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SKY & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

JUNE 2011

Astronomy On Ice

The trials and tribulations of the BLAST balloon-borne telescope. *p. 20*


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SKY & TELESCOPE

June 2011

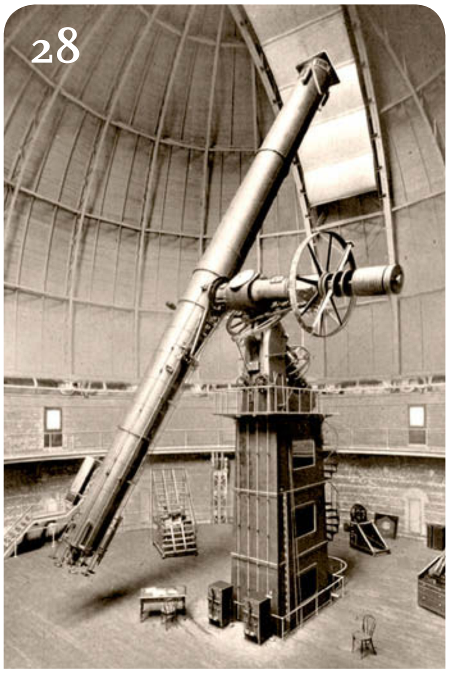
VOL. 121, NO. 6

MARK HALPERN

On the cover: Scientists prepare to launch the BLAST balloon-borne telescope from a site near McMurdo Station in Antarctica.

FEATURES

THIS MONTH'S SKY



S&T ARCHIVE

S&T TEST REPORT

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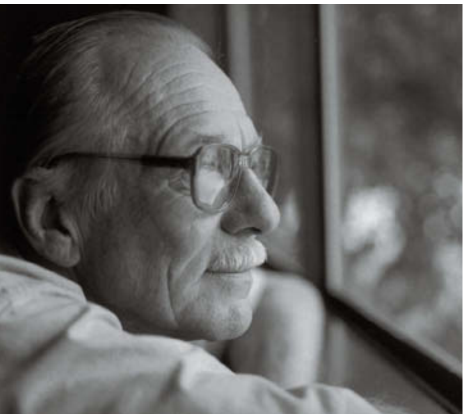
Memories of Leif

ABOUT A YEAR AGO, former *S&T* Editor in Chief Leif Robinson stopped by our office during one of his infrequent trips to the U.S. from his retirement home in Costa Rica. We could sense that his health was declining. But it still came as a shock when Dennis di Cicco walked into my office last February 28th moments after receiving an e-mail that Leif had died the previous day.

As many of you know, Leif was a towering figure in the history of *S&T*, serving 38 years on the editorial staff, the final 20 years (1980–2000) as Editor in Chief. During his tenure the magazine grew in circulation and stature. Following in the footsteps of editors Charles Federer, Jr., and Joseph Ashbrook, Leif adeptly guided the magazine through changing times.



S&T ARCHIVE

I worked under Leif for only six months, during an internship in 1991. But he instilled in me a total commitment to journalistic integrity and accuracy, which are the core principles that still guide everything we do at *S&T*. I've asked Dennis and Alan MacRobert, who worked with Leif for 26 and 18 years, respectively, to reflect on their former colleague.

Dennis: It's impossible to detail, let alone summarize, Leif's influence at *S&T* and on the people who knew and worked with him. I was constantly impressed by how few times he was ever wrong, not just with facts and figures, but with big-picture issues. He spotted the digital revolution before most amateurs owned computers and only a handful had ever heard the term CCD. He led the charge for pro-am collaboration well before it was fashionable. And he was an advocate of organized eclipse tours before they became a cottage industry.

Leif loved to travel, and accompanying him was always an adventure. The staff reveled in the outrageous stories we'd bring back from places such as Australia, Africa, Indonesia, South America, and Mexico. I'll miss Leif's wisdom and vast knowledge about things astronomical and otherwise. I'll miss his advice both professional and personal. I'll miss his friendship. But most of all, I'll miss him. May he rest in peace.

Alan: I came to *S&T* from a career as an editor used to whipping manuscripts into shape, but Leif taught me a lot. He could always make a story more readable and entertaining, and he continued his two predecessors' obsession with accuracy. But most of all, he honored Charlie's and Joe's core principle that made *S&T* a success while so many other magazines came and went: "Put the reader first." That's kept us going for 70 years, and if we last through the changes of the next 70, that will be why.

Robert Naeye
Editor in Chief

SKY & TELESCOPE

Founded in 1941 by Charles A. Federer, Jr. and Helen Spence Federer

The Essential Magazine of Astronomy

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Letters

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Death of Long-Time Editor in Chief

I was so saddened by the news of the passing of Leif J. Robinson (see page 6). He was Editor in Chief when I found *Sky & Telescope* some 20 years ago. Reading his editorials, I got to know Leif's character and felt he was a decent, clever, ethical, educated, and intelligent man. He definitely was instrumental in my continuous fidelity as a subscriber to *S&T*, and his "50 & 25 Years Ago" columns, though short, are among my favorite articles.

"Leif Robinson" will always remain a great name in the amateur astronomy community, and I hope some asteroid will be christened with his name in his honor (if it has not been done already). I feel like I have lost a friend.

Jacques Toraille
Clermont, Ferrand
France

Editor's note: *Asteroid 3819 Robinson is named in Leif's honor.*

Comet Clarifications

Let's hope that the December "storm" of tiny SOHO comets indeed indicates that a major Kreutz sungrazing comet will arrive soon to bedazzle skywatchers ("Mini-Comets Storm the Sun," April issue, page 16). But in alluding to the great 1965 sungrazing comet Ikeya-Seki, your statement that "similar but lesser sungrazing comets were seen in 1843, 1882, 1963, and 1970" propagates a misperception that appears on several NASA-sponsored websites. These other sungrazers were decidedly not "lesser" than Ikeya-Seki.

One way to compare the greatness of comets is by their absolute magnitudes: how they would have appeared at a distance of 1 astronomical unit from both the Sun and Earth. This corrects for differences in observing geometries. In a study of the major 20th-century Kreutz-family comets (*International Comet Quarterly*, Vol. 14, page 89, 1992), former *Sky & Telescope* "Comet Digest" columnist John Bortle derived the absolute magnitudes of comets C/1963 R1 (Pereyra), C/1965 S1 (Ikeya-Seki), and C/1970 K1 (White-Ortiz-Bolleli) as 5.4, 6.4, and 5.8 respectively. A 1964 study by S. K. Vsekhsvyatskii gave the great comets of 1843 and 1882 absolute magnitudes of 4.9 and 0.8. This makes Ikeya-Seki the intrinsically "least great" of the five!

It is mind-boggling to think that, grand as it was, Ikeya-Seki was the runt of the litter of major 19th- and 20th-century Kreutz sungrazers. Surely this bodes well for what we might expect from the next sungrazer; however, much will depend on the observing geometry and solar elongation.

Joseph N. Marcus
St. Louis, Missouri

On the Web

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Science vs. Human Nature

I must disagree with Dale E. Lehman's Focal Point essay, ("Science as Human Nature," April issue, page 86), though I don't recall the article on Galileo's observations of the Moon to which he refers. The reason modern science differs from traditional science, and *is* "foreign to human nature," is that it requires the discipline to control for the possibility of bias on the part of the observer. Everyone today should understand that it was bias in the mind of Percival Lowell that led him to draw repeated maps of canals on Mars. The important point is that Lowell did not realize he was biased, or that his bias could affect what he saw.

Nowadays, people working in public relations say, "Perception is reality." They know that if you want people to spend money, you manipulate their perceptions. Science tells us that reality is independent of our thoughts about it. But people who haven't been trained in this generally don't realize how important it is to know that reality and our perception of reality are two different things.

There's a good reason why the randomized double-blind study is the highest standard for gathering and evaluating data. The researchers themselves have bias that they are not aware of. If they want to publish, they have an obvious bias. In studies with small sample sizes, where statistical reliability goes down, the control of bias becomes especially important.

Among other things, the natural way for humans to think is to make what statisticians call Type I errors — to see causation in every correlation. It takes training, discipline, and scrupulous honesty to do modern science successfully, and those things do not come naturally.

Leon Elliott
Kingman, Arizona

If my years of doing public outreach in astronomy have taught me anything, it's that an understanding of — and appreciation for — science is anything but inherent to human nature. Most people, when asked to explain the scientific method, draw a blank. Even in a society that depends on technology, most of us have little understanding of what a scientist does. So I must disagree with Dale E. Lehman's Focal Point.

Lehman asserts that the fundamental question underlying all science is, "What works?" However, if a caveman killing an animal with a pointy stick is doing science, as Lehman claims, then a sea otter using a stone to break open an abalone shell is a scientist.

I remember when the first close-up pictures of the moons of Jupiter were returned. An astronomer interviewed on TV said how thrilling it was to discover that, not only was each of those worlds

unique, each was beautiful. The interviewer then asked what possible application this could have on Earth. In other words, the interviewer was asking how knowledge of the Galilean moons would make something "work." That we had just improved our understanding of the universe was considered more or less pointless.

Science is not about making things work or bringing a new product to market; those are spinoffs. The finest of our scientists have never contented themselves with such mundane matters as building a better photocopy machine. They have concentrated their efforts on finding our place in the universe and answering fundamental questions that may or may not have practical applications. They have pursued knowledge for its own sake. I believe there is a beauty in that, and I think nobleness as well.

As astronomers, we need to hold onto that concept and spread it to others. To allow ourselves to think that science is natural to human nature, and that others will simply "get it" without help, is to concede defeat.

Gordon Reade
Palo Alto, California

For the Record

✷ *In the April issue, page 62, the lunar eclipse dated "Oct. 17, 2004" happened on October 27th–28th of that year.*

75, 50 & 25 Years Ago

Leif J. Robinson

May/June 1936

Coronal Mystery

"One of the most obvious problems to be attacked through eclipse photographs is the determination of the origin of the coronal [spectral] lines (of which several dozen are known, and none identified); a reasonable hope of solution would seem to lie in securing additional data from photographs taken this spring in the ultraviolet and infra-red."

Not until 1942 did Bengt Edlén identify several of these lines as due to highly ionized atoms, such as iron and calcium, produced by a million-degree coronal temperature.

June 1961

The Sun's a Blast

"From a vast dark sea of gas in the northern half of the sun erupted a brilliant crimson flare, large enough across its base to engulf our earth 20 times. . . .

"Thus began the biggest solar disturbance of recent years. For hours during the geomagnetic storm that followed, long-distance radio communication did not exist over most of the earth, and the orbiting time of satellite Echo I decreased. The decrease was due to both the heating and expansion of the earth's atmosphere."

This solar flare happened on November 12, 1960. Our ability to forecast such events has dramatically improved in the past half century. Yet surprises happen and consequences continue.

June 1986

Milky Way Blackouts

"Anybody who observes the Milky Way on a clear, dark night is soon struck by the prominent breaks or rifts that mark its outline. . . . New information about the nature of these dim regions was recently reported by Thomas Dame and Patrick Thaddeus. . . .

"The observers tuned their equipment to the characteristic emission of carbon monoxide (a tracer of otherwise undetectable hydrogen molecules) at 2.6 mm.

"Dame and Thaddeus discovered that approximately half of the detected emission came from relatively nearby material and half from distant molecular clouds in the inner spiral arms of our galaxy."

***Editor's note:** Due to Leif Robinson's recent passing, this will be his final column. Please see our tribute to Leif on page 6 of this issue to read some of our staff members' fondest memories of him. Starting next month, this column will be produced by senior contributing editor Roger Sinnott.*

Balmy Brown Dwarfs: Spectral Type *Y*?

Two teams of astronomers working independently have turned up what may be the first known members of a new spectral class of "stars" having roughly room temperatures. These would fall in the temperature gap between the coolest known brown dwarfs (440°F, or 225°C) and Jupiter (–190°F, or –120°C). One of the newfound objects has an estimated temperature of roughly 80°F (27°C), nice shirtsleeve weather.

"I think it's pretty neat to find a 'star' that could have a temperature similar to that of Earth," says Kevin Luhman (Penn State University), who led one of the teams. Luhman and two colleagues have been studying their object with NASA's infrared Spitzer Space Telescope. The object, known as WD 0806-661 B, is the companion of a faint white-dwarf star at least 2,500 astronomical units from it.

WD 0806-661 B emits only feeble infrared emission, and none that's been detected at wavelengths shorter than 4.5 microns. Luhman's team "guesstimated" its temperature based on its luminosity at this one wavelength and the inferred age of the white dwarf. If the age and luminosity estimates are correct, WD 0806-661 B should have about 7 times the mass of Jupiter. By some definitions that would make it a "planet-mass object" rather than a "brown dwarf."

Even if its temperature is pleasant, it's not exactly habitable. As a gaseous body it has no surface, and even of you were riding in the gondola of a balloon, you'd be squashed flat by about 15 gs of gravity.

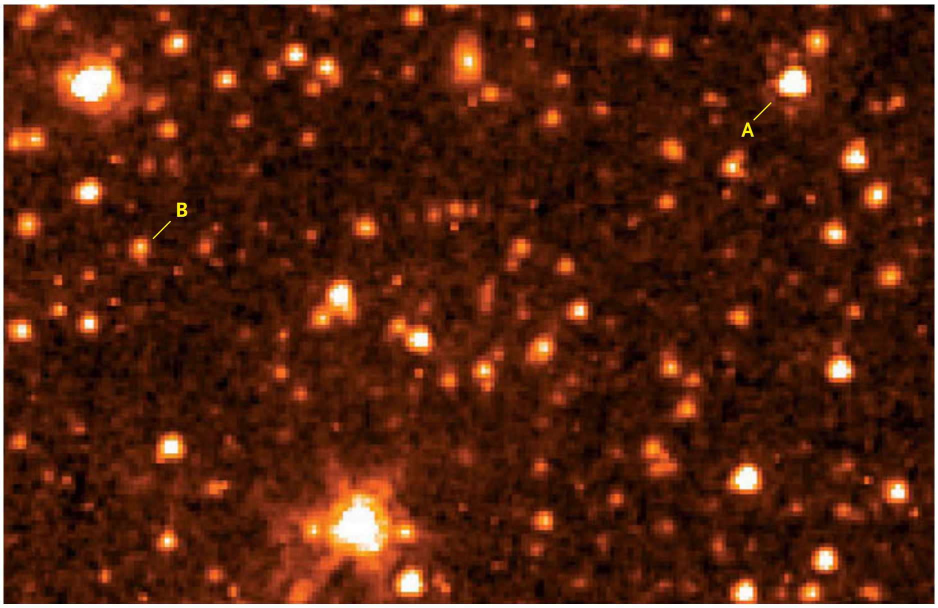
The other group, led by Michael Liu (University of Hawaii), identified a cool object orbiting a slightly warmer brown dwarf in Leo. From near-infrared spectroscopy, Liu and eight colleagues estimate that CFBDSIR J1458+1013 B is roughly 200°F (93°C). Its mass probably falls between 6 and 15 Jupiters.

MICHAEL LIU / KECK OBS.

The supercool dwarf binary CFBDSIR J1458+1013 in Leo is imaged at four near-infrared wavelengths by Keck. The two objects are only 0.11 arcsecond apart, or 2.6 astronomical units as seen projected on the plane of the sky.

At such low temperatures, the new objects should be the first known members of a proposed new stellar spectral class. For more than a century astronomers have classified most stars by their spectra into types *O, B, A, F, G, K,* and *M,* from hottest to coolest. In the last 15 years astronomers have added two new spectral classes, *L* and *T,* for even cooler, dimmer dwarfs. But theorists predict that for *T* dwarfs below roughly 450°F (230°C), new infrared spectral features of ammonia and water clouds should appear and other spectral features should disappear. In 1999 Davy Kirkpatrick (Caltech) proposed to name these objects spectral class *Y.*

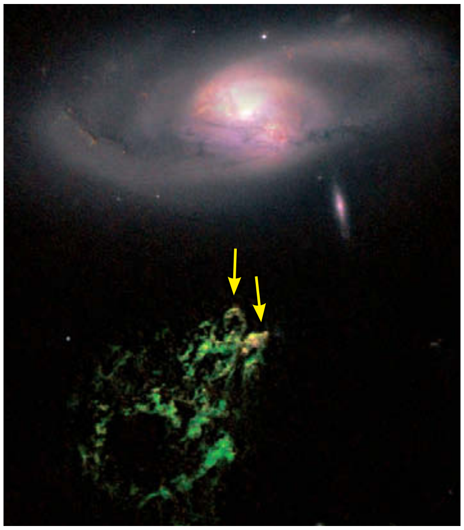
Astronomers haven't obtained good enough spectra of either object to observe such features, so they are only candidates for class *Y.* But they offer a glimpse of what astronomers expect to see when they image warm Jupiters around other stars.



NASA / JPL-CALTECH / K. LUHMAN

The wide pair WD 0806-661A and B, a white dwarf and a brown dwarf in Volans, are imaged here at 4.5 microns in the infrared by the Spitzer Space Telescope.

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



NASA / ESA / WILLIAM KEEL / GALAXY ZOO TEAM

Hanny's Voorwerp (Dutch for "Object") fluoresces due to radiation coming from a now-dead quasar in the galaxy IC 2497 to its north (above). Both objects are about 650 million light-years away. This Hubble image reveals nests of star formation (arrowed) in the green gas, apparently where a jet of matter from the former quasar plows into the gas and compresses it.

New Light on the Voorwerp

The most famous find to come out of the Galaxy Zoo data-mining project (March issue, page 18) has to be Hanny's Voorwerp, a complicated green blob of gas nearly 100,000 light-years wide. Dutch schoolteacher Hanny Van Arkel spotted it in 2007 while browsing Sloan Digital Sky Survey fields on her computer. Astronomers soon concluded that it's a type of *light echo*. The gas is fluorescing in radiation coming from a mini-quasar off to the north in the galaxy IC 2497, but the quasar has since stopped shining as seen from Earth's direction.

That conclusion gained support from the Hubble Space Telescope image above, the best yet. It shows a pocket of young star clusters (arrowed) where a jet from the neighboring galaxy seems to be striking the green gas and compressing it. Such jets are the hallmark of an active galactic nucleus, or mini-quasar. Astronomers now estimate that the quasar turned off 200,000 years ago as seen from Earth, a revision of the 70,000 years suggested earlier. "We just missed catching the quasar," says William Keel (University of Alabama).

Radio observations confirm that the green stuff is just one part of a long, mostly invisible stream of gas curving around IC 2497. This is apparently a tidal tail pulled out when another galaxy swung by the big spiral roughly a billion years ago.

The round hole in the green area is probably the shadow of an object near the galaxy's center that blocked part of the jet.

Adds Keel, "Galaxy Zoo participants have found more, smaller analogs, one fully half the size of Hanny's Voorwerp, which should keep us busy for a good long time."

A Galaxy at Redshift 10

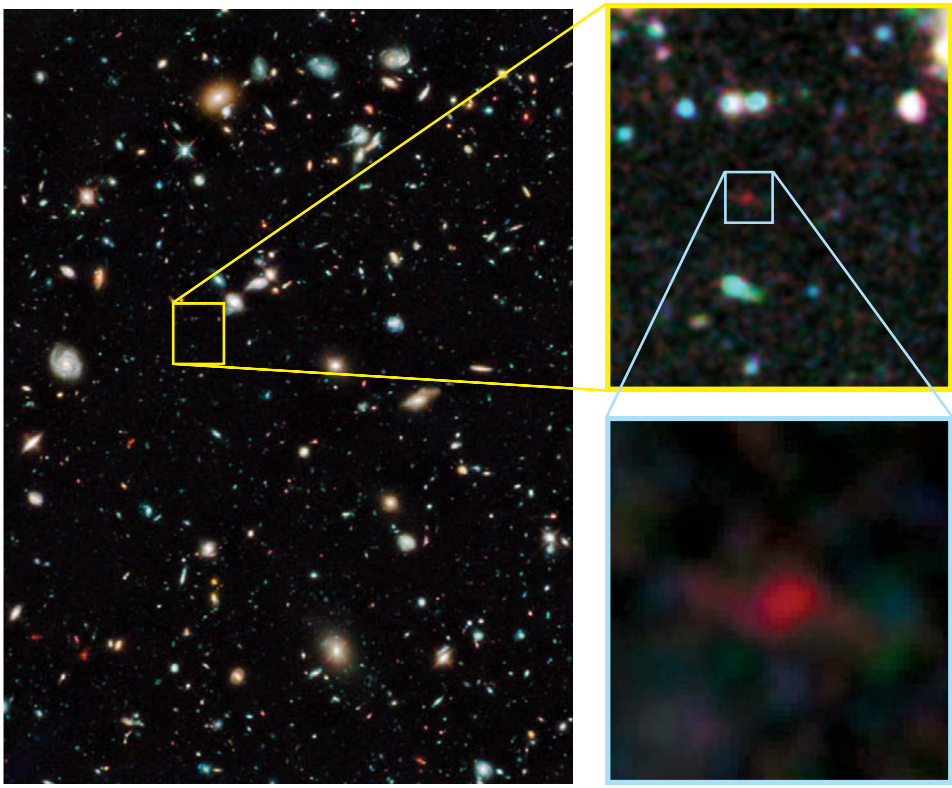
The current "farthest thing ever seen" is a mini-galaxy in the young universe that seems to be at about redshift 10.3. This would mean that its light has been traveling toward us for 13.2 billion years and that we're seeing it when the universe was just 500 million years old — well before star formation reached its peak throughout the universe about 2 billion years later (see pages 24–25).

UDFj-39546284, as it's designated, seems to have just 1% of the mass of the Milky Way, typical of the mini-galaxies that filled the early universe. It was visible only at the longest infrared wavelength that Hubble can detect (1.6 microns), which led to the redshift estimate.

Observations of ultra-high-redshift galaxies help tell how and when galaxies first formed. The discovery team concludes that "starbirth at 500 million years [after the Big Bang] was, astonishingly, about 10 times less than starbirth at 600 million years."

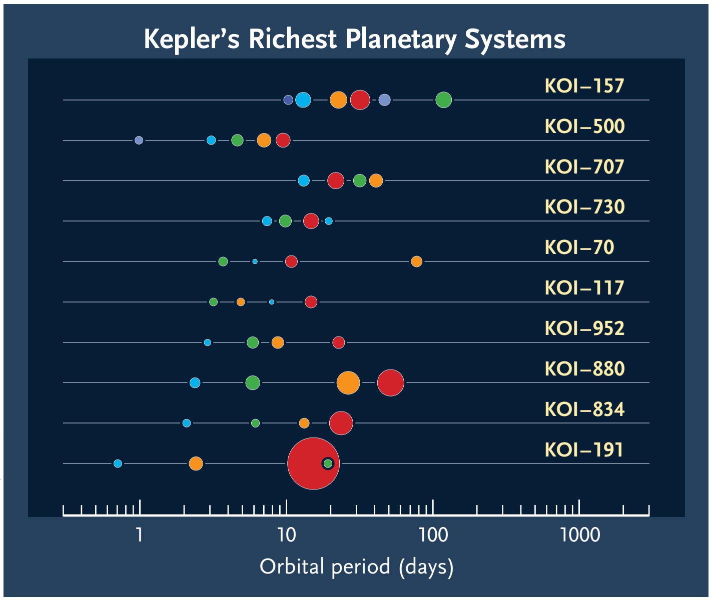
Four Exoplanets in a Tightly Locked Dance

In February the science team for NASA's Kepler mission released data on 170 stars that seem to have two, three, four, five, or even six planets crossing their faces (last month's issue, page 12). This has set off a feeding frenzy among dynamicists eager



NASA / ESA / C. ILLINGWORTH / R. BOUWENS / HUDF09 TEAM (3)

A *very* deep-sky object. The baby galaxy UDFj-39546284 is seen in part of the Hubble Ultra Deep Field 2009–2010, taken with Hubble's Wide Field Camera 3 in the near infrared — the deepest near-infrared image ever made.



Kepler has found 10 stars that have four, five, or six transiting planets. Each horizontal line represents a system. The circles show the diameters of the planets at their correct relative scale. The colors indicate the size order within each system. Note that the horizontal scale is logarithmic, which makes the planets appear more evenly spaced than a linear scale would.

to test theories of planet-planet interactions and planetary-system formation.

Statistically, both Kepler and ground-based searches are finding that when a star is discovered to have one planet, there's about a one-in-five chance that it has at least one more planet discoverable by current techniques. Most newfound planets orbit their stars very closely, because those are the easiest to spot. Multiple-transit systems are especially welcomed because they are less likely to be false alarms, and because they offer clues on how planetary systems originate and evolve.

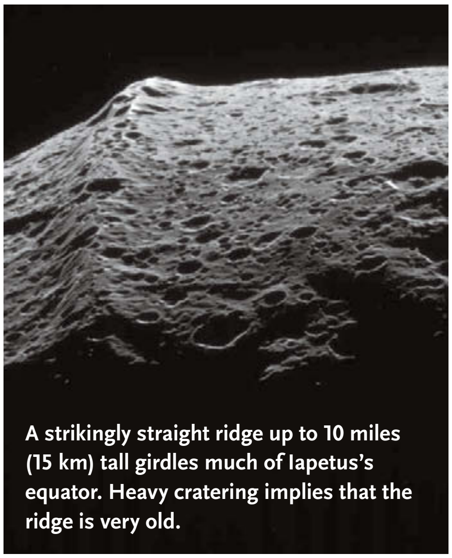
Jack Lissauer (NASA/Ames Research Center) and 25 coauthors have taken a close look at Kepler's most interesting multi-candidate systems. They report that in a remarkable four-planet system around a faint star designated KOI-730 ("Kepler Object of Interest"), all four are locked in a dynamical dance: their orbital periods have a ratio of 8:6:4:3 to a precision of one part in a thousand. In other words, the innermost planet completes eight orbits in the average time it takes the next one out to complete exactly six, the next exactly four, and the outer one exactly three.

Initially the team members thought that the two middle planets shared the same orbit, making the ratio 6:4:4:3. However, they say, "Further study of the light curve strongly supports the 8:6:4:3 period commensurability."

Resonant relationships among exoplanets are expected and often found (*S&T:* January 2005, p. 44), but not always. In the Kepler system with *six* transiting planets, none is in resonance with any other — even though they're nested closely and must interact, swapping a bit of orbital energy whenever one passes another.

What Makes Iapetus So Weird?

Saturn's moon Iapetus has long been known as two-faced, ever since Giovanni Domenico Cassini found in 1671 that it's much brighter when on the western side of its orbit than on the eastern side.



A strikingly straight ridge up to 10 miles (15 km) tall girdles much of Iapetus's equator. Heavy cratering implies that the ridge is very old.

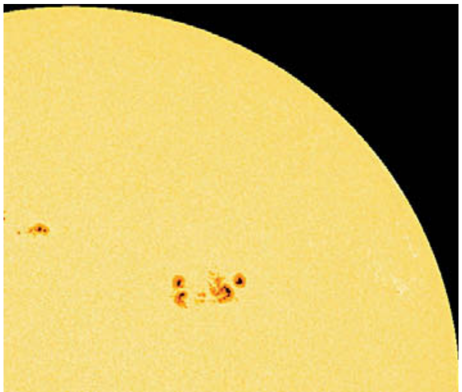
Close-ups by NASA's Cassini orbiter have revealed that one side is snowy and that the dark stuff on the other side neither erupted from within nor drifted down from Iapetus's other neighbors — which had been the two leading theories. Instead, the topmost layer of ice has apparently sublimated (vaporized) away on Iapetus's leading side, leaving a thick coating of carbon-rich dregs.

At the same time, Cassini scientists were confronted with a new Iapetus mystery: a towering, remarkable straight mountain ridge up to 10 miles (15 km) high running right along the moon's equator for a third of the way around. This apparently ancient ridge can't be explained well by ordinary geologic processes and has baffled planetary scientists since its discovery.

Iapetus has another vexing problem. Its rotation rate is locked to its 79-day orbit around Saturn, similar to how the Moon is locked to Earth, but Cassini found that Iapetus is not round but distinctly oblate. This shape implies that it solidified while spinning quite fast, once every 16 hours. But Iapetus is so far away from Saturn that the planet's tidal effect would have a hard time slowing down such a rapid spin. So what did?

Dynamicist Hal Levison and three colleagues at the Southwest Research Institute have taken a stab at making sense of both the "fossil bulge" and the equatorial mountain line. Their scenario: something whacked Iapetus hard enough to create a close-in debris disk and a moonlet orbiting farther out. The scientists find that, by tidally interacting with Iapetus, the moonlet can slow the spin and — bonus! — force the disk to collapse onto the equator to form the equatorial ridge in just a few thousand years. "The infalling debris will have velocities nearly tangential to the surface at only 300 meters per second," says team member Kevin Walsh. There would be more than enough to form the ridge.

All this gravitational give and take would slowly draw the moonlet farther away until it escaped Iapetus's grasp and started orbiting Saturn. But that freedom would have been short-lived: there's a 90% chance that it eventually collided with Iapetus and gouged out one of the big basins now scarring Iapetus's icy crust.



SOHO / MDI

On March 10th the Sun offered observers with safely filtered telescopes a fine array of new spots.

Why the Sun Had No Spots

The solar minimum that recently ended was the longest in more than a century. The same physicists who worry about the consequences of a frenetic solar maximum (next due in 2013; February issue cover story) were scratching their collective heads about this deep, prolonged solar minimum.

The Sun's 11-year activity cycle seems to be governed by a slow flow of the topmost layer from the equator to the poles. Near the poles it sinks to great depths (all the way to the bottom of the convection zone), returns toward the equator, and rises again. This "meridional flow" is similar to some ocean currents on Earth.

A trio of theorists offers a new model of solar circulation that, they claim, explains why the Sun's face remained blank for so long. Dibyendu Nandy, Andrés Muñoz-Jaramillo, and Petrus Martens say the key is how fast the meridional flow moves and how it interacts with a second component motion running around the solar midsection: the Sun's differential rotation. They found that a dearth of sunspots would result if the meridional flow was faster during the first half of the last cycle, from about 1998 to 2003, and slowed in the second half, from 2004 to 2009.

However, others reported last year that the flow *sped up* in the cycle's second half.

In any case, all agree that the upcoming solar maximum should be weak, perhaps one of the mildest on record. ✦

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All These Worlds

The Kepler spacecraft continues to reap a harvest of new planet discoveries.

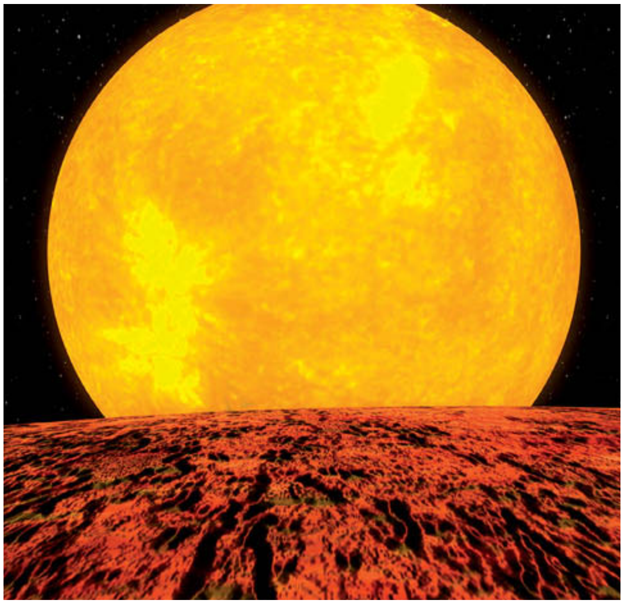
The kepler science team recently made two impressive announcements that give us reason to anticipate more from this wonderful spacecraft as it steadily reveals our galaxy's diversity of planets.

The first is Kepler-11, a bizarre system with 6 planets huddled so close to their Sun-like star that they would all fit inside the orbit of Venus. Thanks to some reliable physics and clever analysis, we know much more about these six new worlds. As they orbit, they gravitationally jostle, like roller-derby skaters pushing and pulling one another ahead or behind, causing subtle changes in orbital timing that reveals the mass of each planet.

With their small distances from the star, these worlds must be smoking hot. Size and mass yields density, which narrows the range of possible compositions. They are all surprisingly light for their sizes, their low densities revealing puffed-out atmospheres. These sizzling, fluffy atmospheres must be furiously losing gas to space. Why are they still there at all? For those trying to understand the evolution of planetary atmospheres, this is juicy stuff.

We can only deduce this information because these planets all orbit in our line of sight. The large majority of randomly oriented systems will not display themselves so conveniently for our interstellar voyeurism. Did we just get lucky? In a sense, yes, except that Kepler is designed to make its own luck. It monitors enough stars (156,000) so that the small percentage of planetary systems that would be randomly oriented in our direction will add up, if planets are reasonably commonplace, to a decent demographic slice. This scheme is paying off in droves of new discoveries, slowly revealing the planetary demographics of our galaxy.

The Kepler strategy of calculated luck is also reflected in the announcement of 1,235 candidate planets discovered during the first 4 months of science operations, including a handful that are roughly Earth-sized and zoned for liquid water. This is not the same as announcing planet discoveries. The Kepler method is sure to produce false positives. A star appearing close to another star might be varying in brightness, or a multiple-star system could mimic a planet discovery. Each candidate must be verified with repeat observations and, where possible, other instruments and methods.

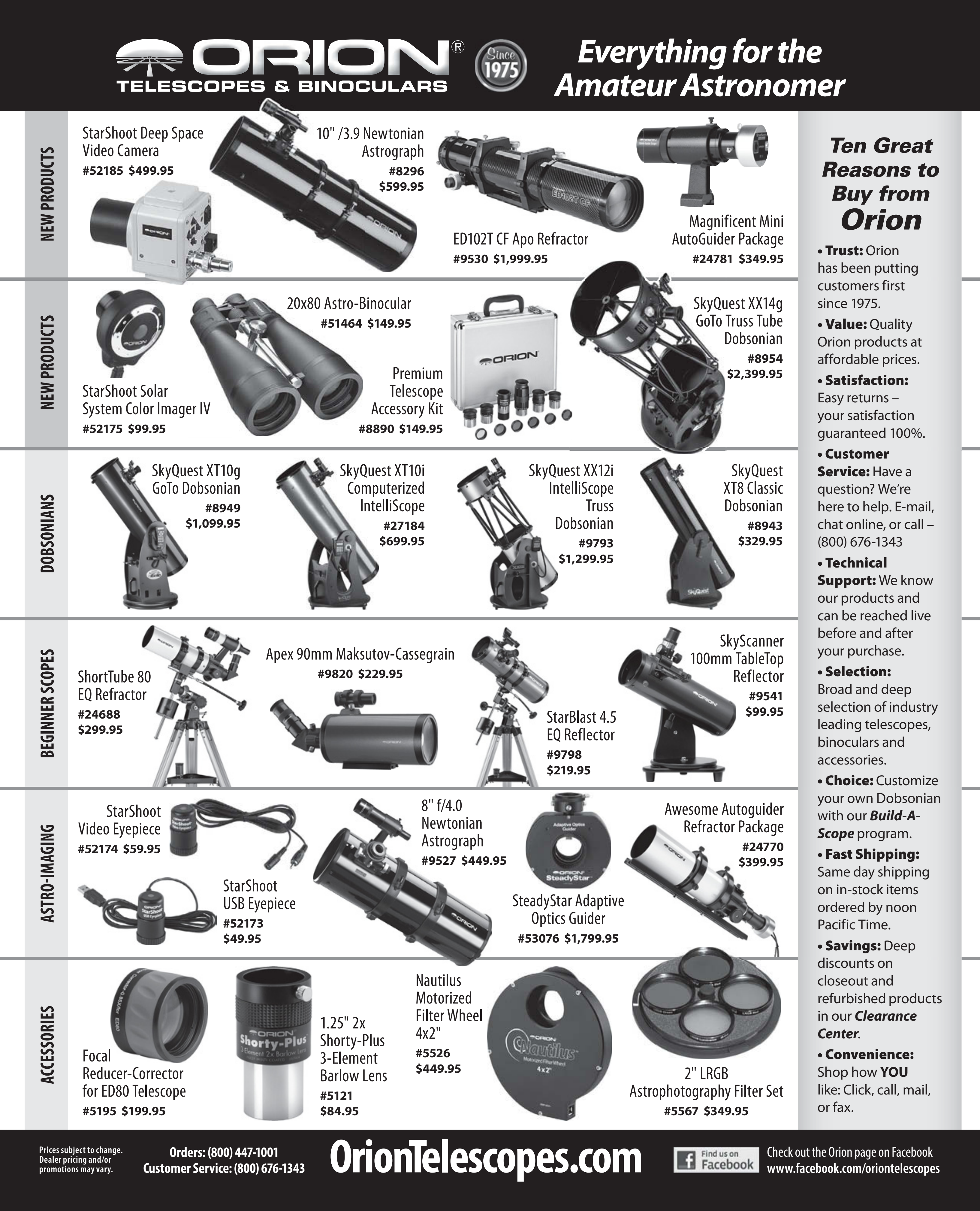


NASA / KEPLER MISSION / DANA BERRY

In science we frequently have a tension about when to release an important result. Should you wait until you're certain, or should you spill the beans when it seems fairly promising? There are risks either way. Often there is no magic moment, and with Kepler the process of discovery is stretched out over years.

I'm thrilled that the Kepler team decided to announce the statistics of candidates. Most will turn out to be actual new worlds. Sharing your data when it's still at this stage of immaturity assumes some maturity among the public. It requires an understanding of probability and uncertainty. This is a crucial part of the mathematical and scientific literacy needed to understand some urgent current issues. So much of the brouhaha over climate change, for example, comes from misunderstanding or misrepresenting of scientific uncertainty. So I applaud the Kepler team for releasing these candidates and expecting people to understand that it will take time to know which ones are really planets. It's a tease — a respectful tease. ✦

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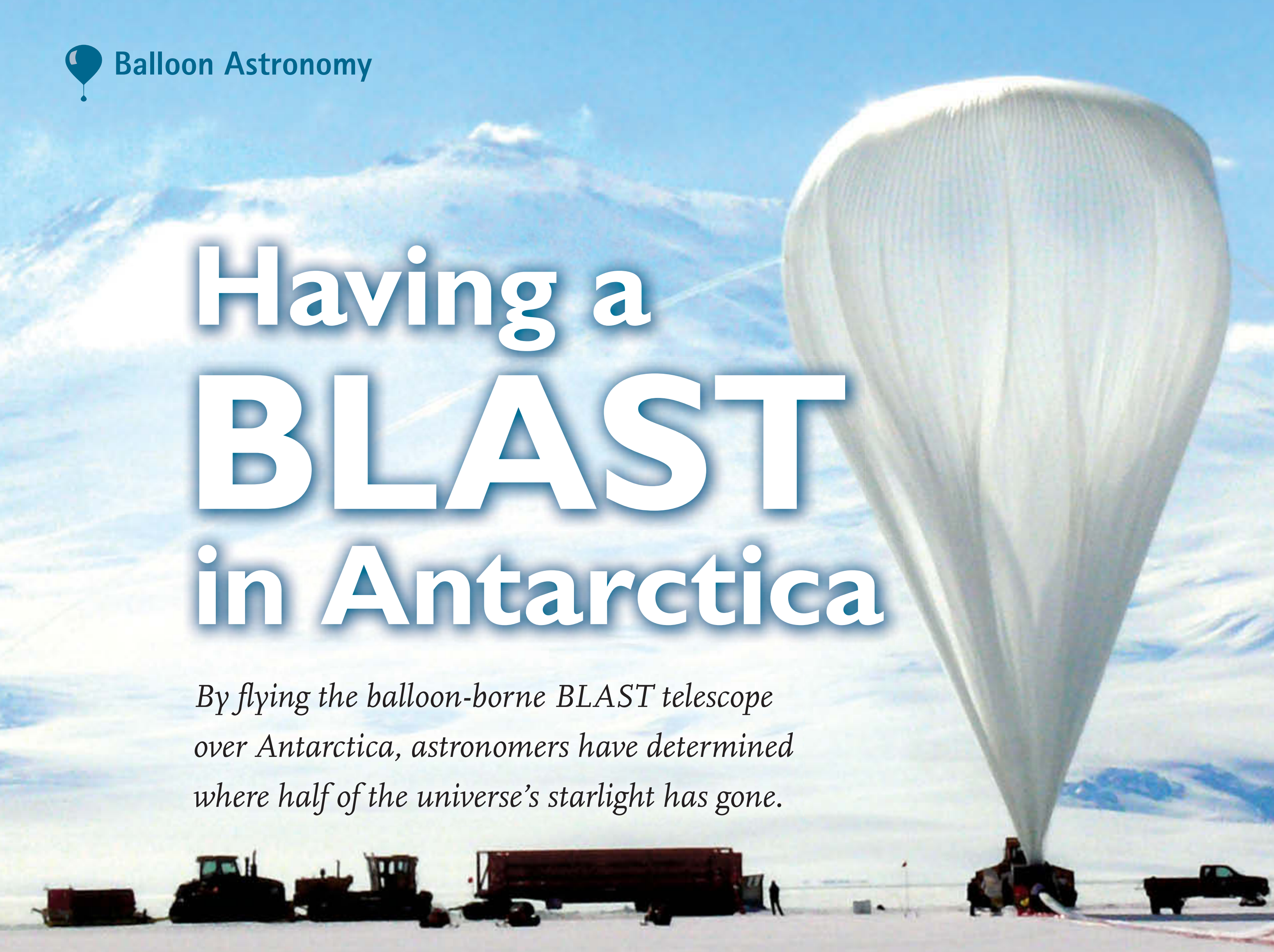


Having a BLAST in Antarctica

By flying the balloon-borne BLAST telescope over Antarctica, astronomers have determined where half of the universe's starlight has gone.

MARK DEVLIN AND MARK HALPERN

IN LATE 2006 our small group of graduate students and scientists traveled to Antarctica with an instrument called the Balloon-borne Large Aperture Submillimeter Telescope, or BLAST. We had a simple goal: Find out where half of all the light ever produced by stars has gone, and from that, figure out the universe's star-formation history.

Our team had spent five years designing, building, and testing this specialized telescope to fly under a NASA high-altitude balloon. The journey would keep us away from our homes and families for months at a time. Our inspiration was the magnificence of the night sky that has compelled every generation to ask, "How did this all get here? How and when did the stars form?"

Our Milky Way Galaxy forms about 4 stars per year, and is about 10 billion years old, so it could have formed 40 billion stars at its current production rate. But our galaxy has more than 100 billion stars. Combined with the fact that many stars have died, the star-formation rate must have been much higher at some point in the past.

Massive galaxies have been observed that are so distant that we see them when the universe was only about 1.5 billion years old. Some of these galaxies were forming stars at rates close to 1,000 times our Galaxy's rate today. If we lived in such a galaxy, we would see a dramatic night sky with 1,000 times more Orion Nebula-type star-forming regions, some of which would be much closer and brighter. There would be 1,000 times the number of young, ultraluminous stars, and there would be a supernova in this galaxy almost once a year! Was our galaxy like this billions of years ago? For all this to be

true, star formation must have taken place as a burst of activity, just a short event on a cosmic timescale. What triggered it? What caused it to stop? BLAST was designed to help answer these questions.

LAUNCH DAY BLAST's maiden Antarctic launch, on December 21, 2006, went off without a hitch, as captured by coauthor Mark Halpern. The towering peak in the background is 12,448-foot Mount Erebus, the southernmost active volcano on Earth.

Where Does Starlight Come From?

Stars form inside giant clouds that consist mostly of hydrogen gas, but which include trace amounts of silicate dust particles. The dust absorbs the ultraviolet light and most of the optical light coming from the very hot and luminous stars forming within the cloud. Although Hubble and other telescopes can take wonderful images of the Eagle Nebula and other star-forming regions, dust obscures our view of the light from where stars actually form. Fundamental information, such as the star-formation rate, must be inferred by other means.

Fortunately for astronomers, the energy from the absorbed light is not lost. It heats the dust to 30°C above absolute zero (30 kelvins) — extremely cold, but still warm enough that it radiates energy in the range of about 0.1 to 1 millimeter. By surveying the sky in this submillimeter portion of the spectrum, astronomers can fully account for the star formation in our galaxy as well as others. But doing so is extremely challenging technically and had never been done until recently.

Much of the energy of star birth is radiated at shorter infrared wavelengths. A spectrometer on NASA's COBE satellite discovered a background glow of infrared and submillimeter light that pervades the universe.

COBE scientists found that this combined infrared/submillimeter background roughly equals the total energy contained in all of the universe's visible light. That's *a lot* of energy. But COBE's angular resolution was very coarse, so the team couldn't determine what produced this extremely important background light. Was this energy from a genuinely diffuse source, like the gas in the early universe, or from a collection of many individual galaxies?

The most obvious known sources for this background light were Ultraluminous Infrared Galaxies (ULIRGs), large galaxies that appear to be undergoing a sudden burst of star formation. What triggered these starbursts? What stopped them? When did most of the stars form? Addressing these questions would require a complete census of these galaxies, determining each ULIRG's age, and showing that they add up to the total brightness of the background light.

Because ULIRGs contain huge amounts of dust, they're extremely difficult to find with optical telescopes. Using a submillimeter instrument on the James Clerk Maxwell Telescope on Hawaii's Mauna Kea, astronomers in the late 1990s finally found a handful of such galaxies, and after another decade astronomers managed to locate about 100 more. While tantalizing, these sources amounted to only a few percent of the background's intensity. The mystery remained.

Hanging from a Balloon

To solve mysteries like this, astronomers have applied increasingly specialized instruments and taken them to ever more exotic places in search of the best possible observing conditions. Earth's atmosphere is the major reason why the earlier measurements were not more successful. Even at Mauna Kea's altitude of nearly 14,000 feet, the atmosphere's thermal emission and absorption limits observations to the relatively long wavelength of 850 microns, probing a limited subset of distant ULIRGs. ULIRGs shine brightest at 300 microns, where the atmosphere is essentially opaque.

The obvious next step was to lift a telescope above most of the atmosphere, where it would have an unimpeded view of the ULIRGs. Suspending an instrument from a large helium balloon and letting it

PREPARING FOR FLIGHT ***Left*****: The BLAST payload hangs from a crane moments before its June 12, 2005 launch (at 2:00 a.m.) from Esrange Space Center, above the Arctic Circle in northern Sweden. The mirror was either damaged by a rough launch or through ice formation during ascent, which compromised the data on BLAST's first flight.** ***Right*****: BLAST team members focus the 1.8-meter telescope at the National Science Foundation's long-duration balloon facility, located about 6 miles from McMurdo Station in Antarctica. The two long, white tubes above the mirror are daytime star cameras, which are used to point the telescope during flight.**

BARTH NETTERFIELD

ANTARCTIC LAUNCH BLAST is just about to take off on its maiden Antarctic flight (and second overall) from the National Science Foundation's balloon-launch complex, near McMurdo Station. The 5,500-pound (2,500-kilogram) payload is at the far right, the red parachute is in the center, and the partially inflated balloon is on the left. Everything to the left of the parachute is part of the balloon, but it does not fully inflate until it reaches its float altitude of 125,000 feet (38 kilometers).

drift in the stratosphere is the most economical way to accomplish this — if your measurements can be performed in a few weeks and if your instrument can be made small enough to launch.

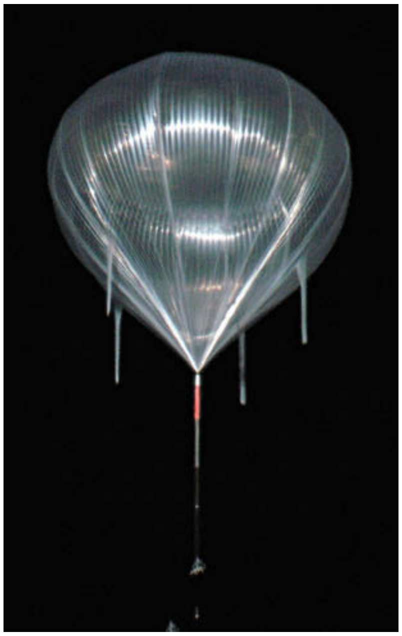
BLAST was designed specifically to probe the largely unexplored submillimeter portion of the electromagnetic spectrum and to produce a statistically significant survey of ULIRGs. The telescope scans the sky autonomously while hanging beneath a 28-million-cubic-foot NASA helium balloon floating 125,000 feet (38 kilometers) above sea level while circumnavigating Antarctica over the course of about 10 to 12 days.

Detecting submillimeter light is a tricky business. The BLAST instrument operates at three different "colors," with bands centered at 250, 350, and 500 microns. Individual photons at these wavelengths have very little energy, about 0.1% that of an optical photon. These photons do not meet the minimum energy threshold to be registered by conventional CCD cameras used on optical telescopes. We need to apply different techniques that are very difficult to implement.

BLAST essentially detects the "heat" from the galaxies. The detectors are *bolometers*, or "heat meters." Imagine your hand as a bolometer. Go outside on a sunny day. With your eyes closed, move your hand across the sky until you feel the warmest point — toward the Sun. Because the Sun is so hot and your hand is relatively cold (5800 K vs. 310 K), this measurement is easy. But if you try to locate the full Moon (about 400 K) at night, you would have a very difficult time because your hand and the object have a similar temperature. If you cooled your hand to 4 K (not a good idea!), the Moon would seem blazingly hot and you would have no problem detecting it.

Since BLAST is trying to detect submillimeter light from galaxies that are a mere 30 K, we need to cool the detectors to 0.3 K. Using bolometers manufactured at

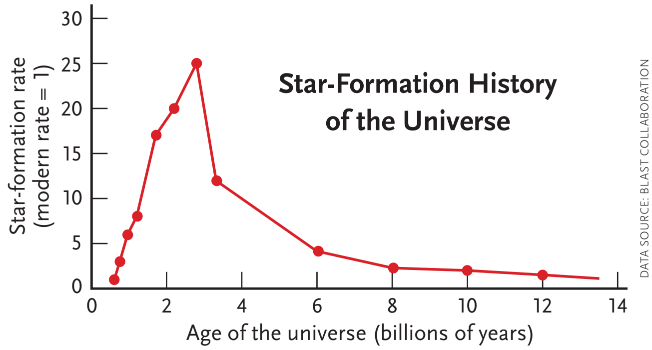
MARK HALPERN



JOE MARTZ

LET THE CELEBRATION BEGIN ***Above***: BLAST team members celebrate the impending first launch from Antarctica. After spending two months in a frigid, barren environment, most of the crew know they will soon be heading home. ***Right***: This image, taken through a telescope, shows the balloon fully inflated after reaching its float altitude of 125,000 feet. It took the balloon about 3.5 hours to reach this altitude.

CHRIS SEMISCH



RELIEVED SCIENTISTS *Left*: BLAST scientists Chris Semisch (left) and Jeff Klein pose with the vessel that contains BLAST's two computers and two hard drives. The computers were totally destroyed when fierce polar winds dragged the parachute and container 120 miles across rough ice. The hard drives were banged up, but miraculously, they retained enough structural integrity to preserve BLAST's precious data. *Right*: Using data from multiple sources including BLAST, astronomers produce graphs such as this one, which plots the universe's star-formation history. Results consistently show that star formation peaked when the universe was only about 3 billion years old and has declined ever since. If the universe's expansion continues to accelerate, star formation will grind to a halt in the far-distant future, and most of the universe's activity will eventually die out in a Big Chill.

NASA's Jet Propulsion Laboratory and homemade low-temperature refrigerators, BLAST's camera achieves the sensitivity to detect these very cold submillimeter galaxies.

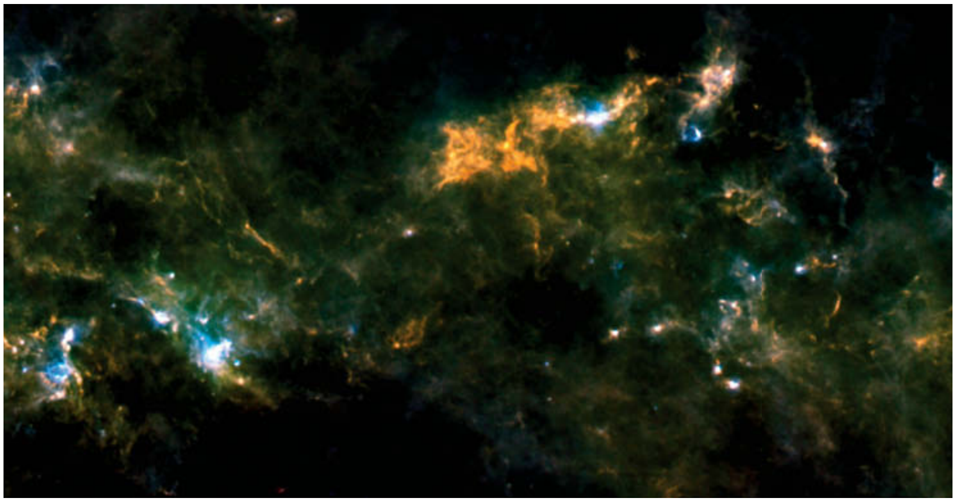
BLAST's primary mirror was damaged at launch on the first science flight from northern Sweden in 2005, limiting its sensitivity. BLAST's second flight, over Antarctica in 2006, was a complete scientific success. The cryogens that keep the camera cold enough to operate lasted 11 days while the balloon circumnavigated the continent.

BLAST provided the first deep observations of the thermal emission from star formation made at wavelengths near its peak energy. Time was divided between galactic sources and distant extragalactic fields. For Milky Way observations, we explored the dynamics of individual star-formation centers. The details of how gas clouds cool and form clumps, and how these clumps break up into individual stars at the final moments of collapse, are crucial if we're going to have a model that tells us the rate at which stars form and how the distribution of star masses is produced.

A Detailed Picture

BLAST's map of star formation in the constellation Vela is an enormous and detailed picture (below). It literally contains thousands of star-forming regions, each of which could host tens to hundreds of nascent stars. It's a first statistically significant glimpse at this earliest stage of stellar birth.

To the uninitiated, BLAST's deep extragalactic images look like smudgy, spotted nonsense (page 26). But the uniform smudgy appearance is because the starburst galaxies (ULIRGs) are so numerous they crowd the image and mostly cannot be resolved. The images contain 1,000 newly discovered ULIRGs in a wavelength regime where only a single one had been seen before. We can estimate rough redshifts (distances) of these galaxies by looking at the three BLAST bands, something earlier measurements were unable to do. If we assume that, on average, they all have temperatures of 30 K, then cosmological redshifting will make the ones that



BLAST COLLABORATION

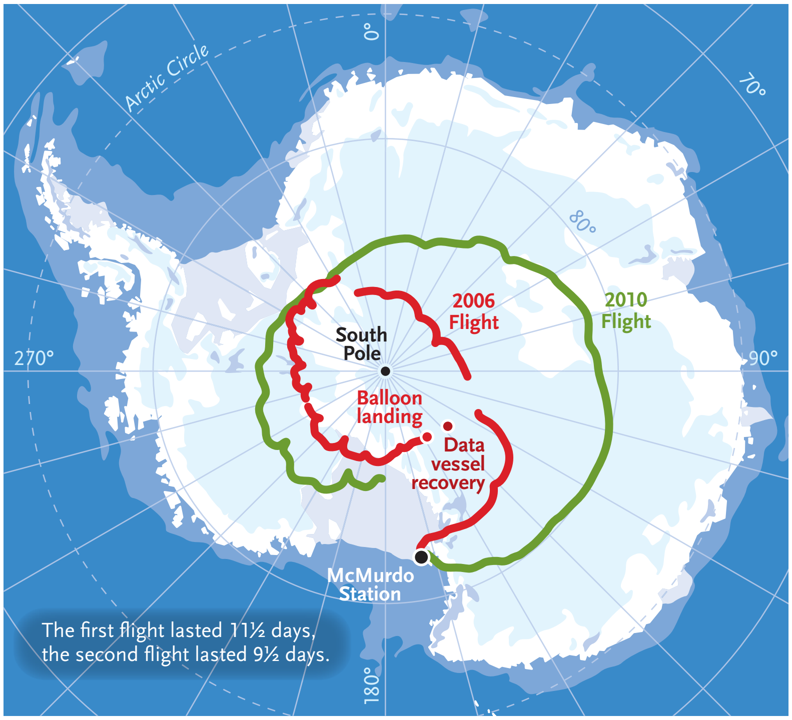
MILKY WAY This BLAST image of the Vela region, taken at submillimeter wavelengths, shows star-forming clouds about 2,300 light-years away. The blue areas show dusty regions heated by young stars to greater than 20 kelvins, green areas are 18 K, and red areas are below 12 K.

To watch clips from the movie *BLAST!* and to purchase the home DVD, and to link to the official BLAST website, visit SkyandTelescope.com/BLAST.

are at higher redshift appear cooler. By measuring the temperature we get the redshift and distance. Since we measure the flux, we can use this information to derive the star-formation history.

Our images also contain the flux from several hundred thousand fainter unresolved galaxies. We have shown that BLAST starburst galaxies account for the entire background light discovered by COBE. Because we can estimate redshifts, we can infer how long ago each ULIRG emitted the flux seen by BLAST. Combining BLAST-measured star-formation rates with infrared data enabled us to produce a star-formation history of the universe, demonstrating that the epoch of rapid star formation peaked about 10 billion years ago. Our universe has experienced its galactic growth spurt and is now approaching middle age.

While BLAST's first Antarctic flight was a stunning success from a scientific perspective, the telescope itself did not survive. At the end of a flight the payload separates from the balloon by radio command and parachutes to Earth. Once the telescope has landed, a second radio command is sent to release the parachute. This command



The first flight lasted 11½ days, the second flight lasted 9½ days.

S&T: LEAH TISCIONE

BLAST! The Motion Picture

When my brother Mark suggested I join him in northern Sweden to capture the balloon launch of his new telescope on video, I had no idea that his casual invitation would lead me on a five-year journey across five continents, including Antarctica, to document an amazing scientific adventure.

The result is *BLAST!*, a feature-length narrative that aspires to reach a mainstream audience by demystifying astronomy and dramatizing the failures and triumphs of an ambitious experiment. Having grown up in a family of scientists, I wanted to emphasize their enthusiasm and expose their personal challenges. My access through my brother gave me a rare opportunity to delve into aspects of science usually ignored by traditional programming.

Breaking convention, however, is never easy. My independent films have been screened all over the world. But *BLAST!* was my most difficult project yet. Capturing a story that stretched around the globe for years with delays and disasters was one thing. Even more daunting was trying to convey complex scientific concepts to a mainstream audience and still keep the narrative engaging.

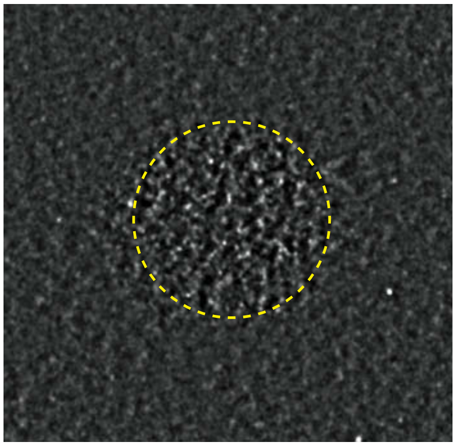
With the help of *BLAST!*'s exotic locations, cliff-hanging story line, and emphasis on the humanity of the scientists, we attracted financing and acquisitions from broadcasters in Sweden, Japan, the Netherlands, and elsewhere. A recent global broadcast on BBC World News reached hundreds of millions of viewers in up to 120 countries. In the U.S., *BLAST!* opened theatrically in New York to enthusiastic reviews from *The New York Times*, *Variety*, and even *The Onion*. Ira Flatow interviewed Mark and me on NPR's *Science Friday* (http://bit.ly/9fwRyn), which led Stephen Colbert to invite Mark on *The Colbert Report* (http://bit.ly/aNsUy6). It's hard to make science more mainstream than that!

BLAST! was chosen as an Official Special Project of the International Year of Astronomy 2009 and is now being shown regionally on select PBS stations in the U.S. We produced an Educational DVD with special versions of the movie and a Teacher's Guide designed for classroom use. And the home DVD with the uncut, feature-length version of *BLAST!* is now available.

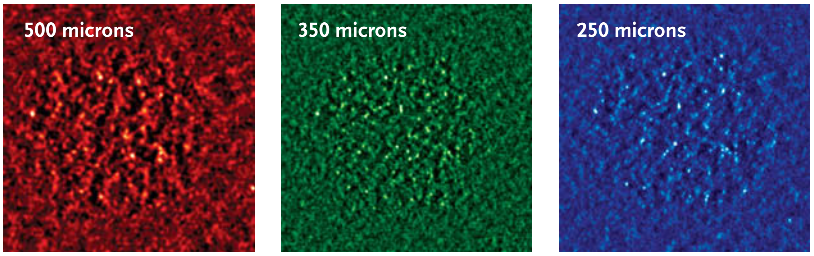
MARK HALPERN

BROTHERS Filmmaker Paul Devlin (left) and astrophysicist Mark Devlin enjoy one of the few relaxing moments of their stay in Antarctica. Despite the beard, Mark is the younger brother. They were raised in New Jersey.

***Paul Devlin** has won 5 Emmy Awards for his work in sports television with CBS and NBC.*



BLAST COLLABORATION (4)



DISTANT GALAXIES The main objective of BLAST was to locate distant star-forming galaxies. *Left:* The large frame consists of a central image (circled) that probes a 0.8-square-degree field at great depth. That field lies inside a larger field imaged at shallower depth, where only the brightest submillimeter sources show up. *Above:* By taking these close-ups of the circled region through three filters of different wavelengths, scientists can estimate each galaxy's redshift (a proxy for distance).

never got through. The Antarctic winds inflated the parachute and dragged BLAST across 120 miles of ice fields, strewing crucial bits of broken hardware as it went, finally lodging in a deep crevasse. Happily, National Science Foundation Polar Programs mountaineers retrieved the data vessel after several aerial searches. The entire epic story is documented vividly in the movie *BLAST!* (see *BLAST! The Motion Picture,* page 25).

Since BLAST's 2006 flight, the European Space Agency launched the Herschel Space Observatory. One of Herschel's instruments has confirmed all of BLAST's results and has probed all the same regions with exquisite precision.

An Ongoing Quest

The BLAST instrument was not completely lost in Antarctica. The cryogenic receiver was ripped off the telescope while it was being dragged. Although it suffered extensive damage (nothing a few good whacks with a hammer couldn't fix!), the bolometers (the heart of the experiment) were unharmed. Retrieving these detectors allowed our team to continue pursuing our scientific agenda. We rebuilt the gondola, telescope, and the associated infrastructure, transforming BLAST into BLAST-pol.

With small polarizing grids added in front of each detector, BLAST-pol is sensitive to the polarization of submillimeter light. In December 2010, we launched BLAST-pol from Antarctica with a new team of graduate students at the helm. It made detailed observations of star formation in our galaxy. The previous flight showed that the gas clouds that eventually collapse into young stars support themselves against gravity for much longer than simple models predicts. One theory is that magnetic fields provide a breaking mechanism that slows the collapse. If true, then the magnetic fields will also align the small dust grains in the clouds, turning them into little antennas oriented the same way. This will cause the light emitted by the dust to be slightly polarized. So, if we can measure the polarization, we can infer if magnetic fields are playing a significant role in star formation.

The instrument landed completely intact, and our team recovered most of it in January. The data analysis is underway and we should have the answer about a year from now. The team is already thinking about what big problem to tackle next. The quest goes on! ✦

MATT TRUCH

RECENT RECOVERY On January 17, 2011, BLAST team members recovered the telescope and data vessel after the most recent flight. This time, the instruments and hard drives were completely intact, which will make it easier to fly the experiment again. The scientists flew to the site in the pictured Twin Otter airplane.

Mark Devlin *is a professor of astronomy and astrophysics at the University of Pennsylvania. He builds instruments to study the structure and formation of the universe, observing from high-altitude balloon platforms, 17,000-foot mountaintops in Chile, and from mountains in West Virginia.*

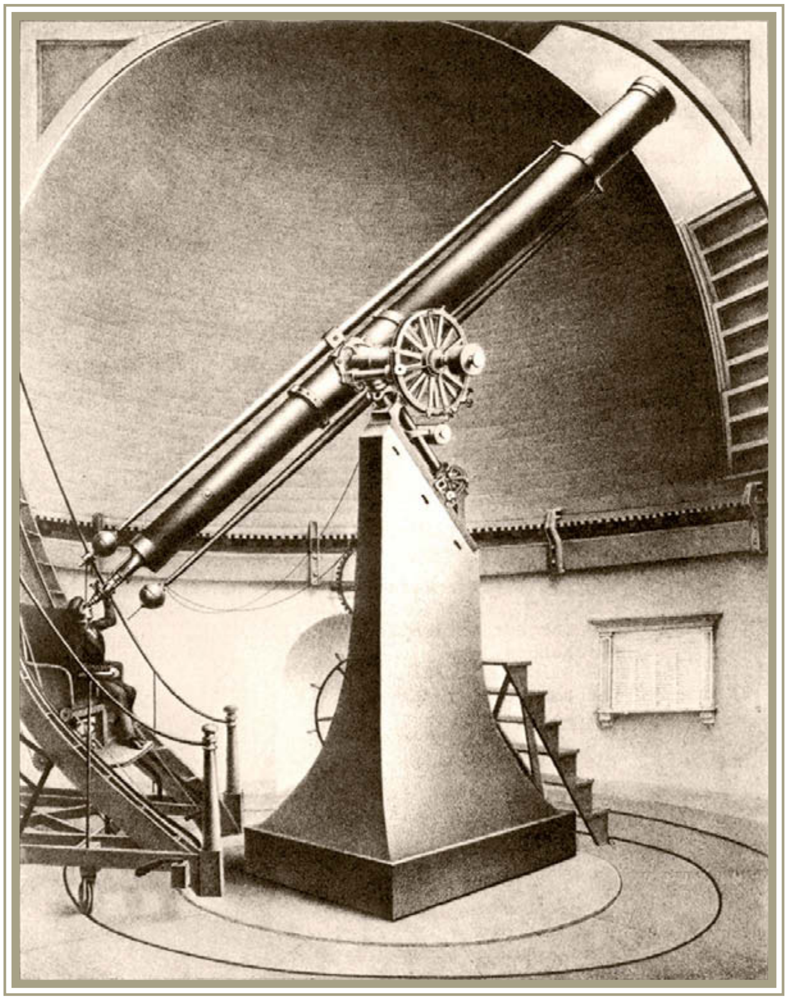
Mark Halpern *is a professor of physics and astronomy at the University of British Columbia. His main work is to study the cosmic microwave background using custom-built instruments, including a cryogenic sounding rocket and WMAP.*

The Great Telescope Race

CREDIT: ROXANA BELL

TRUDY E. BELL

In the 19th century, the United States transformed itself from a scientific backwater into an astronomical juggernaut.



HARVARD COLLEGE OBSERVATORY The Great Comet of 1843 inspired some of Boston's wealthiest citizens to donate enough money for Harvard to purchase this 15-inch Merz & Mahler refractor. It was tied with a nearly identical refractor at the Pulkovo Observatory in Russia as the world's largest telescope, until being supplanted by the Dearborn Observatory's 18½-inch refractor in 1864. The telescope is still mounted in its original dome at Harvard, although it is not currently in operation. All images from the *S&T* archive unless otherwise credited.

"WHILE GREAT BRITAIN alone can boast *thirty* public and private observatories of note, we have not in the whole United States *one* that deserves the name," thundered well-known U.S. astronomer Nathaniel Bowditch in *The North American Review* in 1822.

Nearly half a century after the American Revolution and a decade after the War of 1812, both wars were still within living memory, because the conflicts had so impoverished the young nation that the United States was poorer in the 1820s than the former colonies had been. Great Britain was still not only a bristling military threat, it was also a formidable intellectual titan, as was the rest of Europe. Even though the United States was expanding westward in large gulps, intellectually the New World seemed to many on both sides of the Atlantic to be sinking back into the forest primeval.

In 1826, President John Quincy Adams's first annual message to Congress noted that "throughout the whole American hemisphere. . .we have neither observatory nor observer. . .and the earth revolves in perpetual darkness to our unsearching eyes." Yet his call for building a U.S. astronomical observatory and supporting a full-time astronomer drew highly public ridicule for its memorable image of observatories being "lighthouses of the skies." Over the next decade, the few costly telescopes that were acquired for schools or individuals were all crafted by English, French, or German opticians.

That was then. Fast forward to the end of the Gay Nineties.

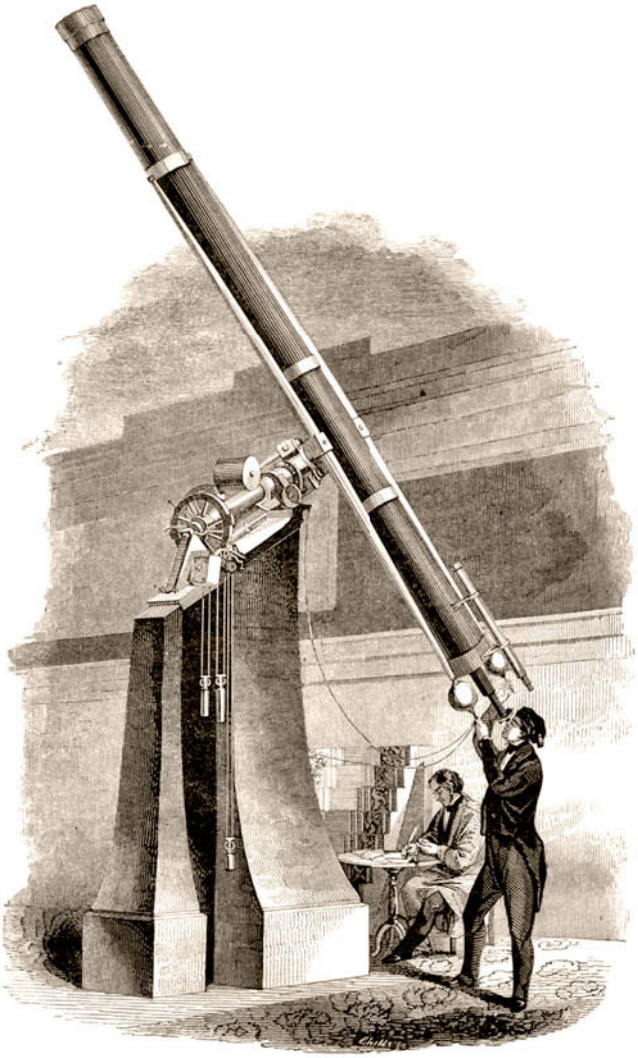
By 1900 the U.S. had more observatories than any other nation — at least 220 (by modern recount) — to the point where several well-known astronomers publicly objected to a literal glut of equipment. Four U.S. observatories had claimed momentary fame as home to the world's largest refractor, all crafted by the *American* firm of Alvan Clark & Sons. Smaller observatories laid claims to other firsts (first in their state, farthest west, highest altitude, largest in their state, largest by that telescope maker, etc.).

Many had been financed by wealthy U.S. philanthropists, or even by public subscription — philanthropy of the common man. "So great, indeed, has become the generosity of those who are not astronomers," commented Lick Observatory astronomer W. J. Hussey in 1897, "that. . . astronomers have only to ask for instruments and observatories to find appreciative persons to supply their needs."

Triumph was especially sweet because "European scientists now come occasionally to see what is doing here," remarked Williams College astronomer Truman H. Safford in 1888. Indeed, by 1900, telescope envy had shifted across the Atlantic to Great Britain. "British observatories would, perhaps, receive a much increased means of support," wrote an anonymous author in *Nature,* "if it were not for the possible impression that the best work can only be done in America."

In less than one human lifetime, the United States utterly transformed itself from a rustic scientific back-

HUDSON OBSERVATORY **The Hudson Observatory (now named the Loomis Observatory), in Hudson, Ohio, was built in 1838, making it one of the oldest in the U.S. It was and still is home to a 3.8-inch refractor made by Simms of London.**



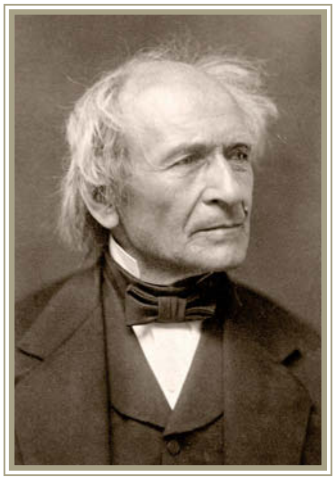
CINCINNATI OBSERVATORY **An observer (probably Ormsby MacKnight Mitchel) looks through the 11¼-inch Merz & Mahler refractor at the Cincinnati Observatory, which was financed by the citizens of Cincinnati.**

water to a world-class astronomical juggernaut. Although other countries also built significant observatories in the 19th century, the sheer magnitude of the U.S. observatory-building movement was internationally unique.

Why did astronomy so grip the imagination of the 19th-century American public that telescope fever swept the nation? U.S. observatory building was actually a broad *cultural* movement, energized by several important nonastronomical motives, which ultimately left American astronomers with too much beautiful equipment and too little ongoing support for research.

Cultural Cold War

Traditionally, historians have claimed that the Leonid meteor storm of November 12–13, 1833, followed by two spectacular comets, inspired some Americans to clamor for telescopes and answers. To be sure, the unexpected Great Comet of 1843 — so brilliant it could be seen even at noon — spurred funding for the Harvard College Observatory to acquire a 15-inch refractor from the excel-



MASTER OPTICIAN Alvan Clark (1804–1887) played a pivotal role in the American telescope-building movement. On 5 occasions (4 in the U.S.) his business's newest refractor ranked as the world's largest.

lent Munich optical firm Merz & Mahler. When mounted in 1847, the Harvard telescope was a twin to that of the Imperial Observatory at Pulkovo near St. Petersburg in Russia, then the largest in the world.

But a purely astronomical explanation is insufficient to explain the sheer power and duration of the 19th-century U.S. observatory-building movement. After all, the comets also hung silently in the heavens over Great Britain, and the meteors also rained over France and Germany. Why didn't the same apparitions inspire similar observatory-building movements in those nations? In the U.S., motives included a mixture of wounded national pride, a wholesale embracing of the Industrial Revolution, a love of antiaristocratic rags-to-riches success stories that became the narrative of American opportunity, and religious appeal.

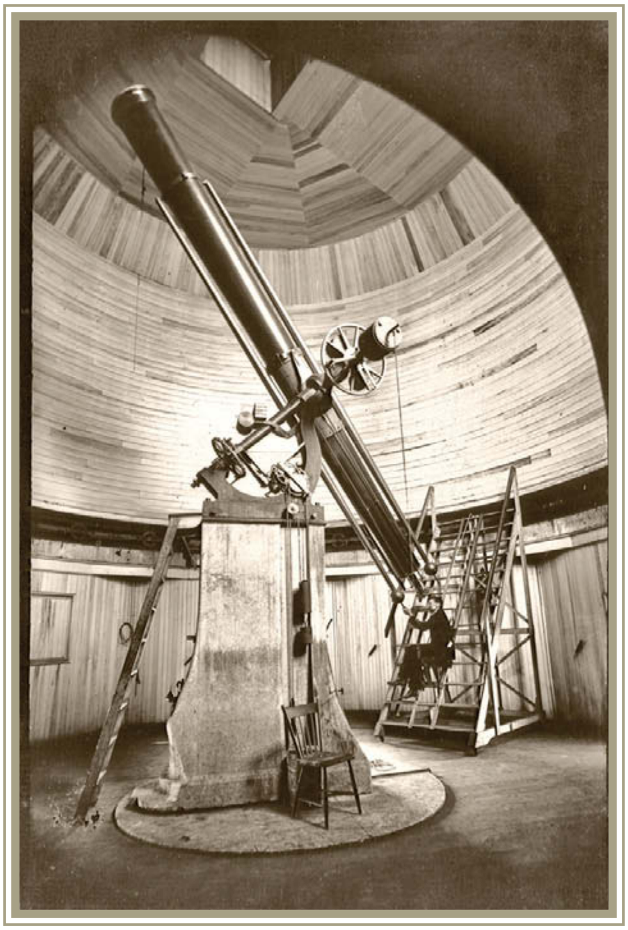
In the early 19th century, Americans smarted under dismaying portrayals by Old World intelligentsia of pioneer society being uneducated and boorish. Yearning for cultural acceptance, Americans internalized European aspirations and sought to emulate European appearances. "An Observatory has long been considered by enlightened nations as one of the noblest objects that can claim the patronage of the public or of individuals," wrote an anonymous correspondent to *The North American Review* in 1818 in a passage much quoted over the next two decades. "We are almost the only nation of any pretensions to learning and the arts, which has totally neglected to provide for this branch of knowledge."

Even blunter were the impatient words of Cincinnati astronomer and railroad surveyor Ormsby MacKnight Mitchel in 1842: "While Russia with its hordes of barbarians boasted the finest observatory in the world [Pulkovo], our own country with all its freedom and intelligence. . .[does not] possess a single observatory within all its vast extent."

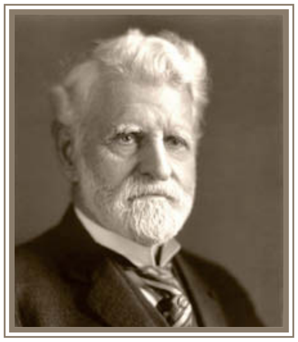
But by 1842 the U.S. had six observatories, including the Hudson Observatory of the Western Reserve College in Hudson, Ohio (founded 1838) and the Philadelphia Central High School Observatory (founded in 1840). But never mind pesky outdated facts. Mitchel's politically incorrect "hordes of barbarians" speech so whipped up the indignation of Cincinnati citizens that within two days he had raised $1,000 (equivalent to between $25,000 and $250,000 today). Three years later (1845), Cincinnati was the proud possessor of an 11-inch Merz & Mahler refractor — largest in the entire United States until surpassed in 1847 by Harvard College Observatory's 15-inch refractor (*S&T:* August 2009, page 30).

The Victorian Space Race

With Harvard's acquisition of a twin "world's largest refractor," did Americans feel equality with Europe? "We are to learn the. . .not very pleasant paradox, that America cannot keep pace with Europe in Science except by going ahead of her," declared Harvard mathematician Benjamin Peirce to the American Association for the Advancement of Science in July 1853. "The New World must begin to build on a new level above that of the Old World, and it must build from its own materials." Thus, the U.S. pitted itself against Europe in a race to build and retain title to the world's largest astronomical refractor — a title that



DEARBORN OBSERVATORY Funded by donors from the Chicago Astronomical Society, Dearborn Observatory's 18½-inch Clark refractor saw first light in 1864 at the old University of Chicago. It was moved to Northwestern University in Evanston, Illinois, in 1889 after the original University of Chicago went bankrupt.



CAPTAINS OF INDUSTRY **Worcester Reed Warner (*left*, 1846–1929) and Ambrose Swasey (1846–1937) founded a company that built the entire mechanical assemblies for the great Lick and Yerkes refractors. They also constructed many other telescopes in the late 1800s and early 1900s for various institutions and individuals, their largest being the McDonald Observatory 82-inch reflector.**

seesawed across the Atlantic for the next three decades.

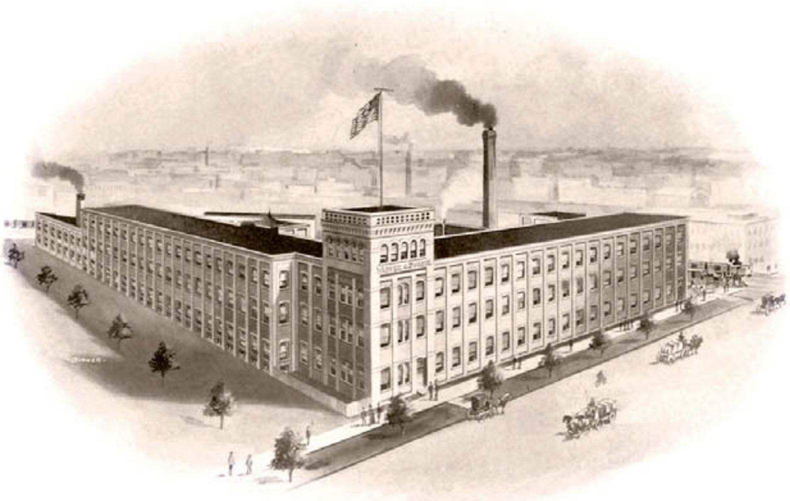
The great telescope race was enabled by the Industrial Revolution, which Americans had firmly grasped. Culturally in the New World, the terms "bold," "technological," and "world's largest" were in the air. When completed in 1825, the 363-mile-long Erie Canal from Albany to Buffalo was the longest canal in the world. Beginning in the 1840s, railroads spread through forest and prairie and even solid rock, followed quickly by telegraph poles and wires alongside the tracks, linking both coasts of the vast North American continent with the pounding of the Transcontinental Railroad's golden spike in 1869. No daring engineering venture, no matter how breathtaking, seemed impossible in America. With every technological conquest, Yankee ingenuity and swagger grew only bolder: what was one world's record but a challenge to set the next? Why not the world's largest telescope?

Moreover, democracy was in the air — an antiaristocracy democratic ideal that asserted that a common bricklayer was every bit the equal of a Boston Brahmin, that intellectual knowledge was not the exclusive hoard of any elite, but that any boy through hard work, luck, pluck, and virtue could triumph over birth and class.

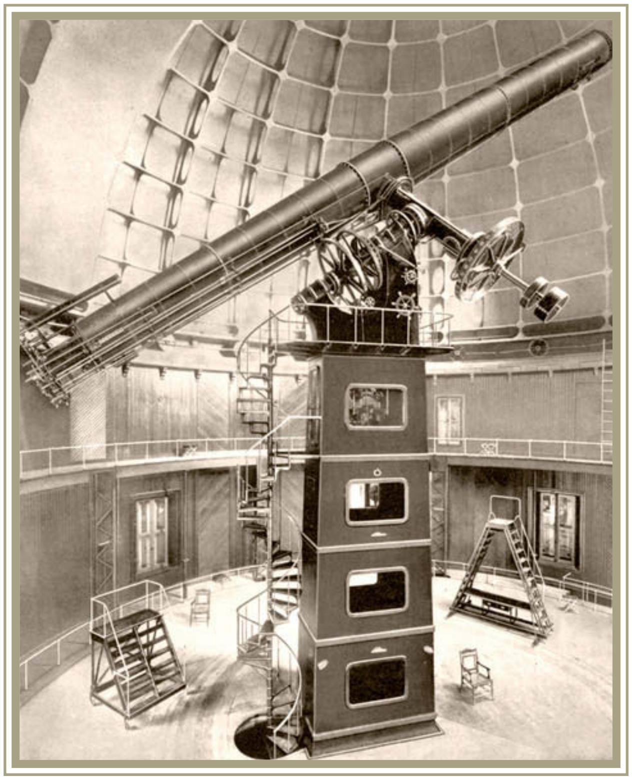
In magazines and books, American telescope makers were portrayed as fitting magnificently into that American myth. Alvan Clark made wonderful copy, starting as a Cambridgeport, Massachusetts printer's engraver and portrait painter who taught himself optical techniques, and in his 50s began fashioning the largest telescopes in the world. So did Worcester Reed Warner and Ambrose Swasey, two New England boys who, seemingly after building the mount and pier of one 9-inch refractor, landed a contract to build all the mechanical parts and the dome of the world's largest telescope, the 36-inch refractor for the Lick Observatory.

Never mind that such popular mythmaking downplayed key facts: Clark's 12 difficult years of optical trial and error and his frustrating struggle as a scientific outsider to get astronomers to recognize his ability, and Warner's and Swasey's 11 crucial years at Pratt & Whitney mastering precision engineering, marketing, and project management before founding their own company.

In the post-Civil War Gilded Age of wealthy industrialists, the American-European great telescope race ultimately became a contest between successful American entrepreneurs who sought to leave their fortunes to noble causes, including observatories. In October 1872, the



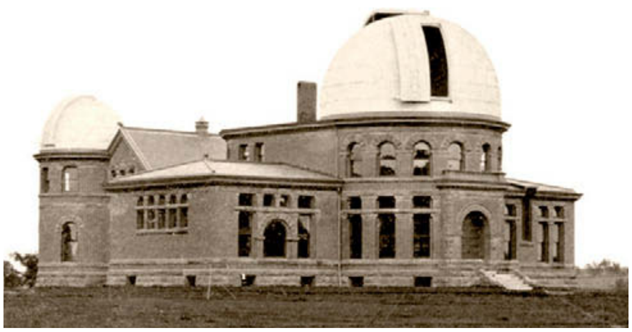
WARNER & SWASEY ***Above:*** **The Warner & Swasey factory in Cleveland, Ohio, as it appeared from 1893 to 1900, typified the explosive growth in U.S. heavy industry during the late 19th century.** ***Right:*** **Being amateur astronomers, Warner and Swasey built themselves a private observatory, equipped with a 9½-inch Brashear refractor, in the backyard of their adjacent homes in Cleveland. The telescope and dome were later donated to Case Western Reserve University.**



LICK OBSERVATORY ***Left:*** **Lick Observatory's 36-inch refractor reigned as the world's largest telescope from 1888 to 1897, when it was supplanted by the Yerkes 40-inch refractor.** ***Right:*** **The observatory, built on Mount Hamilton near San Jose, California, was funded by wealthy businessman James Lick. The observatory remains an important center of research, and its more-modern 120-inch Shane reflector has discovered dozens of exoplanets.**

monthly periodical *Manufacturer and Builder* published the first of an eight-year series of articles calling for "a million dollar telescope" — a call promptly echoed by *Scientific American* and other magazines, and credited in part with inspiring California millionaire James Lick in 1873 to bequeath $700,000 to found the Lick Observatory (completed in 1888).

Andrew Carnegie, in the first publication of his soon-to-be-famous 1889 essay "The Gospel of Wealth," recommended Lick's example to his fellow capitalists, noting that instrumentation technology was progressing so fast "that every few years a new telescope might be judiciously given to one of the observatories upon this continent, the last being always the largest and the best."



GOODSELL OBSERVATORY **Carleton College, in Northfield, Minnesota, completed this new observatory in 1887 to replace a smaller one. Later named Goodsell Observatory, after the donor of the land for the college, it housed a 16.2-inch Brashear refractor.**

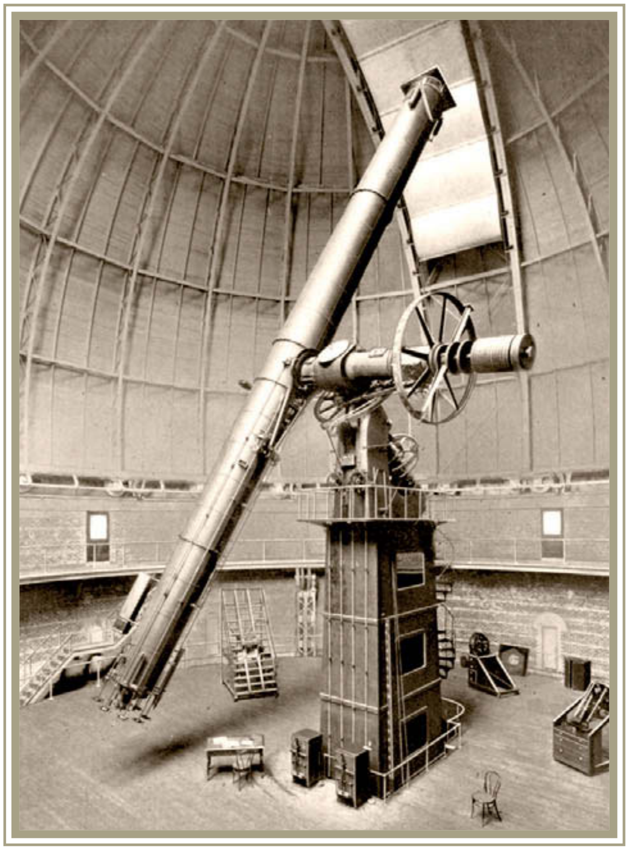
Redefining Culture

"In all ages, astronomy has been an index to the civilization of the people who cultivated it," declared Simon Newcomb, director of the U.S. Nautical Almanac Office and effectively the dean of American astronomy. Not only did the light of science doom superstition to "speedy extinction," Newcomb explained, but also an observatory was a kind of spiritual refuge to "enjoy the fresh air of heaven" — a moral breathing space in our business life "free from those taints which affect this struggle for existence."

The president of the Chicago Astronomical Society went even further: "In some sense, then, the Observatory is a moral institution, an ally of the biblical institute," stated H. A. Johnson at the ceremony for laying a cornerstone for a new building for the Dearborn Observatory in 1888. "The contemplation of the divine wonders of the celestial vault leads the thought away from the small things of time and sense, and opens the eternal volume."

So compelling were such cultural and religious convictions that in speeches and articles, solid practical returns for navigation and geodesy were given a back seat to the intellectual and spiritual utility of astronomy. "The highest value of scientific truth is not economic, but different and more noble," Princeton solar astronomer Charles A. Young concluded in a rousing address to the American Association for the Advancement of Science in 1884. ". . . [S]cience, for truth's own sake, comes to be loved and honored along with poetry and art, leading men into a larger, higher, and nobler life."

YERKES OBSERVATORY Funded by Chicago transportation tycoon Charles T. Yerkes, the great 40-inch Yerkes Observatory refractor, mounted in 1897, still remains the world's largest telescope of its type, though it is no longer being used for research. Like the Lick Observatory, the optics were made by Alvan Clark & Sons and the mechanical assembly by Warner & Swasey.



The Finish Line

By the 1890s, astronomy had so captured the U.S. public imagination that amateur societies had sprung up in many cities. Bankers, lawyers, journalists, and even bricklayers and housewives gathered by the hundreds, sometimes even the thousands, to hear evening lectures on the wonders of the universe. Adoring crowds flocked to observatories in such large numbers that they became an actual pest, compelling several observatories to strictly limit visiting hours.

"In the popular imagination, an observatory exists for the purpose of being visited — like a parsonage," mocked astronomer Mary E. Byrd at the laying of the cornerstone for the second observatory at Carleton College (later named Goodsell Observatory) in Northfield, Minnesota, in 1886, "or that it is held to be some grand celestial amphitheater where there are nightly shows of moon and stars and planets, with the astronomer for chief showman. . .much as Barnum likes to show trained elephants and dancing ponies."

Meanwhile, the demand for telescopes in the U.S. was so great in the last quarter of the 19th century it exceeded the manufacturing capability of Alvan Clark & Sons and John A. Brashear. Indeed, the high demand created a market for a host of now nearly forgotten figures: John Byrne, John Clacey, A. K. Eaton, Harry Fitz, William and David Mogey, Charles A. Spencer, and dozens more. By modern recount, these lesser-known telescope makers collectively built *more than half* the telescopes made in 19th-century America, including both portable and permanently mounted instruments.

So rapid was the growth in the number of American observatories of all sizes that by the end of the century astronomers actually were caught in an ironic bind: they suffered from a glut of equipment, but simultaneously also a shortage of support for ongoing research. "Our country has very many excellent observatories: and yet little work is done in comparison, because no provision has been made for maintaining the work," physicist Henry A. Rowland noted with alarm as early as 1883. "A great telescope is of no use without a man at the end of it," Newcomb cautioned at the dedication of the Yerkes Observatory in 1897. "...[A]llow me to commend to your fostering care the men at the end of the telescope."

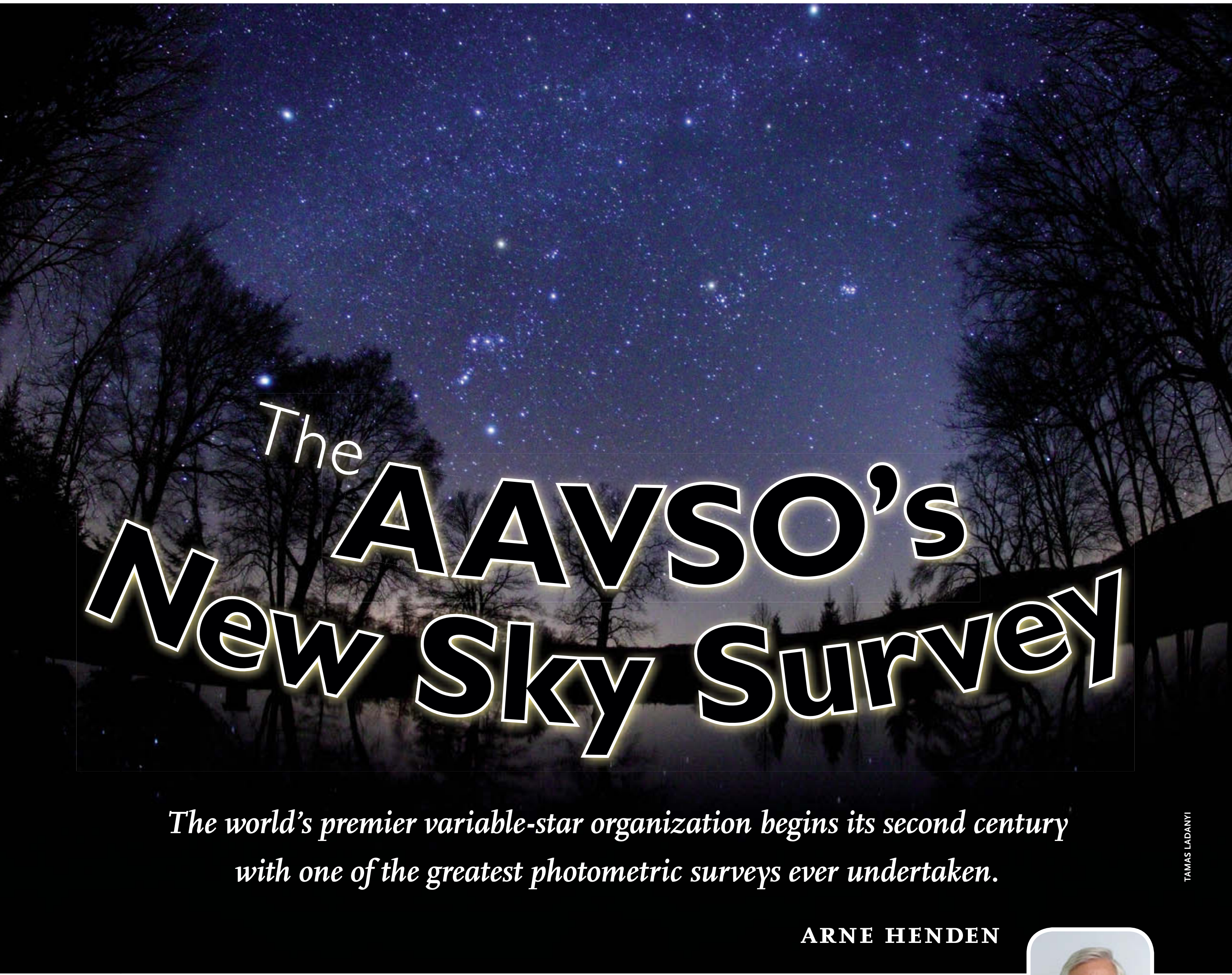
Lack of support for research should have been a predictable downside of founding observatories through cultural appeals to people who fundamentally had no abiding interest in the science of astronomy. Although astronomical research projects had benefactors such as Catherine W. Bruce, Mrs. Henry Draper, and Uriah A. Boyden, they were generally not the same people who founded observatories. And many philanthropists who founded observatories were not interested in funding exacting micrometer or spectroscopic measurements by a lone astronomer hidden under a dome in the wee hours of the night. Instead, these wealthy benefactors sought public affirmation from the press and general citizenry for being a patron of American culture — by creating a tangible institution that was once a symbol of America's shame, but was now her crowning glory. ✦

Listen to an **AUTHOR INTERVIEW**

CREDIT: ROXANA BELL

To listen to a recorded audio interview with author Trudy E. Bell, visit SkyandTelescope.com/telescoperace.

__Trudy E. Bell__ has written 19 bylined feature articles that have captured top journalism awards. She is the author of a dozen books, including the Smithsonian Science 101 volume Weather *(2007). For the second year she is a Presidential Fellow at Case Western Reserve University. Visit her website at www.trudyebell.com.*



The AAVSO's New Sky Survey

The world's premier variable-star organization begins its second century with one of the greatest photometric surveys ever undertaken.

TAMAS LADANYI

ARNE HENDEN

LIFE WAS SIMPLER a century ago when the American Association of Variable Star Observers (AAVSO) was formed. Only a few hundred stars were known to vary in brightness, and the astronomers at Harvard College Observatory who asked a group of local amateurs to monitor them did much of the preparatory work. The astronomers identified the important variables, created finder charts, and used photographic techniques to calibrate comparison stars that the amateurs used to estimate a target star's brightness.

Fast forward to today. There are hundreds of thousands of known variables and thousands of researchers studying them. Many of the observing techniques have improved. For example, we now have digitized views of the sky and accurate astrometric catalogs, which make identifying target stars and generating finder charts relatively easy. But even in 2011, someone has to manually choose comparison stars and determine their accurate magnitudes and colors. Unfortunately, while we have great astrometric catalogs, we don't have an equivalent high-quality photometric catalog covering the entire sky.

The need for such a photometric catalog is greater today than ever before. Exoplanet surveys such as XO or HAT cover large areas of sky looking for stars that experience minuscule dips in brightness due to a transiting planet. These surveys have a significant number of false positives caused by variable stars that mimic these small brightness changes. Time must be spent removing this "chaff" in order to find true transiting systems. Some time is used for spectroscopic studies to measure the candidate star's radial velocity, but knowledge of the star's color, especially as a function of its light-curve phase, is an essential precursor to scheduling a big telescope for spectroscopy.

Photographic archives such as the one at Harvard College Observatory are being digitized (*S&T:* March 2010, page 31), and calibration stars are needed on each plate to derive accurate photometry. Researchers studying asteroid light curves need accurate calibration stars across wide fields since their targets move from night to night. Another use involves data mining of a multicolor photometric catalog itself.

The best existing all-sky photometric data is in the *Tycho-2 Catalogue,* which was generated from the star tracker on the Hipparcos satellite mission. It covers the entire sky down to about 11th magnitude in two colors that are not standard photometric passbands. There are pieces here and there from other projects, but they don't form a homogenous photometric catalog. The Sloan Digital Sky Survey (SDSS) covers 8,000 square degrees of northern sky to fainter than 14th magnitude; a catalog compiled with the Carlsberg Meridian Telescope covers the sky between declinations –30° and +50° in the Sloan-r′ band; and the All-Sky Automated Survey lists stars from 8th to 14th magnitude, but only for the V band. Thus, there is a desperate need for a survey of the entire sky in the magnitude range typically observed by amateurs — roughly stars brighter than about 16th magnitude.

Sky surveys can be very expensive. Witness the many millions of dollars for PanSTARRS, or the southern VLT Survey Telescope, or the half-billion-dollar cost of the upcoming Large Synoptic Survey Telescope. (*Editor's note:* These surveys were described in the September 2008 issue, page 30.) But modern commercial telescopes, imaging equipment, and software have had huge impacts on the field. Just as today's amateur astrophotographers are creating beautiful deep-sky pictures that would have been the envy of professionals with 4-meter telescopes only a few decades ago, the photometric work being done by today's amateurs has astronomers clambering for more.

At the AAVSO, we thought that such a survey was becoming essential to the future of our organization. We were spending hundreds of hours every year generating charts for objects that our observers wanted to study. When a new nova was discovered, we had to quickly find whatever photometric data was available for surrounding stars in order to create a sequence that observers could use to monitor the nova's rapidly changing brightness.

TOM SMITH

The survey telescopes covering the Northern Hemisphere sky are located in Weed, New Mexico. Note the white targets used for making flat-field exposures.

With the great need for a uniform all-sky photometric catalog, and the necessary equipment to create one available at reasonable cost, now was the time to act. Aided by two grants from The Robert Martin Ayers Sciences Fund, we have begun the AAVSO Photometric All-Sky Survey (APASS). This survey will cover the entire sky from 10th to 17th magnitude in five passbands: Johnson B and V, and Sloan g′, r′, and i′. This gives transitional coverage between the Johnson wavelengths traditionally used in the past and the passbands many professionals use today.

The entire sky encompasses 41,254 square degrees. The U.S. Naval Observatory's UCAC3 astrometric catalog was made with an imaging system that covered a square degree in a single exposure. As such it needed 40,000 images to cover the sky once, but it actually required more than 200,000 images taken over six years to produce the final catalog, given the need for overlapping fields to

AARON LACLUYZE

The survey is covering the southern sky with telescopes set up at Cerro Tololo Inter-American Observatory in Chile. They are housed in a clamshell dome (arrowed) originally built for a project to monitor gamma-ray bursts.

remove systematic effects. APASS must cover the sky a minimum of four times to remove night-to-night photometric calibration errors, and do this in five passbands — 10 times more coverage than the minimum required for UCAC3. We have to plan carefully if we expect to accomplish our goals in a reasonable length of time!

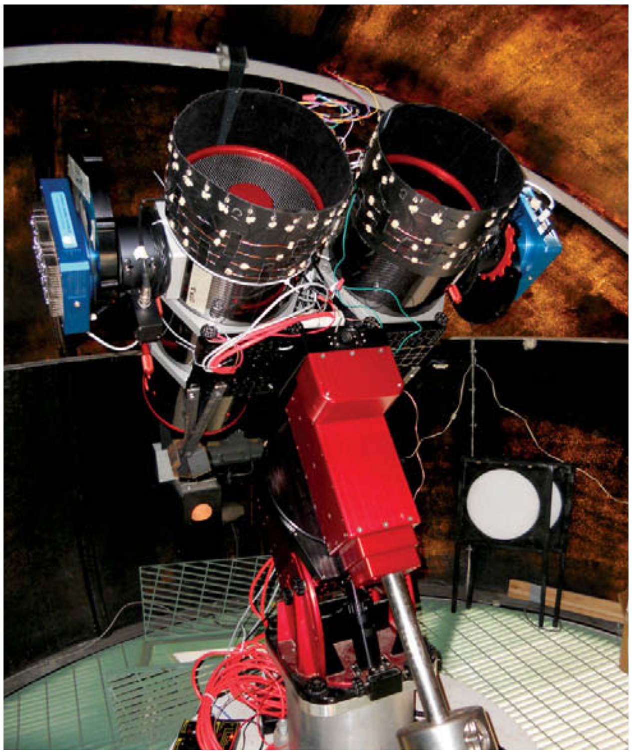
Our first optimization is to establish observing sites in the Northern and Southern Hemispheres, and equip each with twin telescopes on a single mount. Each scope exposes a common area of sky with a different filter, increasing our efficiency by a factor of two. It also ensures that we obtain simultaneous photometry in two passbands, which is often useful for poor sky conditions or for variable stars that change color quickly (such as a rapid eclipsing binary or cataclysmic variable). We do not need the spatial resolution of UCAC, so our cameras have a field of view covering 8.4 square degrees, giving a significant increase in efficiency. We expect the observations for APASS to require about two years.

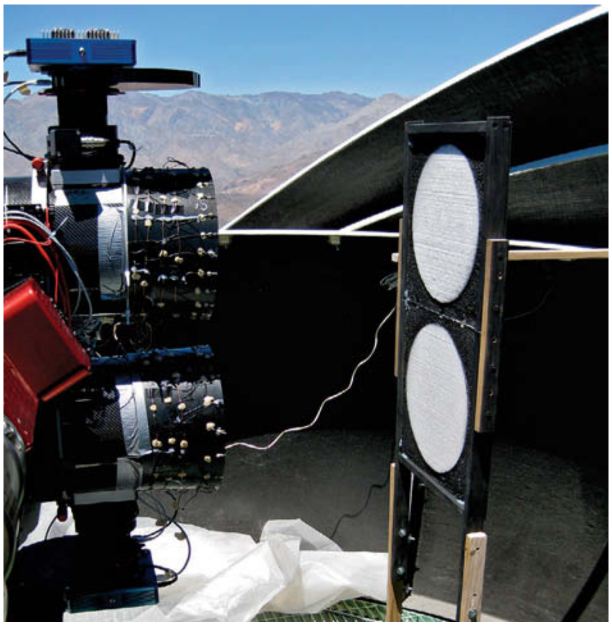
Our survey uses entirely off-the-shelf hardware. The telescopes are Astro Systeme Austria (ASA) N8 astrographs. These 8-inch f/3.6 Newtonian reflectors are well-made, solid performers, with a Wynne corrector near the focal plane to flatten the field and remove the Newtonian's inherent coma. The Apogee U16m CCD cameras use Kodak's 16-megapixel KAF-16803 detectors. Software Bisque provided long-term loan of its flagship Paramount ME, and Diffraction Limited and DC3 Dreams donated the software programs *MaximDL* and *ACP Scheduler*, respectively. Dirk Terrell of the Southwest Research Institute provided the control computer.

The Northern Hemisphere system is currently installed at Tom Smith's Dark Ridge Observatory near Weed, New Mexico. The Southern Hemisphere APASS system is at Cerro Tololo Inter-American Observatory (CTIO) in Chile, where Dan Reichart (University of North Carolina) is loaning us an empty dome and spare Paramount ME.

We take the longer blue exposures (through the B and g′ filters) with one astrograph while the other one is shooting the shorter redder exposures (through V, r′, and i′ filters). As such, we cover each field in the five passbands during the time it takes to obtain the two 180-second blue exposures. With the time needed for image readout and telescope slewing, it takes about 9 minutes per field to acquire the data. We can shoot between 50 and 70 fields per night, so we'll need a minimum of about 330 photometric nights to cover the sky the required four times.

The secret to APASS's productivity is its software, and it was some of the most challenging aspects of our survey. *MaximDL* and *ACP Scheduler* are designed for a single camera on a single mount. To run the twin telescopes, Terrell created a pair of virtual Windows XP operating systems on a single Linux computer. One controls a camera and the Paramount, while the other controls the second camera. Communications between them keeps both imaging systems in lockstep so that APASS doesn't move to its next field until all five exposures are completed. *ACP Scheduler* uses a list of fields created by Doug Welch





AARON LACLUYZE (2)

Described in detail in the accompanying text, each survey installation uses a pair of 8-inch astrographs riding on a single mount. A ring of LEDs mounted on each dew cap illuminates a white panel when making flat-field calibration exposures.

APASS / PROCESSING BY ALSON WONG

While the survey's principal mission is to create a massive database of star magnitudes and colors, the raw data can also be used to assemble accurate color images of the sky. This view of the well-known Double Cluster in Perseus was assembled from exposures made through the Sloan g′, r′, and i′ filters.

(McMaster University) to automatically cover as much sky as possible each night.

Data processing begins in the morning after the telescopes are done imaging. The exposures are calibrated with master dark frames and flat fields on the local Linux computer. Custom software does the star finding and photometry, producing a star list for each image. These are transferred via the internet to the AAVSO's headquarters in Cambridge, Massachusetts, where additional software astrometrically calibrates each star list using UCAC3. The software also uses Landolt and SDSS standards recorded each night to photometrically calibrate the star lists. Stephen Levine (Lowell Observatory) is volunteering his time to handle much of the processing at AAVSO headquarters. The final step is to integrate the star lists with a master photometry database, from which ancillary programs form mean magnitudes for each object and make them available to the world.

Transferring star lists is a much more efficient way of sending data than transferring images. Each night, APASS acquires about 16 gigabytes of images. Transferring this much data to headquarters via our internet connection would take about 30 hours. The compressed star lists only take about 30 minutes. We are also permanently archiving the original and processed images by swapping 1.5-terabyte external drives on the control computers and mailing them to headquarters on a bimonthly schedule.

APASS has been running in New Mexico since December 2009, and has made more than 80 million individual measurements of stars. As of February 2011, approximately 5,000 square degrees of the northern sky have been covered at least twice. The APASS system at CTIO was installed in November 2010 and is progressing rapidly through the southern sky. We have had two data releases totaling 8 million stars from both hemispheres. They are available on the AAVSO website.

While the catalog is being used to create photometric sequences for variable stars in the AAVSO program, professionals are also using it to calibrate photographic plates, to provide flux calibration for multi-object spectrographs, to establish standard stars for multi-night asteroid photometry, and for monitoring bright Cepheid variables with multiple filters. School classrooms can use the data to study galactic reddening, do star counts in different directions, and to map the extent of open clusters, just to give a few examples. We welcome readers to contact the AAVSO if they want to learn more about how they can join in the fun! ✦

A professional astronomer specializing in observing, instrumentation, and software, ***Arne Henden*** *became director of the AAVSO in 2005.*

New Product Showcase

S&T: SEAN WALKER

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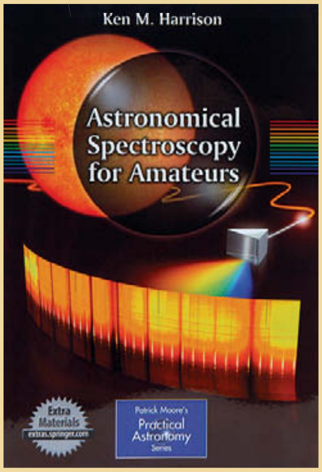
◀ **DOUBLE FILTER WHEEL** Finger Lakes Instrumentation releases its new CenterLine CL1-10 Filter Wheel ($2,495) for large-format CCD cameras. The CL1-10 incorporates two overlapping 5-position filter wheels that hold up to ten 50-millimeter-square filters. The unit's symmetrical design and centrally located aperture evenly distributes mass and eliminates the offset weight problems associated with most filter wheels. Measuring 13½ by 11 inches, the filter wheel's symmetrical design is ideal for shooting at prime focus on large astrographs. It's powered by two internal stepper motors and TruMotion synchronous belts. The internal wheels are supported by ball bearings that provide smooth, quiet, and repeatable operation. The CL1-10 attaches to your CCD camera via a zero-tilt adapter custom machined to fit your particular camera, and is controlled via a USB-2 connection.



S&T: SEAN WALKER

SPECTROSCOPY FOR AMATEURS
Springer, 241 pages
ISBN 978-1-4419-7238-5

Ken M. Harrison's new book *Astronomical Spectroscopy for Amateurs* ($34.95) is a complete guide for people interested in producing real science with their telescopes. Harrison takes the reader through a history of spectroscopy, and presents a thorough explanation of the theory of spectra. Sections include descriptions of the various designs of spectroscopes available today, as well as designs you can build yourself. The author also includes instructions on processing spectroscopic data captured with CCD and DSLR cameras, and gets you started with a series of projects that will produce scientifically useful data.

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Fred Schaaf
Northern Hemisphere's Sky

A Star by Any Other Name

Why are some stars singled out with proper names?

In last month's column I discussed celebrating the 25/50 anniversary of Halley's Comet (25 years since its last return, 50 years until its next).

In commemoration, why not try to observe an object that Halley's Comet passed near in April 1986: the great globular cluster Omega Centauri? It had been cataloged as a star for more than a millennium before Edmond Halley first realized that it's actually a cluster. Late spring is a good time for northerners to try to catch it transiting just above the south horizon after nightfall. I've seen it from almost 41° north, and a bit farther north is possible.

Another object connected with Halley and his comet is the far-south star Beta Carinae, also called Miaplacidus, which lies in Halley's now-forgotten constellation Robur Carolinum (Charles' Oak). The head of Halley's Comet will pass in front of this 1.7-magnitude star on May 8, 2134, one day after the comet's closest approach to Earth since 837.

But Halley's Comet is not my main topic in this column. Instead, we're going to discuss some of the constellations and named stars at the times listed for our all-sky map on page 44, which we can call the Arcturus Hour.

Naming names at the Arcturus Hour. Zero-magnitude Arcturus dominates its constellation Boötes, 1.0-magnitude Spica its constellation Virgo. To the left (east) of Boötes are the semi-circle of Corona Borealis the Northern Crown, Hercules, and then ascending stars of the Summer Triangle (brilliant Vega, Deneb and Altair). To the left of Spica is faint Libra the Scales and (low in the south-southeast) blazing Scorpius the Scorpion.

TUNÇ TEZEL

Here's what the great globular cluster Omega Centauri looks like through binoculars when it's 1° above the horizon.

I'll survey a few of these constellations in an unusual way — on the basis of the proper names of their stars.

We soon find that being part of the zodiac increases a constellation's chance of having many stars with proper names. *A Dictionary of Modern Star Names*, by Paul Kunitzsch and Tim Smart (SkyandTelescope.com/k&s), lists names for six stars in dim but zodiacal Virgo: Spica or Azimech, Zavijava, Porrima, Vindemiatrix or Almuredin, Zaniah, and Syrma (respectively Alpha, Beta, Gamma, Epsilon, Eta, and Iota Virginis).

Some non-zodiacal constellations also have many named stars. Kunitzsch and Smart list seven for Boötes: Arcturus, Nekkar, Seginus, Izar or Pulcherrima, Muphrid, Alkalurops, and Merga — respectively Alpha, Beta, Gamma, Epsilon, Eta, Mu, and h Boötis. Non-zodiacal Hercules is dim but named for the most famous hero in Greek mythology, so it has at least five named stars: Rasalgethi, Kornephoros or Rutilicus, Marsic, Maasym, and Cujam (respectively Alpha, Beta, Kappa, Lambda, and Omega Herculis). And being in the zodiac doesn't save dim Libra from having only two well-known star names: the unforgettable Zubenelgenubi and Zubeneschamali (Alpha and Beta Librae).

But the advantage of being in the zodiac is undeniable: spring's very dim Cancer has four named stars, autumn's dim Capricornus and Aquarius about 10 between them.

Don't forget that each of these named stars is also a sun of its own, worthy of our closer observation. Some are particularly interesting — such as Porrima, Gamma Virginis, the wonderful double star that is Saturn's close companion throughout June 2011 (see page 48). Indeed, we should be fascinated during the several years Saturn takes to traverse long Virgo to watch its progress past the constellation's named stars near the ecliptic: first Zavijava, then Zaniah, Porrima, and Spica. But between Porrima and Spica the planets pass another notable star, Theta Virginis. In his classic work *Star Names: Their Lore and Meaning*, Richard Hinckley Allen wrote: "Moderns have no name for it, but in the *Surya Siddhanta* it was Apami-Atsa, the Child of the Waters." ✦

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


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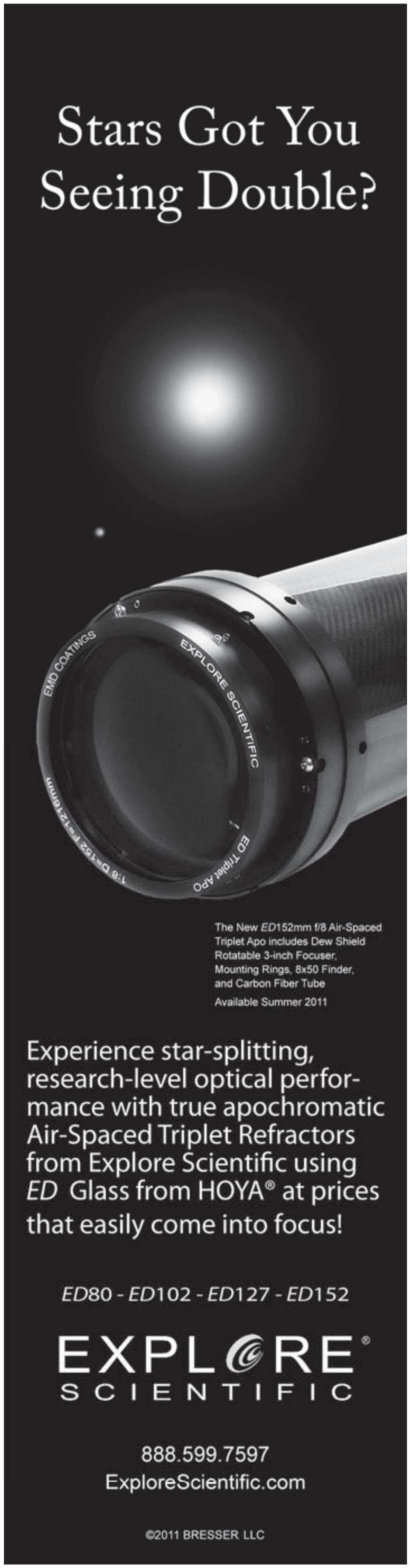
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MOON PHASES

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		

PLANET VISIBILITY

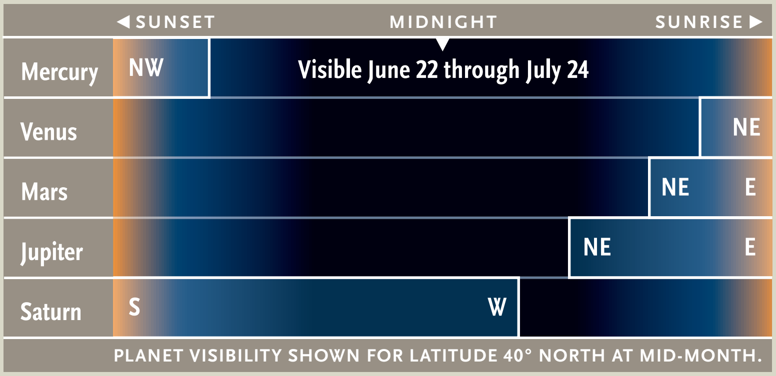


IMAGE BY TONY FLANDERS

SUNRISE, SUNSET, AND TWILIGHT last longest around the summer solstice. Make sure you find time to savor them fully!

June 2011

1 NEW MOON (5:03 p.m. EDT). A partial eclipse of the Sun is visible over much of the Arctic. Parts of Japan, Alaska, and the Canadian Maritimes also experience a very slight partial eclipse; see SkyandTelescope.com/2011Jun01.

3–5 DUSK: In North America, the waxing crescent Moon is below Castor and Pollux, the Twin Stars, on June 3rd, between Procyon and the Twin Stars on the 4th, and left of the Twin Stars on the 5th, as shown on page 48.

6–12 EVENING: Saturn makes its closest approach to the fine double star Gamma Virginis (April issue, page 56). They're less than 16′ apart, visible in a single telescopic field of view at 180× — or higher with a wide-angle eyepiece.

8 FIRST-QUARTER MOON (10:11 p.m. EDT).

9–11 EVENING: The waxing gibbous Moon passes below Saturn and Spica, as shown on page 48.

14 Evening: Antares is right of the Moon.

15 FULL MOON (4:14 p.m. EDT). A total lunar eclipse is visible over all of Africa and Australia, most of Asia, and parts of Europe and South America; see SkyandTelescope.com/2011Jun15.

19–22 PREDAWN: Mars (magnitude +1.4) and the Pleiades fit in the same 5° binocular field of view. Look for them low in the east-northeast about 25° lower left of much brighter Jupiter.

21 THE LONGEST DAY of the year in the Northern Hemisphere. Summer begins at the solstice, 1:16 p.m. EDT.

23 LAST-QUARTER MOON (7:48 a.m. EDT).

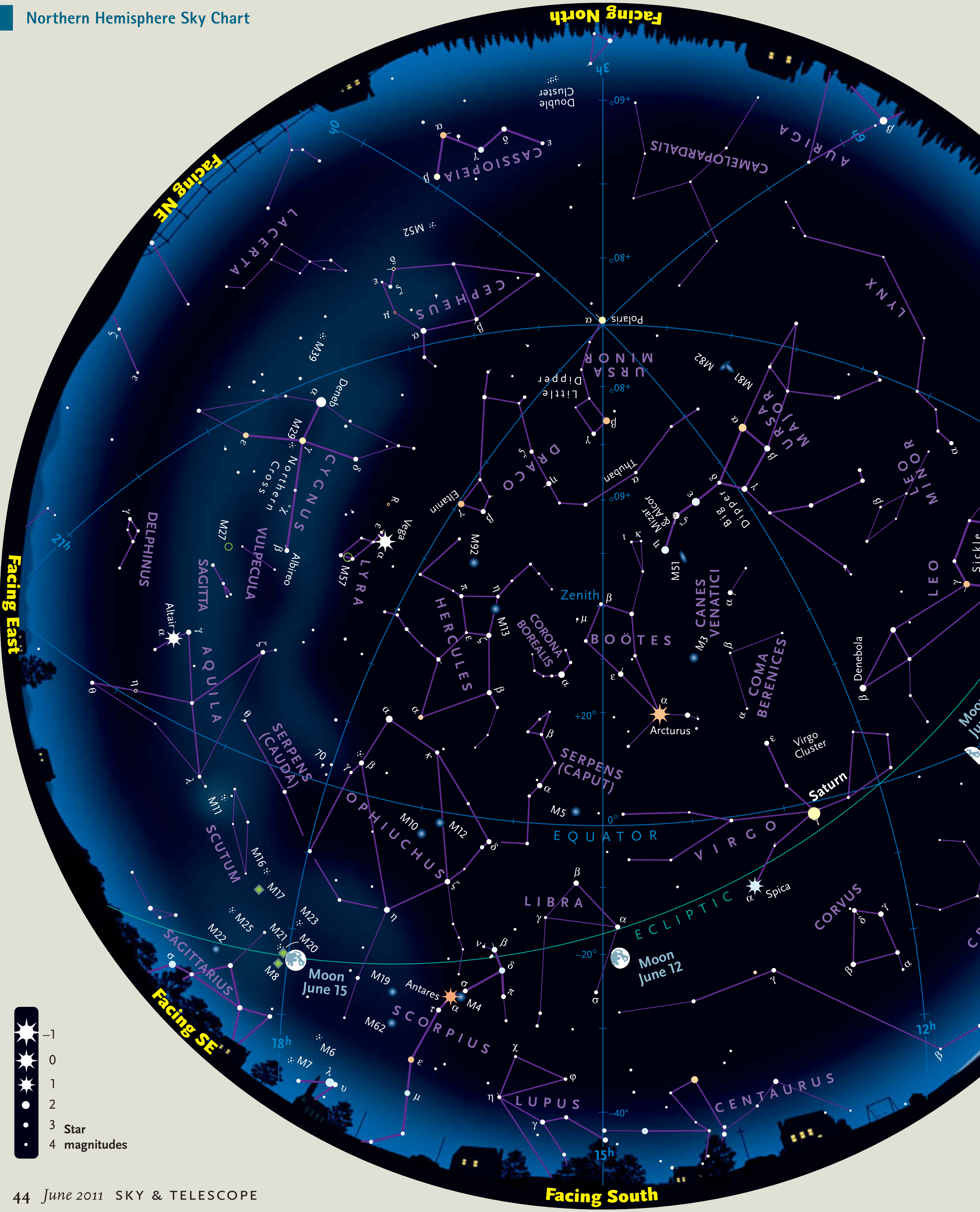
28 DAWN: Look above and below the thin crescent Moon for the Pleiades and Mars, respectively. The view is best about an hour before sunrise.

29 DAWN: The very thin crescent Moon forms a triangle with Mars and Aldebaran. The best views are about 45 minutes before sunrise.

30 DAWN: North Americans can search for an extremely thin crescent Moon 1° to 3° lower left of Venus just above the east-northeastern horizon starting a half hour before sunrise, as shown on page 49. Clear air and a completely unobstructed horizon are essential, and binoculars will be a huge help.

DUSK: Mercury forms a straight line with fainter Castor and Pollux low in the west-northwest 45 minutes after sunset.

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


Facing North
Facing NE
Facing East
Facing SE
Facing South
Double Cluster
CASSIOPEIA
CAMELOPARDALIS
AURIGA
LACERTA
M52
CEPHEUS
LYNX
Polaris
URSA MINOR
Little Dipper
M82
M81
URSA MAJOR
M39
Deneb
M29
Northern Cross
CYGNUS
DRACO
Thuban
Eltanin
Mizar & Alcor
Big Dipper
LEO MINOR
Vega
LYRA
M57
M27
VULPECULA
Albireo
SAGITTA
DELPHINUS
M92
M51
CANES VENATICI
LEO
Sickle
Zenith
HERCULES
M13
CORONA BOREALIS
BOÖTES
M3
COMA BERENICES
Denebola
Altair
AQUILA
Arcturus
Virgo Cluster
SERPENS (CAUDA)
SERPENS (CAPUT)
Saturn
M11
SCUTUM
OPHIUCHUS
M10
M12
M5
EQUATOR
VIRGO
M16
M17
LIBRA
Spica
ECLIPTIC
CORVUS
M23
M25
M21
M20
M22
M8
SAGITTARIUS
Moon June 15
M19
Antares
M4
Moon June 12
M62
SCORPIUS
M6
M7
LUPUS
CENTAURUS
18h
15h
12h
21h
0h
3h
6h
+20°
0°
–20°
–40°
+60°
+80°
–1
0
1
2
3
4
Star magnitudes

Using the Map

WHEN

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

*Daylight-saving time.

HOW

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

Example: Rotate the map so that "Facing NW" is at the bottom. About two-thirds of the way from there to the map's center is the Big Dipper. Go out, face northwest, and look two-thirds of the way up the sky. There's the Dipper!

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

Watch a SPECIAL VIDEO

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

Binocular Highlight: M104 and the Crow

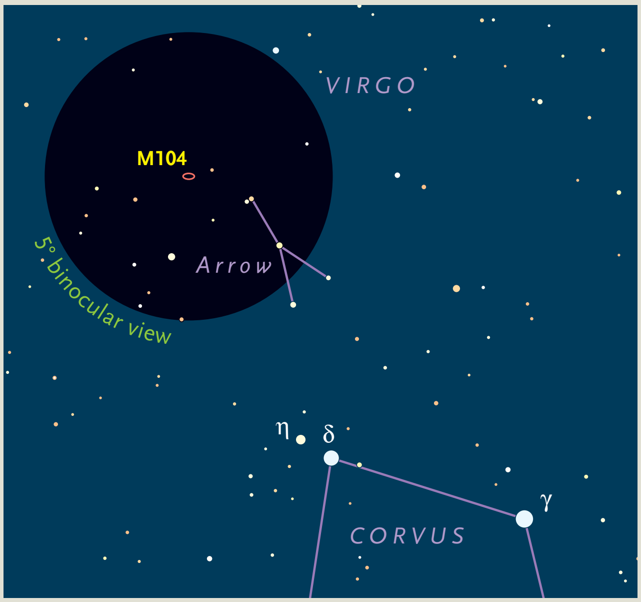
Although the constellations have precisely defined boundaries, this isn't apparent when viewing the actual sky. Indeed, when it comes to finding our away around, it's often simpler to associate some objects with the "wrong" constellation. Galaxy **M104** is a good example. Technically it belongs to the constellation Virgo, yet for me it's the prize possession of Corvus, the Crow.

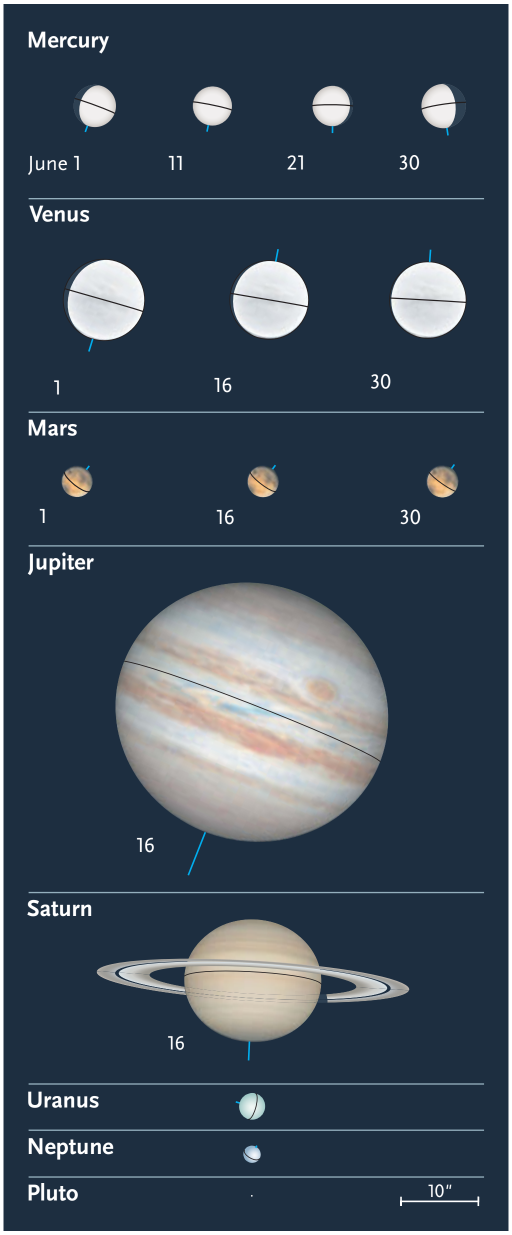
The easiest (and most visually interesting) route to M104 is to begin with the attractive binocular pair of Delta (δ) and Eta (η) Corvi. Just north of these stars we come to an arrow-shaped asterism of 6th-magnitude stars. Look closely at the topmost star in the arrow. In my 10×50s, I can resolve it into three components. Our target galaxy is just a little northeast of this triple.

M104 is a nearly edge-on galaxy, widely known as the Sombrero Galaxy from its appearance in big telescopes and in photographs. An outlying member of the Virgo Cluster, M104 is one of the easier binocular targets in that collection. However, the galaxy is not exactly a "gimme" — especially if your skies are brightened by light pollution.

At magnitude 7.9, M104 isn't particularly faint, but because of its proximity to a handful of field stars, discerning the galaxy's full extent can be a tricky proposition. In 10×50s, the galaxy appears obviously wider along its east-west axis. The impression of elongation is enhanced by groupings of stars on either side of M104 and a faint star just to its west. I can separate the star from the galaxy if I resort to using my 15×70s, but otherwise it tends to merge with M104's glow. ✦

— *Gary Seronik*



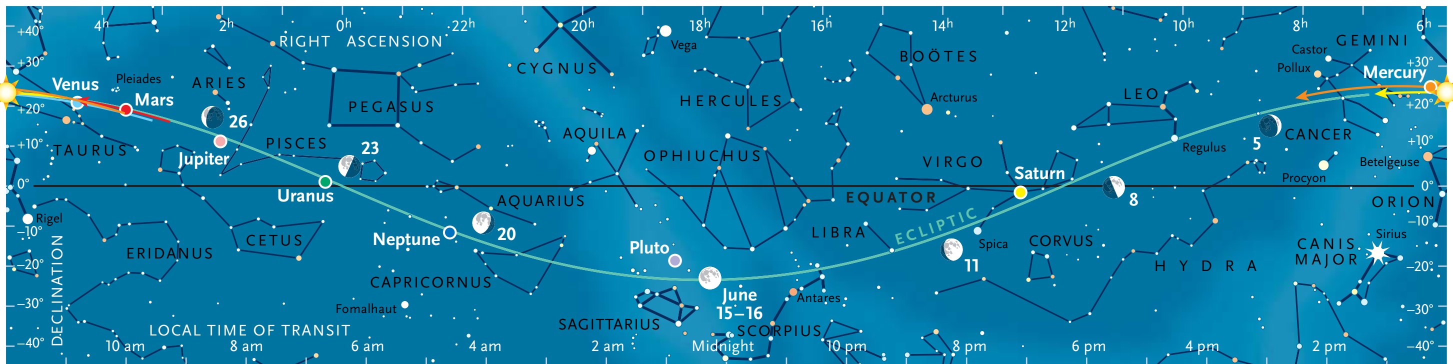


Sun and Planets, June 2011

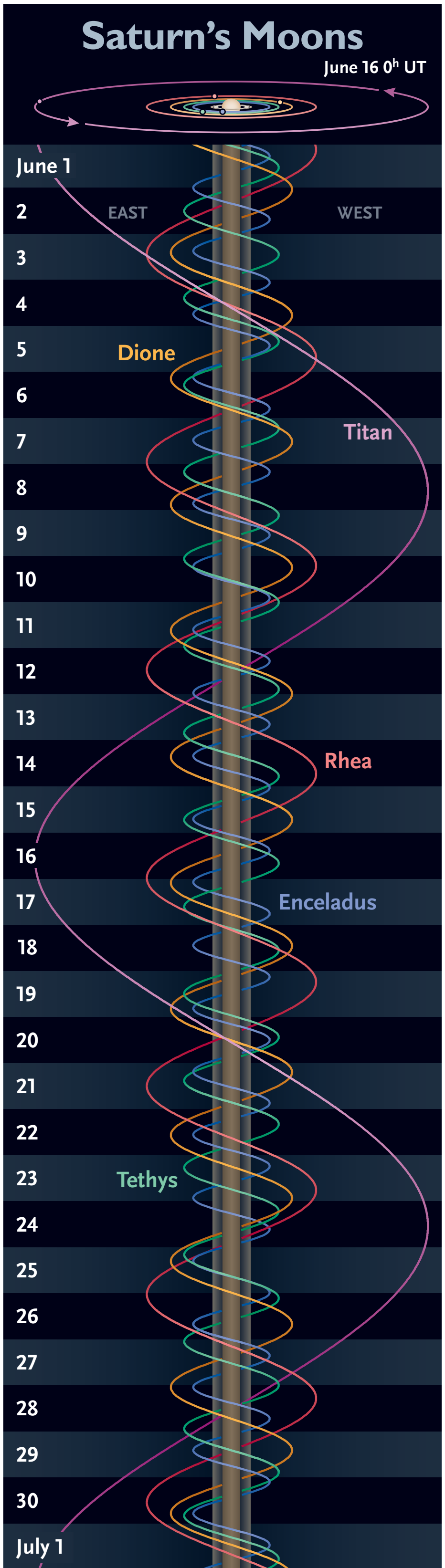
	June	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	4^h 33.6^m	+21° 57′	—	–26.8	31′ 33″	—	1.014
	30	6^h 33.7^m	+23° 13′	—	–26.8	31′ 28″	—	1.017
Mercury	1	3^h 36.8^m	+18° 09′	14° Mo	–1.0	5.5″	85%	1.226
	11	5^h 03.8^m	+23° 23′	3° Mo	–2.2	5.1″	99%	1.319
	21	6^h 38.6^m	+24° 55′	10° Ev	–1.3	5.2″	93%	1.282
	30	7^h 53.5^m	+22° 46′	18° Ev	–0.5	5.8″	77%	1.168
Venus	1	3^h 09.2^m	+16° 19′	21° Mo	–3.8	10.6″	93%	1.579
	11	3^h 58.6^m	+19° 30′	18° Mo	–3.8	10.3″	95%	1.617
	21	4^h 49.8^m	+21° 50′	15° Mo	–3.8	10.1″	96%	1.650
	30	5^h 37.1^m	+23° 04′	13° Mo	–3.8	10.0″	97%	1.675
Mars	1	2^h 51.7^m	+16° 00′	25° Mo	+1.3	4.1″	98%	2.284
	16	3^h 35.7^m	+19° 02′	28° Mo	+1.4	4.1″	97%	2.257
	30	4^h 17.2^m	+21° 14′	32° Mo	+1.4	4.2″	97%	2.226
Jupiter	1	1^h 49.8^m	+10° 06′	41° Mo	–2.1	34.8″	100%	5.671
	30	2^h 10.9^m	+11° 57′	63° Mo	–2.2	37.0″	99%	5.327
Saturn	1	12^h 42.3^m	–1° 43′	120° Ev	+0.8	18.3″	100%	9.078
	30	12^h 42.6^m	–1° 52′	93° Ev	+0.9	17.4″	100%	9.536
Uranus	16	0^h 16.5^m	+0° 59′	80° Mo	+5.9	3.5″	100%	20.232
Neptune	16	22^h 11.9^m	–11° 43′	114° Mo	+7.9	2.3″	100%	29.587
Pluto	16	18^h 26.7^m	–18° 47′	167° Mo	+14.0	0.1″	100%	31.054

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-June; 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.



The wavy lines represent five of Saturn's satellites; the vertical bands are Saturn's globe and rings. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). The ellipses at top show the actual apparent orbits; the satellites are usually somewhat north or south of the ring extensions.

Fred Schaaf
Sun, Moon, and Planets

Giant Planets at Dusk and Dawn

Saturn and Jupiter are best viewed at opposite ends of the year's shortest nights.

JUNE 2011 OFFERS eclipses for many people (though not most North Americans) and interesting planetary sights for all.

The partial solar eclipse on June 1st happens mostly across the Arctic, but a tiny bite out of the Sun can be seen as far south as northern Japan, central Alaska, and parts of the Canadian Maritimes. June 15th's very long and deep total eclipse of the Moon is visible at least in part almost everywhere *except* North America. See SkyandTelescope.com/2011Jun01 and SkyandTelescope.com/2011Jun15 for details on both eclipses.

Saturn is fairly high in the south-southwest at nightfall for almost everyone on Earth. In contrast, the four planets that gathered at dawn in May are still mostly very low for observers at mid-northern latitudes — and now they're scattering. One of the participants, Mercury, drops out of the morning twilight and peeks up in dusk toward the end of June. The other three (Jupiter, Mars, and Venus) are spread from moderate height in the east (Jupiter) down to very low in the east-northeast (Venus) in the dawn skies of June.

DUSK AND EVENING

Mercury is brightest (magnitude –2.3) at superior conjunction on the night of June 12–13, but that's when it's unobservable almost directly behind the Sun. Skywatchers at mid-northern latitudes should be able to see Mercury in the evening sky without optical aid starting around June 22nd — the beginning of a long but rather low apparition. By month's end Mercury has faded to magnitude –0.5, but it's far enough from the Sun to remain about 5° above the west-northwestern horizon 45 minutes after sunset. On that last day Mercury forms a nearly perfect straight line with Pollux and Castor, as shown on the facing page.

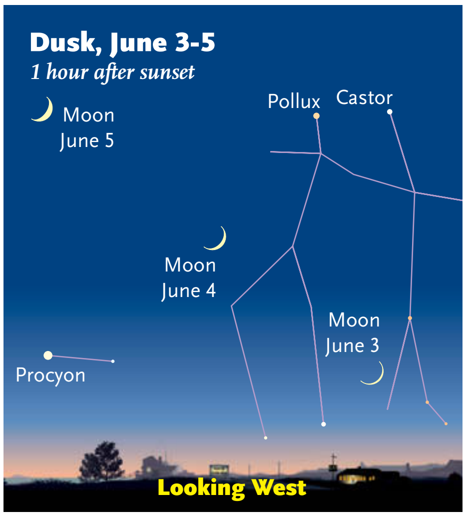
Saturn shines at magnitude +0.8 about halfway up the south sky at dusk as June begins. It appears a little lower each evening, but even at month's end it's still 30° up in the southwest as the sky grows fully dark. The rings reach a minimum tilt of 7.3° from edgewise in early June, but they will open up to 10° by mid-September, when Saturn finally disappears into the sunset glow.

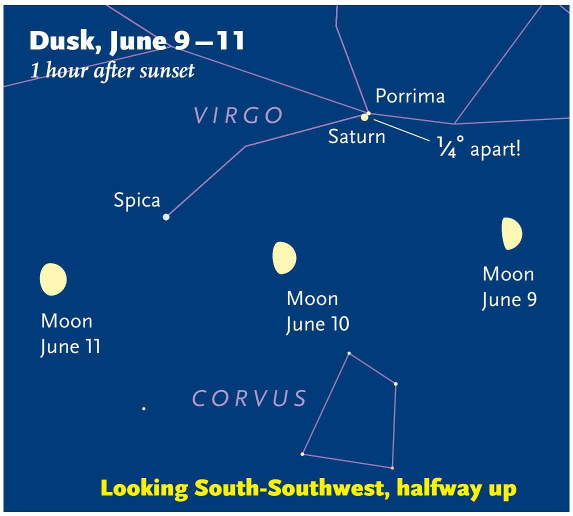
Saturn halts retrograde motion (westward relative to the stars) on June 14th and then begins direct motion (eastward). But this turnabout is slow so that Saturn this month stands almost motionless among the stars — and in a very interesting place. Saturn spends the entire month within ½° of the 3rd-magnitude double star Gamma Virginis (Porrima) — with planet and star separated by as little as ¼° around June 11th. This month offers a rare opportunity to use moderately high magnification and see the double star (separation only 1.7″) split in the same field of view as Saturn's globe and rings.

MIDNIGHT TO DAWN

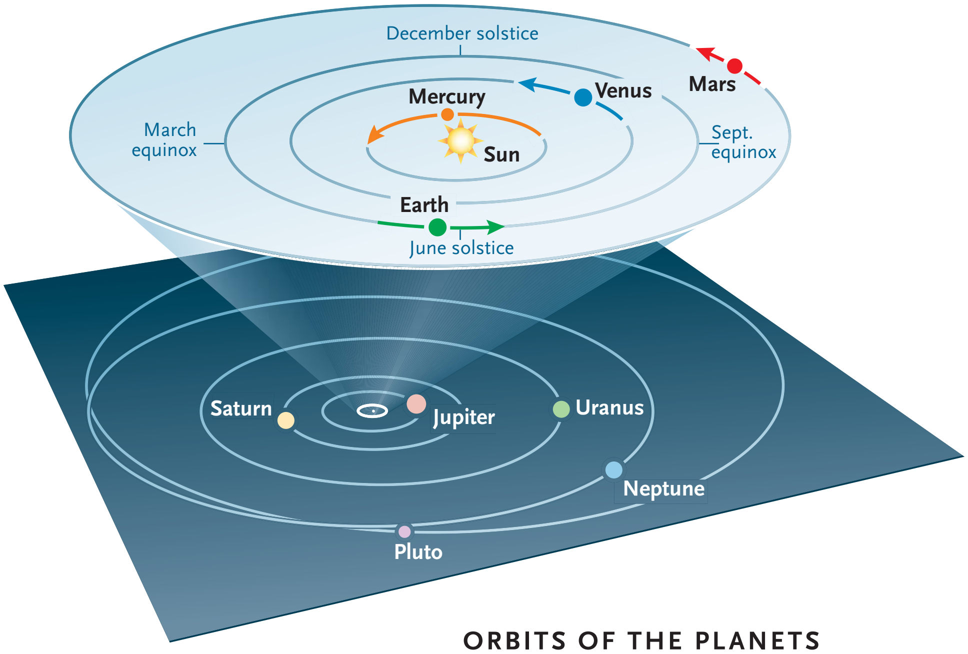
Pluto, in Sagittarius, reaches opposition on June 28th, so it's highest in the south in the middle of the night, around 1 a.m. daylight-saving time. You will probably need at least an 8-inch telescope in very dark skies to pick this 14th-magnitude world out of the rich Milky Way star fields.

Uranus and **Neptune** are in Pisces and Aquarius, respectively. Both are reasonably high in the predawn sky, and easy to find with a telescope and the charts at SkyandTelescope.com/uranusneptune.





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.



ORBITS OF THE PLANETS

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

DAWN

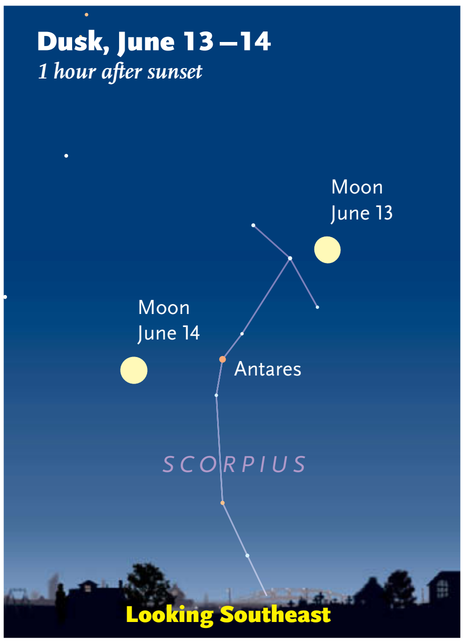
Jupiter shines at magnitude –2.1 or –2.2 near the southwestern corner of Aries. It rises about 2 hours before the Sun on June 1st and almost 4 hours before sunup on June 30th. But the best time to observe it telescopically is when it's higher, in morning twilight.

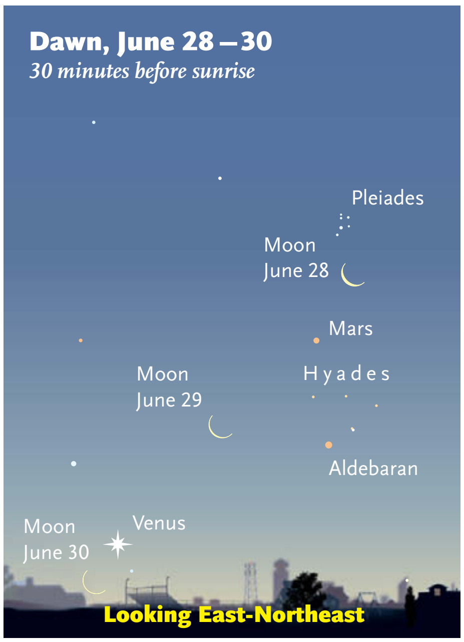
That's also when you can see much fainter **Mars** (magnitude +1.3 or +1.4) far to Jupiter's lower left. And if you wait until a half hour before sunrise, you can also see **Venus** shining at magnitude –3.8 to Mars's lower left. This long line of worlds is the last remnant of May's amazingly compact four-planet congregation.

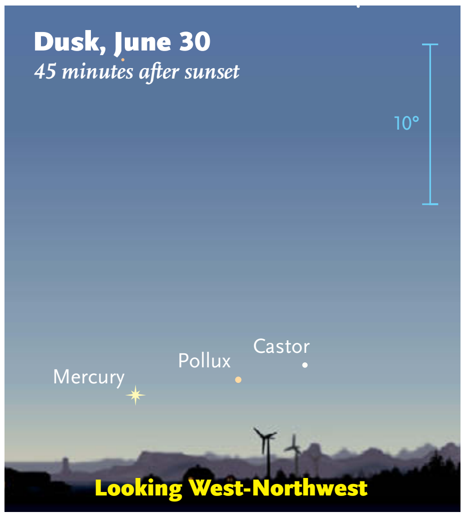
MOON AND SUN

The waxing crescent **Moon** passes through Gemini during evening twilight on June 3rd and 4th and below Regulus on the 6th and 7th. The waxing gibbous Moon poses below Saturn and Spica from June 9–11 and is left of Antares on June 14th, the day before full Moon. A slender waning lunar crescent shines between the Pleiades and Mars on the morning of June 28th. It forms a triangle with Aldebaran and Mars the next morning. Finally, about 30 minutes before sunrise on June 30th, an ultrathin Moon is close to the lower left of Venus.

The **Sun** arrives at the June solstice at 1:16 p.m. EDT on June 21st, starting summer in the Northern Hemisphere and winter in the Southern Hemisphere. The Sun and Moon are involved in two June eclipses, as described above. ✦







The Best Lunar Map So Far

NASA's LRO mosaic shouldn't spell the end to lunar observing.

THE MOON WAS THE FIRST object other than Earth that spacecraft visited at the dawn of the space age. There have been nearly 50 missions to study the Moon since Luna 2 arrived in 1959, but only now are high-quality image maps of our entire satellite becoming available.

Up until 1960 there were mostly hand-drawn maps and a few photographic atlases of the side visible from Earth, but the far side was completely unknown. Various lunar spacecraft gradually provided images of the entire far side, but it wasn't until the Clementine mission in 1994 that a single spacecraft imaged nearly the entire surface. Unfortunately, most Clementine images were obtained under full Moon lighting conditions, so surface topography was poorly represented with the exception of the poles.

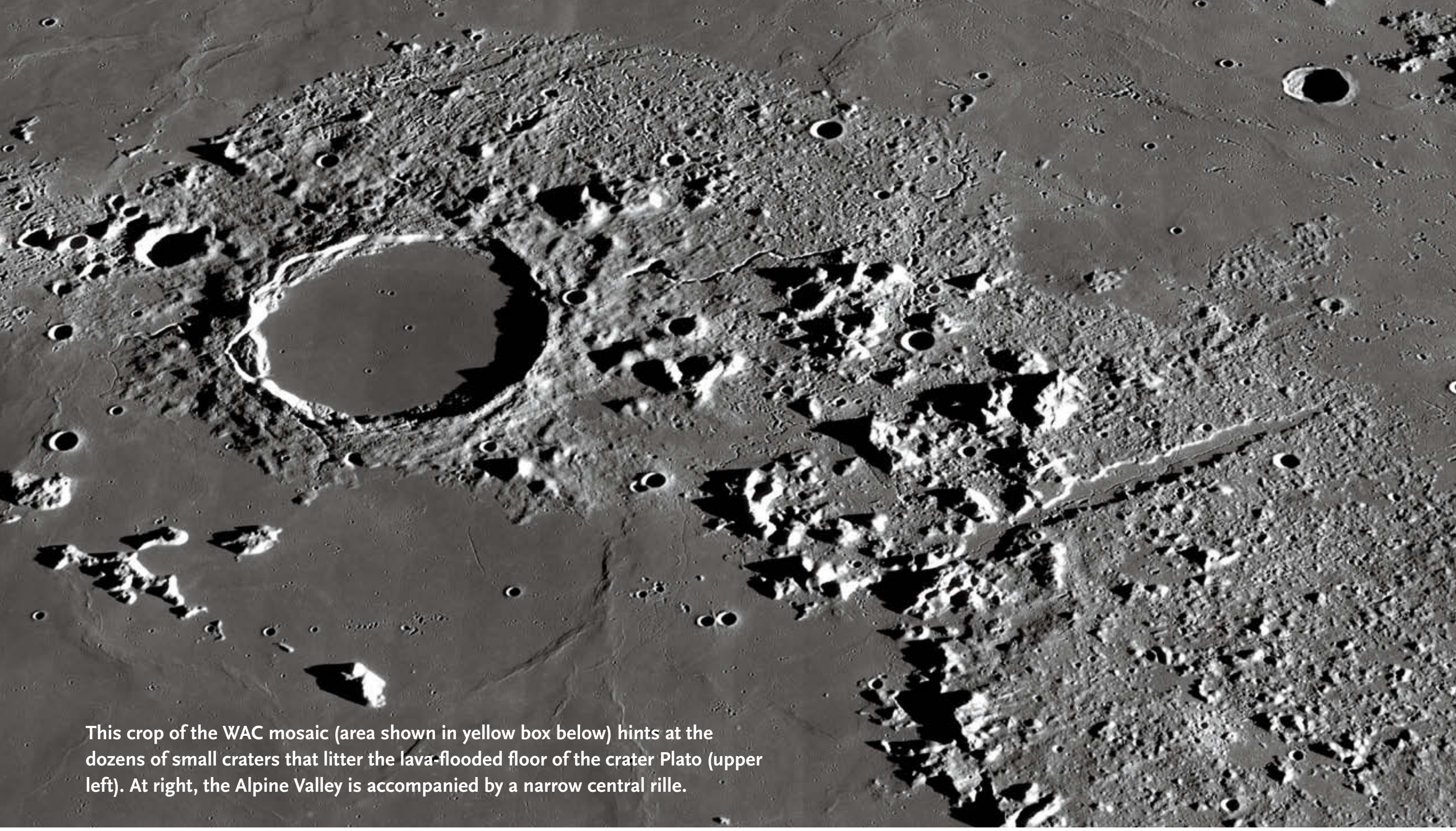
In the mid-2000s, Europe, China, India, and Japan each sent orbiters to the Moon, but none of these missions thus far have produced high-resolution mosaics of the entire surface. Finally, there is a magnificent new mosaic of the nearside that was obtained by NASA's Lunar Reconnaissance Orbiter (LRO). This spacecraft is equipped with a high-resolution camera that reveals objects on the lunar surface only a few feet across. This Narrow Angle Camera (NAC) has captured well-publicized images of all the Apollo landing sites and most of the Soviet landers, as well as millions of extreme close-up views of the lunar surface.

Lesser known until now is the spacecraft's smaller Wide Angle Camera (WAC), which records broad views yielding resolution of roughly 500 feet per pixel. For a two-week span during December 2010, WAC captured images under a nearly constant illumination angle. Scientists have combined the images into a massive mosaic depicting the entire near side of the Moon. The image is so large that whenever it is printed, its scale is reduced so much that the splendid detail it shows is lost. Fortunately, the LRO team at Arizona State University has found a way around this. Its website displays the mosaic in a zoomable browser (http://wms.lroc.asu.edu/lroc_browse/view/wac_nearside) that allows easy viewing and enlargement of any place on the nearside. You should try it, because you will see the Moon as never before.

Viewing the Moon at 500-foot resolution — about 8 to 10 times sharper than the best visual observations possible from your backyard — is best appreciated by starting at a familiar location. Most observers are familiar with **Plato** and know that if they can detect a few of the largest craters on its floor, that the seeing is pretty good and their telescope optics are in collimation. The WAC mosaic reveals more than 100 craters within Plato. Farther east, the central rille that we strain to observe on the floor of the Alpine Valley is clearly shown along with many small impact craters, a ridge or two, and small offsets. You may, as I did, spend nearly an hour just cruising

NASA / GSFC / ARIZONA STATE UNIVERSITY

NASA's Lunar Reconnaissance Orbiter spent mid-December 2010 shooting a complete mosaic of the Moon's Earth-facing hemisphere with its Wide Angle Camera (WAC). Each of the 1,300 image strips used to create this 560-megapixel map were recorded at a similar illumination angle to reveal shallow topographical features.



This crop of the WAC mosaic (area shown in yellow box below) hints at the dozens of small craters that litter the lava-flooded floor of the crater Plato (upper left). At right, the Alpine Valley is accompanied by a narrow central rille.

NASA / GSFC / ARIZONA STATE UNIVERSITY

across this mosaic, zooming in to reveal unprecedented detail on features that caught my interest. If you ever tire of this nearside mosaic, there are also six additional new mosaics of the Moon centered at 60° increments, each recorded at roughly 100-meter (330-foot) resolution (http://lroc.sese.asu.edu/news/index.php?/archives/345-Farside!-And-all-the-way-around.html).

You may look at these spectacular mosaics with both a sense of awe and disappointment. Is the 400-year period of telescopic observation of the Moon at an end? Is there any useful telescopic work left for amateurs to do? The answers are no and yes. Amateurs won't detect any small features that aren't depicted in this and other LRO mosaics. But observers can still usefully monitor the Moon for impact flashes, helping to refine the present bombardment rate. High-resolution telescopic imaging near the terminator may detect low slope features not seen on the present mosaic. But the most satisfying reason to observe the Moon is to increase your personal understanding of the origin and evolution of its surface. ✦

WAC mosaic or not, ***Chuck Wood*** *continues to observe the Moon with his four backyard telescopes.*

The Moon • June 2011

Phases

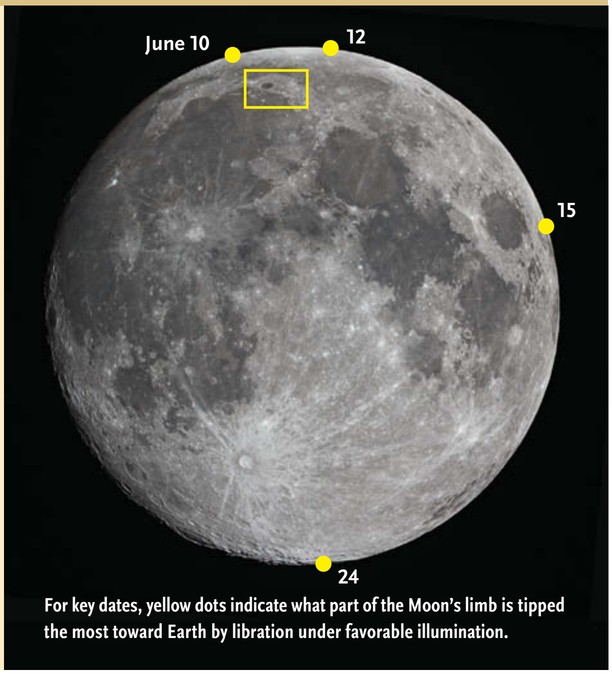
New Moon	June 1, 21:03 UT
First quarter	June 9, 2:11 UT
Full Moon	June 15, 20:14 UT
Last quarter	June 23, 11:48 UT

Distances

Perigee	June 12, 2^h UT
226,380 miles	diam. 32′ 48″
Apogee	June 24, 4^h UT
251,560 miles	diam. 29′ 31″

Librations

Byrd (crater)	June 10
Nansen (crater)	June 12
Neper (crater)	June 15
Drygalski (crater)	June 24



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

Binocular Sights for City Nights

HUGH BARTLETT

Plan well, and even a light-polluted sky offers riches for binocular astronomy

WHEN I GOT MY first telescope, I always brought along modest (8×42) binoculars to locate my targets in wide fields before narrowing in with the scope. Over the years my telescopes grew larger and more expensive. But those original binoculars still accompany me on every observing session. At home they stand by the door and remain one of my favorite ways to view the night sky. Often, when I don't have the time to set up a telescope, I use them to scan for familiar targets — and often chance upon an intriguing double star or an interesting pattern to add to my list of celestial sights that are visible with binoculars through light-polluted skies.

Here then is the fourth and last in my series on binocular showpieces, both famous and unfamiliar, for light-polluted observers who may not realize how much there really is to see even under poor conditions.

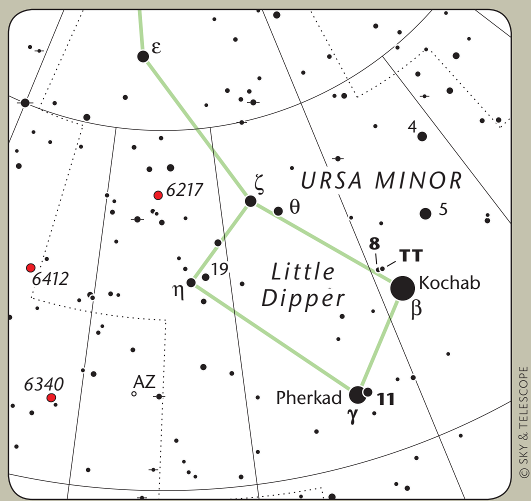
The photos here serve as finder charts for many of the sights, but every amateur astronomer needs at least one detailed star atlas. For binocular observing I like the *Pocket Sky Atlas*. It's compact, inexpensive, and it shows all stars to magnitude 7.6 with hundreds of deep-sky objects to magnitude 10, 11, or 12 depending on type. The descriptions here give each object's right ascension, declination, and *Pocket Sky Atlas (PSA)* chart number.

***Hugh Bartlett** shares the sky with the public at the Chabot Space and Science Center in Oakland, California. You can e-mail him at hughandmaret@earthlink.net.*

Gamma and 11 Ursae Minoris — **Star pair and more**
R.A.: 15^h 21^m — **Dec: +71.8°**

The third-brightest star in the Little Dipper is a fairly easy double for the unaided eye: magnitudes 3.0 and 5.0, ¼° apart. But to discern these stars' shades of amber and white, you need binoculars.

And while you're here, check the much fainter pair 8 and TT Ursae Minoris just inside the lip of the Little Dipper's bowl, 0.8° northeast of bright Kochab. They're 7th magnitude, yellow-orange and orange, 0.1° apart. TT is a semiregular variable that hardly budges from magnitude 7.0, essentially identical to 8 UMi. Will you ever catch it brighter or fainter? Labels for TT, 8, and 11 have been added to the chart below. *PSA Chart 41.*



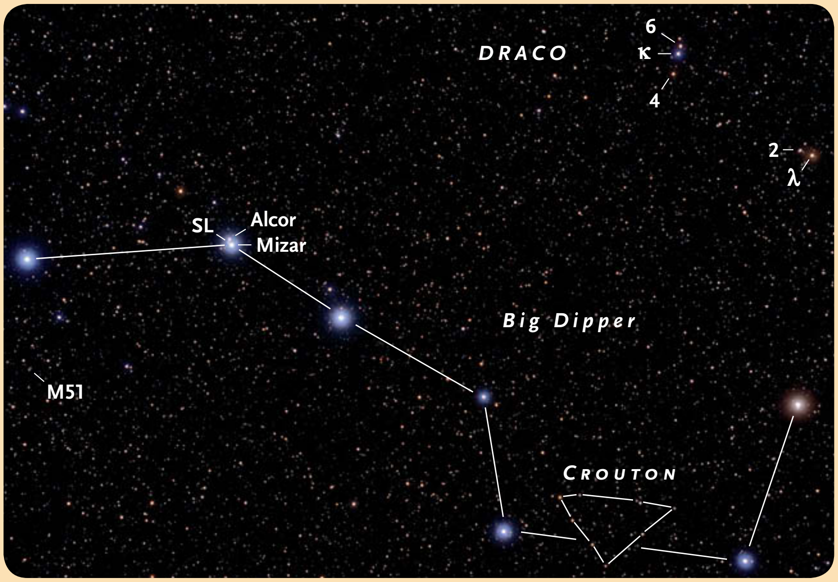
LOS ANGELES PHOTO: ISTOCKPHOTO

Mizar and Alcor **Star pair and more**
R.A.: 13h 24m **Dec: +54.9°**

Sometimes called the "Horse and Rider," this famous naked-eye pair (magnitudes 2.0 and 4.4, separation 0.2°) in the handle of the Big Dipper contains a faint binocular Easter egg. Not quite between the two is Sidus Ludovicianum, "Ludwig's Star," magnitude 7.6, remembered for an 18th-century astronomer who laid an egg by announcing to the world that it was a new, moving planet. *PSA Chart 43.*

λ and 2 Draconis **Star pair** **R.A.: 11h 31m** **Dec: +69.3°**
κ and 6 Draconis **Star pair** **R.A.: 12h 33m** **Dec: +69.8°**

These two groupings are positioned like the blown-off pieces of a pressure-cooker lid on the Big Dipper. Lambda Draconis, the Dragon's tail-tip, is orange-red with an orange companion: magnitudes 3.8 and 5.2, separation 0.4°. Kappa, blue-white, is part of a little row of four; the other three are orange. Kappa's closest companion among them is 6 Dra; magnitudes 3.8 and 5.0, separation ¼°. *PSA Chart 31.*



ALL ASTROPHOTOS COURTESY AKIRA FUJII

Sunken Crouton **Asterism**
R.A.: 11h 35m **Dec: +56°**

A little-known triangle asterism sits in the bottom of the Big Dipper's bowl like a sunken crouton in a bowl of soup. It's made of stars 5th to 7th magnitude, so it's noticeable in binoculars (with a little effort) even through a polluted sky.

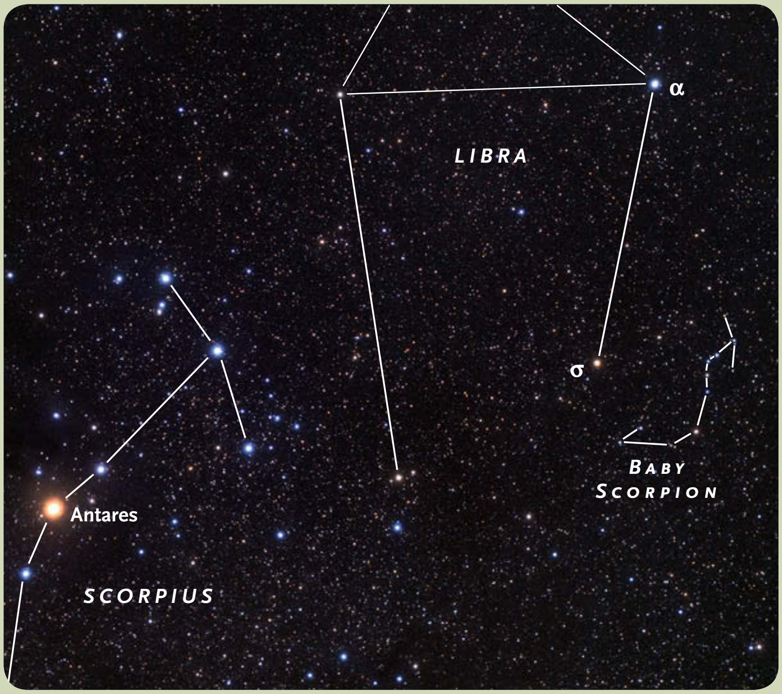
Why isn't it better known? It's not exactly eye-grabbing, but once you've found it once or twice, it's always there waiting when you scan the Dipper. How many other interesting little asterisms await your discovery with just a bit of imagination? *PSA Chart 32.*

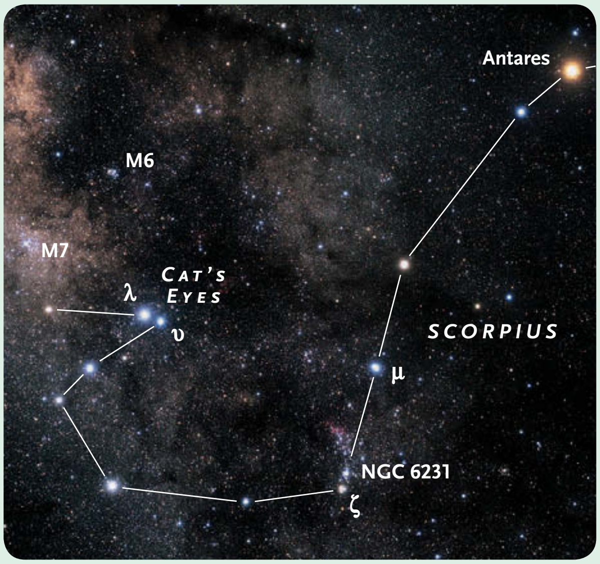
Alpha¹, Alpha² (α¹, α²) Librae **Double star**
R.A.: 14h 51m **Dec: –16.0°**

Turning to the southern sky, scan 18° (about three binocular fields) west from the top of Scorpius to find α Librae, or Zubenelgenubi (extra credit for memorizing the name). This is a wide, landmark binocular pair, magnitudes 2.7 and 5.2, yellow-white and blue-white, 231″ apart. The reason the fainter one received the α¹ designation is because it's the western of the two, and hence it was the first to cross the north-south crosshair in a star cataloger's transit telescope. *PSA Chart 57.*

The Baby Scorpion **Asterism in Hydra**
R.A.: 14h 48m **Dec: –26.1°**

From Zubenelgenubi move 10° due south to find Sigma (σ) Librae and the Baby Scorpion, with a shape reminiscent of Scorpius but only 5° long. Its stars are magnitudes 5 to 8. *PSA Chart 57.*





Mu[1], Mu[2] (μ[1], μ[2]) Scorpii — **Star pair**
R.A.: 16h 52m — **Dec: –38.0°**

This stunning white duo is the third bright star down the body of Scorpius from Antares. Magnitudes 3.0 and 3.6, separation 0.1°. *PSA Chart 58.*

Zeta[1], Zeta[2] (ζ[1], ζ[2]) Scorpii and NGC 6231 — **Star pair and more**
R.A.: 16h 54m — **Dec.: –41.8°**

One binocular field south of Mu are Zeta[1] and Zeta[2] Scorpii, blue and orange-red, magnitudes 2.6 and 3.6, 408″ apart. A third star of magnitude 6.0 lies just to their south, forming a roughly equilateral triangle with them.

North of this group by ½° lies the 5th-magnitude open cluster NGC 6231. North of there runs a curving spray of stars nearly 2° long known as Collinder 316. The whole array looks a bit like a false comet with the Zeta pair (or triple) as its head. The field is sometimes called the Scorpius Jewel Box. Too bad it's so far south! *PSA Chart 58.*

Cat's Eyes, M7 and M6 — **Star pair, open clusters**
R.A.: 17h 34m — **Dec.: –37.1°**

The brightest stars in the Scorpion's tail, Lambda (λ) and Mu (μ) Scorpii, are known as the Cat's Eyes, though the eyes are unequal and are usually seen at an odd tilt for a cat. They're bright, magnitudes 1.6 and 2.6, and 0.6° apart.

They're also the starting point for finding the big cluster M7 and the more compact cluster M6 about one binocular field (5°) to the east-northeast and north-northeast, respectively. A splendid pair of clusters near a splendid pair of stars! But again, quite far south. *PSA Chart 58.*

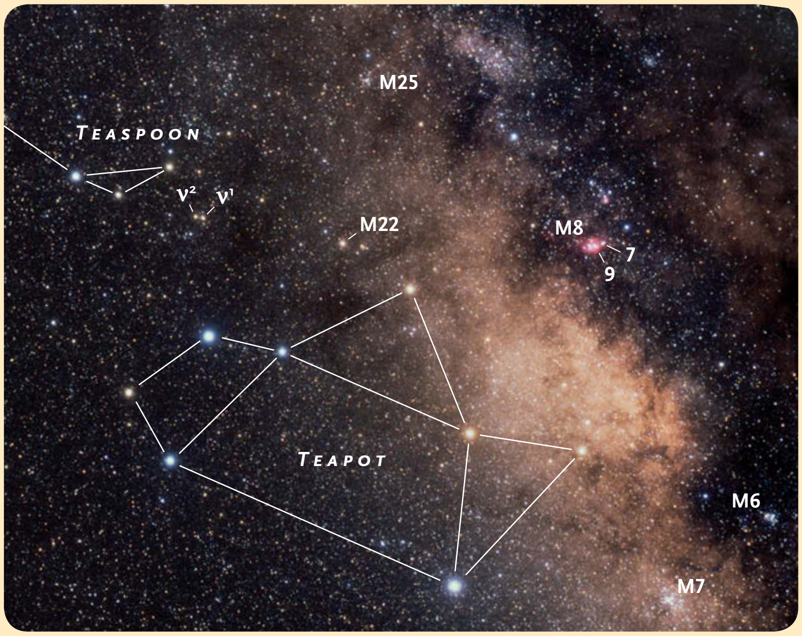
M8; 7 and 9 Sagittarii — **Nebula and stars**
R.A.: 18h 03m — **Dec: –24.4°**

The Lagoon Nebula, one of the best diffuse nebulae anywhere, can be detected in binoculars even through skyglow. It's above the puff of "steam" — the Large Sagittarius Star Cloud — rising from the spout of the Sagittarius Teapot.

Binoculars show the star 9 Sagittarii (magnitude 5.9) embedded in it, 7 Sagittarii (magnitude 5.4) just to its west, and a magnitude-6.9 star just to its east. Many fainter stars lie in and around the nebula. The whole array is more than ½° wide. *PSA Chart 67.*

M22 — **Globular cluster**
R.A.: 18h 36m — **Dec: –23.9°**

About half a binocular field (2.4°) northeast from the top of the Sagittarius Teapot lies the second-closest globular cluster, about 10,000 light-years away. At magnitude 5.1 it's a showpiece in any instrument. Binoculars show it as a hazy gray "star," brighter at its center. *PSA Chart 67.*



Nu[1], Nu[2] (ν[1], ν[2]) Sagittarii — **Double Star in Sagittarius**
R.A.: 18h 54m — **Dec: –22.8°**

Less than a binocular field (4.2°) east of M22 are these lovely yellowish twins, magnitudes 4.9 and 5.0, generously separated (by ¼°) and delicately tinted. A couple degrees farther northeast is the brighter bowl of the Sagittarius Teaspoon. *PSA Chart 67.*

 Johnny Horne

Orion Parsec 8300M

Does Orion's newest CCD camera live up to claims that it's the company's best model yet for deep-sky photographers?

ALL IMAGES COURTESY OF JOHNNY HORNE

Orion Parsec 8300M

U.S. price: $1,999.95
Orion Telescopes & Binoculars
OrionTelescopes.com; 800-447-1001

ORION Telescopes & Binoculars continues to grow its presence in the world of astronomical imaging. Today the company boasts nine models of electronic cameras. It also has a full range of imaging telescopes, equatorial mounts, and astrophotography accessories, making it the only North American manufacturer to offer all the major components necessary for a serious deep-sky setup. In the past I've reviewed Orion's StarShoot II camera (April 2008 issue, page 32) and the StarShoot Pro (February 2009, page 34). This time I had a chance to put the company's newest flagship CCD camera — the Orion Parsec 8300 — through its paces.

The Parsec is built around Kodak's 8.3-megapixel KAF-8300 chip, which features 5.4-micron pixels and an imaging area measuring 14 by 18 millimeters. The small pixels make the Parsec attractive to users of short-focus refractors and Newtonian reflectors. The chip has anti-blooming protection (to prevent streaks on bright stars), high sensitivity, and low dark current, which is further reduced by a regulated, two-stage thermoelectric cooler that can bring the chip to as much as 35° C below ambient air temperature. The camera is Orion's first to have a mechanical shutter, so you can make dark frames without

Orion's Parsec 8300 CCD camera is the company's most advanced model yet. Available with either a Kodak KAF-8300 chip for "one-shot" color or monochrome shooting, the Parsec features fan-assisted, two-stage thermoelectric cooling and a mechanical shutter. The author was particularly impressed with the images it produced, calling them by far the best he's ever made with his 33-year-old, 12½-inch telescope.

The combined weight of the camera and filter wheel require that a telescope's focuser be reasonably robust. Both devices require their own USB 2.0 computer connections, but only the camera has a 12-volt DC power cord, since the filter wheel is powered through its USB cable.

having to manually cover the telescope's aperture — a major convenience.

The Parsec is offered in two models. The 8300C is a "one shot" color camera, while the 8300M is a monochrome camera, which can be used with the optional Orion Nautilus Motorized 4″ × 2″ Filter Wheel ($449.95) and 2-inch Orion LRGB Imaging Filter Set ($349.95) to produce color images. Both cameras must be controlled by external computers via USB 2.0 connections (the Nautilus filter wheel also requires a USB 2.0 connection).

Since many astrophotographers prefer the greater sensitivity and versatility of a monochrome camera, *S&T* borrowed the Parsec 8300M and Nautilus filter wheel for this review. I tested them in my backyard observatory with a 33-year-old 12½-inch Classical Cassegrain, working primarily at the telescope's f/4 Newtonian focus. The setup included a Baader MPCC coma corrector and covered a field slightly more than ¾° wide at an image scale of 0.88 arcsecond per pixel.

The camera comes with a 60-day trial version of *MaxIm DL Pro*, which runs on Windows XP, Vista, and 7 operating systems. When the trial period ends, Parsec owners are entitled to a $100 discount on the purchase of a permanent license for the software. *MaxIm* has many advanced features for capturing and processing images, including the ability to automate the imaging process, which is especially desirable for color work.

The Parsec requires 12-volt DC power with a maximum draw of about 2 amps. It comes with a wall transformer as well as a cable for powering it with a car battery. While the USB cables for the camera and filter wheel are about 9½ feet long, the transformer cord is less than 6 feet, and required me to use an AC extension cord for my observatory setup.

WHAT WE LIKE:

Outstanding image quality

MaxIm DL software (trial version) included

Attractive price

WHAT WE DON'T LIKE:

Orion's camera-lens adapter won't reach focus with the filter wheel

The 2¼-pound (1-kg) camera is roughly 4 inches square and 3 inches deep, and the front aperture has standard female T-threads (a 2-inch nosepiece is supplied). There's a convenient ¼-20 tripod socket on the camera body as well as another on the filter wheel. I used the one on the camera to attach a "safety cable" between it and the telescope to prevent a disaster should the camera slip from the telescope's focuser.

Orion recently introduced adapters that allow you to use the Parsec with Canon and Nikon camera lenses. This is an extremely welcome accessory for those of us who want to do wide-field imaging. Unfortunately, the adapters only work with the camera alone, since the added back focus required for the Nautilus filter wheel places the lenses too far from the CCD to reach focus. There's no problem focusing without the filter wheel, but some provision would need to be made for adding an infrared-blocking filter, since most camera lenses perform poorly when used without one on astronomical CCD cameras.

The only problem I had getting everything set up and

The author assembled this full-frame view of the Horsehead Nebula in Orion from sequences of 200-second sub-exposures through red, green, blue, and clear (luminance) filters that were captured automatically with the *MaxIm* camera-control software and his 12½-inch telescope working at f/4.

Shown with the filter wheel's cover removed, the 2-inch filters will not vignette the Parsec's KAF-8300 chip even when used with very-fast-focal-ratio optics. As explained in the text, however, the added back-focus requirement of the filter wheel prevents it from being used with Orion's new camera-lens adapter.

working involved the filter wheel. While it comes with stand-alone control software that worked fine, you must install a separate ASCOM driver for the filter wheel to be controlled by *MaxIm*. I had initial problems with *MaxIm* "seeing" the filter wheel. I never did get to the bottom of the problem, since I found a relatively straightforward workaround that involved unplugging the Nautilus USB cable and then reinserting it at the start of each imaging session after all the software was running.

Under the stars

I only needed to look at the first raw images as they downloaded from the Parsec to realize that this camera delivers on its promise of high resolution, low dark current, and high sensitivity. My first deep-sky exposure of the large spiral galaxy NGC 253 bested anything I had ever shot on film with this telescope.

Downloading a full-resolution image takes about 20 seconds in the "normal" readout mode and 14 seconds in the "fast" mode. Binning the pixels 2-by-2 boosts the camera's sensitivity and speeds up the download time, at the expense of lower image resolution. I found binning useful for composing shots and achieving rough focus. A mouse-selectable subframe and the fast download setting allow short focusing exposures to be read out rapidly. *MaxIm* can display large digits for a selected star's peak pixel values and its "full-width half-maximum" diameter, making it relatively easy to achieve critical focus, even when you're watching the monitor from several feet away.

I had used a "light" version of *MaxIm* for my review of an earlier Orion camera, but the full version is far more advanced, and, accordingly, there was far more for me to learn. I certainly recommend that people new to the software spend time doing indoor tests before venturing outside in the dark. I had the relative comfort of working in a domed observatory with a desktop computer, but becoming comfortable with the software and learning to configure the camera for automated LRGB imaging sequences still took a few nights. *MaxIm* can control two cameras at once, allowing one to be used as an autoguider, though I used my 20-year-old SBIG ST-4 to autoguide my test images.

The Parsec 8300M created the most impressive deep-sky images I have ever made with my old 12½-inch scope, assembled from commercial parts in 1978. The high-resolution chip brought the vintage telescope to a new level.

Quick Look *by Dennis di Cicco*

Tele Vue's New Delos Eyepieces

U.S. price: $345 estimated street price
Tele Vue dealers worldwide
www.televue.com

S&T: DENNIS DI CICCO

Tele Vue has a new line of eyepieces. But unlike the company's most recent product introductions, this one doesn't push the optical envelope — at least not when you look at it on paper. Looking *through* the eyepieces, however, is a different matter.

With a family resemblance to the groundbreaking Ethos line, the physically smaller Delos eyepieces are made in 6- and 10-mm focal lengths (more are planned). Their 72° apparent fields rank behind those of the 100° Ethos and 82° Nagler designs, but are larger than the highly regarded 68° Panoptics.

The Delos models have a touch more than 20 mm of eye relief, making them comfortable for the majority of those who wear eyeglass. And they are compatible with Tele Vue's Dioptrx astigmatism correctors. The eyepieces have sliding eye guards that are infinitely adjustable (no click stops) and lock in place with a collet when you twist the

This view of the colorful nebulosity surrounding the star Merope within the Pleiades star cluster shows how the Parsec 8300M's anti-blooming feature effectively suppresses blooming artifacts on bright stars while maintaining the CCD's sensitivity to faint light.

MaxIm is an ideal platform to drive the Parsec and well worth the discounted $399 cost for a permanent license when the 60-day trial ends. This would bring the combined price of the Parsec, filter wheel, LRGB filters, and permanent license to a little less than $3,200. That's still very attractive for such an advanced camera-control and image-processing package.

The Parsec is a compact camera that takes full advantage of the capabilities of Kodak's KAF-8300 chip. Anyone who has been shooting with cameras having smaller chips will be immediately impressed by the Parsec's large, detailed images. ✦

Longtime newspaper photo editor and astrophotographer ***Johnny Horne*** *used the Parsec 8300M as an excuse to upgrade his telescope for advanced CCD imaging.*

WHAT WE LIKE:

Essentially perfect optics

"Immersive" observing experience

WHAT WE DON'T LIKE:

Trying to nail down why the observing experience is so pleasurable

textured grips in opposite directions. I really like this feature, since it keeps the eye guard fixed when I'm swapping eyepieces in and out of scopes.

Delos is the Greek island that mythology holds as the birthplace of Apollo (god of light) and his twin sister, Artemis (goddess of the Moon). Furthermore, the name pays homage to Tele Vue's Paul Dellechiaie, who did the optical design for the Delos and Ethos lines.

The Delos eyepieces I tried were on loan from Tele Vue. Made to test different styles of barrel engraving, they were otherwise identical to production models. I spent several nights viewing the Moon, Saturn, stars, and nebulae with a variety of telescopes, including a 6-inch f/12 Maksutov, a 12-inch f/5 Newtonian, and a Tele Vue NP-101 (4-inch f/5.4) apo refractor.

The Delos eyepieces are "easy" to look through despite the need to position your eye carefully in the exit pupil. They have flat fields, delivering absolute pinpoint stars from edge to edge with no hit of color aberration. The view, especially during the daytime, is very pure with no noticeable color tint. And there wasn't a hint of ghosts or reflections, even with the brightest stars. To be fair, I wasn't expecting less, given the high standards Tele Vue has obviously set for itself with its recent eyepiece designs.

What caught me a bit off guard, however, was something that's best described as the observing experience. It was distinctly pleasurable. Realizing that such perceptions are highly personal, I initially attributed it to the wide, yet defined, apparent field (I could see the entire circular field stop without moving my eye — something I find comforting). But after comparing views through many eyepieces, including one that, on paper, should have had a similar "feel" to the 10-mm Delos (a Tele Vue 9-mm Nagler type 6), I decided it was something else.

The Delos's very large eye lens is 1.4 inches (35 mm) wide, making it appear far out in my peripheral vision when I'm observing. As such, I have the sensation of looking out of a circular window rather than into an eyepiece. I have other eyepieces with large eye lenses, but the "window" effect seems more pronounced with the Delos. I'm curious to hear if others agree.

Regardless, Tele Vue has once again proven that we should never become complacent with the idea that the "last word" in eyepiece design has been written.

Eclipsing Binaries of Summer

Try your skill at some analogs of Algol.

Most issues of *Sky & Telescope* contain a table showing when the bright variable star Algol is at minimum brightness. We omit the table in late spring and early summer, when Algol is too low to observe from mid-northern latitudes. But summer has two similar bright variables of its own.

Algol is the brightest and best-known example of an *eclipsing binary* — a double star whose orbit is aligned so that one component periodically blocks some or all of the other one's light. In most cases there's a *primary eclipse* when the cooler star passes in front of the hotter star, and a *secondary eclipse* when it's the other way around.

Beta Lyrae

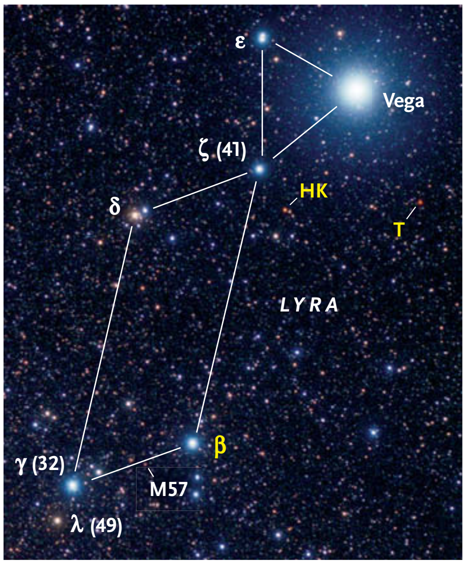
The brightest eclipsing binary of summer is Beta (β) Lyrae, also known as Sheliak, 6° south-southeast of dazzling Vega. It varies from magnitude 3.3 to 4.3 with a period of 12.94 days — up from 12.89 days in 1784, when John Goodricke discovered its variations. The increase is due to the fact that the two stars orbit so close to each other that the more massive one siphons about 4.5 Earth masses of material per year off the atmosphere of its companion. The stolen gas forms a disk around the massive star that blocks most of its light, making it, paradoxically, the fainter of the two from our viewpoint. The net effect is that we're essentially viewing one strangely shaped object with two bright parts. Its brightness varies continuously as we view it from different angles, as shown below.

To estimate Beta Lyrae's brightness, compare it to the other stars that form Lyra's distinctive geometric shape. At its brightest, Beta is a near-twin of nearby Gamma (γ). At its faintest, it's 0.2 magnitude fainter than Zeta (ζ) to its north.

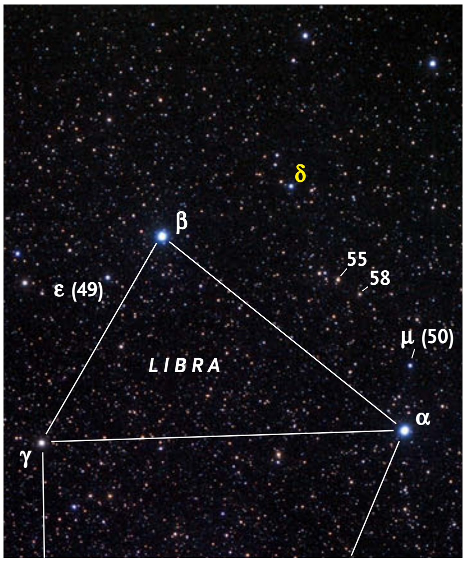
If you want to make more accurate measurements, try using a digital SLR, as explained on page 64 of the April issue. If you obtain a light curve this way, report it to the American Association of Variable Star Observers (www.aavso.org). The star's changing orbital period needs to be tracked; the changes are key to helping scientists understand Beta Lyrae's evolving nature, which is still fairly mysterious. In addition, there's strong evidence that some primary eclipses are shallower (less dim) than others, but nobody knows why.

If you have a telescope, don't forget to check out M57, the Ring Nebula, just ¾° east-southeast of Beta Lyrae. Also, Beta has a 6.7-magnitude companion 46″ to its southeast, a lovely sight at low power.

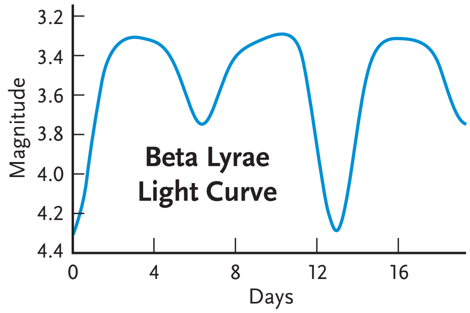
While you're in the area, use binoculars or a telescope to search out two of Lyra's other variable stars using the photograph at lower left: T and HK Lyrae. These are remarkable not so much for their variability as their color. Most so-called red stars,

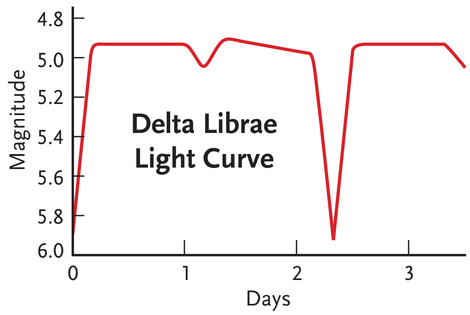


AKIRA FUJII (2)



Magnitudes of comparison stars are shown with the decimal point omitted. Mu (μ) Librae is a tight double star whose components add up to magnitude 5.0.





Minima of Beta Lyrae

Date	UT	Date	UT
May 12	4:12	Aug. 10	18:28
May 25	2:48	Aug. 23	17:05
June 7	1:24	Sept. 5	15:43
June 20	0:01	Sept. 18	14:21
July 2	22:37	Oct. 1	12:58
July 15	21:14	Oct. 14	11:36
July 28	19:51	Oct. 27	10:14

Minima of Delta Librae

May	UT	16	19:17	June	UT	16	1:27	July	UT
2	20:09	19	3:09	2	2:18	18	9:19	2	8:29
5	4:00	21	11:00	4	10:09	20	17:10	4	16:20
7	11:52	23	18:52	6	18:01	23	1:02	7	0:12
9	19:43	26	2:43	9	1:53	25	8:54	9	8:04
12	3:35	28	10:35	11	9:44	27	16:45	11	15:55
14	11:26	30	18:26	13	17:36	30	0:37	13	23:47

See SkyandTelescope.com/eclbin2011 for more information about these predictions.

such as Antares, are actually a rich orangy white. But T and HK are carbon stars, with atmospheres containing carbon compounds that absorb most of the blue and green light. So carbon stars have a deep, saturated color that's variously described as ruby red or copper. T Lyrae, which varies irregularly around 7th magnitude, is the brighter and redder of the two. Little-known HK Lyrae shines around 8th magnitude and is less shockingly red.

Delta Librae

The other bright, easy, eclipsing binary of summer is Delta (δ) Librae, which varies from magnitude 4.9 to 5.9 with a period of 2.327 days. Ultraviolet observations hint that there may be a small amount of mass transfer between the components, but for most purposes they behave like two distinct stars. The pair shines at almost constant brightness 70% of the time, when the light from both reaches us unimpeded. During primary eclipse, the brightness drops rapidly for 4½ hours and then rises again over the same amount of time. Secondary eclipse is barely perceptible.

You'll probably need binoculars to see Delta Librae well. At its brightest, Delta is a near-twin of Epsilon (ε) Librae, on the opposite side of Beta. When Delta is in eclipse, you can estimate its brightness by comparing it with the string of 5th- and 6th-magnitude stars to its southwest, labeled in the photograph on the facing page. Again, for high-precision measurements you'll need a digital SLR or CCD camera. There's a long-standing debate whether Delta Librae's orbital period is stable or gradually increasing; perhaps you can help settle it. ✦

The Far Country

The Serpent's head hosts showpieces bright and faint.

Come with me now, Pilgrim of the stars,
For our time is upon us and our eyes
shall see the far country
and the shining cities of Infinity.
— Robert Burnham, Jr., *Burnham's Celestial Handbook*

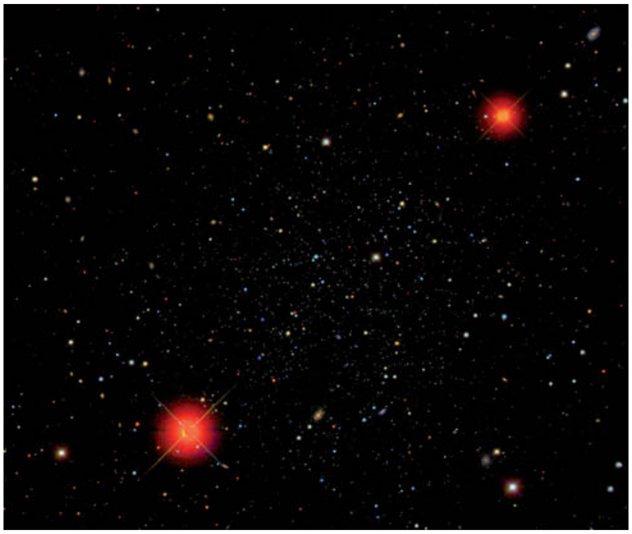
SERPENS IS A FASCINATING and unusual destination for pilgrims of the stars — the only discontinuous constellation in the sky. It represents the serpent being held by Ophiuchus, whose figure divides Serpens into two unconnected parts. East of Ophiuchus we see Serpens Cauda, the serpent's tail, while to the west we find Serpens Caput, which includes its head.

Come with me now to Serpens Caput, which hosts **Messier 5**, one of the most spectacular globular clusters in the northern sky. Following an imaginary line from 109 to 110 Virginis and continuing it for nearly that distance again will bring you right to this lovely cluster. In my semirural sky, M5 is bright even in my 8×50 finderscope, where it's closely guarded by the 5th-magnitude star 5 Serpentis.

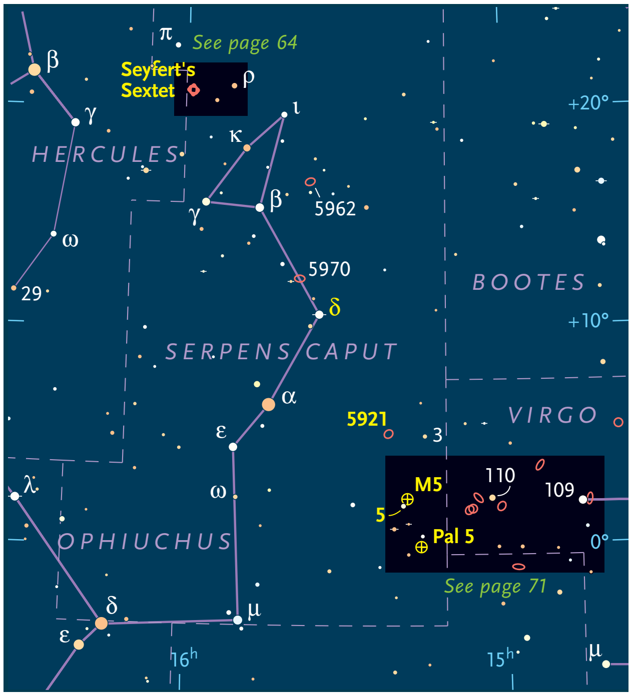
M5 is quite pretty in my 130-mm refractor at 37×, ruffled with a diamond-dust halo elongated northeast-southwest for 14′. The cluster's brilliant 3′ core intensifies toward a dazzling nucleus. At 102× starry rays and arcs adorn the halo, with many relatively bright gems sharply standing out from the fainter chips. Outliers stick closer to home in the northwestern quadrant than elsewhere. M5's glittering core is partly resolved into stars across its entire face, and pale yellow **5 Serpentis** is revealed as a double star, whose bright primary minds a much fainter, reddish orange companion to its northeast.

Through my 10-inch reflector at 213×, M5 is a glorious abundance of suns! I see the halo's sparse outer fringes spanning 21′, and its arcing stars bring to mind a multi-armed spiral galaxy such as the Pinwheel (M101 in Ursa Major). Another twist of the imagination coifs M5 in an untidy hairdo, with most of its tousled tresses drooping roughly southeastward. The cluster is positively opulent in my 14.5-inch reflector at 276×, and the outermost part of its core is threaded with a twisty dark lane meandering most of the way around it.

Just 2.3° south-southwest of M5, we come to a much more difficult globular cluster, **Palomar 5**. With my 10-inch scope at 220×, I see a delicate 6½′ haze set between a 9.0-magnitude star to the southwest and a 10.6-magnitude star off the opposite side. A faint fore-



These frames from the Sloan Digital Sky Survey have identical exposures and scales (both are 13.5′ wide). They show the dramatic contrast between two globular clusters: rich, nearby Messier 5 (*left*) and faint, distant, star-poor Palomar 5.



Bright Messier 5 and NGC 5921 should be easy to locate with this chart, which shows stars down to magnitude 6.5. A detailed chart for Seyfert's Sextet appears later in this article, and the article "Galaxies near Bright Stars" has a detailed chart that includes Palomar 5.

ground star pins the northern edge and another sits near the cluster's center. A few painfully dim stars pop in and out of view. The 14.5-inch reflector at 170× shows about 15 very faint stars, mostly in the southwestern half of Pal 5.

Why the big difference in appearance between M5 and Pal 5? M5 is approximately 24,000 light-years away and rules 286,000 stars, while Pal 5 is an incredible 76,000 light-years distant and commands only 5,000 stars. Pal 5 is being torn asunder by tides exerted by our galaxy. Its population of low-mass stars depleted, Pal 5's remaining stars average twice the mass of those in normal globular clusters. Studies indicate that tidal debris is smeared into opposing tails that span 10° on the sky and contain more mass than the cluster itself.

NGC 5921, the brightest galaxy in Serpens at magnitude 10.8, resides 3.1° northeast of M5 and 1.7° east of 3 Serpentis. Its light is unevenly distributed, making some parts much easier to see than others. Through my 130-mm refractor at 37×, the galaxy is a small elongated smudge visible with averted vision. It crowds the northwesternmost of three stars that form a nearly equilateral 3′ triangle. At 102× the galaxy is 1½′ long and one-quarter as wide, tipped north-northeast and accented by a slightly brighter center.

Through my 10-inch reflector at 118×, NGC 5921 is a 2′ × 1′ oval with a small bright core. Boosting the power to 192× reveals a little wisp curving more or less northwest from the oval's north-northeastern end and another arcing southeast from its opposite end. A very dim oval halo tilts northwest. The view is very nice at 220×. The wisps can be followed a bit farther along their curves, and the halo covers 3′ × 2′. A very faint star hugs the edge of the halo west-northwest of the galaxy's center.

NGC 5921 is a barred spiral galaxy, with the bar running the length of an interior ring. With my 10-inch scope, I see these two structures blending together as the central oval while the wisps proceed from its tips. Can you distinguish the bar from the ring?

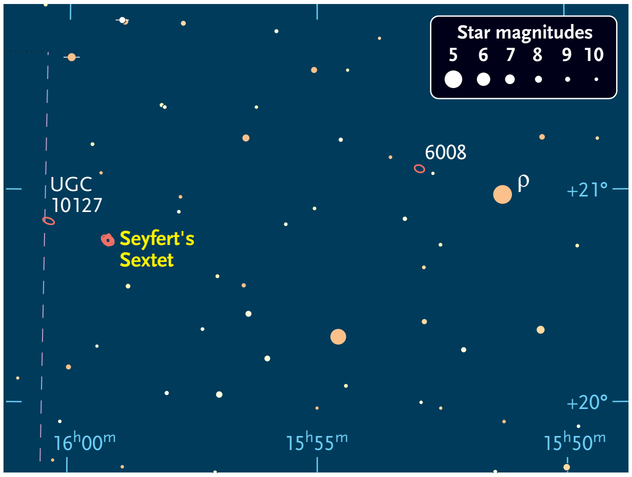
Next we'll climb up to **Delta (δ) Serpentis**, a bright star pair with the companion 4.1″ south of its primary. They're well separated through my 130-mm refractor at 102×, and both appear yellow-white. About 210 light-years away, these stars are subgiants evolving away from the main sequence of stable stars that burn hydrogen in their cores. Currently shining with 76 and 31 times the luminosity of our Sun, Delta's components are on their way to becoming giant stars. This transition takes but a small fraction of star's life, making subgiants relatively rare.

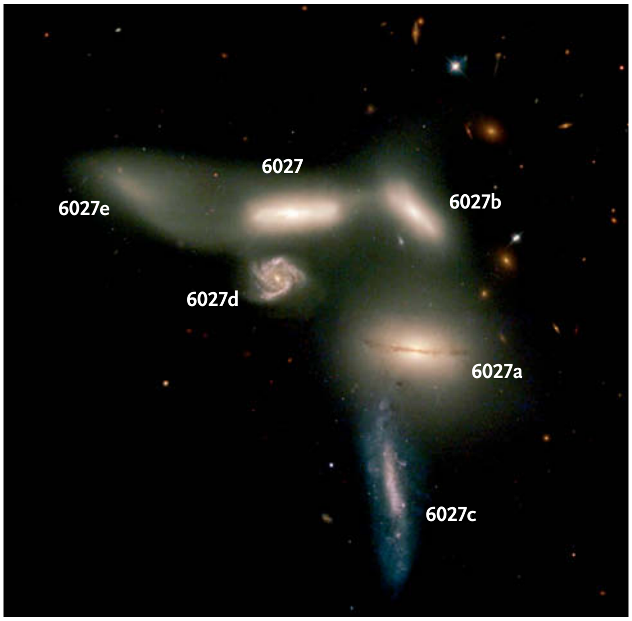
Serpens Caput is also home to the renowned galaxy group **Seyfert's Sextet**, an ultracompact bunch of galaxies crammed within 2′ on the sky. Despite the name, there may be only four related galaxies here, about 200 million light-years distant. The smudge in the northeast is probably a tidal tail or the remains of a shredded galaxy, while the little face-on spiral is thought to be a background galaxy more than four times farther away. The physically

Treasures of the Serpent's Head

Object	Type	Magnitude	Size/Sep.	RA	Dec.
Messier 5	Globular cluster	5.7	23′	15^h 18.6^m	+2° 05′
5 Serpentis	Double star	5.1, 10.1	11.4″	15^h 19.3^m	+1° 46′
Palomar 5	Globular cluster	11.8	8.0′	15^h 16.1^m	–0° 07′
NGC 5921	Galaxy	10.8	4.9′ × 3.9′	15^h 21.9^m	+5° 04′
Delta Serpentis	Double star	4.2, 5.2	4.1″	15^h 34.8^m	+10° 32′
Seyfert's Sextet	Galaxy group	12.6	1.8′	15^h 59.2^m	+20° 46′

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.





NASA / ESA / STSCI / JAYANNE ENGLISH ET. AL.

The Hubble Space Telescope captured Seyfert's Sextet in exquisite detail. Sadly, no eyepiece view will even come close.

associated objects are packed together so closely that they occupy less space than our own Milky Way.

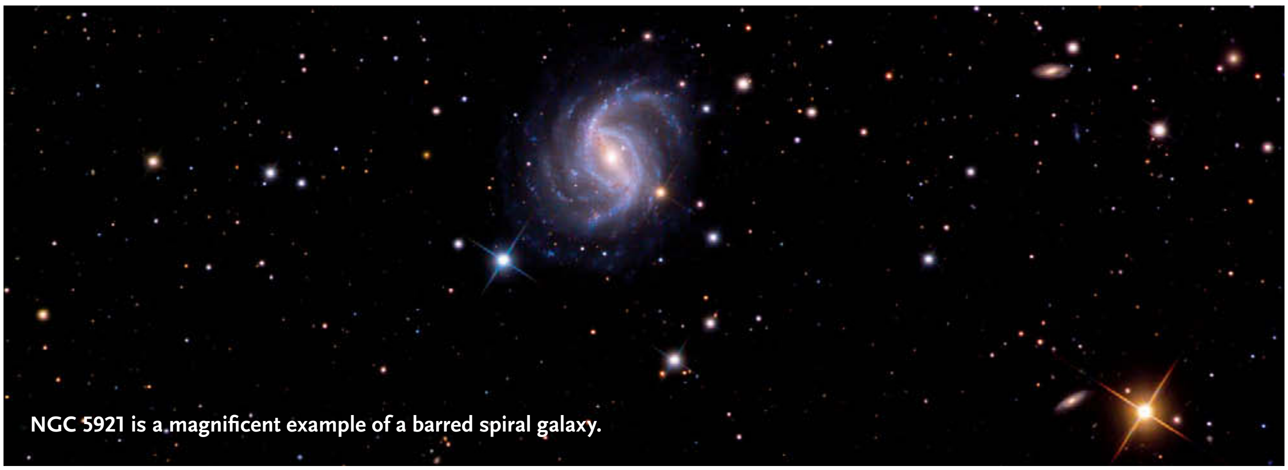
The members of Seyfert's Sextet have visual magnitudes ranging from about 13.5 to 15.6, the brightest being NGC 6027. Carl Seyfert discovered the other objects in this assemblage in 1948, and he later designated them NGC 6027a through 6027e. In 1982 Paul Hickson lettered the five galaxies in his catalog of compact groups, so those are also known as Hickson 79a through 79e. Because the NGC and Hickson letters differ, they have often been mixed up.

Seyfert's Sextet is visible as a very faint fuzzy patch in my 130-mm refractor at 117×. The slightly lumpy glow is too large to be only one galaxy, and I suspect it's a blend of the three brightest. My 10-inch scope at 220× reveals three fuzzy lumps nicely sandwiched between two faint stars about 1¼′ east-southeast and 1¾′ west. They are NGC 6027 (Hickson 79b), NGC 6027b (79c), and NGC 6027a (79a).

My 14.5-inch reflector at 276× shows another star east-southeast of the galaxies. NGC 6027 appears brightest and has a brighter center. NGC 6027b seems to be the next brightest, while NGC 6027a looks larger but a little dimmer. NGC 6027c (79d) and NGC 6027e are visible with averted vision, the latter just a ghostly blur. I could discern the galaxies more easily at 315×, and I thought I might be catching a glimpse of NGC 6027d (79e) now and then, so I boosted the magnification to 441×. Fortunately, the transparency of the sky and the seeing (image steadiness) were both good that night, and I was able to spot little NGC 6027d. Evidently I needed to get it far enough away from brighter NGC 6027 to detect.

While seeing Seyfert's Sextet as a blended glow isn't too difficult, trying to distinguish individual objects is not for the faint of heart. I spent more than an hour carefully studying the group with my 14.5-inch reflector, but it's a thrilling accomplishment to ferret out the shining cities of this far country. ✦

Sue French *welcomes your questions and comments at scfrench@nycap.rr.com.*



ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA

NGC 5921 is a magnificent example of a barred spiral galaxy.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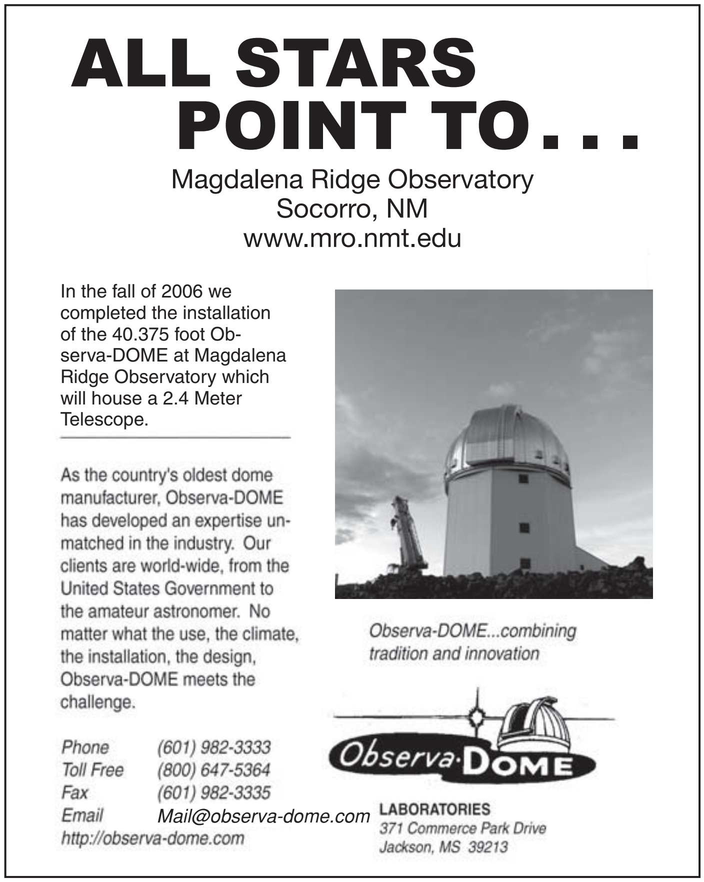
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A 12-inch Planet Catcher

A long-focus Newtonian offers superb high-power viewing.

The newtonian reflector is unique among telescope designs. No other configuration boasts as broad a useful range of apertures and focal ratios. This makes the humble Newtonian ideal for customizing for a specific observing task. And when it comes to high-magnification views of the planets, it's hard to beat a long-focus reflector. From my own experience building a 6-inch f/9 Newtonian (described on my website), I know that these scopes can really deliver the goods.

Another fan of long-focus Newtonians was the late Tom Cave. This mirror-making legend and master planetary observer from southern California had the means to build essentially any reflector he desired, but when it came to crafting one for his personal use, he chose a 12-inch f/11 Newtonian. By his account, it was a stunning success. "My memories of the breathtaking images that the telescope delivered on the first night of really good seeing are undimmed by the passage of time," Cave wrote. "They surpassed my fondest dreams — minor divisions in the rings of Saturn stood out boldly and Jupiter displayed a fantastic welter of intricate belt detail."

DOUG ZUBENEL

Doug Zubenel's 12½-inch f/10 Newtonian is dubbed "Planet Catcher" for good reason — it excels at high-contrast views of solar-system targets. That same contrast also provides great views of deep-sky objects, especially globular clusters and planetary nebulae, which are Zubenel's main observing interest.

Some 50 years later, De Soto, Kansas, telescope-maker Doug Zubenel set out to build his own dream scope. "I really liked the photos I'd seen from the 1950s of Clarence P. Custer's Springfield-mounted, long-focus Newt," Doug recalls. "I also thought it would be great to have an instrument similar to Leslie Peltier's 12-inch refractor, which I had the privilege of using many times in the 1970s." With that in mind, Doug ordered a 12½-inch mirror-grinding kit from Willmann-Bell and got busy.

Doug found that one of the trickiest issues when it comes to a long-focus mirror is the shallowness of the required curve. Indeed, it's so shallow that the mirror won't automatically become a sphere during polishing, as shorter focal-ratio optics tend to do. "I found it challenging simply getting the mirror spherical," he recounts. "Nice wide channels in the pitch lap did the trick, and the mirror needed just the slightest bit of deepening to bring it to its final figure." In the end, it turned out very well indeed — good enough to win second prize for optics at Vermont's annual Stellafane convention in 2006.

In an effort to replicate the views he had with Peltier's big refractor (but minus the color aberration inherent in an achromatic lens that size), Doug opted to make his Newtonian's spider with three curved vanes, thus eliminating the diffraction spikes produced by straight-vaned spiders. The vanes were fabricated from 1-inch-wide strips of 1/32-inch-thick aluminum.

While a curved-vane spider only appears to lessen diffraction effects, using a small secondary mirror actually reduces the total diffraction within the image. "I use two secondaries in this scope," Doug reports. "For lunar and planetary viewing, I install one with a 1.83-inch minor axis. But for deep-sky viewing with 2-inch eyepieces, which benefit from a larger fully illuminated field, I swap in a 2½-inch flat." Each secondary is mounted in its own holder so he can quickly install either one without the need to recollimate the system.

As the picture on the opposite page makes obvious, a 12½-inch f/10 is a *big* telescope. With more than 12 feet of focal length, the scope needs a very rigid tube and a sturdy mount. The tube is made from ¼-inch-thick Sonotube sealed inside and out with polyester resin. "The inside diameter is 16 inches, which provides plenty of air space around the primary and helps keeps the thermals down," Doug notes. The Planet Catcher's heavy-duty equatorial mount and drive system is the work of Doug's long-time friend and talented machinist, Mike Larkin of Blue Springs, Missouri.

Did Doug's efforts pay off? "Planet Catcher saw first light on the evening of August 20, 2003," he recalls. "I excitedly aimed the scope at Mars, then only days from its close approach to Earth, and stared in awe as Solis Lacus — the eye of Mars — stared back at me!" And Mars wasn't the only eagerly awaited target. Saturn also beckoned, but Doug had to wait two long months for a morning of excellent seeing before he got his first really good look. "At 635×, Saturn was absolutely unbelievable," Doug enthused. "With the rings opened up, I could even see the thin, black hairline of the Encke Gap in the bright, outer A ring."

Tom Cave would have been pleased!

Readers can contact Doug via e-mail at dougzubenel@gmail.com. ✦

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*Contributing editor **Gary Seronik** has built numerous telescopes, several of which are featured on his website, www.garyseronik.com.*

DOUG ZUBENEL

Planet Catcher's curved-vane spider yields refractor-like views by eliminating the diffraction spikes that typically accompany bright stars and planets in telescopes having straight-vane spiders.

Galaxies near Bright Stars

S. Kent Blackwell

These faint fuzzies are easy to find, but not always easy to see.

LATE SPRING and early summer usher in moderate temperatures, a welcome relief following the cold winter observing months. This seasonal change also ushers in a plethora of deep-sky objects, many of them remote galaxies. Finding these elusive objects can be challenging for both beginners and seasoned observers.

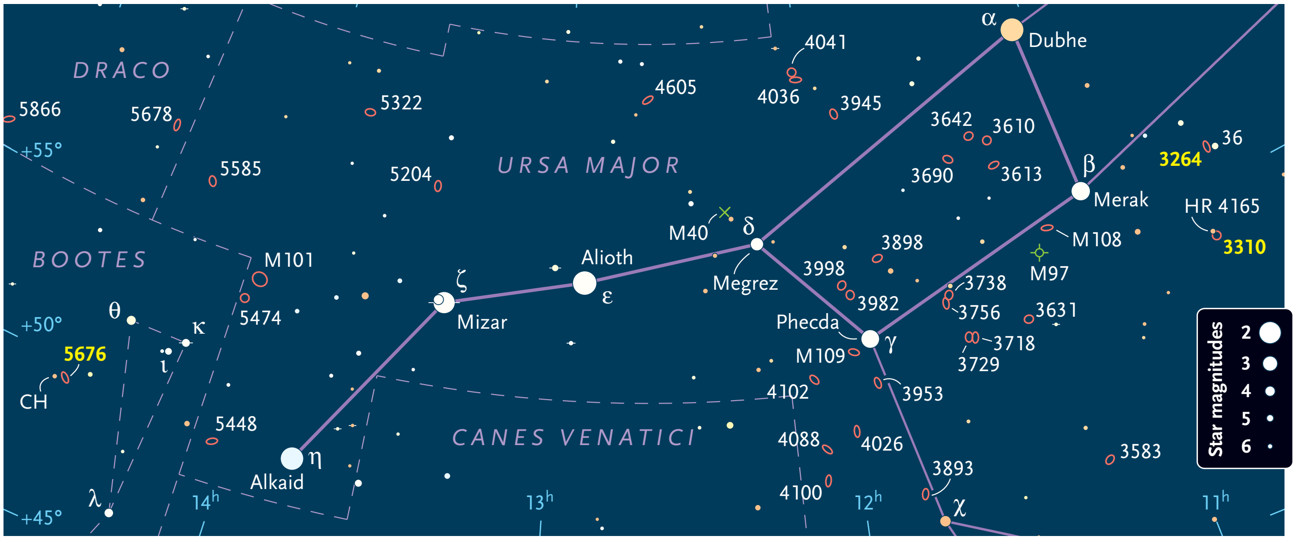
For the past few years I've assembled a list of deep-sky objects that happen to lie next to bright stars. An example in the winter sky is NGC 2024, the Flame Nebula, which is next to the 2nd-magnitude star Alnitak (Zeta Orionis) in Orion's Belt. A glimpse through a telescope shows the nebula as large hazy glow suspended northeast of the bright star.

Although the spring sky doesn't contain a multitude of bright stars such as Alnitak, there are still plenty of fainter naked-eye stars that can be used as guideposts to find deep-sky objects. I have compiled a list of 16 galaxies visible in late spring and early summer, most of which lie within 40′ of a star that's 5th magnitude or brighter. That means that both are visible simultaneously in the field of a typical Plössl eyepiece at 60×. In a few cases you will have to stretch a little farther, or use a fainter star as a guidepost.

This article contains star charts for all the objects described in it, but if you want to find other objects near bright stars, you will need your own charts. They can be displayed on the screen of your laptop or printed on paper — everyone has his or her own preference. While computer charts offer greater detail and larger scales, laptops are susceptible to battery failure when used in the field. An excellent and economical choice of a printed atlas is *Sky & Telescope's The Pocket Star Atlas*. The scale is quite

SHERRY AND STEVE BUSHEY / ADAM BLOCK / NOAO / AURA / NSF

Glare from 109 Virginis is visible at the bottom of this photo of NGC 5746, one of the finest edge-on spiral galaxies in the sky. The star off NGC 5746's tip glows at magnitude 8.5. North is to the upper left.



respectable, yet it's small enough to nearly fit in the glove box of your car on the way to an observing site.

Another helpful accessory is a good pair of binoculars. They don't have to be big — 7×35's are perfectly adequate — because you're only using them to help find the relatively bright stars that will serve as guideposts to your target objects.

Like all galaxies, the ones in this tour are best viewed under dark skies. Many of them should be visible from suburban backyards through an 8-inch telescope, but the darker your skies are, the greater the chances of your seeing interesting details within the galaxies.

Let's start our tour near the well-known Big Dipper asterism. About 4¼° west-southwest of Merak (β Ursae Majoris), the southernmost "pointer" star, is the 5.6-magnitude star HR 4165, as shown in the chart above. The star appears faint to the naked eye, and may even be invisible if there's too much skyglow, but it's easily seen in binoculars and finderscopes.

HR 4165 appears quite bright through a telescope, but this shouldn't prevent you from seeing **NGC 3310**, a 10.8-magnitude galaxy only 10′ to the star's south-southwest. This face-on spiral will probably appear as a fuzzy round spot, resembling an unresolved globular cluster.

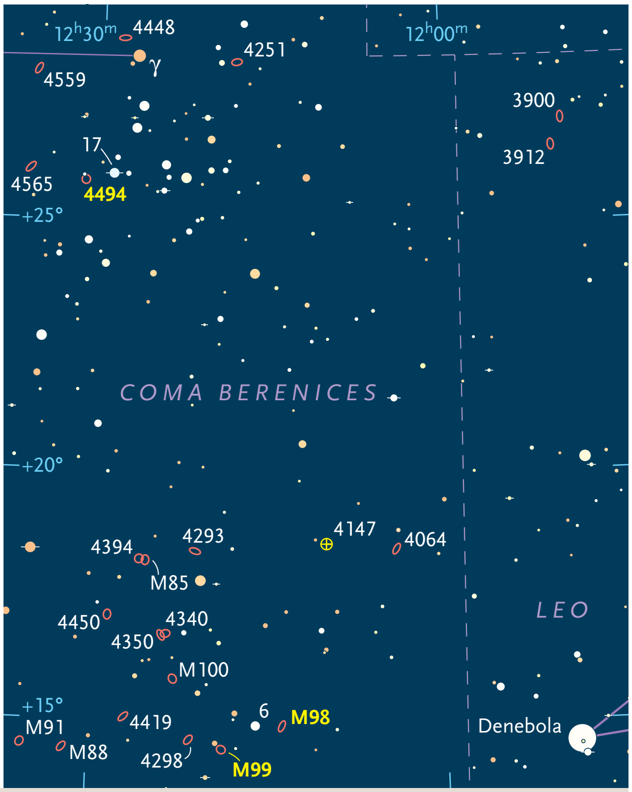
Now let's try a fainter galaxy near a somewhat brighter star. Scan 2½° north-northwest from HR 4165 (or 4¼° west from Merak) for 4.8-magnitude 36 Ursae Majoris. If this star is centered in a telescope at 60×, **NGC 3264** will be in the same field 16′ to the star's east-northeast. This large, 12.0-magnitude edge-on galaxy is visible in a 6-inch telescope under dark skies. Normally it would be difficult to find, but the bright star helps pinpoint its exact location.

If you have trouble seeing NGC 3264 — or any of the galaxies in this article — trying moving the guidepost star just outside the field of view, so that its glare doesn't mask the galaxy's glow. Higher magnifications can also help, by increasing the apparent separation between the star and galaxy. Calculate the field of view of each of your eyepieces so you can use it to measure the distance. Other tricks for finding faint objects are averted vision — looking off to the side of your target — and moving the telescope gently back and forth.

Moving to the opposite end of the Big Dipper, the star at the end of the handle is Alkaid, η Ursae Majoris. Scan 7½° east of Alkaid, into the northwestern corner of Boötes, where you'll find the irregular variable star CH Boötis, which fluctuates between magnitudes 5.7 and 5.9. The large, 11.2-magnitude galaxy **NGC 5676** lies about 19′ to the west-northwest of CH. Interestingly, CH lies at a distance of approximately 800 light-years, but the galaxy is about 100 million light-years away.

POSS-II / CALTECH / PALOMAR OBSERVATORY

This frame from the Palomar Sky Survey is similar to what you'd see through a telescope, with NGC 3310 10′ south-southwest of the 5.6-magnitude star HR 4165.



POSS-II / CALTECH / PALOMAR OBSERVATORY

Above: **Studies hint that the barred spiral galaxy NGC 5850 may have been disrupted by a close encounter with the giant elliptical galaxy NGC 5846, shown here 10′ to 5850's west-northwest. Note tiny, bright NGC 5846A nestled just south of NGC 5846.**
Left: **This chart shows stars down to magnitude 8.5. The labels for HD 107170 and 109030, near the target galaxies M99 and NGC 4494, have been omitted for clarity.**

Galaxies near Bright Stars

Object	Constellation	Magnitude	Size	RA	Dec.
NGC 3310	UMa	10.8	3.1′ × 2.4′	10^h 38.8^m	+53° 30′
NGC 3264	UMa	12.0	2.9′ × 1.2′	10^h 32.3^m	+56° 05′
NGC 5676	Boo	11.2	3.9′ × 1.8′	14^h 32.8^m	+49° 27′
Messier 98	Com	10.1	9.4′ × 2.8′	12^h 13.8^m	+14° 54′
Messier 99	Com	9.9	5.3′ × 4.6′	12^h 18.8^m	+14° 25′
NGC 4494	Com	9.8	4.8′ × 3.5′	12^h 31.4^m	+25° 47′
NGC 5334	Vir	11.3	4.2′ × 3.0′	13^h 52.9^m	–01° 07′
NGC 5345	Vir	12.4	1.6′ × 1.5′	13^h 54.2^m	–01° 26′
NGC 5746	Vir	10.3	7.4′ × 1.3′	14^h 44.9^m	+01° 57′
NGC 5740	Vir	11.9	2.8′ × 1.5′	14^h 44.4^m	+01° 41′
NGC 5813	Vir	10.5	4.0′ × 2.8′	15^h 01.2^m	+01° 42′
NGC 5814	Vir	13.8	0.9′ × 0.5′	15^h 01.4^m	+01° 38′
NGC 5806	Vir	11.7	3.2′ × 1.6′	15^h 00.0^m	+01° 53′
NGC 5838	Vir	10.9	4.2′ × 1.5′	15^h 05.4^m	+02° 06′
NGC 5846	Vir	10.0	4.0′ × 3.7′	15^h 06.5^m	+01° 36′
NGC 5850	Vir	10.8	4.5′ × 3.9′	15^h 07.1^m	+01° 33′

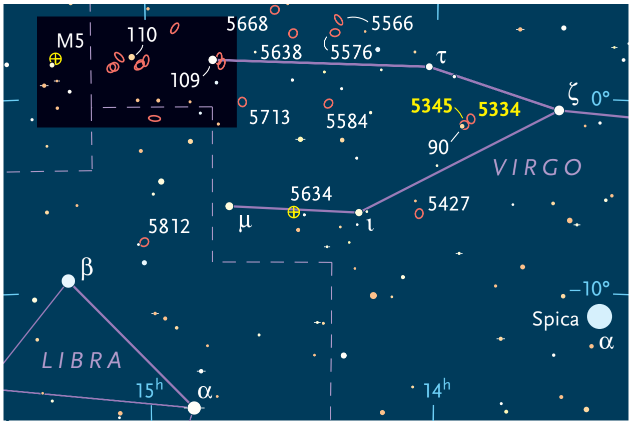
Angular sizes are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

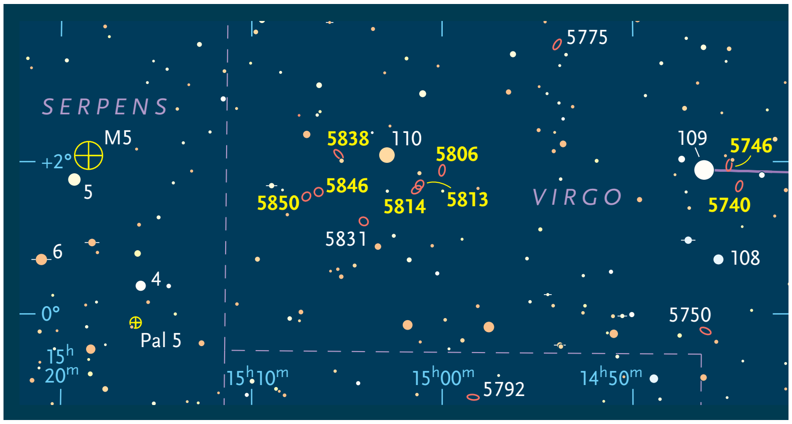
Shifting south to the Virgo Cluster, the 10.1-magnitude galaxy **M98** is rather faint for a Messier object, but it's easy to locate because it happens to lie 32′ due west of the 5.1-magnitude star 6 Comae Berenices. If you're viewing at 60× or higher, you may need to de-center 6 Comae, placing it near the eastern edge of the field, in order to get the star and galaxy into the same view. The galaxy's edge-on appearance is easily discernible in small telescopes.

Now move the telescope almost 1° east-southeast of 6 Comae and look for the 6.5-magnitude star HD 107170, which is plotted but not labeled on the chart at upper left. The 9.9-magnitude galaxy **M99** will look like a faint reflection 10′ southwest of the star. M99 was the second galaxy (after M51) to have its spiral structure recognized. Both discoveries were made by Irish astronomer William Parsons (Lord Rosse) in the spring of 1848. A hint of M99's structure is visible in large amateur telescopes, especially the northern spiral arm.

Many other galaxies crowd the Coma Berenices area, but a particularly interesting one is 9.8-magnitude **NGC 4494**, which lies just 6′ south-southwest of the 7.9-magnitude star HD 109030. To locate it, first find the 5th-magnitude double star 17 Comae Berenices, then move about ½° eastward. The 10th-magnitude galaxy has relatively high surface brightness, appearing like a ghostly image of HD 109030.

We'll finish this tour in eastern Virgo, which is highest in the south shortly after the sky grows fully dark in late May and early June. If you center the 5.2-magnitude star 90 Virginis in a telescope at 80× and then scan 35′ to the northwest, the 11.3-magnitude barred spiral galaxy **NGC 5334** will enter the field of view before the star leaves it. The galaxy will appear faint and elongated in an 8-inch telescope, but it should be easy to see in smaller telescopes if you shift the star out of the field of view. If you want a greater challenge, look for **NGC 5345**, only 8′





Left: **This chart of eastern Virgo shows stars to magnitude 6.5. Labels have been omitted for clarity inside the black box at upper left. A close-up of this area appears at right.** ***Right:*** **This close-up chart can be used to find the galaxies discussed in this article and the faint globular cluster Palomar 5, which is described in "Deep-Sky Wonders" on page 62.**

northeast of 90 Virginis. At magnitude 12.4 it should be visible in a 10-inch telescope even in moderately light-polluted skies, but you'll have to shift 90 Virginis completely out of the field to see it.

Our standard constellation "stick figure" shows 3.7-magnitude 109 Virginis at the left end of Virgo's upper leg. If you center this star in a telescope at 80×, you should see the 10.3-magnitude galaxy **NGC 5746** 20′ to the west. This large, low-surface-brightness edge-on spiral should be visible in an 80-mm refractor in a dark sky, and it's easy in larger telescopes. The slightly fainter face-on spiral **NGC 5740** 31′ to the west-southwest of 109 Virginis can fit in the same field of view, making a beautiful trio.

ADAM BLOCK / NOAO / AURA / NSF

Messier 99 is a splendid example of a face-on spiral galaxy.

Just 4° east of 109 Virginis is the 4.4-magnitude star 110 Virginis, which lies in the foreground of a modest but attractive galaxy group. Scan 36′ southwest from the star at about 80× and look for **NGC 5813**, a large elliptical galaxy that's quite easy to see. **NGC 5814** lies less than 5′ southeast of 5813, but at magnitude 13.8 this small galaxy is perhaps best reserved for users of large telescopes. Also in the field will be 11.7-magnitude **NGC 5806**.

Now we'll look on the opposite side of 110 Virginis, where the main concentration of this galaxy group lies. Start with 10.9-magnitude **NGC 5838** 38′ due east of the star. Then move another 34′ southeast to find **NGC 5846**, the massive elliptical that dominates the entire group. At magnitude 10.8, it's the brightest non-Messier galaxy in our tour. Large scopes may also show **NGC 5846A**, a tiny but intense galaxy embedded in NGC 5846's halo 40″ south of the larger galaxy's core, as shown in the image on the facing page. And finally, look 10′ east-southeast of NGC 5846 for **NGC 5850**, a large galaxy whose low surface brightness make it seem fainter than its listed magnitude of 10.8 suggests.

When a star lies in the same field as a deep-sky object, not only does it provide an easy way to find the object, but it also makes a very attractive view. It's also staggering to think how close they appear yet how far in actual distance they are from each other.

The coming summer season offers even more beautiful deep-sky objects near easy-to-find stars. One particularly notable example is the famous Veil Nebula, a supernova remnant whose westernmost arc slices through the 4th-magnitude double star 52 Cygni. There will be a detailed observing guide to the Veil in a future issue of *Sky & Telescope*. ✦

Kent Blackwell *observes the deep sky with telescopes big and small from dark sites near his home on the Virginia coast. You can reach him at kent@exis.net.*

Layering Image Contrast

Bring out the faintest details in your images with this powerful *Photoshop* technique.

R. JAY GABANY

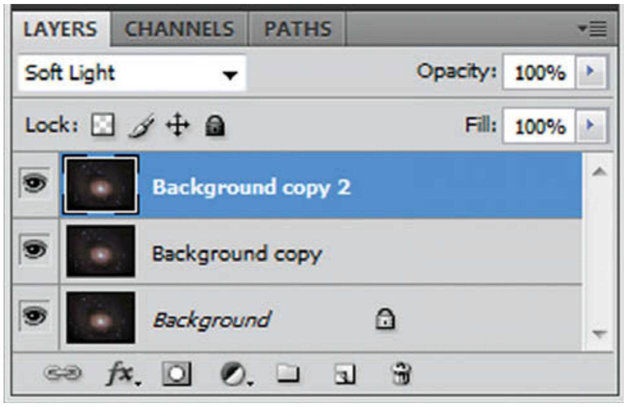
The ever-increasing quality of amateur astrophotos creates a conundrum for imagers. Since there are so many great pictures to look at, many people invest only a few seconds looking at an image unless something hooks their attention, reels them in, and provides incentive to linger.

Three essential image ingredients for capturing a person's attention are color, clarity, and contrast. Each tends to overlap the other, but when carefully managed together, they enable the astrophotographer to produce truly memorable pictures.

Of the three, contrast is perhaps the most important because it involves the viewer's ability to distinguish between an object and its background. The human eye is more sensitive to changes in contrast than luminance. Controlling contrast in astronomical images is challenging because of their large brightness range.

Light intensity (pixel values) of an astronomical image can be plotted as a graph called a histogram that shows us the amount of information recorded in the bright, faint, and dark regions of the image. Most of the interesting information is often in the faint region, where our eyes

Left: **Extracting faint detail from CCD images can prove a daunting task for today's astrophotographers. Author R. Jay GaBany uses a powerful technique he calls Layered Contrast Stretching (LCS) to bring out faint structures buried in his images. The original view of M74 at left displays a basic, non-linear stretch, whereas the right half uses LCS layers to enhance the fainter areas. All images are courtesy of the author.**



Right: **Enhancing your photos using LCS requires image layers and masks. After creating two layer copies of an image, you change the layer blending mode of the top layer from Normal to Soft Light and the middle layer from Normal to Screen. The Screen layer doubles brightness values of the lower layer, while Soft Light increases contrast and color saturation.**

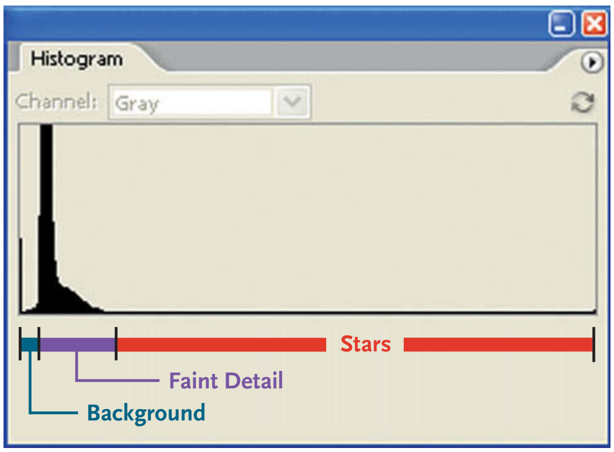
are most sensitive to contrast variances. Unfortunately, this also tends to be the noisiest area of an image.

Images with a sufficient signal-to-noise ratio have the greatest contrast potential. Many astrophotographers mistakenly think the principal benefit of longer exposures is the ability to capture fainter objects, and there is some truth to this. However, the biggest reward of long exposures is the increased signal-to-noise ratio because it improves contrast in the faintest areas.

Excellent calibration frames, particularly flats, are also critical for producing compelling pictures because of their impact on the data's signal-to-noise ratio. A good flat will help to distinguish faint structures from the background sky that would otherwise be masked by noise or mistaken as brightness gradients.

Stretching Out the Truth

Digital images store light intensity values based on the number of photons striking each pixel of the imaging chip. The value for a pixel that receives 200 photons will be twice that of a pixel collecting only 100. As a result, a significant portion of the faintest information captured by the camera's sensor is squeezed into a small portion of the histogram that has to be rescaled or stretched. You can do this with tools such as Digital Development (DDP), found in many astronomical image-processing programs. But these tools offer only limited control of the entire image. My personal reliance on these one-stop histogram-stretching algorithms waned several years ago in favor of a more hands-on technique I use in *Adobe Photoshop.*



Astronomical objects have a large ranges of brightnesses, so virtually all deep-sky astrophotos require nonlinear stretching to show the entire extent of the subject. This histogram plots the intensity of various components of a typical nebula image before any processing. Everything to the right of the peak represents the brightest information in the image, primarily stars.

While there are several methods for making global contrast adjustments in *Photoshop,* I find that the Curves and Levels tools provide more control than DDP, plus the application has other less-obvious functions that enable even greater control. But once I'm done uniformly stretching the entire image, it's time to dig into specific regions to accentuate contrasts and give my images that extra hook to hold the observer's attention.

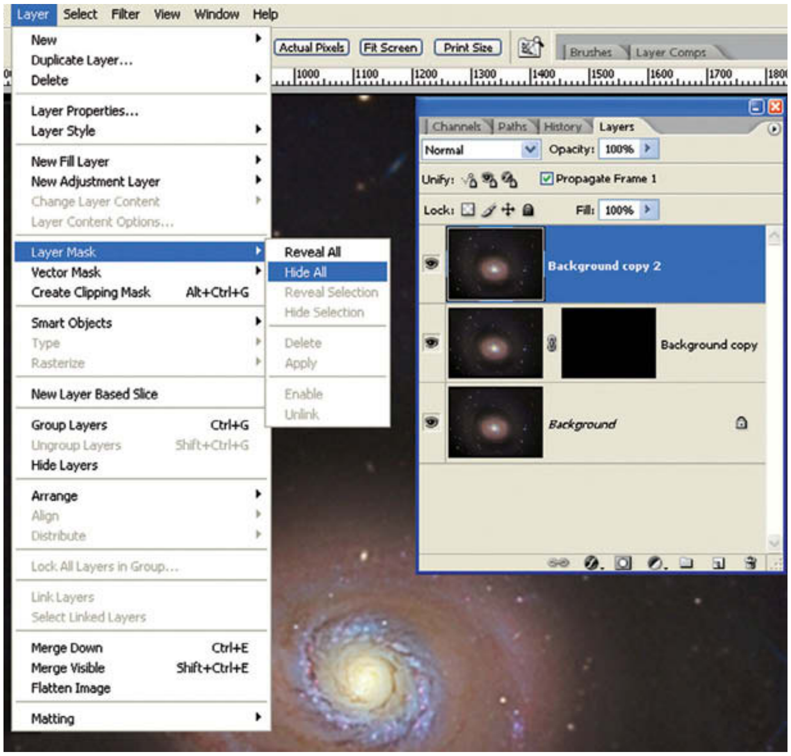
Layered Contrast Stretching

Several years ago I began using a technique I call Layered Contrast Stretching (LCS). It is highly effective for managing subtle contrast variances and increasing the intensity difference between faint structures and their background. The approach also enables me to enhance images at any post-calibration stage. It's important to note that this technique shouldn't be used on images intended for scientific research.

LCS leverages *Photoshop's* ability to blend multiple images in layers. Typically an altered version of the astrophoto is placed into a layer on top of the original picture, then the two images are proportionately mixed.

I manage the proportional control of the mix by adjusting the opacity of the layer and by using masks that hide or reveal selected portions of the layered picture. These functions are the most powerful tools for managing contrast and producing pictures with rich color and good clarity because they offer virtually infinite control of the blending process.

Here's how you do it. Open an image you've previously stretched. Also display the Layers window (Window/



Selectively blending the two layers with the background image requires that a layer mask be added to each copied layers, as shown here. These masks initially hide the effect of their respective layers on the background image.

Layer) and keep it open throughout the process. Next, copy the picture (Layer/Duplicate Layer) twice to create two additional layers. At this point, there will be three identical layers. Next, change the top layer blending mode to Soft Light and the middle layer to Screen. Soft Light adds sharp contrast to the image's histogram and increases color saturation without adding noise, whereas Screen essentially doubles the brightness value of the image's tonal curve.

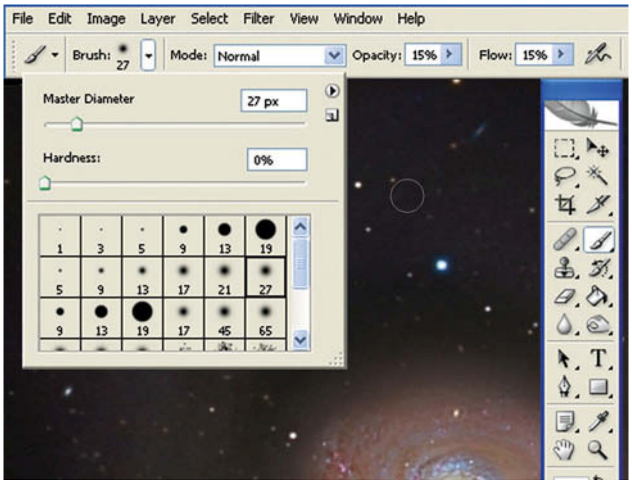
Next, add layer masks to the top and middle layer (Layer/Layer Mask/Hide All). At this point, only the image in the bottom layer, known as the Background, will be visible. Now it's time to begin blending the top and middle layer images into the bottom image.

Select the paint brush from the Tools Palette, making sure its foreground color is set to white. Set its hardness to 0% and its opacity and flow to 15%. Find an area of your image that contains a low-contrast structure and adjust the size of the paint brush so that its diameter approximates or is slightly larger than the structure's size.

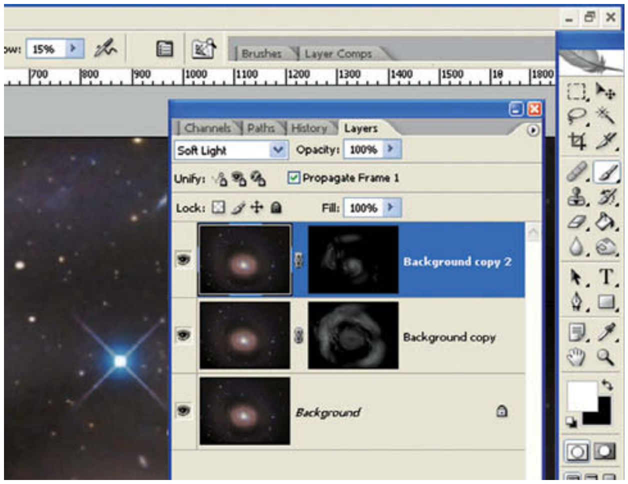
If the area of low contrast is faint compared to the surrounding region, select the Screen layer mask, and simply paint over that region of the picture with the brush. If the area is brighter than the surrounding region, select the upper Soft Light layer mask.

You may not notice much difference with the first stroke of the paintbrush, but repeating the stroke several times will start to visibly change the image. You can often get a good feel for the changes made by blinking the layer off and on (clicking the "eye" box to the left of the layer thumbnail).

As you paint, you are blending that portion of the Screen or Soft Light layer with the original image visible in the Background layer. Because your brush is soft, the amount of blending varies within the brush stroke itself. At the center of the brush stroke, the opacity is 15% but this drops off considerably toward the edges of the brush,



Painting the masks with the Paint Brush tool allows imagers to selectively blend the layers. Because we want to build our blending mask slowly, we should lower the brush's opacity and flow settings. The brush radius (displayed as a circle) should also be adjusted to cover the width of the area you'd like to enhance.



Soft Light and Screen blending layers add distinctly different enhancements to your image. Paint on the Screen layer mask (middle layer) in areas you want to brighten, such as faint nebulosity. Paint on the Soft Light mask (top layer) in areas where additional contrast is required, such as in the inner core of galaxies.

resulting in a "feathering" effect. While each individual brush stroke produces relatively insignificant changes, the changes imparted by additional brush strokes accumulate in a somewhat random manner.

This technique makes it difficult for the user to "paint" a structure into the final image where none previously existed. It also enables us to exaggerate the contrast around the structure and thus make it more evident.

If a structure appears too bright using the Screen layer mask, paint on the Soft Light layer mask to darken it. The picture will benefit from simultaneous strokes to both layer masks, too. The Soft Light layer is also useful to darken dim structures such as threads of dark dust seen in distant galaxies.

You can also introduce other layers to enhance contrast using LCS. An Overlay layer is like Soft Light on steroids, so use an even lower opacity brush when masking it in. Linear Dodge and Linear Burn layers will have a dramatic effect on contrast, so I apply these sparingly and with brush settings of only 5% or less. Interestingly, Color dodge and Color burn are also effective, even on monochrome images. Although it's considered a sharpening tool, the High Pass filter (Filter/Other/High Pass) is a wonderful method for enhancing subtle contrast. I use it sparingly and rarely exceed a radius setting of 7 pixels.

LCS is extremely powerful for increasing the contrast of faint structures. Often an inspection of the image using *Photoshop's* Equalize function (Image/Adjustments/Equalize) will help identify where dim regions are located so you can target them for enhancement using this technique.

I frequently revisit my old images to see if LCS can improve my earlier results. It can increase the impact of a picture and make the wonders of the universe more evident for casual viewers. ✦

***R. Jay GaBany** is the recipient of the American Astronomical Society's 2011 Chambliss Amateur Achievement Award (*S&T: *April 2011, page 18).*


LCS works on any deep-sky astrophoto. The author processed this image of M20 with LCS to enhance both the outer reflection nebula and the dark lanes within the core.

◀ ABOVE A CAULDRON OF FIRE
Andrea Gabrieli
The Milky Way rises above the summit of Kilauea in Hawaii. Cascading down from upper left, the star cloud M24 is followed by pinkish M8 before our gaze lands at Baade's Window, a clearing through which we peer at old stars populating the inner regions of our home galaxy.
Details: *Nikon D700 DSLR camera with 24-70mm zoom lens. Total exposure was 30 seconds at ISO 6400.*

▼ A LONELY PLANETARY
Dean Salman
Purgathofer-Weinberger 1 (PuWe1) is a large, though exceedingly faint planetary nebula located in Lynx, which will test the skills of observers and astrophotographers alike.
Details: *8-inch f/4 Maksutov-Newtonian astrograph with SBIG ST-10XME CCD camera. Total exposure was 28 hours through Astrodon color and hydrogen-alpha filters.*

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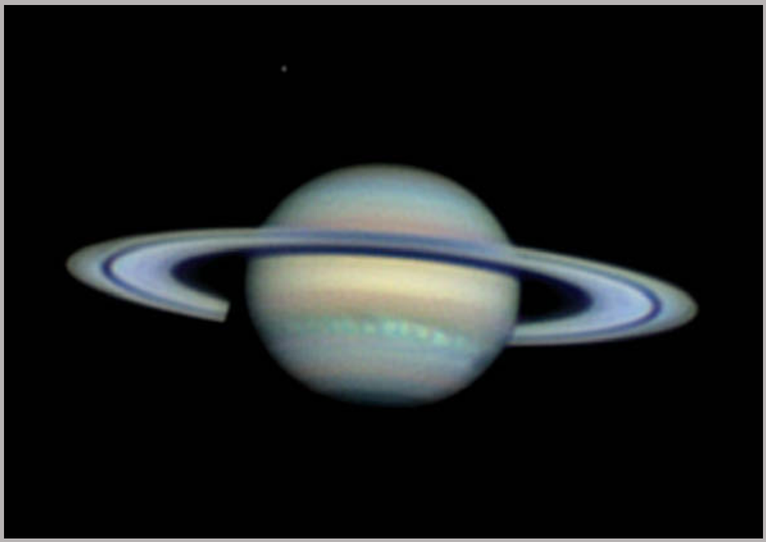

▲ **BEYOND THE GALACTIC VEIL**

Neil Fleming

Often favorite targets early in the year for northern observers, M81 and M82 reside in Ursa Major behind thin wisps of galactic dust within our Milky Way. **Details:** *8-inch TMB 203 f/7 refractor with SBIG STL-6303 CCD camera. Total exposure was 36 hours through Astrodon color and hydrogen-alpha filters.*

◀ **SATURN STORM RAGES ON**

Wayne Jaeschke

A bright storm erupted on Saturn during mid-December 2010, and has since spread to encircle the planet at roughly 40° north latitude. South is up in the photo. **Details:** *Celestron C14 Schmidt-Cassegrain telescope with Point Grey Research Flea3 video camera. Stacked video frames recorded through Astronomik color filters.*

NEW YEAR SHOWPIECE

Edward Henry

Prominent at the beginning of each year, M42 dazzles observers with its expansive tendrils of nebulosity surrounding the Trapezium star cluster at its heart.

Details: *10-inch Meade Schmidt-Cassegrain telescope with SBIG STL-4020CM CCD camera. Mosaic of nine frames totaling more than 40 hours of exposure.* ✦

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IN THE NEXT ISSUE

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Spacecraft reveal that active volcanoes are all over the solar system, but many are quite different from those on Earth.

Neptune's Year in Review
As Neptune completes a full orbit since it was discovered in 1846, it's a good time to reflect on one of the great stories in the history of astronomy.

Dive into the Whirlpool


We present a detailed guide to the spiral arms of this magnificent face-on galaxy.

Amateur Astronomy's Next Step
Obtaining spectra of planets, stars, and other astronomical objects has become easy, affordable, and scientifically rewarding.

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Focal Point Daniel N. Baker

Paralyzing Effects at NASA

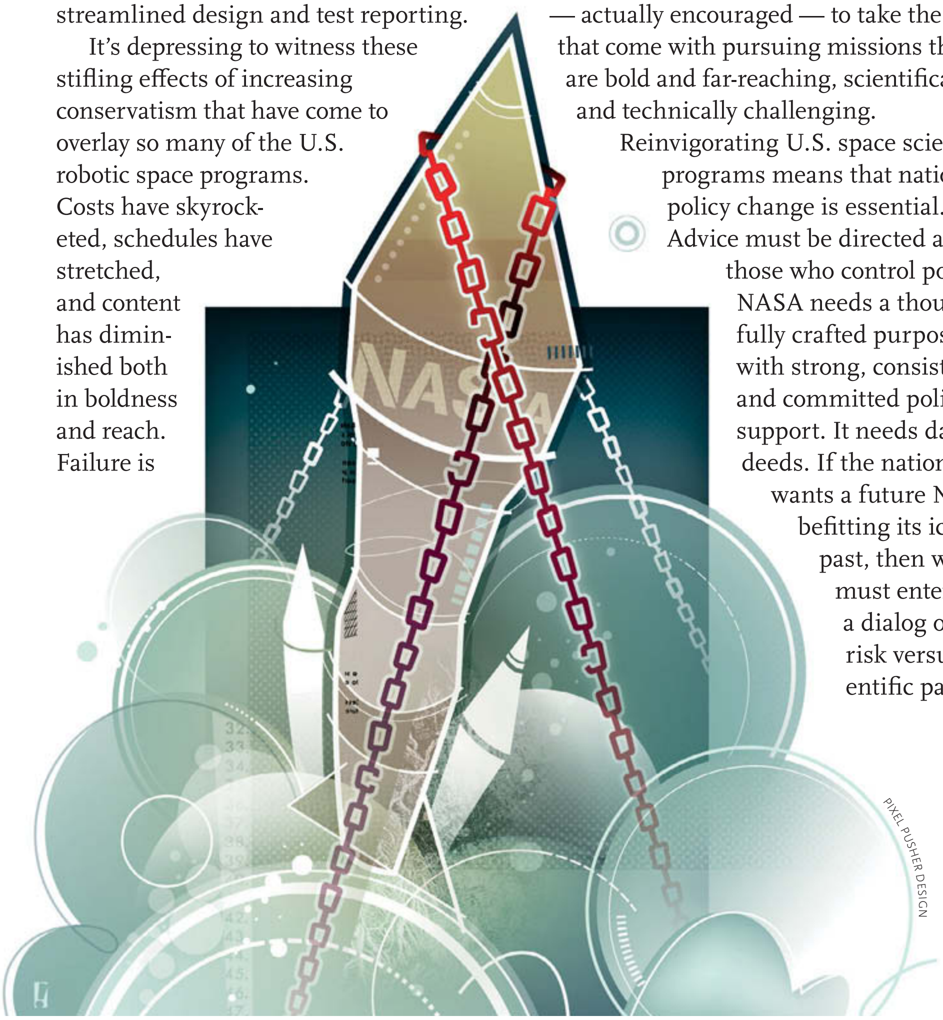
Excessive risk aversion threatens the future of U.S. robotic space exploration.

The recent record of U.S. robotic space missions is quite sobering. NASA's James Webb Space Telescope is now estimated to cost in the $6 to 7 billion range. The cost of the next Mars rover has grown to well over $2 billion and its launch has been delayed more than two years. Numerous other space missions are plagued by countless briefing charts, huge numbers of reviews, and heavy loading of overseers when they should feature streamlined design and test reporting.

It's depressing to witness these stifling effects of increasing conservatism that have come to overlay so many of the U.S. robotic space programs. Costs have skyrocketed, schedules have stretched, and content has diminished both in boldness and reach. Failure is no longer an option. Everyone can understand the pressures for assured success in such forefront space missions. But the institutional reaction to that pressure — attempting to avoid failure often regardless of cost — is ultimately eroding NASA's capabilities and mortgaging its future, especially in this era of budgetary austerity.

To reverse the decline and to again propel the U.S. into indisputable international leadership, NASA must be allowed — actually encouraged — to take the risks that come with pursuing missions that are bold and far-reaching, scientifically and technically challenging.

Reinvigorating U.S. space science programs means that national policy change is essential. Advice must be directed at those who control policy. NASA needs a thoughtfully crafted purpose with strong, consistent, and committed political support. It needs daring deeds. If the nation wants a future NASA befitting its iconic past, then we must enter into a dialog on risk versus scientific payoff.



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NASA must be asked to attempt unimaginably bold missions of discovery across the breadth of its portfolio. NASA's charter must leverage the public's appetite for adventure, Hollywood's imagination for daring deeds, and the nation's strategic need to continually push technology. We should allow occasional failure in exchange for bold attempts, so NASA can someday afford to operate robotic submarines on Europa, sail boats on Titan's methane lakes, cruise about in Saturn's rings, move an asteroid, provide solutions to the challenge of climate change. Do missions crisply, visibly, and affordably. Yes, affordably.

The value of civilian space — of exciting scientific and technological adventure — has seemingly been lost in this nation. We need again to take greater risk and increased initiative. That is different than being careless. But whatever is done, NASA's mission must be courageous and nearly impossible to imagine as being achievable. Risk taking, with the tremendous benefits of success and the possibility of heartbreaking failure, must again become the mainstay of NASA's mission. NASA was born, thrived, and endured under this prior paradigm. It's the recipe for a lasting presence.

Civilian space exploration can again become a hallmark of national pride and an engine of scientific accomplishment. Anything less is doomed to deepen the downward spiral of an admired but declining national treasure: NASA. ✦

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