more really bright or big planetary nebulae. But the Summer After-Dusk Sky features high views of the two most famous and widely observed of all these stellar death-clouds. Summer isn't summer for astronomers without reveling in M57, the Ring Nebula in Lyra, and M27, the Dumbbell Nebula in Vulpecula. And there's the remnant from a tremendously greater stellar disruption: the Veil Nebula in Cygnus.

Galaxies and dark nebulae. Okay, summer evenings are starved of galaxies if you go by numbers. The Virgo Galaxy Cluster is setting, and M31 in Andromeda is still low in the northeast. But at this time one other galaxy — a galaxy cleft, fretted, and blotched with dark clouds of gas and dust — makes a shining arch high across the sky. Its name is the Milky Way. ✦

Mars Threads a Gap

The fiery planet passes between Saturn and Spica at dusk.

Low in the west-southwest at nightfall, three similarly bright but differently colored lights converge in the first half of August, then diverge in the second half. These are the planets Saturn and Mars and the star Spica.

A few hours after this trio sets, very bright Jupiter rises in the middle of the night. Venus rises far to Jupiter's lower left around 3 a.m. daylight-saving time. And from mid- to late August, Mercury pops up fairly early in morning twilight.

DUSK

Mars passes between **Saturn** and Spica low in the west-southwest at dusk before mid-month. The three are less than 20° high in mid-twilight for viewers around latitude 40° north, which is very low for detailed telescopic views of the planets. But the primary excitement is the naked-eye spectacle: watching the shifting pattern of these three similarly bright objects — enhanced by the nearby Moon around August 21st.

Saturn, creeping slowly eastward, is 4½° north-northwest of Spica in the first half of August, and it's still less than 5° north-northeast of Spica at month's end.

Mars, by contrast, moves eastward rapidly. It starts the month 7½° west of Saturn and Spica and passes between them on the American evenings of August 13th and 14th. Saturn, Mars, and Spica form a short, nearly straight line both nights. From August 8th through 19th they form a "trio" — a temporary grouping of three celestial objects within a circle less than 5° wide. But by August 31st Mars lies 9½° upper left of Saturn and 11½° from Spica.

Spica is always magnitude 1.0, Saturn is 0.8 in August, and Mars dims slightly from 1.1 to 1.2. Mars is golden-orange, Saturn whitish gold, and Spica icy white with a hint of blue. Binoculars make these hues more obvious.

EVENING & LATE NIGHT

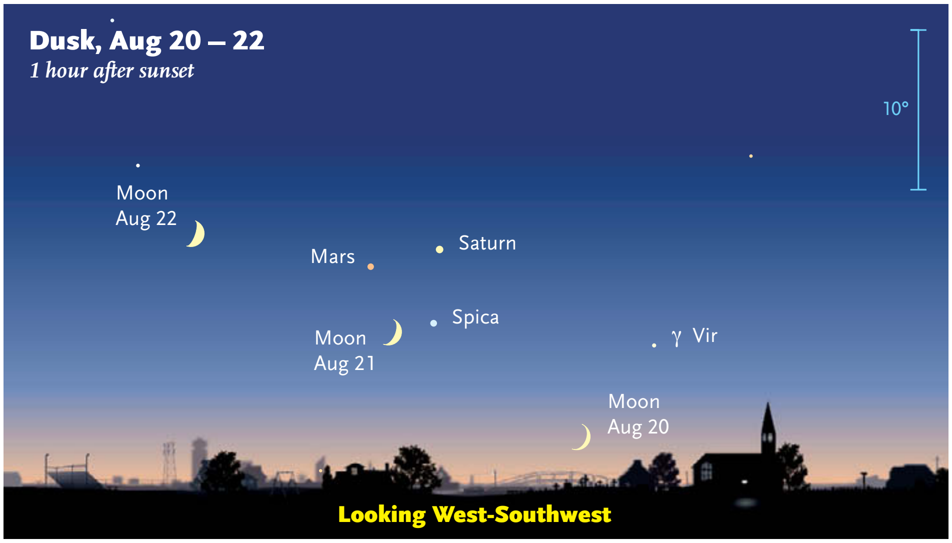
Neptune reaches opposition in Aquarius on August 24th, so it's highest in the middle of the night this month. The distant planet shines at magnitude 7.8 and appears 2.4″ wide through a telescope.

Uranus rises around nightfall but isn't highest in the south until the small hours of the morning. It glows at magnitude 5.8 in extreme northwestern Cetus, and is 3.6″ wide. Finder charts for Neptune and Uranus will appear in next month's issue and are online at **skypub.com/urnep**.

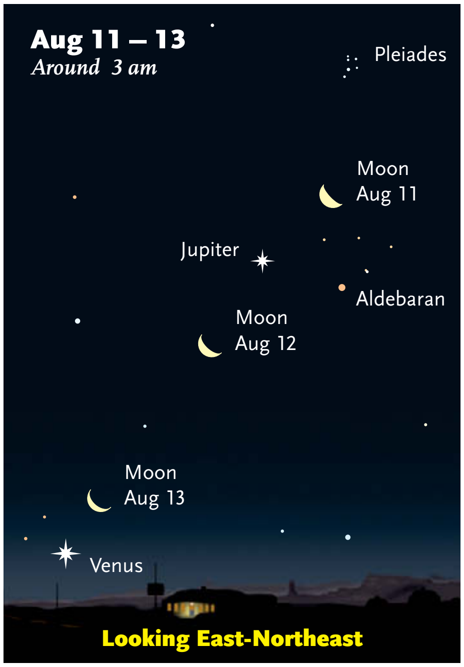
Pluto is in Sagittarius, so it's highest in mid-evening. Use the finder chart on page 52 of the June issue to spot this challenging 14th-magnitude spark.

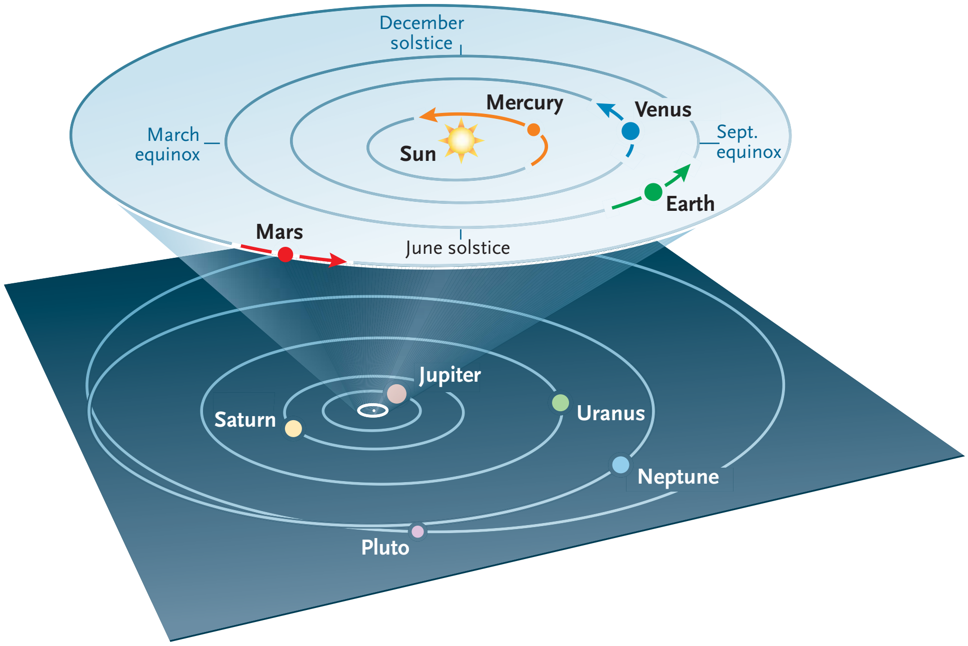
MIDNIGHT TO DAWN

Jupiter comes up around 1 or 2 a.m. (daylight-saving time) as August begins, and two hours earlier at month's end. Jupiter brightens marginally, from mag-



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





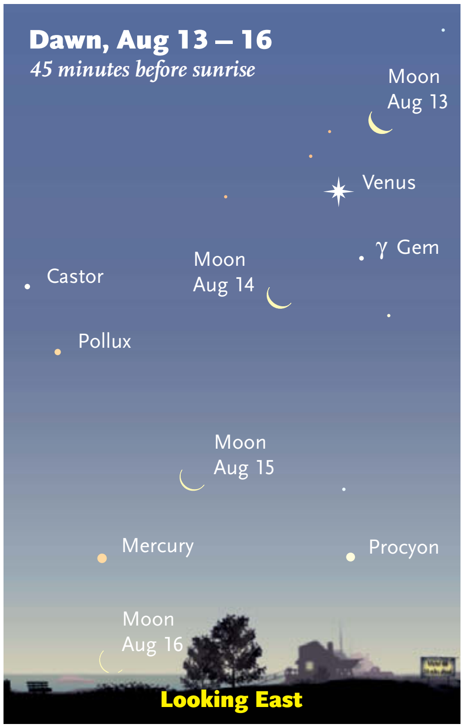
ORBITS OF THE PLANETS

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

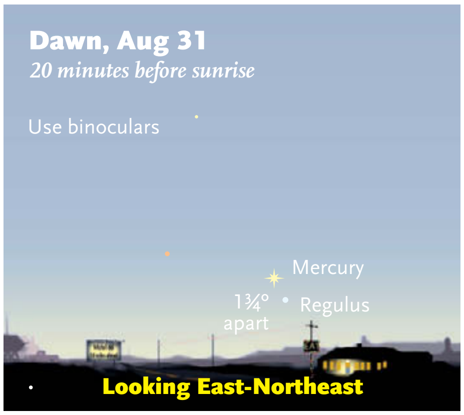
nitude –2.2 to –2.3, while inching slowly away from Aldebaran and the Hyades in Taurus. The best time for telescopic views of Jupiter this month is early in morning twilight, when the planet is 40° to 60° high in the east or southeast.

Venus rises about the same time all August: around 3 a.m. daylight-saving time. It accomplishes this by racing eastward against the westward seasonal progression of the constellations, starting the month about 2° from Zeta Tauri and ending in eastern Gemini near Cancer.

Venus and Jupiter were close companions in July, but Venus leaves much slower Jupiter behind in August; they end the month almost 40° apart. But Venus is ready for its solo, which turns out to be a virtuoso performance — one of the two loftiest morning apparitions of its 8-year cycle. Watch as Venus reaches greatest elongation, 46° west of the Sun, on August 15th. By that morning it rises about 3½ hours before the Sun (seen from latitude 40° north). Near its greatest elongation Venus is fascinating to observe in a telescope, appearing half-lit.



Mercury springs up to its own greatest elongation, 19° from the Sun, on August 16th — just one day after Venus. This is a high but brief apparition of Mercury for mid-northern skywatchers. Mercury probably isn't bright enough to see without binoculars before about August 10th, but then it brightens and climbs rapidly, hitting magnitude zero by greatest elongation. It's then rising about 1½ hours before the Sun, far to Venus's lower left. Mercury continues to brighten after greatest elongation, but it falls rapidly in August's last week.



By August 31st Mercury is buried deep in bright morning twilight, very low in the east-northeast 20 minutes before sunrise. But it's worth a look anyway, because binoculars and telescopes will then show much fainter Regulus just 1¾° to Mercury's lower right.

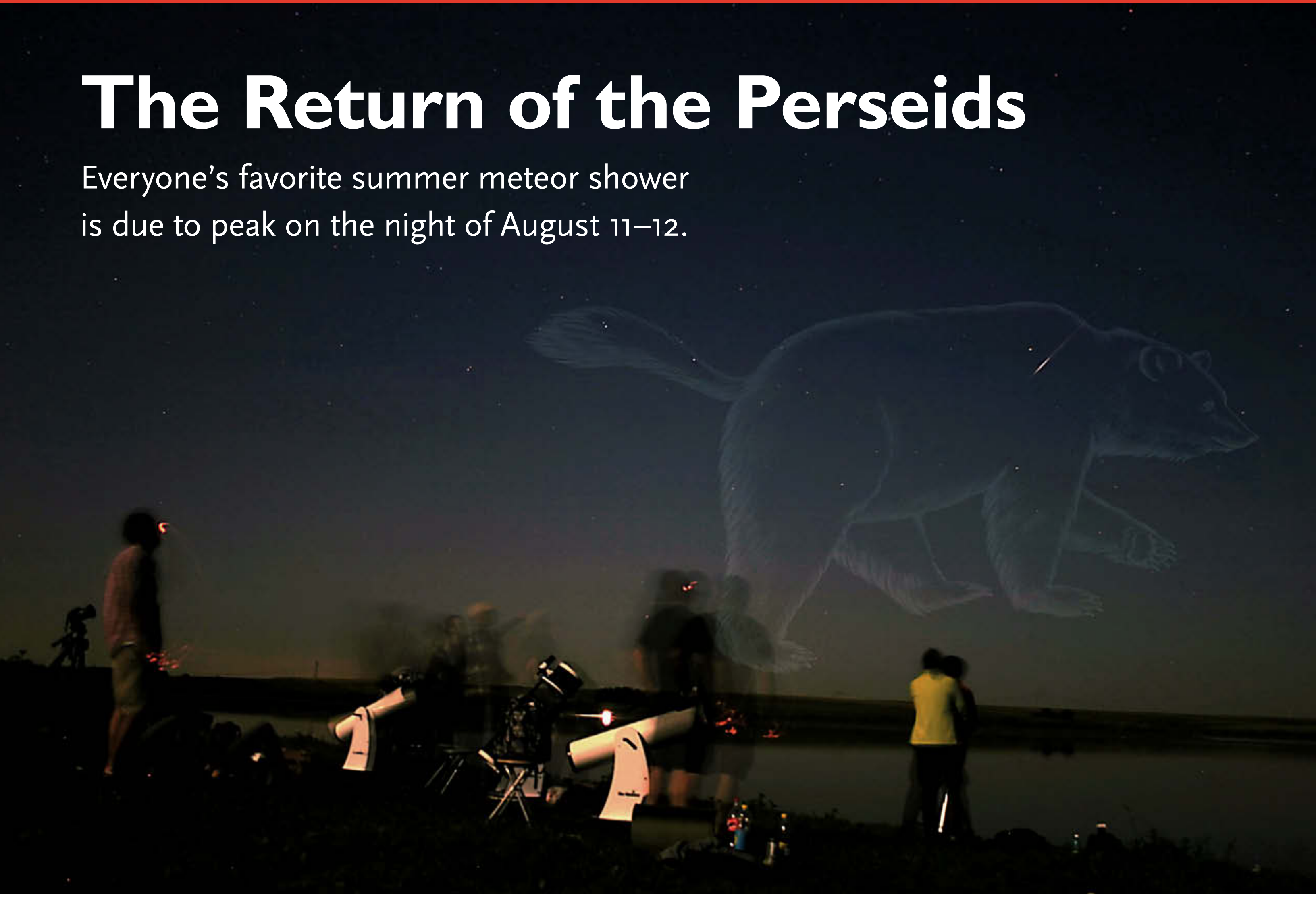
MOON PASSAGES

The **Moon** forms a tight, almost equilateral triangle with Jupiter and Aldebaran before the American dawn of August 11th. A thinner lunar crescent hangs close to Venus's upper right at dawn on August 13th — then occults Venus in daytime for most of North America (see page 51). The Moon is much farther upper right of Mercury on August 15th.

The Moon is new on August 17th, then reappears in the evening sky. The waxing crescent floats near Spica at dusk on August 21st with Mars and Saturn not far above them. The crescent Moon, star, and two planets then all fit in a circle just over 6° in diameter — a stunning sight in wide-field binoculars. ✦

The Return of the Perseids

Everyone's favorite summer meteor shower is due to peak on the night of August 11–12.



Above: **On the night of August 12–13 last year, amateurs from Bucharest, Romania, drove to a relatively dark lakeside for a night of observing. In this time exposure, Curtasu Mihai caught a Perseid darting to the bowl of the Big Dipper. He later added a ghostly Ursa Major.**

The Perseids aren't quite the richest annual meteor shower — in most years that honor goes to the December Geminids — but they're surely the most watched. The Perseids arrive in the August vacation season when nights are comfortable and families are often in places darker than usual.

This year the Perseid shower should reach its peak late on the night of August 11–12, a Saturday night and Sunday morning. A few Perseids always dart across the stars in the evening, but the shower really gets under way only after 11 or midnight local time, as its radiant (perspective point of origin) in northern Perseus rises high in the northeast. The higher a shower's radiant, the more meteors will appear all over the sky.

A thick waning crescent Moon comes up by 1 or 2 a.m. that night. But its modest light, notes the International Meteor Organization (IMO), "should be considered more of a nuisance than a deterrent," even for serious meteor-counting efforts (described at **skypub.com/meteors**).

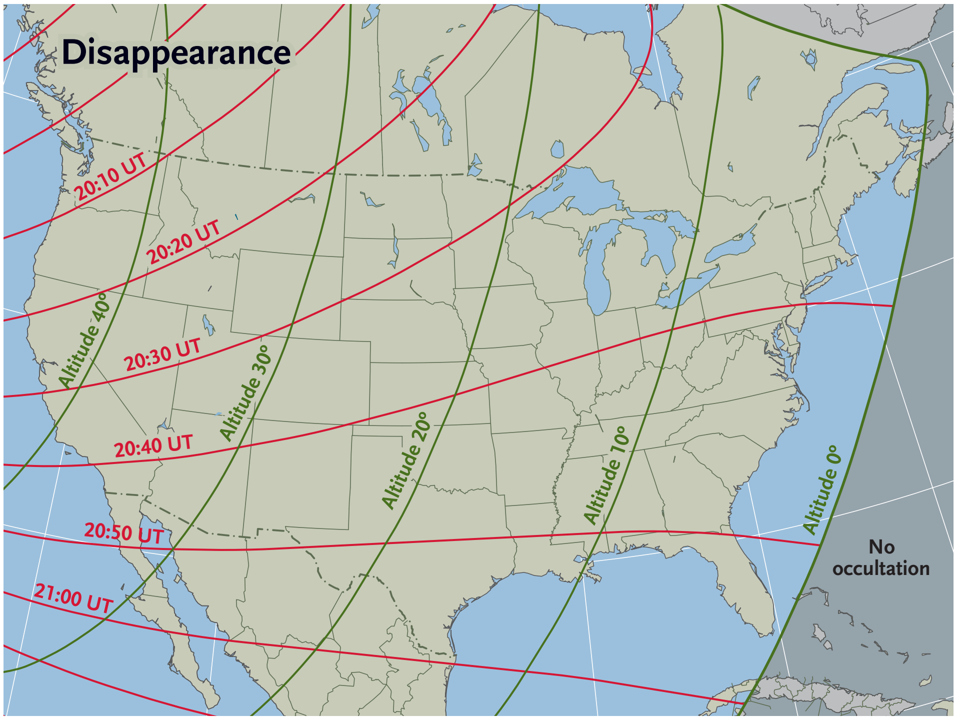
With luck, you may see one or two Perseids a minute on average after midnight. Rates should increase through the morning hours as the radiant gains altitude, until dawn finally interferes.

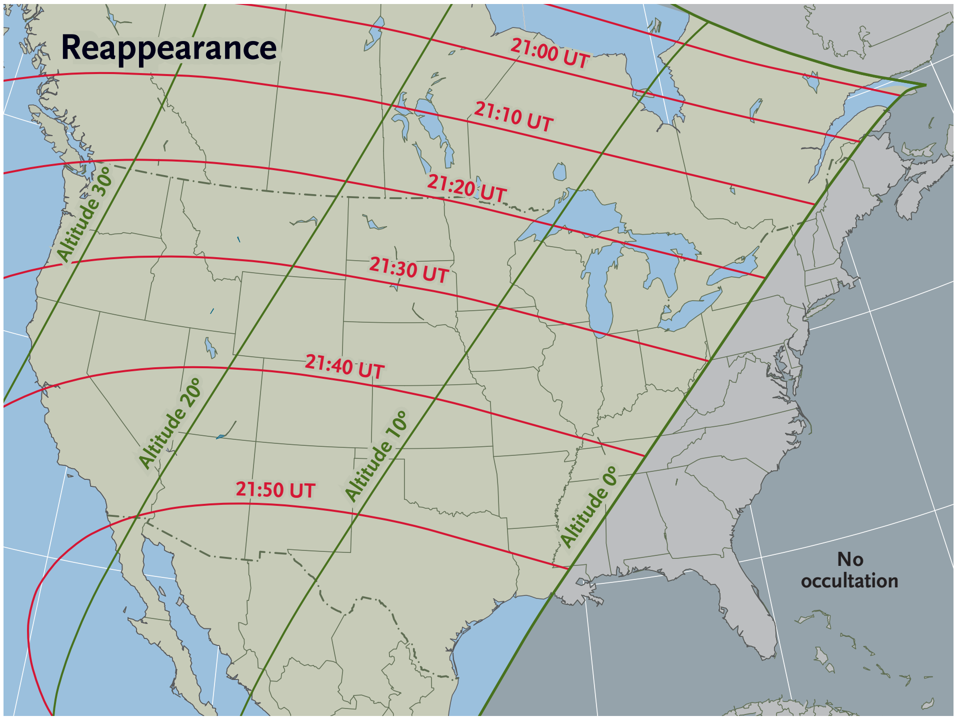
The shower's true peak, as determined by meteor counters observing continuously in relays around the globe, has been arriving several hours ahead of or behind schedule in recent years, according to the IMO. These recent peaks correspond to anywhere from 7^h to 19.5^h Universal Time August 12th this year. So, you might sight almost as many Perseids on the morning of the 13th (with a thinner Moon) as on the 12th.

You're also likely to notice Perseids for several nights before and after. Rarer ones show up as early as mid-July and as late as August 24th. When you see a meteor during this period, follow its path far backward across the sky. If the line passes through a spot between northern Perseus and Cassiopeia (near the Double Cluster), a Perseid is almost surely what you saw.

Alan MacRobert

A Daytime Occultation of Venus





Mark your location, then interpolate between the red curves to find the Universal Time of Venus's disappearance and reappearance. Remember that 20:00 Universal Time is 4:00 p.m. Eastern Daylight Time, 3:00 p.m. CDT; 2:00 p.m. MDT; 1:00 p.m. PDT. The green lines show Venus's altitude above the horizon at the time of the event.

In broad daylight on the afternoon of Monday, August 13th, telescope users across most of North America can watch the edge of the thin waning crescent Moon blot out bright, half-lit Venus in a blue sky.

Venus will be near its greatest elongation, 46° from the Sun. Unfortunately, this is a *western* elongation of Venus, so the planet and the dim Moon will be will be sinking in the west while the Sun is still blazing high in the sky.

West Coast observers have the best view. Here the Moon will still be some 40° high when its sunlit limb moves across the bright white planet between 1 and 2 p.m. Pacific Daylight Time, depending on where you are. Venus will reappear from behind the Moon's invisible dark limb as much as an hour or more later, seeming to emerge from nowhere into the blue.

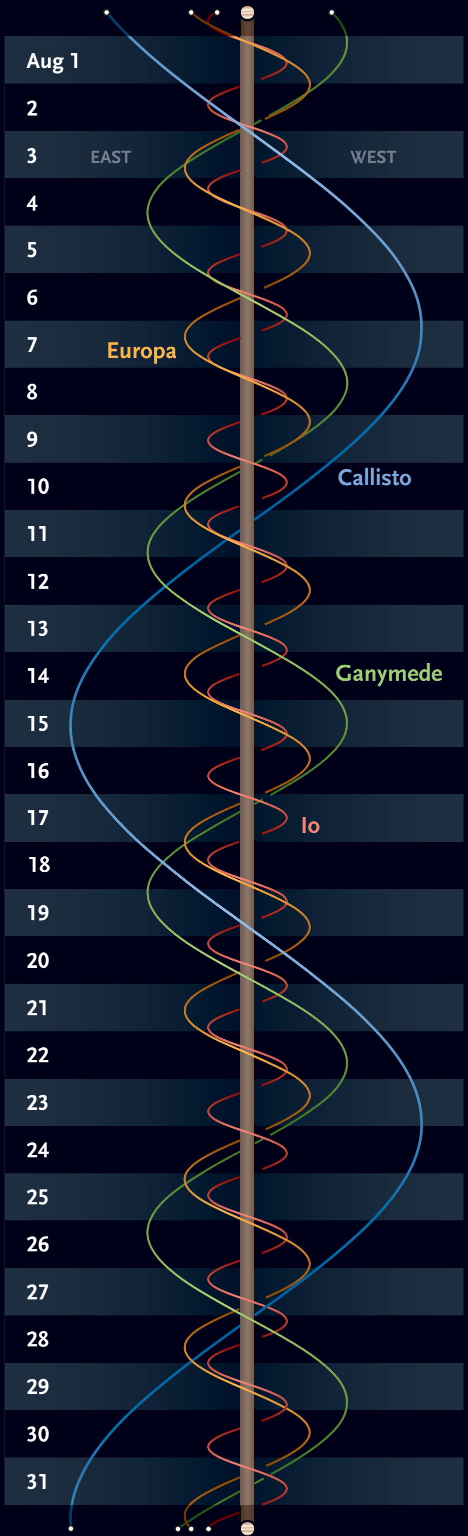
These dramatic events happen lower in the sky and later in the afternoon the farther east you are. Near the East Coast only the disappearance can be seen at all: with the Moon 3° above the west-northwest horizon as seen from Boston, 5° from Washington D.C., and 8° from Atlanta. You'll need an open low view and very clear air.

Finding where to look might not be easy. The crescent Moon is often difficult or impossible to see in the bright daytime sky when it's lower than the Sun is. Use your finderscope or binoculars to sweep the sky 46° (four or five fist-widths at arm's length) to the Sun's celestial west. The little white point of Venus is likely to stand out better than the dim crescent, so watch for it.

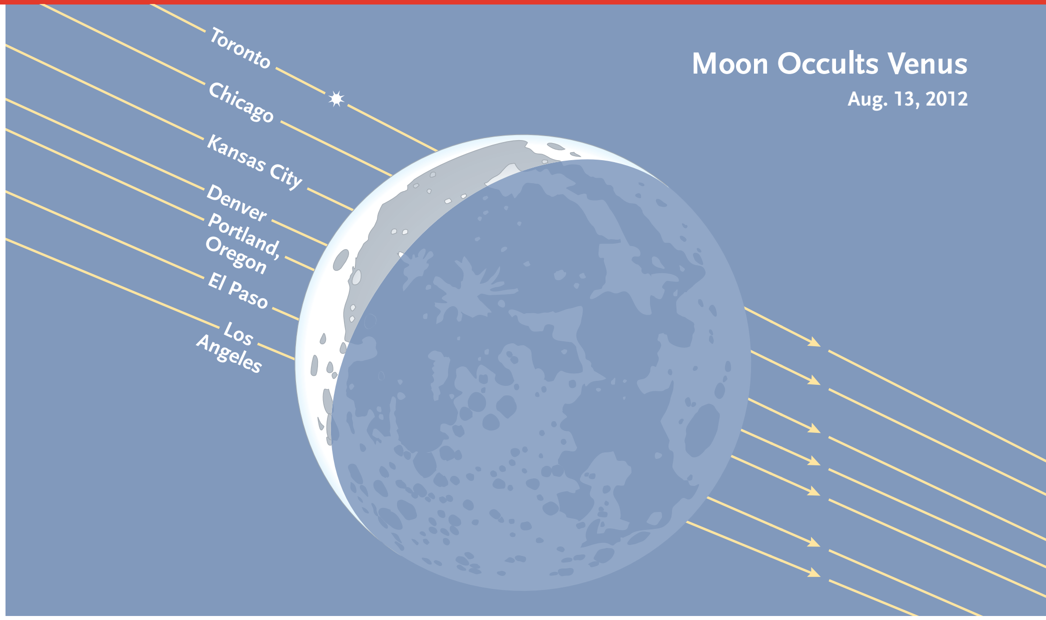
The Moon's limb will cross Venus in slow motion. The planet's half-lit face will be 12″ wide from east to west, so the Moon will take at least 25 seconds to cover and uncover it. Watch as Venus takes on un-Venuslike shapes during the process.

The maps here tell when the disappearance and reappearance happen at your location, and the altitude of the Moon and Venus above your horizon at that time.

Jupiter's Satellites



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.



Some sample disappearance and reappearance times: at San Francisco, 1:27 and 2:40 p.m. PDT; Chicago, 3:37 and 4:29 p.m. CDT; Atlanta, disappearance only, 4:46 p.m. EDT; New York, disappear-ance only, 4:39 p.m. EDT.

You can find a detailed timetable for hundreds of cities and towns across North America and in northeastern Asia (where the occultation happens before sunrise) at **skypub.com/aug2012venusoccultation**. The first part of the table is for the disappearance; scroll nearly halfway down for the reappearance listings.

Venus, Jupiter, Vesta, Ceres All Pass the Hyades

Brilliant Venus and Jupiter blaze in the east before dawn's first light this summer, from mid-July onward. And interesting things less obvious are going on right nearby.

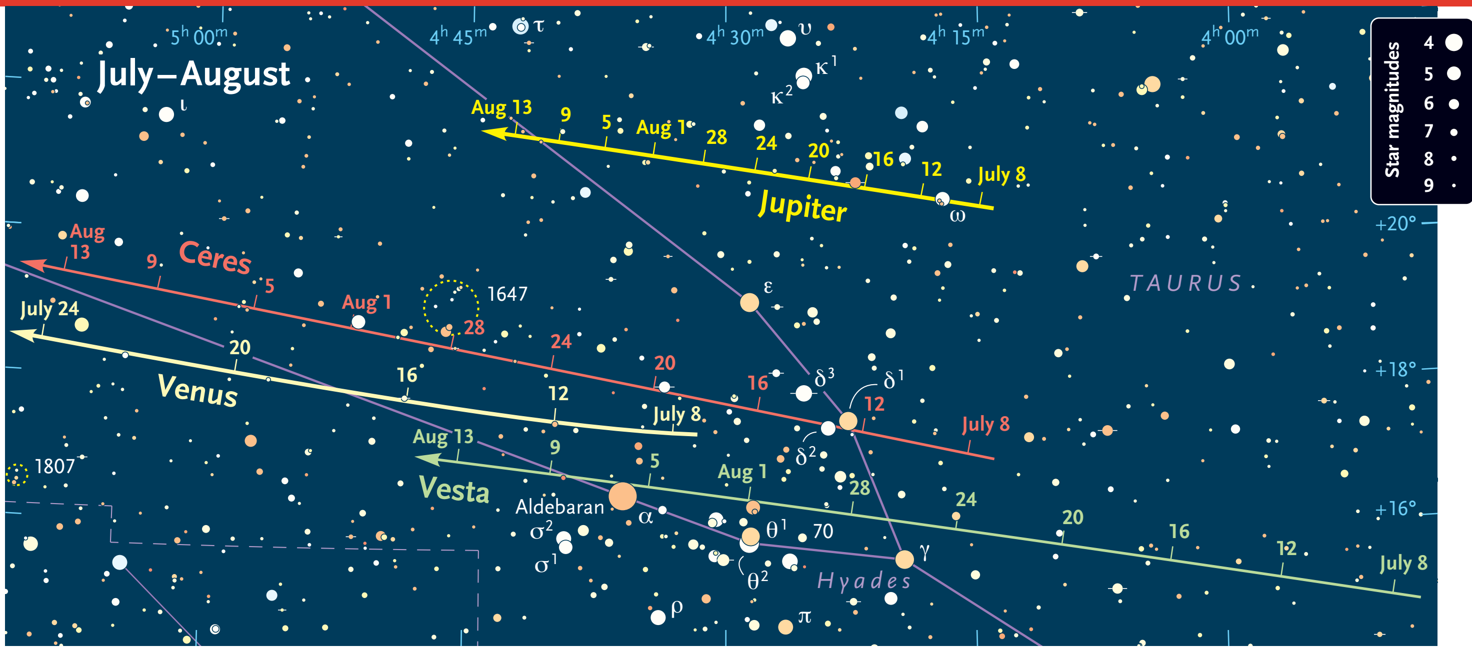
Both planets shine near Aldebaran and the Hyades in July. Jupiter stays near these stars through September, while Venus moves away. And the solar system's two most prominent asteroids, Ceres and Vesta, are also passing through. You can find them with a small telescope using the maps on the facing page.

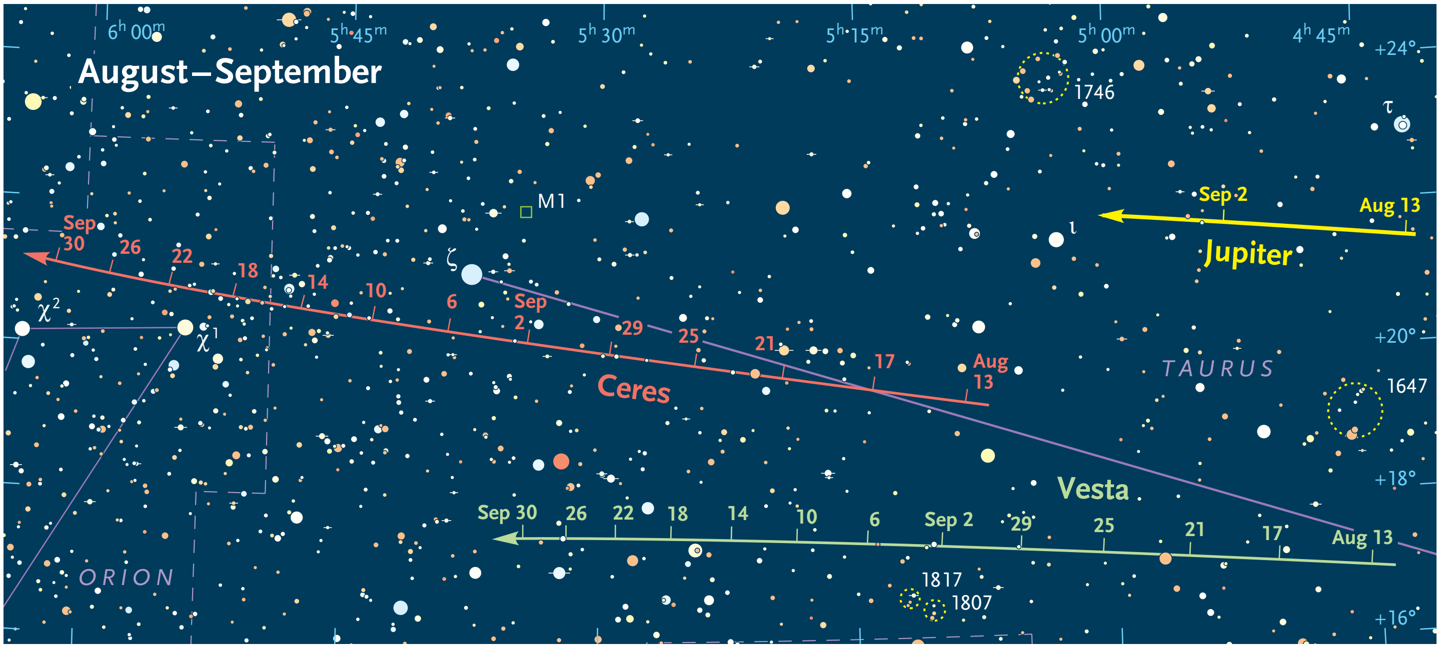
Neither asteroid is currently bright. Ceres is about magnitude 9.0 for most of July through September, and Vesta is roughly 8.2. But that puts them in easy reach of a small telescope.

On the asteroids' paths, ticks show their positions at 0^h UT every four days. Put pencil dots where they and the planets will be on their paths at the time you'll observe. Starting from Aldebaran or a planet, star-hop your way to the asteroids' exact spots. Plan your route in advance, using the faintest stars only as you close in. Use the blue declination ticks along the charts' right edges to tell how big your finderscope's and main telescope's fields of view appear on the map.

Ceres and Venus cross the Hyades in early and mid-July, when this part of the sky is very low in the east before the first light of dawn. You'll need to plan carefully when and where to set up your scope.

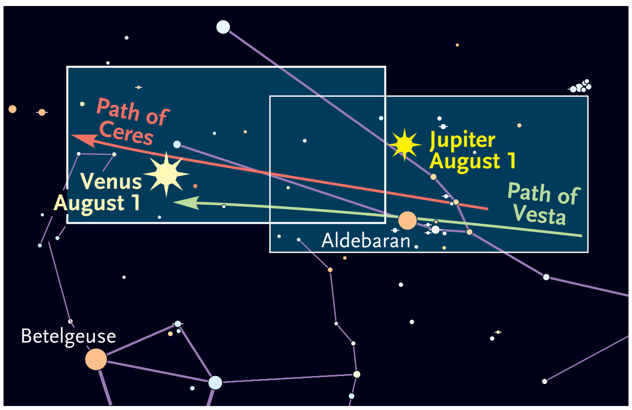
Vesta follows along through the Hyades in late July and August, when the scene is higher before dawn. Vesta stands about 0.3° from Aldebaran on the American mornings of August 5th and 6th.





Both asteroids will come to opposition in December, when Ceres will max out at magnitude 7.0 and Vesta at 6.4. We'll have another map in that month's issue.

Not often do these two asteroids appear close together. Only every 17 years does Vesta, with an orbital period of 3.63 years, catch up to and pass slower Ceres, which has a 4.60-year orbit. And the last time this happened, in October-November 1996, they were poorly placed near the Sun. This year they never get much closer together than 6°, but they're much better located. ✦



Four solar-system objects, two dazzling and two faint, cross the vicinity of the Hyades before dawn this summer. The ticks are at 0^h Universal Time on the dates marked (which falls on the afternoon or evening of the previous date in the time zones of the Americas).

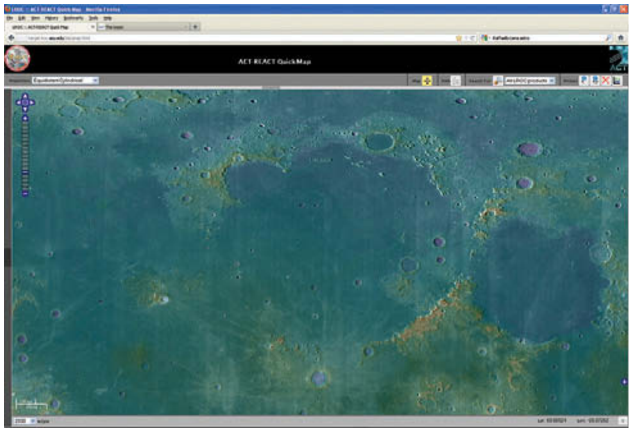
A Tool for Lunar Observers

Measuring the lunar surface adds science to your observations.

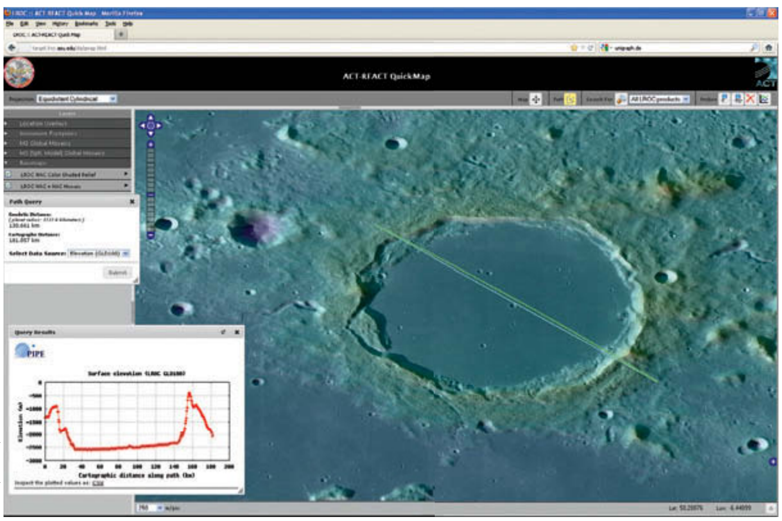
Most readers of *Sky & Telescope* are familiar with the phenomenal high-resolution images acquired by NASA's Lunar Reconnaissance Orbiter, or LRO for short (June issue, page 18). Best known are its sensational close-up views of the regolith disturbed by Apollo astronauts walking and driving rovers across the lunar surface. But few observers are aware that LRO images and topographic data have been combined into exciting new tools that can help us understand what we see at the eyepiece.

The LRO camera team has created the ACT-REACT Quick Map (**http://target.lroc.asu.edu/da/qmap.html**), a global lunar mosaic that makes it easy to access any part of the Moon's surface. Quick Map opens as a global view and lets you zoom in to 100-meter (330-foot) resolution — about 10 to 20 times better than the sharpest backyard views. It also includes hyper-resolution image strips of about 20% of the lunar surface that allow you to zoom down nearly to an astronaut's perspective.

Several additional capabilities have recently been added to Quick Map, but the one I have the most fun exploring is the Path tool. This feature lets you plot a virtual tour on the lunar surface by selecting origin and destination points, with any number of bends in between. Begin by selecting the Path tool and clicking the start of your journey, then finish by double-clicking the end point. Once the path is selected, a small window titled Path Query opens, with the geodetic distance of your plotted path, followed by the cartographic distance, which takes into account the vertical distance along the route. Clicking the Submit button within the Path Query window then displays a cross-section graph of elevation variations along your chosen route. Plotting such a topographic traverse across a 10-kilometer (6.4-mile) diameter crater such as Plato E will astonish you with graphic evidence that most craters are excavated far deeper than their rims protrude above the surrounding lunar surface.



One of the new features in the ACT-REACT Quick Map (shown above)allow you to explore lunar topography using the Lunar Reconnaissance Orbiter WAC and NAC data. Color-coded elevation measurements are based on the WAC digital terrain model.



NASA / GSFC / ARIZONA STATE UNIVERSITY

Using the Path tool allows you to measure the Moon's surface elevation along a chosen path. The red line at left reveals that the gently sloping floor of the crater Plato rises gradually toward the southeast.

You can use the Path tool to discover that some barely detectable mare ridges, such as those in Sinus Aestuum, may actually be 250 to 300 meters high. In some cases, mare on one side of a ridge is hundreds of meters lower than on the other side — proof that mare ridges are geological faults that have displaced the lunar surface.

Careful observers can use Quick Map to confirm their observations and imaging results. For example, if you're trying to detect the smallest observable craterlets on the floor of **Plato**, you can compare your best image or sketch with the LRO mosaic in Quick Map. Simply use the Path tool to measure the diameter of the smallest feature you've recorded to find out if it is 1.5, 1.0, or even an incredibly small 0.8 kilometer wide.

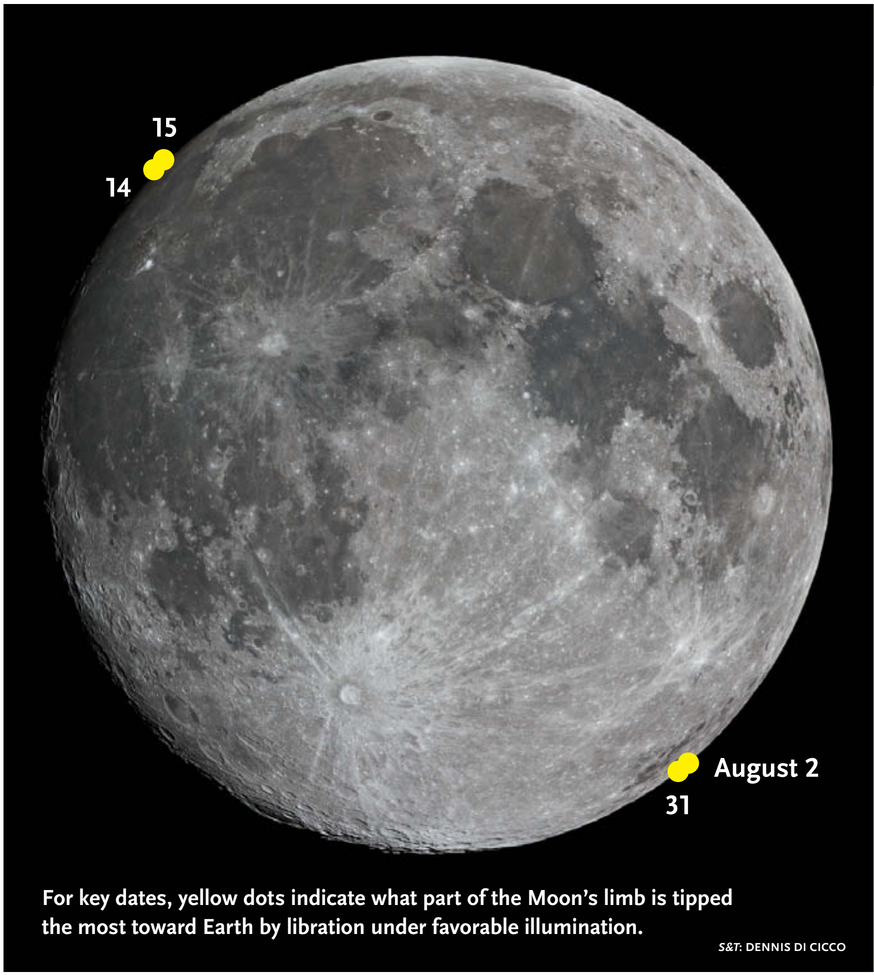
Backyard astronomers can often see lunar details a few kilometers wide, and shadow magnification — shadows appearing longer than the projecting feature is high — emphasizes the heights of mountains and depths of craters. Often you're unaware of how high or deep a feature is, and whether there's a gradual slope in elevation over dozens of kilometers that can distort shadow measurements. For instance, measuring a traverse across Plato with the Path tool reveals that the crater's floor descends 200 to 250 meters toward the northwest. If a new volcanic eruption occurred within Plato (as is often dreamed of by transient lunar phenomena observers), the fluid lavas would flow toward the northwest side of the crater floor.

It's difficult to tear yourself away from plotting traverses across every lunar feature: each time, there's new information to test your geology skills. These topographic cross-sections can transform our casual observing into genuine research.

Lunar aficionado Maurice Collins of New Zealand wondered if the famous lava flows starting on the western side of Mare Imbrium flowed downhill. Quick Map quickly revealed that indeed they did, for the whole mare surface gradually declines to the east by roughly 600 meters, or about 2,000 feet. In Rome, Raffaello Lena used Quick Map to determine the diameter and height of a relict island of old lava — a *kipuka* to use a Hawaiian term — that he captured in an image. The low Sun illumination of the telescopic view displayed an abrupt change in slope at the edge of the kipuka, invisible in the LRO mosaic, but the topographic data revealed that it is 500 meters (1,640 feet) high.

The availability of exquisite LRO data does not reduce the value of amateur observations of the Moon, but in fact makes our observations more meaningful by literally adding another dimension of information. As one observer commented, "It's so neat to verify our observations while using and pushing our telescopes to their limits." ✦

*To get a daily lunar fix, visit contributing editor **Charles Wood's** website: **lpod.wikispaces.com**.*



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

S&T: DENNIS DI CICCO

The Moon • August 2012

Phases

FULL MOON
August 2, 3:27 UT

LAST QUARTER
August 9, 18:55 UT

NEW MOON
August 17, 15:54 UT

FIRST QUARTER
August 24, 13:54 UT

FULL MOON
August 31, 13:58 UT

Distances

Apogee 247,679 miles	August 10, 11^h UT diam. 29′ 59″
Perigee 228,726 miles	August 23, 19^h UT diam. 32′ 28″

Librations

Lyot (crater)	August 2
Galvani (crater)	August 14
Volta (crater)	August 15
Furnerius (crater)	August 31

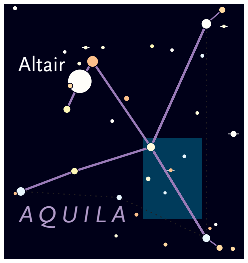
Aquila's High Heaven

A tiny region in the Eagle contains many diverse nebulae.

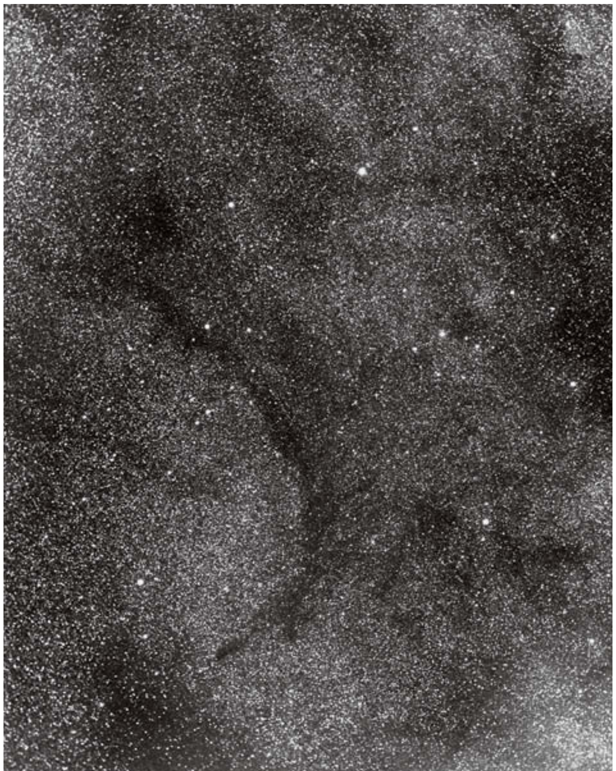
Bird of the broad and sweeping wing!
Thy home is high in heaven,
Where wide the storms their banners fling,
And the tempest clouds are driven.
— James Gates Percival, *To the Eagle*, 1826

Aquila, the Eagle, is one of three constellations contributing a corner star to the vast asterism known as the Summer Triangle. Unlike its partners Cygnus and Lyra, however, Aquila holds no bright deep-sky wonder that easily comes to mind. Yet even a small area of this constellation will offer a host of sights befitting its home amid the riches of the Milky Way. Let's spotlight a few that ride on Aquila's tail, as it's depicted on the all-sky chart at the center of this magazine.

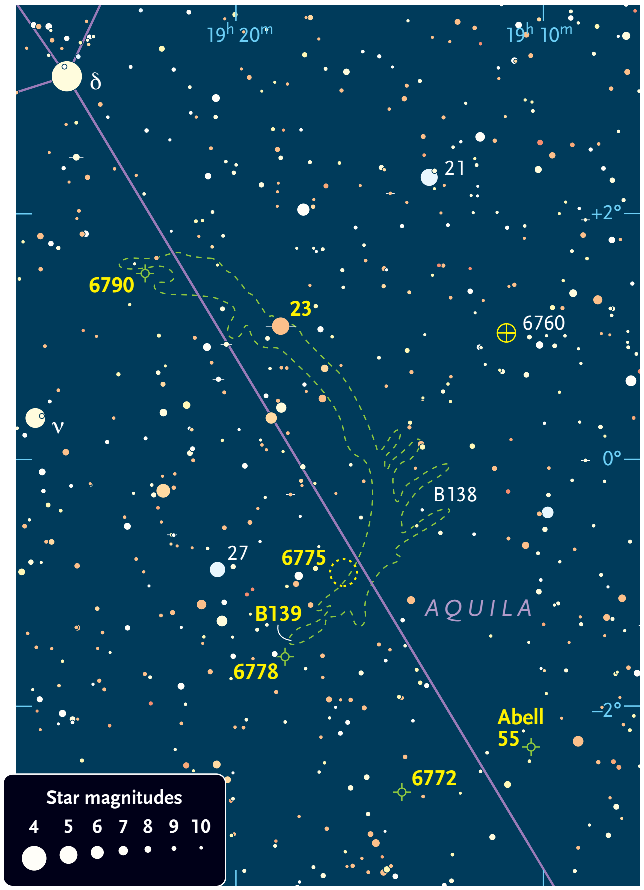
We'll begin with the lovely double star **23 Aquilae**. Through my 130-mm refractor at 91×, its bright, gold primary snuggles a considerably dimmer companion to its north. The pair is nicely split and very pretty at 117×. The first sighting of this double is often attributed to Friedrich Georg Wilhelm Struve, but credit truly belongs to William Herschel, whose 1781 discovery predates Struve's birth. Herschel's description calls the primary pale red and the secondary dusky, while Struve's account lists them as yellow and blue. What colors do you see?

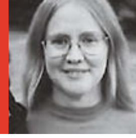


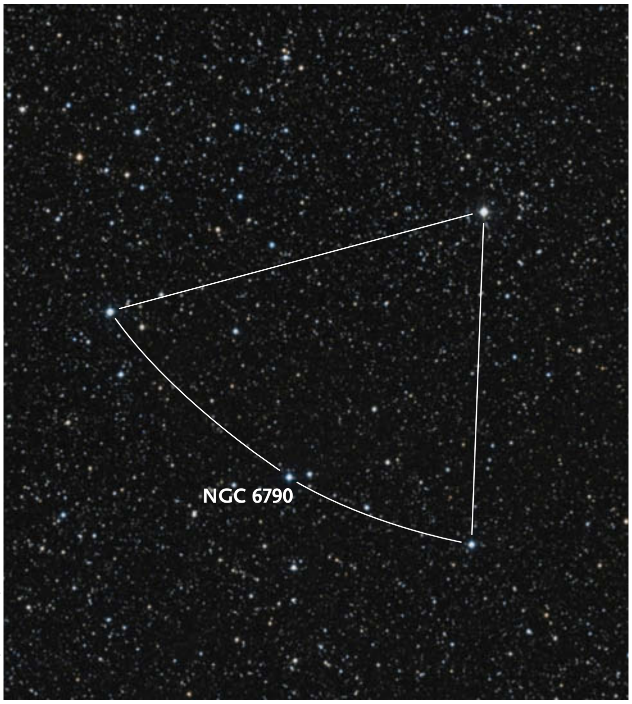
NGC 6790 dwells 1.2° east-northeast of 23 Aquilae. Of the 10 *New General Catalogue* planetary nebulae in Aquila, NGC 6790 is the brightest and one of the smallest. With its light



The crescent-shaped dark nebula B 138 dominates the southeastern quadrant of plate 40 in E. E. Barnard's photographic atlas.







POSS-II / CALTECH / PALOMAR OBSERVATORY

The author sees NGC 6790 as the central "star" on the arc of a 9′ pie wedge. The stars along the northern edge of this asterism are shown on the chart on the facing page.

concentrated in a tiny area, the planetary masquerades as a star at low magnifications. This little nebula begins to betray its true nature at 117× in my 130-mm scope. It isn't as sharp as the stars, and it glows with an unstarlike turquoise hue. It lies in a 9′ asterism that looks like a generously cut pie wedge pointing northwest. The point of the wedge is the asterism's brightest star, and the pie crust is an arc formed by NGC 6790 and two flanking stars. The nebula appears a bit brighter than the crust star to its northeast. At 234× NGC 6790 is clearly a very small disk with a bright center. The longer dimension listed in the table to the right includes faint lobes that are unlikely to be seen visually.

NGC 6790 is thought to be a young planetary nebula, on the order of a few thousand years old, but with a large uncertainty due to the planetary's poorly known distance. Estimates made over the past decade place it anywhere from 4,000 to 13,000 light-years away from us.

Now we'll drop down to 27 Aquilae and sweep 1° west to **NGC 6775**, a 13′ gathering of stars whose status as a cluster is dubious. Through my 130-mm refractor at 37×, the area holds a granular haze with a disconnected patch to the east that enfolds a clump of very faint stars. At 117× this outlier spans 2′ and displays seven stars embraced in a misty glow of unresolved suns. To the west, a loosely scattered collection of 20 faint stars tumbles northwest to southeast and widens as it goes. The two groups blend together fairly well in my 10-inch reflector at 213×, creating a 40-star cluster with vague, irregular boundaries.

An 18′ trapezoid of four 7th- to 9th-magnitude stars is centered 18′ east-southeast of NGC 6775. The two stars forming the wide base point southward to the dark nebula **Barnard 139**. My 130-mm scope at 63× shows a 10′ × 2′ bar of darkness passing through a check mark made by four stars, magnitudes 11 to 13. The check mark's long branch runs north-south, with the short branch taking off from its southern end and trending northwest. An 11th-magnitude star punctuates the east-southeastern end of this shadowy nebula. Through my 14.5-inch reflector at 170×, the bar appears lumpy and remains nearly devoid of stars.

In the magnificent 1927 posthumous work *A Photographic Atlas of Selected Regions of the Milky Way*, Edward Emerson Barnard points out that B139 sits off the southern end of B138, a huge arc of dark nebulosity averaging 10′ in width and spanning 3° on the sky. Describing B138 on Plate 40 of the atlas (shown on the facing page), Barnard writes that it "looks like a great black lizard crawling south. Its body is curved toward the west, and the head is the sharply defined black spot B139." Dark projections give legs to Barnard's dusky lizard.

B139 points to an 8th-magnitude star 9′ off its east-southeastern tip. The planetary nebula **NGC 6778** sits 5′ west-southwest of this star. My 105-mm refractor at 47× merely shows a tiny, faint, gray spot. A magnification of 87× lends some dimension to the nebula, which stands

Highlights of Central Aquila

Object	Type	Mag(v)	Size/Sep	RA	Dec.
23 Aql	Double star	5.3, 8.3	3.2″	19^h 18.5^m	+1° 05′
NGC 6790	Planetary nebula	10.5	4.5″ × 2.0″	19^h 22.9^m	+1° 31′
NGC 6775	Open cluster?	—	13′	19^h 16.5^m	–0° 55′
B139	Dark nebula	—	10′ × 2′	19^h 17.9^m	–1° 26′
NGC 6778	Planetary nebula	12.3	21″ × 16″	19^h 18.4^m	–1° 36′
NGC 6772	Planetary nebula	12.7	70″ × 56″	19^h 14.6^m	–2° 42′
Abell 55	Planetary nebula	13.2	57″ × 52″	19^h 10.4^m	–2° 20′

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.

NGC 6772 is a squared-off ring about 1′ wide.

MARTIN A. GUERRERO / LUIS F. MIRANDA / IAA-CSIC / NOT
ABOVE RIGHT: GUNNAR HURTIG / ADAM BLOCK / NOAO / AURA / NSF

This false-color image of NGC 6778 shows nitrogen emissions as red, oxygen as blue, and hydrogen as green.

out better with an O III filter. The planetary is dimmer around its edge at 127× without a filter.

In my 10-inch scope at 115×, NGC 6778 is a moderately small and bright oblong tipped east-southeast. At 213× it appears almost rectangular with faint extensions lining the long sides. My 14.5-inch scope at low power adds a blue-gray hue to the nebula. At 276× the bright region resembles two fat bars that cross in the center at a very narrow angle (like a pair of nearly closed scissors). These crossed bars overlay a fainter haze that bows outward along the long sides.

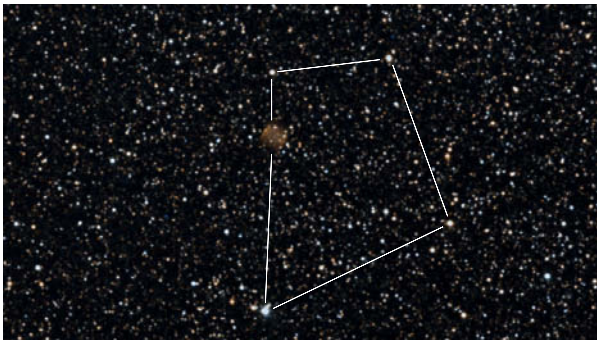
A paper (Brent Miszalski et al.) in *Astronomy & Astrophysics* last year proved that NGC 6778's central star is a tight binary with a hasty orbital period of only 3.7 hours. While the primary is on its way to white-dwarfhood, the companion is a main-sequence star fusing hydrogen in its core, as does our Sun. The combined pair weighs in anywhere from 15th to 18th magnitude, depending on what source you use. I didn't see it, but if you do, please let me know how bright you think it is.

About 2° south of NGC 6775, you'll find a distinctive chain of stars that's about 1° long and visible in a 50-mm finder under moderately dark skies. The planetary nebula **NGC 6772** lies ¼° west of the fork in the chain's north-northeastern end. With the 105-mm refractor and an O III filter at 47×, I can spot the nebula with direct vision and can hold it steadily in view with averted vision (that is, by looking a little off to one side of the object). Keeping the filter and boosting the power to 87× presents me with a roundish, moderate-size disk. I can see the nebula well through my 130-mm scope at 164×, and I estimate a diameter of 1′ — about the same as the width of the Ring Nebula (M57) in Lyra.

NGC 6772 is charmingly peculiar through larger telescopes. The 10-inch scope at 115× makes it look squarish with a small, slightly darker center. Narrowband or O III filters aid the view. NGC 6772 is an easy target for the 14.5-inch. At 170× the nebula tilts north-northeast, and its broad rim is uneven in brightness.

Sweeping 52′ west of NGC 6772 brings us to a yellow 8th-magnitude star, and veering 21′ northwest from there we find a 9′ trapezoid of four 10th- to 12th-magnitude stars. **Abell 55** (PK 33-5 1) lies along the eastern side of the trapezoid, three-quarters of the way from the trapezoid's brightest star to its faintest star. This planetary nebula is visible through my 10-inch scope at 115× as a faint, sizable, roundish glow. It stands out a bit better with a narrowband filter. With my 15-inch reflector at 133×, the nebula is rather easy and appears a little less than 1′ across with some extremely faint stars very close to it. A UHC filter improves the nebula, and an O III filter even more so.

Fashioned from material driven from dying stars, Aquila's planetary nebulae are the tempest clouds of the celestial Eagle, soaring in his high heaven. ✦



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Abell 55 lies along the long edge of a 9′ star quadrangle.


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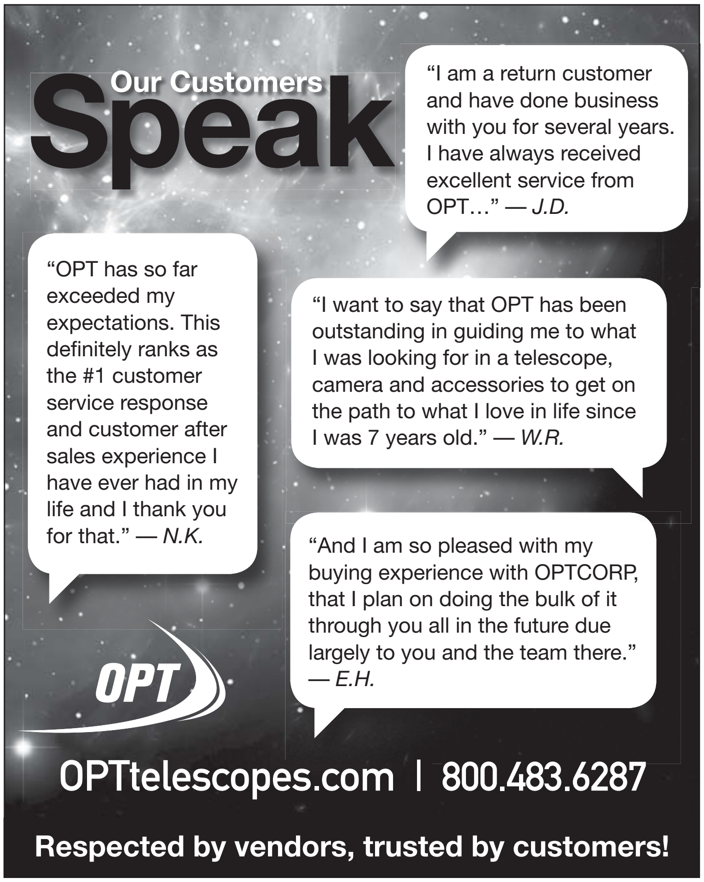
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The Herschel Project

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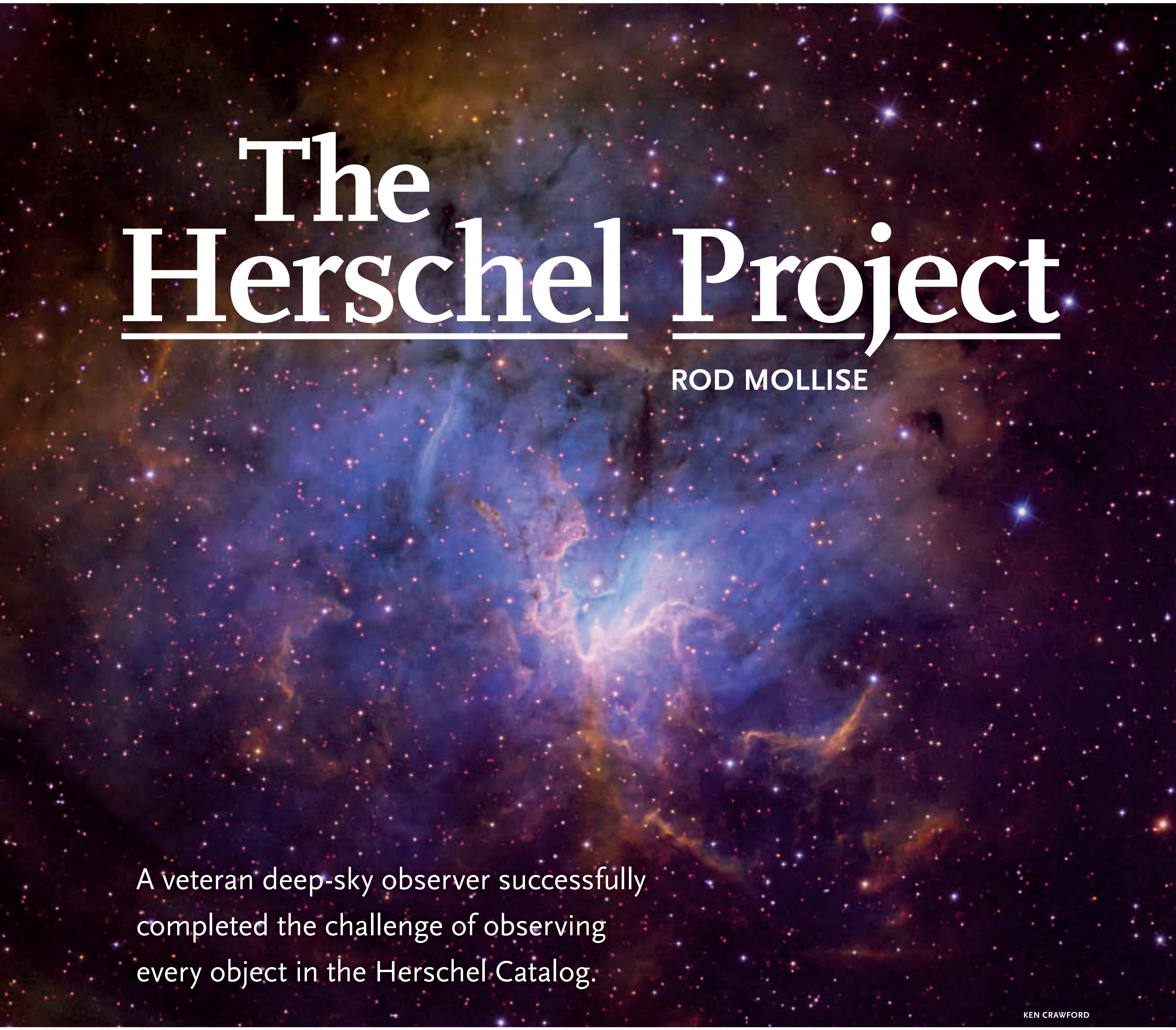
A veteran deep-sky observer successfully completed the challenge of observing every object in the Herschel Catalog.



KEN CRAWFORD

A RARE NEBULA NGC 1491 in Perseus is one of the few emission nebulae in the Herschel Catalog. It is also one of the most spectacular Herschel objects, both visually and photographically.

IS IT POSSIBLE to run out of deep-sky objects to observe? Probably not. Not given the thousands of galaxies, nebulae, and clusters visible to the eye in modest telescopes and the tens of thousands more that can be captured with a camera. But three years ago I *thought* I had.

I had tracked down the brighter objects, the Messiers, when I was a novice astronomer, and had moved on to more exotic quarry. I had seen everything from dim galaxy groups to forgotten planetary nebulae to seldom-observed star clusters. Was I done? At a star party a few years ago I thought I was. I wanted to see something new, and didn't know what that could be.

Then I remembered the Herschel Catalog, the approximately 2,500 objects discovered by William Herschel

READY TO TAKE ON THE UNIVERSE Noted book author and observer Rod Mollise of Mobile, Alabama, poses with one of the two workhorse telescopes he used to complete the Herschel Project: a Celestron 8-inch Schmidt-Cassegrain.

ROD MOLLISE

and his sister Caroline in the 18th century. The Herschel objects went on to form the core of the NGC list of objects visible from the Northern Hemisphere. I had seen some of them, 400 of the best and brightest, the Herschel 400, culled from the 2,500 by members of Florida's Ancient City Astronomy Club. But that left a lot of Herschels. What if I took on the whole big thing?

Observing that many faint and reputedly difficult objects sounded scary, but maybe that's what I needed. Like Julie Powell, who set out to cook all of Julia Child's recipes in *Mastering the Art of French Cooking*, maybe I was ready for a life-changing challenge. That night at the star party I resolved to take on the Herschels, all of them, and dubbed my quest, which I would document in my blog, "The Herschel Project."

The Challenge

Unlike Ms. Powell, whose Julie-Julia Project had a time limit of one year, I decided not to set a date for crossing the finish line. Our weather in the Deep South made that a fool's errand. I'd observe all the Herschels, re-observing the Herschel 400, and I would not dilly-dally. But I would take as much time as I needed.

How tough are the 2,500? There are more galaxies than anything else, and the faintest one, NGC 2843, has the frighteningly faint magnitude value of 16.3. The good news is that the dim galaxies are almost all small — NGC 2843 is less than 1′ across — and have sufficient surface brightness to show up in surprisingly small apertures. Also, I found that many of the galaxies look brighter, sometimes appreciably brighter, than their assigned magnitudes (depending on the source).

I used my 12-inch f/5 Dobsonian reflector for most of the visual observing, but I had little problem seeing 13th-magnitude and even fainter galaxies with my 8-inch Schmidt-Cassegrain telescope under good skies. There's no doubt, however, that at least 12 inches of aperture makes the 2,500 easier, and under light-polluted skies even that is not enough.

I had to conduct much of The Herschel Project from my astronomy club's substantially light-polluted observing site. On poorer evenings, I often used a long-exposure Mallincam Xtreme deep-sky video camera on the SCT. The camera routinely captured 16th-magnitude background galaxies in near real time, and Herschel objects were trivially easy. Seeing the images of faint fuzzies on the video monitor made it easier to see the dimmest Herschel objects visually in the eyepiece.

There's a certain nobility to finding objects the old-fashioned way, by star hopping, matching patterns in the telescope's finder to what's shown on a chart. But that's not the way I attacked the Herschels. I was pretty certain I wouldn't live long enough to complete The Project if I did it that way, and I was more interested in seeing than finding. My Dob was equipped with digital setting circles and my SCT was sitting on a computerized Go To mount.

In addition to my computerized telescopes, one other tool proved vital to the success of The Herschel Project: an "observing planner" program called *SkyTools 3* that I reviewed in the April 2010 issue. It enabled me to easily generate a list of all 2,500 objects, find and remove nonexistent ones (more than 100), tick off objects as I observed them, and record detailed log entries. *SkyTools* kept me well organized, vital for a project of this magnitude.

Getting Started

Late summer is a good time to get started on the Herschels because it offers a wonderful selection of objects of all types. The summer constellations are hanging in and autumn's star patterns are on the rise. We'll jump all over the sky, but completing The Project was a different experience. There are so many targets in some constellations, especially in spring, that I spent many evenings in one small area. I don't have space in this article to describe every object in the catalog, but here are some highlights.

LIBBY HARRELL / ADAM BLOCK / NOAO / AURA / NSF

PLANETARY IN AQUILA **Planetary nebula NGC 6804 is about 4,200 light-years away. Though discovered by William Herschel in the late 1700s, it was not identified as a planetary until 1917.**

Aquila is a curious constellation. The Eagle wings along the summer Milky Way, so you'd think he'd be loaded with deep-sky objects. Surprisingly, he only has a few worthy of notice, including a mere 10 Herschels. When I first spotted 12.4-magnitude **NGC 6804**, it actually looked more like a faint galaxy than a planetary nebula. A bit of staring at it in my 12-inch telescope, though, and it took on a more planetary-like appearance. It's an attractive gray ball 1.1′ in diameter with a fairly dim central star of magnitude 14.4.

NGC 6946 is in Cygnus, but it really ought to be in Cepheus. It's located in "The Chimney," an odd area of Cygnus that protrudes into the neighboring constellation. No matter where it's located, it's a beautiful face-on SABc spiral galaxy. In my Dobsonian under dark skies, its pinwheel-like arms were surprisingly visible. At magnitude 9.8 and 10.5′ across its longest dimension, this galaxy is not so large that its light is dimmed tremendously, but it's big enough to give up considerable detail.

What makes NGC 6946 a true standout among the many Herschel galaxies is the presence of an open star cluster, **NGC 6939**, only 40′ to the northwest. In a wide-field eyepiece, both the cluster and galaxy are in the same field, which is an unforgettable sight. The 10′-diameter NGC 6939 shines with a combined magnitude of 10.1 and is well resolved in 8-inch and larger telescopes. It looked round to me at first, but after a while, its mix of blue and gold suns seemed to arrange themselves into spiral patterns and it began to look like a strange "outline" of the nearby galaxy.

ROBERT GENDLER

CEPHEUS CLUSTER NGC 7762 is one of the most visually satisfying open clusters in the Herschel Catalog. The cluster is nearly 2 billion years old and about 2,600 light-years from Earth.

TWO FOR THE PRICE OF ONE NGC 6946 (lower right) is a face-on spiral galaxy in Cygnus that surrenders considerable detail in large telescopes. But wide-field eyepieces can also capture open cluster NGC 6939 (upper left) in the same view.

ALSON WONG

M31 STAR CLOUD Just as our Milky Way has huge star clouds, the same goes for the Andromeda Galaxy. The bright cloud NGC 206 dominates the center of this image.

ROBERT GENDLER

I don't think there's a single constellation that doesn't contain at least one Herschel galaxy, even cluster-heavy Cepheus. Given **NGC 1184**'s fairly dim magnitude of 13.0, I expected this Cepheus galaxy to be at least slightly challenging. But even in my C8 it was not. This 3.4′ × 0.8′ edge-on lenticular was easy with direct vision. In the 12-inch, I saw a small, bright central area and a razor-thin disk. Unlike many of the faint smudges I encountered in the Herschel 2,500, this one really looked like a galaxy.

Most of the Herschel Catalog consists of galaxies, but there are quite a few open star clusters too, such as Cepheus's **NGC 7762**. Although the open clusters are usually fairly disappointing, this pretty one is an exception. Approximately 15′ in diameter, it consists of tiny stars arranged in a vaguely rectangular pattern. There's a prominent line of stars just off-center that caught my attention.

The Brighter Herschels

Herschel objects have a reputation for being dim and difficult, but that's not always the case. There are, in fact, 16 Messiers among them. The Andromeda Galaxy isn't in there, but one of its satellites is, **NGC 185**, 7° to its north in Cassiopeia. At magnitude 10.1 and 11.7′ × 10′ in size, this dwarf-elliptical galaxy was attractive in the C8. An elongated center is surrounded by bright oval haze set in dimmer haze. A tiny, star-like nucleus was visible with the 12-inch.

M31 is not a Herschel object, but I visited it to tick off **NGC 206**, the huge star cloud inside one of the galaxy's spiral arms. I sometimes have trouble seeing this nebulous patch, but on a good night, especially one when

ROBERT GENDLER

OWL OR E.T.? NGC 457 in Cassiopeia is one of the brightest objects in the Herschel Catalog. Its dozens of bright stars form a figure that some visualize as an owl and others as E.T.

the seeing is steady, it stands out like a sore thumb 41′ southwest of M31's center.

If you want a spectacular Herschel open cluster, it doesn't get better than **NGC 457**, the renowned 5.1-magnitude E.T. (or Owl) Cluster (see photo on previous page). Its brightest star, Phi Cassiopeiae, forms one of the "eyes" of the stick-figure alien. NGC 457 was amazing visually, but it became more amazing when I turned the Mallincam on it. The camera began to pick up tiny and dim PGC galaxies winking into view among the cluster's stars. The more I worked the list and saw wondrous sights such as this, the better my perspective on the universe became. The distant stars of NGC 457 are mere next-door neighbors compared to the unimaginably distant PGC galaxies.

A Deepening Appreciation

Nebulae are few and far between in the Herschel Catalog. But there's a good one in Cassiopeia: **NGC 7635**, The Bubble Nebula — famous because of beautiful long-exposure images. I had a difficult time seeing the bubble shape formed by looping streamers, even in the 12-inch equipped with a nebula filter. Plenty of nebulosity was on display in a wide-field 13-mm eyepiece, but mostly the impression was "haze around an 8th-magnitude star."

Herschel galaxies range from the "barely there" to the "spectacular." **NGC 7331**, The Deer Lick Galaxy, is among the latter. It was beautiful in my 8-inch, with a large, bright, and elongated middle and hints of a sweeping spiral arm. Why is it "The Deer Lick"? Because numerous small galaxies hover nearby, like deer clustered around the salt lick of big NGC 7331. My Dobsonian revealed two

KEN CRAWFORD

COSMIC BUBBLE NGC 7635 in Cassiopeia is commonly known as the Bubble Nebula. A hot but aging star in the center sculpts the 10-light-year wide nebula with its fast and powerful wind.

THE DEER LICK GALAXY A group of small, faint galaxies form a deer-like pattern above the bright spiral galaxy 7331. But the smaller galaxies are about 10 times farther than NGC 7331's approximate 45-million-light-year distance.

S&T: SEAN WALKER

Read a BONUS AUTHOR INTERVIEW

To read more from Rod Mollise about his challenging Herschel Project, visit skypub.com/herschelproject.

with fair ease in an 8-mm eyepiece, **NGC 7337** and **NGC 7335**. A third, **NGC 7336**, was at least suspected.

As Pegasus sinks, Perseus rises; let's head to the other side of the sky for a taste of that hero's Herschels. **NGC 1624** is a passable small open cluster 1.9′ across composed of 12 to 15 fairly prominent stars. But that's only half the story. A quick glance at it in the 12-inch showed it to be embedded in subtle but real nebulosity. Even without a filter, it was obvious that a cloud surrounds the cluster's handful of 12th-magnitude-range stars. The nebula was round and reminded me a little of the Cocoon Nebula in Cygnus (IC 5146).

NGC 1605, our next Perseus target, is an open cluster, though it's not much of an open cluster. I'm including it because it's typical of many of the groups you will encounter as you travel the 2,500. In my 12-inch Dob at 200×, all I saw were five or six faint stars in a shapeless pattern. One slightly brighter red-orange star was visible 2′ to the east of the cluster's center. Borderline objects such as this one gave me a greater appreciation for Herschel's achievement at seeing the faintest objects. It's amazing given the primitive nature of the telescopes and eyepieces that he was able to see things like this.

Winter Objects

We don't normally associate the winter constellations with galaxies, but they are there. Perseus is loaded with them, including **NGC 1169**, which is a standout. At magnitude 12.3 it's not overly dim for a Herschel object, and it's large enough at 3.5′ × 2.1′ to be easy to spot. This Sb spiral has a slightly brighter center and an elongated disk. When I first put my eye to the eyepiece, my reaction was, "Oh my god, I've discovered a supernova!" Alas, my "supernova" turned out to be a dim field star superposed on the galaxy.

THE HERSCHEL CATALOG

For more information about the Herschel Cat-alog and its 2,514 objects, visit **http://messier.seds.org/xtra/similar/herschel.html**. Canadian astronomer Lucian J. Kemble compiled the catalog, but British astronomer Richard Hook helped restore the list after some objects were lost. According to the website cited above, the Herschel Catalog is considered less reliable than the much smaller Messier Catalog in terms of duplications and other errors.

S&T: SEAN WALKER

MINI-COCOON **NGC 1624 in Perseus is classified as an open cluster, but careful inspection also reveals a surrounding patch of nebulosity that's reminiscent of the Cocoon Nebula in Cygnus.**

Nobody would call **NGC 1175** "prominent," but once you know what you're looking for in this galaxy-rich area of Perseus (a photograph helps) this near-14th-magnitude edge-on Sa galaxy is not overly difficult. It's strongly elongated, 1.9′ × 0.5′, with a stellar-like core that winked in and out in my Dobsonian at 200×. If nothing else, this galaxy provides a taste of what you'll face in many of the Herschel 2,500 galaxy fields: little elongated wisps that don't jump out at you, but that won't defeat you either.

Let's end this Herschel run on a high point with Perseus's lovely **NGC 1491**, an exceptional emission nebula. It was easily visible in the 12-inch with both 8- and 13-mm wide-field eyepieces, and I couldn't decide which provided the better view. Lower power brings in more of the star-laden field, but a bit more magnification pulls out more nebulosity. It's a substantial cloud around, but not precisely centered on, a magnitude-11.1 star. Screwing a UHC-type nebula filter onto my eyepiece almost made this vaguely comma-shaped 5′ × 10′ patch spectacular.

It took me several years to complete the Herschel Project. Did it change my life? I thought I knew the sky extremely well, but my odyssey at least gave me a better idea of the treasures hidden in its out-of-the-way corners. I also developed a feeling of kinship with those legendary astronomers, William and Caroline Herschel. One cold night I had had enough and was ready to pack up the telescope. Then I heard a faint voice, a female voice it seemed: "Rod, you know it was so cold one night when Brother and I were observing that the ink in my inkwell froze as I was taking notes. Don't you think you'd better get back to the telescope?" And I did. You'd better believe I did. ✦

Check out S&T *contributing editor* ***Rod Mollise****'s blog at* ***http://uncle-rods.blogspot.com***.

Restoring a Gem *of the* Clarks

FRANCIS J. O'REILLY

After decades of troubles, a priceless refractor lives anew.

ALL PHOTOS BY JAMES HENDRICKSON UNLESS OTHERWISE CREDITED.

Frank Seagrave was born in 1860 into a wealthy family in Providence, Rhode Island. At age 14 he witnessed the 1874 total eclipse of the Moon, and from that day forward he was fascinated by astronomy. Soon he was traveling twice a week to Harvard College Observatory in Cambridge, Massachusetts, a round trip of 100 miles, where the Harvard astronomers granted the eager youth access to the library and instruments. As a present for his 16th birthday, his father ordered a world-class refractor from Alvan Clark & Sons in Cambridgeport, Massachusetts, America's most esteemed telescope manufacturers. It cost $2,310.80, which in 2012 terms would be about $50,000. The firm delivered the finished telescope to Providence in 1878.

The refractor was certainly advanced for its day. Its objective lens was an 8¼-inch (8-inch clear aperture) f/13.4 crown-and-flint doublet. The equatorial mount had a weight-driven clock drive that was precisely regulated by a spinning flyball governor. The working parts were primarily brass with some bronze and steel. It would have been a fine prize for the leading gentleman astronomers of 19th-century England, much less a youth in America.

Seagrave put the telescope to good use. He was never a classically trained astronomer — his education stopped at private school — but he became an accomplished mathematician. In addition to many other observations, he used the telescope to measure positions of asteroids and comets to determine their orbits. His computation of the orbit of Comet Halley, and his prediction of the time and place of its reappearance two years ahead of its return in 1910, put him on the astronomical map. He submitted many of his orbit computations to Edward C. Pickering, director of the Harvard College Observatory, and in 1912 Pickering put him in charge of observing variable stars with Harvard's 15-inch refractor.

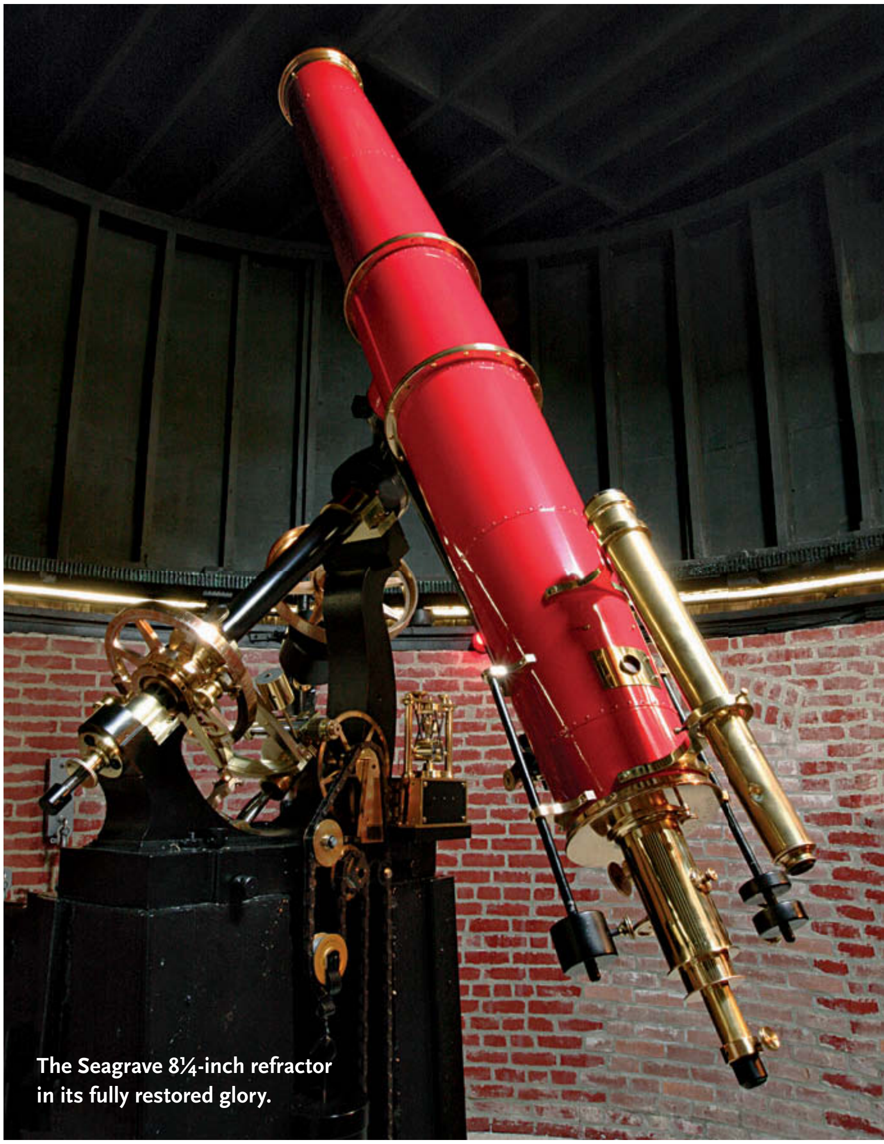
Seagrave originally built an observatory for his telescope in his backyard at 119 Benefit Street near the center of Providence. As light pollution grew worse, in 1914 he purchased land in North Scituate 10 miles west of the city and there built a tall brick observatory with a rotating turret. This unique building has now housed the refractor for nearly a century. But its time there was not always happy.

Decades of Decline

Seagrave died in 1934, and in 1936 the observatory and telescope were sold to a newly formed astronomical society, the Skyscrapers. In subsequent years the telescope underwent many modifications, some good, others not.

The weight-driven clock drive had been built before the age of electricity. Society members replaced its right-ascension slow-motion system with an electric drive,

OVERHAUL Chief restorers Allen Hall (far left) and Richard Parker (top) reattach the Seagrave refractor tube to its mounting with the help of Stephen Siok.



The Seagrave 8¼-inch refractor in its fully restored glory.

which ultimately damaged the mechanism due to the lack of a clutch to relieve stress when the motor forced it against a limit. This damage compromised the telescope's ability to track the sky accurately.

When initially delivered, the refractor's steel tube was painted light green. Various people repainted the tube several times. Between 1936 and 1966 someone removed the system for lifting the drive weights by hand and installed an electric lift system in its place. Then the entire weight-driven system and the bronze right-ascension wheel were replaced with an electric Mathis gear assembly in an attempt to make the telescope suitable for astrophotography. The original flyball governor was put on display in the observatory's anteroom.

In 1974 a burglar broke into the observatory and took the flyball governor. It was later found smashed on a rock behind the observatory, rendered useless. Other original drive parts were put in storage, and some were misplaced.

By 2003 the telescope and its drive had deteriorated to a point that if it were to continue as a viable instrument, something had to be done.

A Slow Rebirth

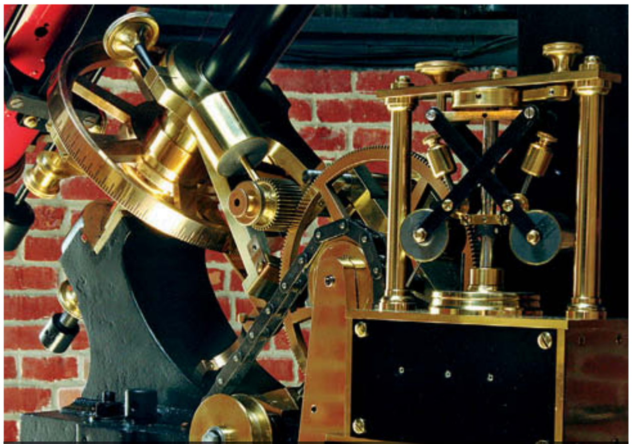
Allen Hall's earliest astronomical memory is of the day when, as a young teenager, his father took him to Seagrave Observatory to observe through the Clark. Hall remembers ascending the stairs to the observing room, seeing the whirring flyball governor, and hearing the click of the wire speed-reducing coupling. That night he observed Jupiter, and the memories shaped the rest of his life.

Hall went on to become a mechanical engineer and an accomplished machinist. Decades later, in 1999, he returned to the area, rejoined the Skyscrapers, and became concerned about the refractor's condition. In 2003 the Skyscrapers trustees charged Hall with restoring the telescope not just to working order but to a state that would "evoke an emotional reaction, in not only our members but the general public as well, that would speak to the quality, craftsmanship and ingenuity of Alvan Clark."

The first step was to remove key components, clean off the lacquer that had been applied in earlier restoration efforts, and restore missing components to the extent possible. Many stored parts were in poor condition. Hall cleaned and installed them along with a temporary electric drive until he could restore the old weight drive and build a new flyball governor for it.

Fabricating the governor was no small feat. All patterns and drawings from Alvan Clark & Sons had been lost. Hall searched his memory to recall how the governor looked, obtained what photos of it he could, and built a new one from scratch, being careful to use historically correct materials, primarily brass and steel. Along the way he enlisted the aid of another telescope-making legend, Richard Parker of Tolland, Connecticut. In 2009 they installed the new governor and the old weight drive. These additions re-created the telescope's historical appearance while enabling it to track the sky.

But problems remained. The telescope required about 115 pounds (52 kg) of weights to drive it, far more than was originally needed. The original chain suspending the weights had been lost, and modern chains did not fit the



19TH-CENTURY HIGH TECH The telescope's weight-powered clock drive is at center. At right is the re-created flyball governor regulating the drive's speed.

DAN LORRAINE

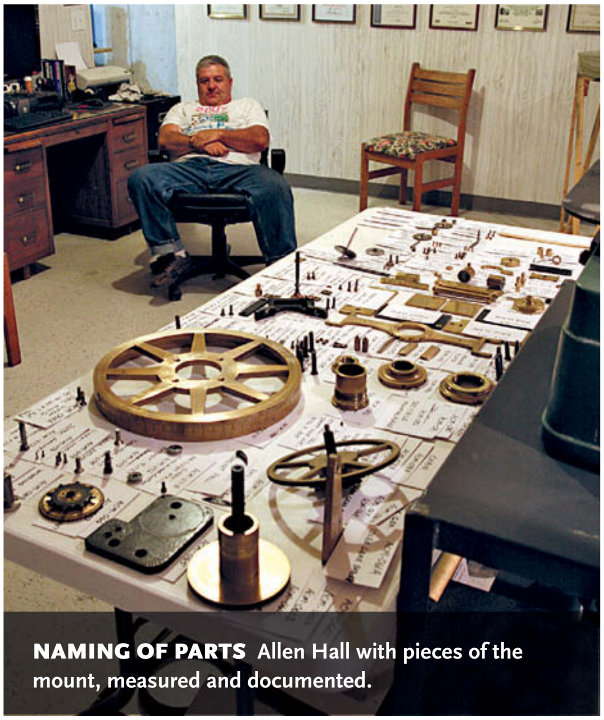
The Skyscrapers

In 1932 Professor Charles Smiley of Brown University, with a small group of amateurs, formed the Amateur Astronomical Society of Rhode Island, better known as The Skyscrapers. Today the society maintains, on its North Scituate grounds, not just the Seagrave Memorial Observatory with the restored Clark refractor, but also the 12-inch Patton Telescope (a Newtonian reflector built in the 1920s and pictured in *Amateur Telescope Making, Book I*) and modern, imaging-capable 12- and 16-inch Meade Schmidt-Cassegrains. These three scopes are housed in roll-off-roof observatories. The society runs telescope-making classes and conducts weekly observing sessions, weather permitting, to which the public is invited.

Also on the grounds are a small museum and hall where the society holds its monthly meetings and, since 1952, its annual AstroAssembly. Taking place this year on September 28th and 29th, AstroAssembly features daytime speakers, an equipment swap market, and an evening lecture and observing session. Read more at **theskyscrapers.org**.

1878 sprocket well, resulting in binding and sudden loads. Missing were the original built-in magnifying glasses for reading the telescope's right ascension and declination circles. In July 2009 the Skyscrapers board called upon Hall's services again, asking now for a total restoration.

Hall and Parker dismantled the telescope and split it between their home workshops. Determined not to let engineering information be lost yet again for future generations, they cataloged, measured, and documented every part in a computer-aided design (CAD) program. The disassembled parts were then carefully cleaned by Hall and others, including Richard Parker, Stephen Siok,



NAMING OF PARTS Allen Hall with pieces of the mount, measured and documented.

For more photos and info: skypub.com/seagrave.

David Heustis, Robert Horton, James Hendrickson, Steven Hubbard, and the author. All metal parts were carefully bathed in lacquer thinner, scraped of remaining grime, polished with brass polish, and buffed as needed.

Brass and bronze are soft metals. After 132 years the parts showed considerable wear, corrosion, grime, dents, and in some cases, fatigue fractures. Some screws were damaged, a problem because when the telescope was built, thread standardization was still a work in progress. Two screws were remanufactured with custom threads.

To prevent further oxidation, brass parts were lacquered. Steel parts were repainted. In early September 2010 the telescope was finally ready for reassembly. Meanwhile in North Scituate, James Brenek was busy restoring the observatory's tile floor and building a wooden table to go next to the telescope for charts and drawing materials.

The telescope was carefully reassembled at the observatory over two weekends and one weeknight — in time to be placed into service at the Skyscraper's' annual AstroAssembly on October 2, 2010. The first object the restored telescope looked upon was Venus as a thin crescent near the Sun in the daytime. The refurbished weight drive mechanism, calibrated using a strobe light, tracked perfectly on Venus all day until it set below the tree line.

All members hailed the project as a success. This venerable instrument, now restored to its original condition as delivered by the Clarks in 1878, will continue to bring pride and great views to all Skyscrapers and guests. ✦

Francis J. O'Reilly is president of the Astronomical Society of Greater Hartford, past president of the Westchester Amateur Astronomers, and a member of the Springfield Telescope Makers. He runs public star parties in the New York area.

Five Performance Killers

Does your Dob disappoint? The solution could be a few simple tweaks.

KNOWLEDGE IS POWER. The more you know about your Newtonian reflector, the better equipped you'll be to achieve its peak performance. In my experience, a well-made and well-adjusted reflector is capable of holding its own against a premium apochromatic refractor — an instrument synonymous with optical perfection. Yet many reflectors fall short of this benchmark.

Part of the reason is because this comparison is inherently unfair. Premium performance comes with a cost, and a $400 Dobsonian is unlikely to keep up with a $4,000 apo. But reflectors often fail to deliver their best performance needlessly. Based on years of experience building and using telescopes, here is my take on the five biggest reasons a reflector can fall short of perfection. They are listed in order of increasing importance.

The Newtonian reflector is one of the most versatile optical configurations ever created. Whether home built (such as this one) or commercially manufactured, a good Newtonian can rival the performance of any optical design — the key is to ensure the scope is tuned up to deliver its peak performance.

GARY SERONIK

5 Obstruction

The impact of a Newtonian's central obstruction on the visibility of fine planetary detail is a hot-button topic for internet forums. Despite the intensity of this debate, obstruction effects are well understood and fairly simple to quantify. William Zmek summarized it beautifully in the July 1993 issue of this magazine. Zmek's rule of thumb states that subtracting the diameter of the obstruction from that of the primary mirror gives you the equivalent aperture of an unobstructed instrument when it comes to contrast resolution.

In other words, an 8-inch reflector with a 1½-inch obstruction has the potential to resolve the same low-contrast planetary detail as an unobstructed 6½-inch scope. Furthermore, when the obstruction is less than 20% of the diameter of the main mirror, its effects become very difficult to see at all. Short of rebuilding your scope with a low-profile focuser and smaller secondary mirror, this is something you're mostly likely going to have to accept as inherent in a reflector's design.

4 Baffling

I've seen Newtonians that are well baffled against stray light, and others that allow all kinds of unwanted illumination to pollute the view. A Newtonian doesn't need an elaborate set of ring baffles such as those found in quality refractors, but you should make sure that the only light reaching your eyepiece is coming from your primary mirror. One easy way to confirm this is to put a collimation plug (simply a cap with a small hole drilled in its center) in the focuser, and have a look. If you can see the ground behind the primary mirror, or look past the top of the telescope tube, you have some work to do.

3 Optical Quality

Optical quality certainly matters, but these days it's usually not the problem if a Newtonian seems to be underperforming. Most of the commercial mirrors I've evaluated in the last decade have been pretty good — a few have even been outstanding. Still, if you can rule out all other causes, the quality of your scope's primary mirror might be suspect. Fortunately, a simple star test can help you figure out if this is the case. The best how-to guide on the subject remains Harold Richard Suiter's excellent book, *Star Testing Astronomical Telescopes* (Willmann-Bell).

❷ Thermal Management

This is near the top of my list for two reasons. First, a warm telescope mirror can significantly harm image quality — especially at medium and high magnifications. Second, the problem is often misdiagnosed as bad atmospheric seeing, and as such, it's simply ignored. If your scope has a good mirror, adequate baffling, is properly collimated, and still doesn't deliver good planetary views, there's a good chance the problem is thermal management. I covered this topic in this year's May's issue, page 70, and the bottom line is that installing a fan behind the primary mirror can do wonders. Unlike a central obstruction, thermal problems are not inherent in a Newtonian — there's no reason to live with them.

❶ Collimation

This is the biggie. Poorly collimated optics can make a quality mirror look downright bad. But there's good news — misaligned optics can easily be remedied. All reflector owners should know how to collimate their telescopes. Being unable to do it is like owning a guitar without understanding how to tune it. Learn basic collimation, and check your scope's optical alignment regularly. An inexpensive collimation plug is the only tool you really need. I'll cover the topic of collimation in an upcoming issue.

No telescope is perfect — every instrument has its shortcomings, some of which are simply part of the design, while others arise from how the design is implemented. But there's a difference between "perfect" and "useful." Although we should do what we can to make sure our scopes are running well, don't get so obsessed with absolute perfection that you never take the time to enjoy the wonders that even an imperfect scope can show you. ✦

*Contributing editor **Gary Seronik** scans the skies above his Victoria, B.C. home with a well-behaved fleet of home-built reflectors. He can be contacted through his website, **www.garyseronik.com.***

Shooting Rocket Launches

With a little foresight, capturing that Kodak moment of liftoff is easy and rewarding.

Christopher Hetlage

Whether it's the joy of watching your kids igniting a model rocket in the backyard or the majesty of a giant missile heading into space, everyone gets a thrill counting down the final seconds and waiting for liftoff. And for the latter, once the main engines fire, you experience the power of that magnificent machine as a pounding in the chest that's unlike anything else.

Although NASA's Space Shuttle program came to an end in 2011, there are still plenty of satellites and space probes launched each month into Earth orbit and beyond. Photographing a rocket blasting off toward space is just as exciting as pulling off a great astrophoto.

Planning Ahead

Photographing most rocket launches is relatively straightforward, but there are a few nuances you should keep in mind in order to achieve the best results.

Launches are scheduled well in advance, but many things can delay liftoff by hours or even days. If you plan a trip to shoot a launch, ideally you should add at least a week after the scheduled date to accommodate inclement weather and other unanticipated scrubs. Several websites that keep tabs on most launches around the globe, but my favorite is **www.spaceflightnow.com**. It lists the locations, dates, and times of most rocket launches.

Shooting a launch isn't like taking other types of daytime photographs. Although autofocus and auto-exposure settings work well for most daytime shots, the intense brightness of rocket ignition can play tricks with autofocus and auto-exposure systems when you're using telephoto lenses. You don't want to miss a shot while your camera is hunting aimlessly for focus. Set your camera to full manual mode and find the focus position before launch. Once focus is established, use a piece of tape on the lens to ensure you don't knock the focus ring as you

CREDIT (2)

It takes planning and ingenuity to take eye-popping close-ups of a launch like this shot by Hap Griffin of NASA's Mars rover Curiosity. *Left:* The author's friend Rich Simons uses a long telephoto lens and a gimbal tripod head to enable smooth tracking of a fast-moving rocket. All photos are courtesy of the author unless otherwise credited.


ATLAS

Often the best close-up shots are recorded using remote platforms designed to protect the cameras from the elements.

move your camera to follow the rocket's flight.

Your viewing location will also determine what lens to use. When photographing a launch from miles away, look for landmarks, buildings, or groups of people in your surroundings that can enhance a composition. A tiny, lone plume in the distance doesn't make an interesting picture.

Heat radiating from the ground between you and the launch pad will blur and distort close-up shots made with long telephoto lenses, much like how poor seeing can play havoc in astrophotography. You don't need a real tight shot of the rocket itself — many dramatic launch photos incorporate the massive exhaust plumes into the scene.

If you're photographing a day launch, I suggest a lens of at least 300-mm focal length and an exposure of 1/1,000 at f/8, and ISO 100. I use these settings for most of my launch shots if it's a cloudless, sunny day. On overcast days you may have to use longer exposures and higher ISO speeds. If you're using a long-focal-length telephoto lens, you'll need a tripod to take sharp pictures. If you're using large, heavy lenses, a gimbal tripod head works very well as you track the rocket rising into the sky.

Night launches are a different event altogether. Start shooting the rocket on the pad just as its engines ignite. Once it takes off, you'll only see the illumination of the engines themselves. Exposures of 1/200 at f/8 and ISO 200 should capture the rising craft, because the rocket engines are quite bright. Another great technique is to take a time exposure of the entire launch using a wide-angle or fisheye lens.

Avoid using high-speed burst or continuous shooting settings; the typical digital camera has a limited memory buffer that can hold only a few frames. Once the camera's buffer is full, you'll have to wait for the camera to write the images to its memory card before it can take another shot. To avoid missing any opportunities, take a shot every second or so. A programmable intervalometer can make this process easier, particularly with remote cameras.

Remote Shooting

If you have the opportunity to place a remote camera close to the launch pad, you'll have a few more things to consider. You'll need to protect your camera from the elements and have some method for triggering the shutter at the crucial moments of launch.

Protecting your equipment from rain, wind, and possibly chemical exposure from the rocket exhaust is an essential function of a remote platform. Because NASA doesn't allow access close to the launch pad within a day or two of the scheduled launch, your camera may sit for days unattended, and you can't simply run out there to cover up your equipment in a rainstorm. Some photographers construct a small box to house the camera. Others simply wrap their cameras in plastic trash bags, leaving just the front of the lens exposed. To further protect my lenses, I find that a plastic cup works well as a makeshift rain

Space Shuttle *Atlantis* embarks upon STS-132 as seen from NASA's VIP site, 3 miles from launch pad 39A at KSC in Florida.

shield. It's also important to secure your tripod firmly to the ground. The last thing you want is to return to your camera and see that it was blown over before the launch. Tent stakes and zip ties work well for securing your tripod on soil, whereas sandbags are helpful on hard surfaces.

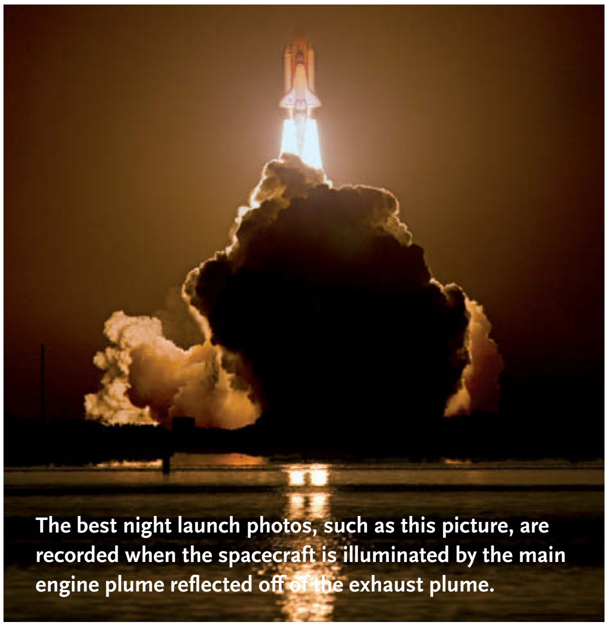
Finally, you'll need some way to trigger your exposures at launch time. When I attended the final Shuttle launch in July 2011, I placed eight cameras around the pad, some as close as 50 yards from the shuttle itself! For each camera I used a sound trigger that is activated by the roar of the rocket's main engine, and that continuously fired as long as there was adequate noise.

Location, Location, Location

There are several major launch facilities in the United States, though the three primary sites used by NASA are the Kennedy Space Center (KSC) in Florida, Vandenberg Air Force Base in California, and the Goddard Space Flight Center's Wallops Flight Facility in Virginia. Each facility has public viewing locations, though KSC is by far the best for photography. Your photos will only be as good as your camera's location, so spend some time scouting your area. Here are some of the best spots to shoot from around KSC.

The closest you can physically be to launch pad 39A is the VIP site, three miles away. This is by far the best place to watch a launch. Access to the VIP and the Press sites are through special invitation only. The VIP site is typically reserved to contractors, family members, and congressional representatives. But you can contact your congressman to request a VIP pass because they receive tickets to every launch. You can also try to arrange to shoot the event for a newspaper, magazine, or website. Working with a media company can help you obtain a press pass, which often comes with a tour of the launch facility.

Many excellent launch photos incorporate the crowd of onlookers and various foreground objects.



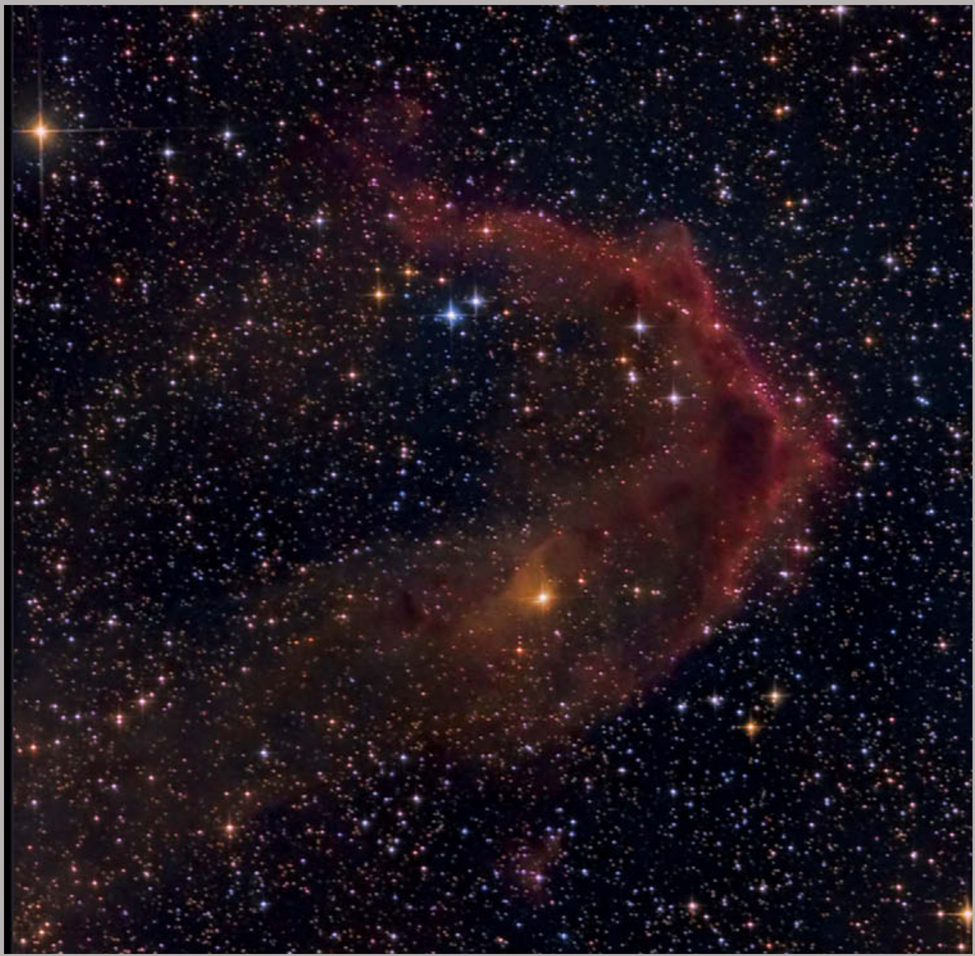
The best night launch photos, such as this picture, are recorded when the spacecraft is illuminated by the main engine plume reflected off of the exhaust plume.

Historically, the best location near KSC for the general public to watch a launch is the NASA causeway that runs between Titusville and Cocoa Beach, roughly seven miles from launch pad 39A. Back in the days of the Apollo program, tens of thousands of people would line the causeway. Since the 9/11 terrorist attacks, access to this site has been restricted, so you must either enter with an official NASA employee or purchase tickets ahead of time from the KSC Visitor Center. Although the Visitor Center itself is located slightly more than seven miles from Pad 39A, the view from there is blocked by trees and is thus not a good place to shoot a launch.

Outside of NASA property, the next closest place to view a launch is Titusville, located directly across the Indian River from KSC. It can be a very dramatic place to photograph a launch. From here you have a direct view of the space center across the water.

If you prepare well in advance and have a thorough game plan, then you'll come away from the launch with plenty of excellent photos. Try not to spend all your time photographing the launch — watching it is a huge thrill, but if you're looking through a camera's viewfinder the entire time, you'll miss out on much of the experience. Don't forget to take some time to look up and just enjoy the moment! ✦

Chris Hetlage is a seasoned rocket-launch enthusiast. See more of his images at ***www.imagingthecosmos.com****.*



◀ **SIDE STREETS IN ORION**

Kfir Simon

Rarely imaged, Barnard 35 in Orion presents astrophotographers with a subtle mix of reddish hydrogen nebulosity and yellowish dust.

Details: *Boren-Simon 10-inch f/2.8 PowerNewt Astrograph with SBIG ST-8300M CCD camera. Total exposure was 109 minutes through Baader Planetarium color filters.*

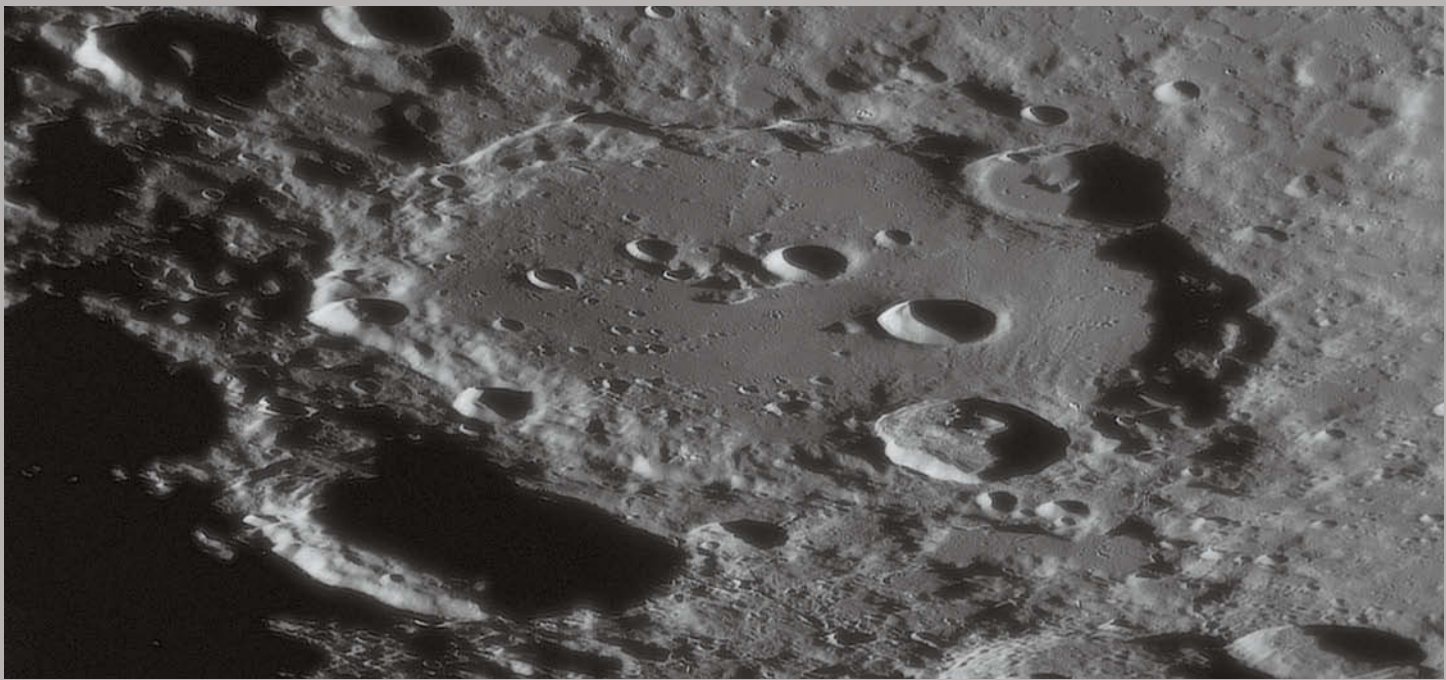
Visit skypub.com/gallery for more of our readers astrophotos online.

▼ **BATTERED LUNAR SWATH**

Mike Wirths

This high-resolution view of the crater Clavius reveals tiny craterlets as small as 1 kilometer across.

Details: *18-inch Starmaster Dobsonian telescope with a Lumenera Infinity 2-2M video camera. Stack of hundreds of frames recorded through a True Technology red filter.*



▲ **SUNSET ECLIPSE AT THE VLA**

Johnny Horne

Several eclipse chasers traveled to the Jansky Very Large Array radio telescope in New Mexico to view the May 20th annular eclipse. Only a few came away with a shot as stunning as this.

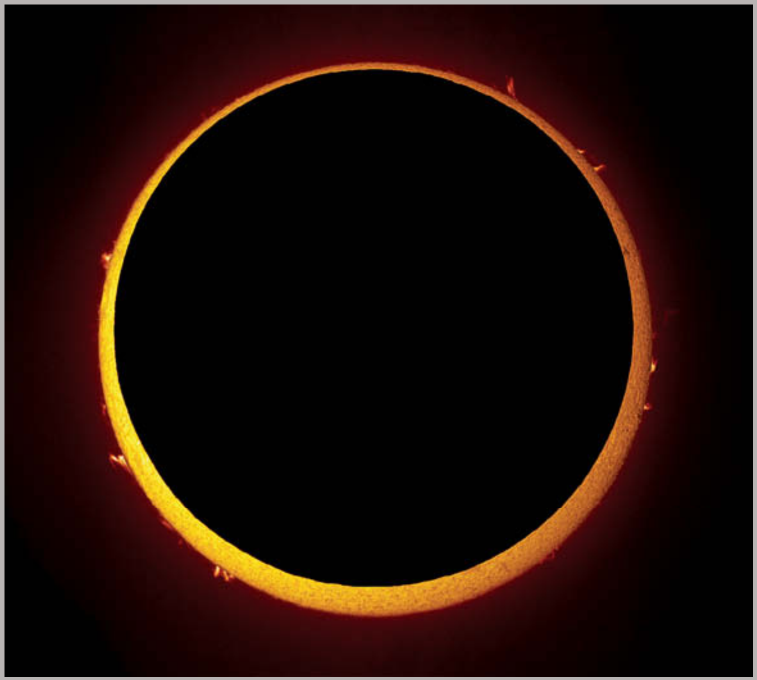
Details: *Nikon D300 DSLR with 80-200 mm zoom lens. High-dynamic-range composite of 9 exposures ranging from 1/60 to 1/8000 second.*

► **BLACK HOLE SUN**

Jim Lafferty

The ring of fire appearance of the annular eclipse is greatly enhanced in this image captured through a solar hydrogen-alpha telescope.

Details: *Lunt Solar Systems LS100T/Hα solar telescope with an Imaging Source DMK 41AU02.AS video camera. Stack of multiple frames.*



▲ **AURORAL RIBBONS**
Phil Hart
Shimmering bands of the aurora borealis over Tombstone Park in Canada's Yukon territory compete with Venus and Jupiter (at left) for the camera's focus.
Details: *Canon EOS 5D Mark II DSLR camera with 24-mm lens at f/1.4. Five-frame panorama, each frame exposed for 8 seconds at ISO 800.*

◄ **DUSTY CEPHEUS**
John A. Davis
Thick tendrils of interstellar dust permeate this region of Cepheus, punctuated by three bluish reflection nebulae from the bottom left to top: vdB 152, vdB 149, and vdB 150.
Details: *Takahashi FSQ-106EDX with SBIG STL-11000M CCD camera. Total exposure was 5¼ hours through Baader Planetarium color filters.*

► **SOUNION SUPERMOON**
Anthony Ayiomamitis
The closest full Moon of 2012 rises over the ancient ruins of the Temple of Poseidon in Sounion, Greece.
Details: *Takahashi FSQ-106N with Canon EOS 5D Mark I DSLR camera. Single exposure of 1/200 second at ISO 200.* ✦

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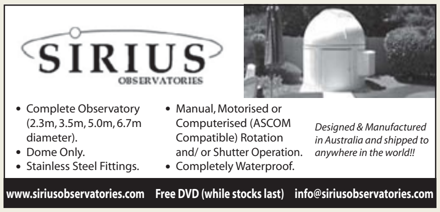

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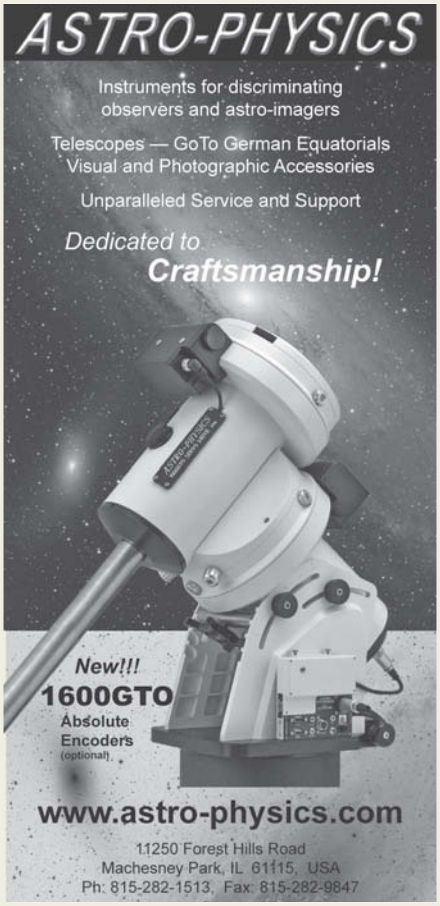

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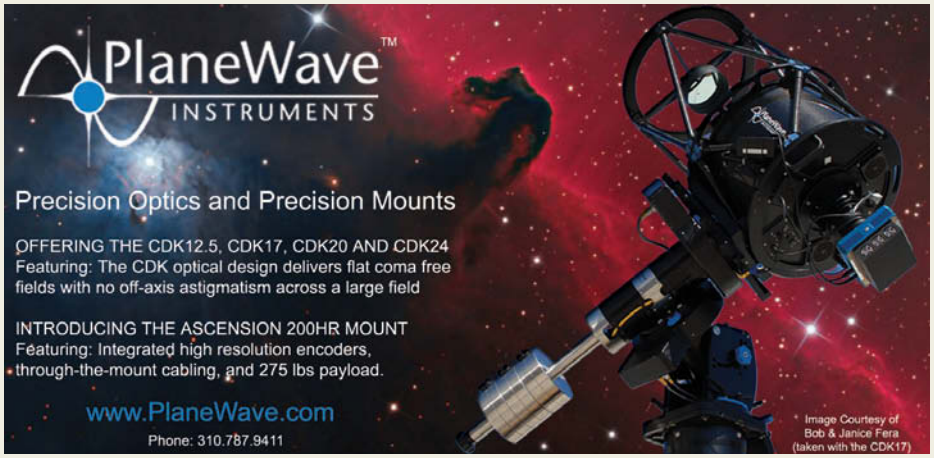

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From Martian dust devils to Saturnian lightning, it's not just Earth that experiences extreme weather events.

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NASA's Dawn mission is returning spectacular images and science from the asteroid Vesta.

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Host a Backyard Moon Party

It's easy to give participants a night they will never forget.

Are you aware that most people have never observed the Moon through a telescope? You don't have to be a Ph.D. astronomer to introduce people to our closest celestial neighbor. You just need a willingness to share your enthusiasm and your telescope. Moon party participants will never forget the first time they see the Moon up close and personal. Here are some simple guidelines to help you organize and run a successful Moon party.

• **Determine which evening is best.** Although weekends are always good, the Moon may not cooperate, so you must be flexible. Consider hosting your party when the Moon is out early, say 9:00 p.m. or so. This is not too late for most people, even if they must go to work or school the next morning. Choose a primary and alternate date, in case of poor weather. Though observing a full Moon sounds like a great idea to the novice, features along the terminator of a crescent or gibbous Moon look much better.

• **Select a night with other great targets.** I recently hosted a Moon party when the Moon and Venus were near each other in the western sky and Mars and Saturn hovered in the east. It was the perfect night to observe the Moon and several planets. Although I had no doubt the Moon would be a hit, I also knew Saturn and its rings would be spectacular. As with the Moon, most participants said the only places they had ever seen Saturn were in books, magazines, or television. Mars and Venus were popular, but not nearly as much as the Moon and Saturn.

• **Publicize the Moon party.** Create a one-page flyer (with a Moon photo) that identifies the date, time, and place. Provide a phone number or e-mail address for people who have questions. Distribute copies of your flyer at appropriate locations a few days before the party. Spread the word with phone calls, text messages, and social media.

• **Make your party educational.** People tend to be overwhelmed when they view the Moon through a telescope for the first time; they don't fully comprehend what they see because they have never observed lunar craters, mountains, or maria in such detail. As host, educate them *before* they look through the eyepiece. With a little up-front knowledge, their time at the eyepiece will be much more rewarding. For example, before a recent Moon party, I determined that two large craters — Atlas and Hercules — would stand out in the northernmost part of the waxing crescent Moon. Lunar maria including Tranquillitatis, Fecunditatis, Crisium, and Undarum would also be easy targets that night. I was prepared to discuss the sizes and ages of these features as people were viewing them through my telescope.

• **Identify lunar features.** I bring my Apple iPad and run an informative astronomy app named *Moon Atlas*. It generates a 3-D globe of the Moon that you can manipulate with your fingers. Before participants looked through the eyepiece, I held up the iPad and pointed out prominent lunar features. Sure enough, many observers spotted the craters and maria and received satisfaction in realizing that for the first time in their lives they had observed and recognized specific features on the Moon. That's an experience they'll always remember. ✦

KATHY MATHOSIAN

Mark Mathosian (far left, holding an iPad) hosts a Moon party for his friends and neighbors.

*Freelance writer and photographer **Mark Mathosian** (mmathosian@aol.com) resides in Boca Raton, Florida. His hobbies include photographing the Moon and collecting meteorites.*

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