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SKY & TELESCOPE

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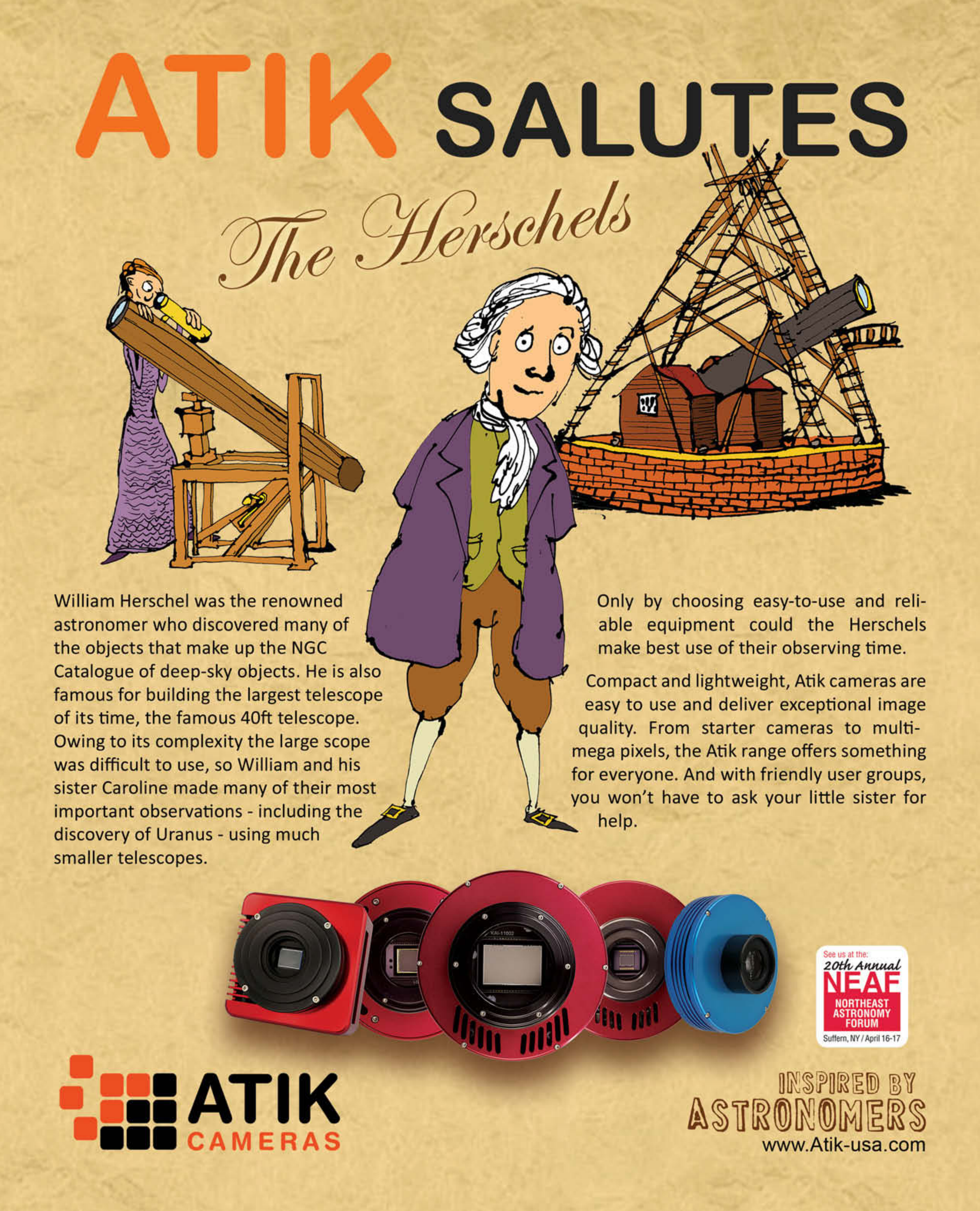
ATIK SALUTES
The Herschels
William Herschel was the renowned astronomer who discovered many of the objects that make up the NGC Catalogue of deep-sky objects. He is also famous for building the largest telescope of its time, the famous 40ft telescope. Owing to its complexity the large scope was difficult to use, so William and his sister Caroline made many of their most important observations - including the discovery of Uranus - using much smaller telescopes.
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SKY & TELESCOPE

April 2011

VOL. 121, NO. 4

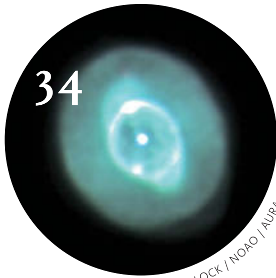
RON MILLER

On the cover: An imaginary planet orbits an imaginary star. When it comes to hosting planets, not all types of stars are created equal.

FEATURES

THIS MONTH'S SKY

S&T TEST REPORT



ADAM BLOCK / NOAO / AURA / NSF

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BABAK A. TAFRESHI

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Mars on Earth

THERE AREN'T MANY PLACES on Earth that resemble the surface of Mars, so I'm fortunate in having experienced two of them.

In August 2003 I visited the Atacama Desert in northern Chile with a tour group. Ostensibly, we were there to see the four 8.2-meter reflectors of the European Southern Observatory's Very Large Telescope. But we spent considerable time visiting geological wonders, including Valle de Marte (Valley of Mars). Several Atacama locations have had no measurable precipitation in more than a century, making them some of the few places on Earth where biologists can scoop up a cubic meter of dirt and find no trace of life. In this sense, the Atacama resembles large tracts of the Martian surface.

But the Red Planet's surface wasn't always bone dry. For example, huge outflow channels — sculpted by catastrophic floods billions of years ago — cut across its surface. Long ago I learned that a terrestrial analog exists in my own country: the Channeled Scablands of eastern Washington state. This region was scarred by a series of massive floods during the last Ice Age. A large glacial lake known as Lake Missoula repeatedly drained whenever an ice dam fractured, sending enormous volumes of water rampaging across eastern Washington.

TOM FIELD

***S&T* Editor Bob Naeye at a vantage point overlooking Dry Falls.**

Following a trip to Seattle (January 10th to 13th) to cover the American Astronomical Society meeting, then a brief jaunt to British Columbia to visit *S&T* contributing editors and friends Ken Hewitt-White and Gary Seronik, I drove back to Seattle and met up with amateur astronomer Tom Field. Tom and I then drove to the Scablands. We saw spectacular landforms carved by the floods, including Palouse Falls, Dry Falls (five times larger than Niagara Falls, but with no flowing water), Grand Coulee, Moses Coulee, and West Bar (a location alongside the Columbia River where wave action formed giant ripples in the terrain). I had to get back to *S&T*'s Cambridge office, so Tom and I could spend only two days in the Scablands, but we were thrilled to see these dramatic and bizarre geologic features — clear evidence of enormous floods.

I want to thank University of Arizona geologist Vic Baker for recommending specific sites in the Scablands, and for sending us scientific papers about the floods. For those of you interested in geology and Mars, I strongly recommend a trip to the Scablands and the Atacama Desert. I'll be leading a trip to Chile, including a visit to the Atacama, this September with Spears Travel. See www.spearstravel.com/groups for more information. It will be a *great* trip!

Robert Naeye
Editor in Chief

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The Essential Magazine of Astronomy

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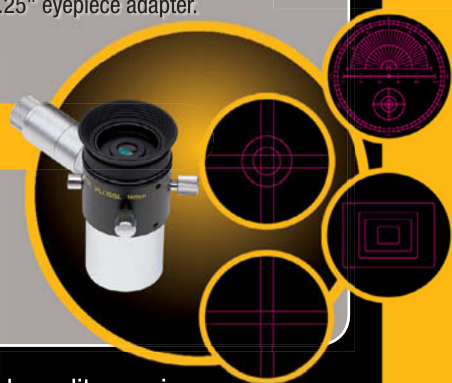

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Captivated Young Astronomer

I am a 14-year-old living in the suburbs of New Jersey, with the lights of New York radiating into the night sky. I own a nice pair of binoculars and a small telescope. Every night, weather permitting, I go outside to look at the night sky. I usually can only see bright stars and planets, never any Messier objects or nebulae. I once tried to find the Andromeda Galaxy, but in such light-polluted conditions it was a dauntingly impossible task. I wonder why I wake up in the middle of the night to find the same star, planet, or the Moon, exactly as I did the night before. What is it that keeps me going back for more?

I believe the fact that we don't fully know everything about space is why we keep exploring the night sky. We, as humans, cannot stand to know that something in space is happening without our awareness. It's rewarding to find a new object in the night sky, and it's also exciting to know that there is something not fully understood by science. I love reading about all of the Mars missions, and I love the fact that there could have been water, which meant there could have been life.

In my book, not knowing is more exciting than knowing. Maybe this is why I drag myself out of bed to look at the night sky, to experience the thrill of not knowing. Although discoveries are nice, the mysteries of space are what intrigue us all.

Nicolas Azulay
Millburn, New Jersey

Sun Complications

Alan MacRobert's sidebar is a nine-paragraph sketch that should be expanded into a book ("Why Is the Sun So Complicated?" February issue, page 25). I can't remember reading an explication of these concepts, (energy flow, positive feedback, chaos, and emergent phenomena) which makes the grand leap into declaring their profound generality.

Humanity-as-transient-byproduct-of-energy-flow is an idea I've long entertained but never seen made explicit. It is sometimes strongly implicit in popular science literature, but authors seem to stop just short of stating it flat out.

I wish Mr. MacRobert's article had included a 'Further Reading' addendum. What publications might he suggest? And in what field? (Chaotic molecular biology? Emergent anthropology? Complexity theoretic evolutionary genomics?)

William S. O'Donnell, Jr.
Chicago, Illinois

Editor's note: *You can start with the excellent Wikipedia entry on "emergence," then find the book* A Different Universe: Reinventing Physics from the Bottom Down *by Nobel Prize-winning physicist Robert B. Laughlin (2005). — Alan MacRobert*

Superstorm Consequences & Responsibility

Thank you for publishing the excellent article "The Perfect Solar Superstorm" in the February 2011 issue of *Sky & Telescope* (page 28). It's very important to point out the social consequences of an intense solar storm event. The United States should consider setting up a stockpile of some spare extra high-voltage (EHV) transformers to be prepared for such a solar storm, as well as other emergencies such as a hurricane, earthquake, or terrorist attack. I have worked for years in an effort to get the Federal Government interested in protecting the infrastructure from electromagnetic events. What follows is an excerpt from my latest effort with the Federal Communications Commission.

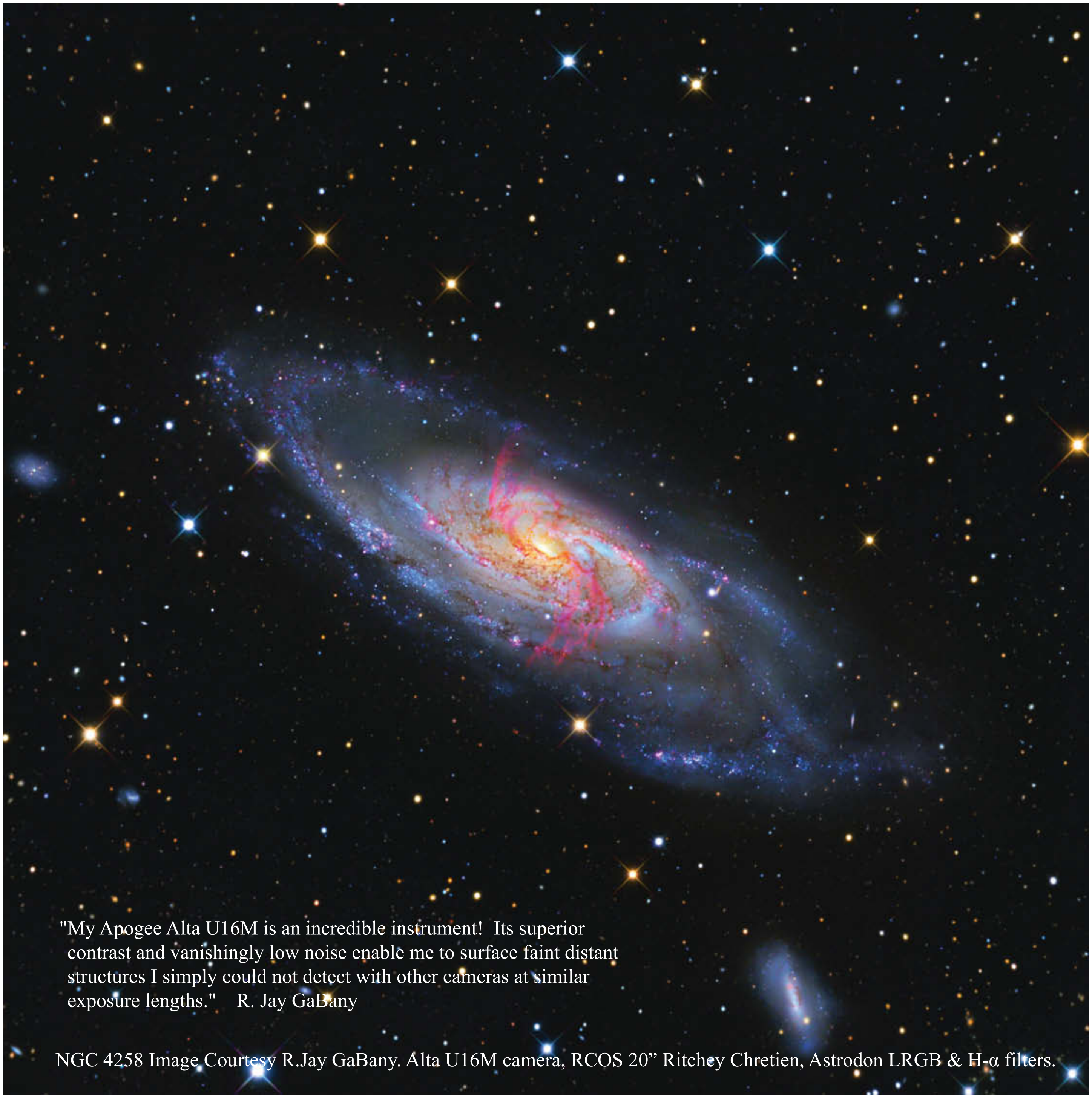
"An electromagnetic pulse (EMP) attack consists of the detonation of a nuclear weapon at an altitude of a couple of hundred miles above the United States. . . . The radiation from the nuclear explosion interacts with the Earth's atmosphere to generate an intense pulse of radio waves that can disable and destroy electronic communications and other electronic equipment over a wide area of the Nation. . .

"A related, but not identical situation can occur due to the stream of charged particles radiated by an intense solar flare. This natural event can induce damaging currents into communications and electric power grids. . .

"Both EMP attacks and intense solar storms can disable electronic communications and other electronic systems over wide areas of the United States. This is a situation where numerous network nodes are disabled at the same time.

"The impact of EMP attacks and solar storms is so broad, simultaneous, and comprehensive that it would take a long time to restore service to the Nation. During this long period of time much of our modern communications would not be available. This situation goes beyond the dual failures considered in [the FCC's Notice of Inquiry] to the simultaneous failure of thousands of network nodes and endpoint equipment at the same moment. Thus the Commission's question 'Besides single points of failure, are there dual failures that could impact a large number of users for an extended period of time?' is answered. Yes, you can have most of your network equipment failing at the same moment. This equipment will be down for a long period of time. . .

"The Commission should take the first step of issuing a Notice of Inquiry



NGC 4258 Image Courtesy R.Jay GaBany. Alta U16M camera, RCOS 20" Ritchey Chretien, Astrodon LRGB & H-α filters.

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(NOI) requesting specific engineering approaches and designs for practical protections. This NOI should also request specific draft language for regulations. Comments from the general public, governmental organizations, and EMP experts should be requested.

"The Commission should also cooperate with the Department of Defense, National Academy of Sciences, and amateur radio organizations to consider initial designs for civilian equipment resistant to EMP and solar storm effects. Finally, the Commission can publicize the subject of EMP and solar storm protection and engage in dialogue with Congress about possible steps to provide protections for America's basic electronic infrastructure."

Nickolaus Leggett
Reston, Virginia

Music for Dwarf Planets

Holst's *The Planets* is common astronomical theme music, and it is interesting to read James Reid's article about its origins ("An Astronomer's Guide to Holst's *The Planets*," January 2011 issue, page 66). As was mentioned, it goes out to Neptune. Before Pluto's reclassification, composer Colin Matthews continued the Neptune segment with *Pluto — The Renewer*. A recording from 2001 with both the Holst and Matthews pieces is available as a CD and all segments are available on iTunes.

Over the last 8 years, my group of scientists and students from Williams College and MIT have been observing Pluto's atmosphere by studying occultations of stars, so it's of particular interest to us that this first dwarf planet has its own musical suite.

Jay Pasachoff
Williamstown, Massachusetts

For the Record

✷ *The nebula on page 77 of the January 2011 issue is IC 1805, not NGC 1795.*

✷ *Sirius B was discovered by Alvan Graham Clark, not by his more famous father Alvan Clark, as implied on page 36 of the February 2011 issue.*

✷ *The three brightest stars in the chart on page 60 of the February 2011 issue are barely legible. A corrected version is available at SkyandTelescope.com/errata2011.*

50 & 25 Years Ago

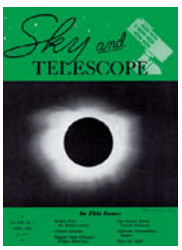
Leif J. Robinson

April 1961

Solar Granulation Speed "The granular structure of the sun's surface . . . is a visible indication of convection and turbulence in the solar atmosphere. Since such turbulence usually involves motions along our line of sight, small Doppler shifts should be detectable in the absorption lines of the solar spectrum.

"A spectral line is actually an image of a narrow strip of the solar surface at a particular wave length. . . . [Red and blue shifts] along the strip produce fine 'line wiggles,' which because of the turbulence are constantly fluctuating. . . .

"J. W. Evans and H. A. Mauter . . . showed a movie of the line wiggles. Its frames were taken at successive five-second intervals. . . .

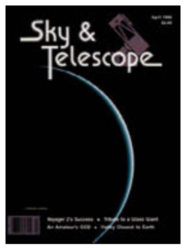


"A typical maximum velocity is about 0.6 kilometer per second."

Improved techniques now yield velocities of 1.5 to 2.0 kilometers per second.

April 1986

First Visit to Uranus "Mission personnel at the Jet Propulsion Laboratory in California engineered both long-distance repairs and a number of clever technical innovations. . . . By the time Voyager 2 reached Uranus, it was actually much better equipped to study this distant world's clouds, rings, and moons than it was when it left Earth."



Of Cosmonauts and Astronauts "A 27-year-old Russian pilot named Yuri Alexseevich Gagarin left Earth on the first manned space flight 25 years ago. . . .

"The explosion of the Space Shuttle *Challenger* last January 28th cruelly reminded us that even a quarter century after Gagarin's pioneering voyage, space flight is still a daring and dangerous adventure that is anything but routine."

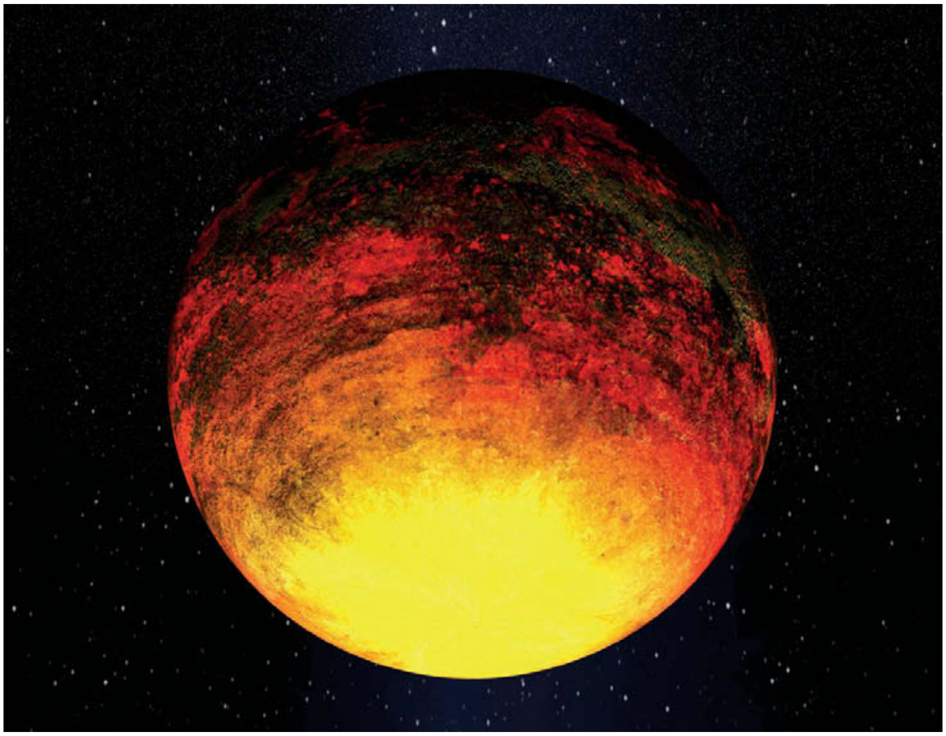
To get astronomy news as it breaks, visit SkyandTelescope.com/newsblog.

A Planet as Dense as a Cannonball

The science team for NASA's Kepler mission has announced hundreds of new extrasolar planet candidates, where stars under Kepler's watch seem to be periodically transited by small, dark bodies. One star even has *six* transiting objects. But only a few candidates so far have been solidly confirmed by determining that they have planetary masses. This is done by measuring the star's radial-velocity wobble in response to the planet's motion, a slow process that requires high-precision spectrographs at ground-based observatories.

But already one confirmed Kepler planet leaps out as really weird. Kepler-10b is only 40% larger than Earth in diameter, as determined by how much its silhouette dims its star during transits. But it has 4.6 times Earth's mass, as determined by the star's gravitational wobble. Those numbers, which are known to fairly high precision, yield a whopping average density: 8.8 grams per cubic centimeter, as much as pure iron. By comparison, Earth is the densest planet in the solar system with an average of 5.5 grams per cm^3.

Kepler-10b's high density — even considering the expected compression of material in its interior — means that it must be almost entirely rock and metal. The actual mix remains unknown. Due to gravitational compression and remaining uncertainties in the planet's mass, it could have a composition similar to Earth's.



NASA

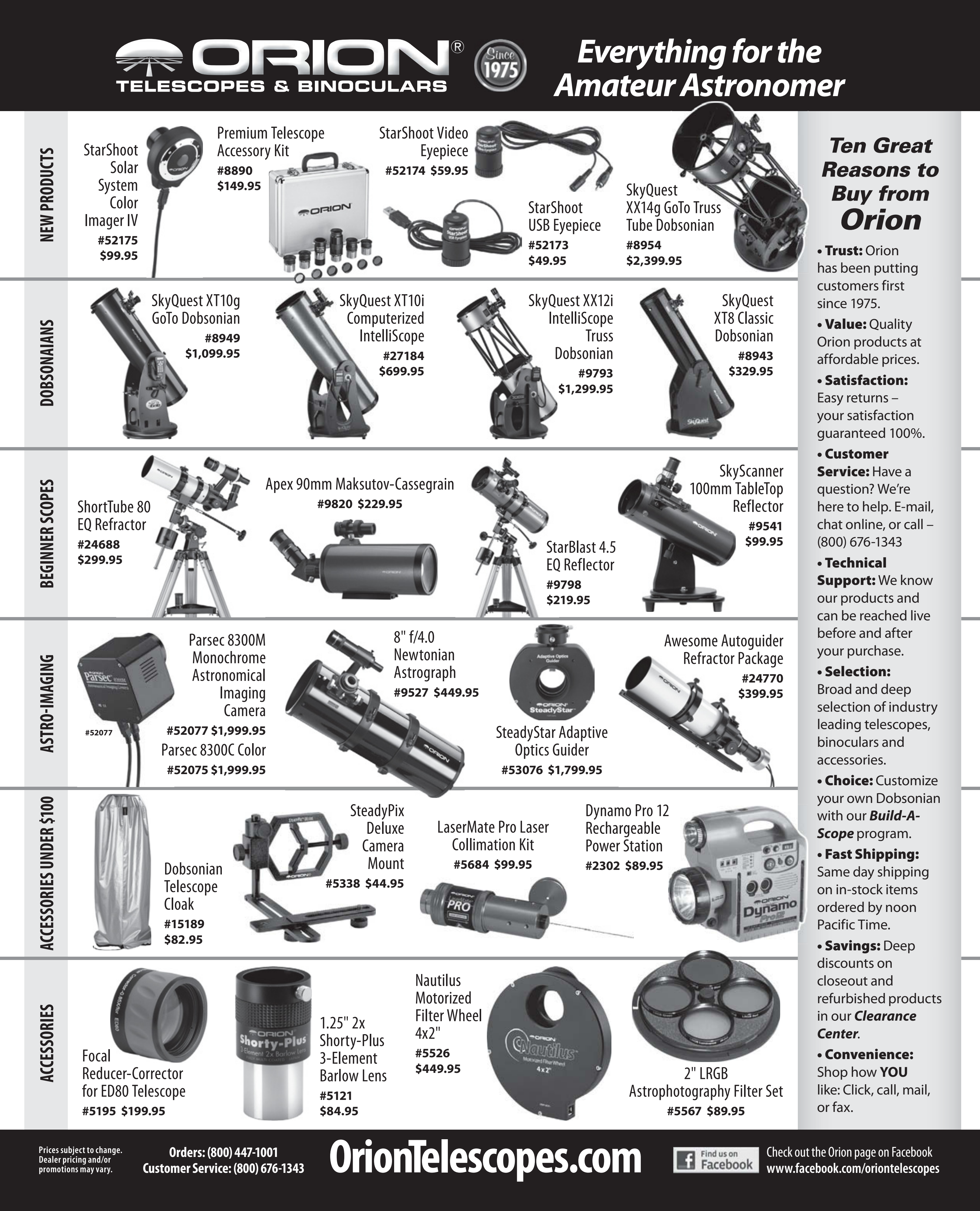
Kepler-10b orbits so close to its star that it must be tidally locked, with one side always facing the star and the other facing away. If it has no atmosphere to distribute heat, the permanent noon area should be yellow-hot and the night side black, as in this artist's concept. In reality, the entire day hemisphere would be dazzlingly lit by the nearby star's white light — 3,600 times brighter than sunlight on Earth.

Or, says exoplanet researcher Sara Seager (MIT), "The planet could be an iron world, born from mantle stripping by a giant impact." Or it might be the core of a gas giant that has had all its gas stripped off.

Kepler-10b whirls around its host star in only 20 hours. That means it's 60 times closer to its star than Earth is to the Sun. The star, Kepler-10, is a near-twin of the Sun, shining at 11th magnitude 560 light-years away in Draco. It's one of the brighter stars under the spacecraft's watch; Kepler tracks its brightness so well that the team has untangled the star's surface oscillations caused by pressure waves ringing through its interior. Such "stellar seismology" yields a star's size, mass, and luminosity to high precision, in this case to within 2 to 6 percent. This in turn allows unusual accuracy for the planet's own size and mass.

At a January press conference, Kepler team member Natalie Batalha (San Jose State University) announced the discovery as "the first unquestionably rocky planet orbiting another star." That raised the eyebrows of scientists working on the French-led CoRoT exoplanet-transit mission; they announced the discovery of a rocky planet with similar characteristics two years ago. That was CoRoT-7b, the broiling "Planet from Hell" of *S&T*'s May 2009 cover story. The most current analysis of CoRoT-7b puts it at 6.9 ± 1.4 Earth masses. But Batalha points out that Kepler-10 is a more stable star than CoRoT-7, with less "noise" in its radial-velocity readings. This enabled a more precise measure of Kepler-10b's mass.

CoRoT scientists Hans Deeg and Brandon Tingley responded diplomatically: "The models of planetary compositions are still quite speculative at this point. Given the similarities between these two worlds, it's quite likely that in the end that they will turn out to be the same class of planet, whatever that may be. Neither of them are gas giants, that much is certain."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The Most Distant Galaxy Cluster

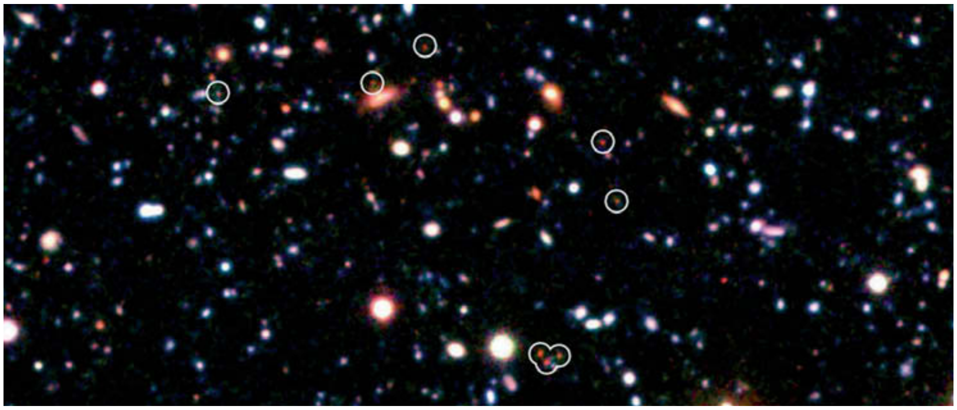
What are the largest gravitationally bound objects in the universe? That would be galaxy superclusters. We live in the outskirts of the nearest one, the Virgo Supercluster, even though it's centered 55 million light-years away. Look farther and the universe is riddled with them, connected by streamers and walls of galaxies like an endless cobwebby foam. These streamers and walls are the largest structures of any kind that exist. The wider you look beyond that, the cosmic foam simply becomes more uniform.

By contrast, the universe was extremely smooth and structureless when it emerged from the Big Bang. Clumping began with small pieces having the masses of dwarf galaxies or less. These clumps gathered to form galaxies of increasingly large size.

When did galaxies themselves start clustering? We don't know, but a group led by Peter Capak (Caltech) has just pushed back the envelope. Using deep exposures at many wavelengths, Capak and his colleagues found a group of gravitationally bound mini-galaxies at redshift 5.3, when the universe was only 1.1 billion years old. The previous record-holding early clusters were between redshifts 4 and 5.

The cluster, named COSMOS-AzTEC3, has about 12 galaxies bright enough to be detectable. All are much smaller than our Milky Way, like other early galaxies, and are bursting with star formation. One already harbors a black hole with an estimated 30 million solar masses. It's likely that since the era in which we see them, these galaxies have fallen together and merged to form a single galaxy much like our own.

As this issue went to press, other astronomers announced a galaxy likely to be at a redshift of 10.3, corresponding to 500 million years after the Big Bang. This is the highest redshift yet found. More details will appear in next month's issue.



SUBARU / NASA / JPL-CALTECH

The circled red smudges, in the constellation Sextans, are members of a cluster of young mini-galaxies seen in the early universe 1.1 billion years after the Big Bang. Since then they have probably fallen together to form a large galaxy like our Milky Way.

A Black Hole Too Big For Its Galaxy

One of the most important discoveries about galaxies in the last couple decades is that nearly all have a supermassive black hole in their centers. Moreover, the mass of the hole is closely tied to the size of the galaxy's central bulge of old, yellow stars, and especially to the bulge stars' range of velocities.

Clearly, the hole and the bulge somehow "know about" each other — even though the hole has only about a thousandth the mass and roughly a billionth the diameter. A scale model: if a galaxy's central bulge were a hundred miles across, its central black hole would be roughly the size of a sand grain.

The current theory is that black holes were so active early in galaxies' history that their jets and winds cleared all the star-forming gas out of the galaxies' inner regions, halting star formation there early. And somehow the number of stars that formed before the gas cleared out (today's bulge stars) was tied to the activity and mass of the hole.

A. REINES ET AL. / NRAO / AUI / NSF / NASA

The dwarf galaxy Henize 2-10 imaged by the Hubble Space Telescope. The supermassive black hole candidate is in the tiny vertical streak between the two large, bright arcs near center.

But Amy Reines (University of Virginia) and her colleagues have found a black hole that breaks this relationship. In the star-forming dwarf galaxy Henize 2-10, they discovered a black hole with roughly 2 million solar masses. That's half the mass of the Milky Way's hole, even though Henize 2-10 has only a few percent the mass of the Milky Way and lacks any central bulge at all.

This odd case may say something about one of astronomy's most pressing chicken-or-egg questions: Which came first, supermassive black holes or their galaxies? Reines suggests we may be seeing a rare case of "early" galaxy formation happening very late, giving us a window to processes common in the early universe. If so, it would suggest that the holes grew to their full sizes first.

The Comet Tale of Asteroid Scheila

In the wee hours of December 11th, University of Arizona astronomer Steve Larson was on cosmic patrol, taking images in northern Leo with the Catalina Sky Survey's 26-inch (0.7-m) Schmidt telescope.

There he noticed something odd about the asteroid 596 Scheila. It didn't look like a starlike pinpoint. It was fuzzy, with a 13th-magnitude glow extending a few arcminutes west and north. Other astronomers quickly confirmed its new cometary appearance.

Scheila, a main-belt asteroid, had never been seen as anything but normal since its discovery in 1906. A series of images

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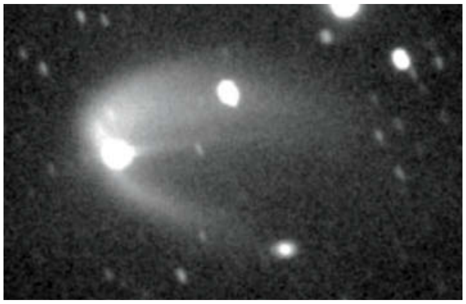


CATALINA SKY SURVEY

Asteroid 596 Scheila, imaged on December 15th by Alex Gibbs with the 1.5-meter reflector at Mount Lemmon, Arizona.

in 2005–06 by amateur Brian Warner had revealed a well-behaved asteroid rotating every 15.9 hours. But a spectrum suggested that Scheila is a rare T-type asteroid; these have dark surfaces that are a close spectral match to a bare comet nucleus.

Fainter asteroids have been seen undergoing cometary outbursts (January issue, page 22), but if Scheila is a long-dormant comet, it's a big one. Current estimates put its diameter around 70 miles (110 km).

What happened? Continued observations might distinguish an intrinsic, cometlike gush of gas and dust from an external whack by a smaller asteroid. The latter, notes dynamicist David Nesvorny (Southwest Research Institute), might give Scheila's orbit and/or its spin rate "a measurable change if the impactor was massive enough." He calculates that a 1-km object with one millionth of Scheila's mass, striking at 5 km per second, would tweak the orbit's semimajor axis by about 75 km — 50 times larger than the orbit's current uncertainty.

Hubble imagery is also planned.

Thunderstorms that Shoot Antimatter

NASA's Fermi Gamma-ray Space Telescope is watching some of the most extreme phenomena in the distant universe, but little did the Fermi team expect it to be hit from below. Nevertheless, in what lightning researcher Steven Cummer (Duke University) calls "One of most exciting discoveries in geosciences in quite a long time," Fermi has discovered that thunderstorms on Earth sometimes shoot beams of antimatter up into space.

Antimatter particles match familiar particles such as protons and electrons but have the opposite electric charge. When particles of matter and antimatter meet, they annihilate each other to produce gamma rays. The process can also work in reverse. When a high-energy gamma-ray hits or skims by something, it can decay into a particle-antiparticle pair. But as Cummer told an American Astronomical Society meeting in January, "The idea that any planet can produce antimatter and beam it into space in narrow beams

Positron engine: a thunderstorm off Madeira, Portugal.

DON AMARO

Mini-Comets Storm the Sun

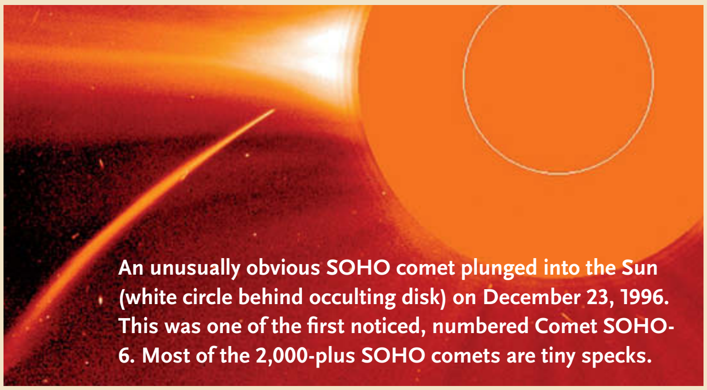
The Solar and Heliospheric Observatory (SOHO) was designed to study the Sun. But since its launch in 1995, it has also caught twice as many comets as all the astronomers in history combined.

Most of its finds are just tiny specks of comet material a few meters across, dazzlingly lit and furiously vaporizing in their final hours plunging toward — and often into — the Sun. Dozens of amateurs around the world have made a project of examining the images sent back every 12 minutes by SOHO's LASCO camera to find these moving bits. The tally of SOHO comets passed 2,000 last December.

The amateurs' diligent monitoring may pay off in an unexpected way. From December 13th to 22nd, the Sun experienced an unusual storm of 25 incoming mini-comets, all on similar orbits. These could be the forerunners of something bigger. A very big comet in the same orbital family was Comet Ikeya-Seki of 1965, one of the great comets of the last millennium. Similar but lesser sungrazing comets were seen in 1843, 1882, 1963, and 1970.

All of these are members of the "Kreutz family," named for 19th-century astronomer Heinrich Kreutz, who first noticed their orbital relationship. A landmark study by the late Brian Marsden (Minor Planet Center) found that all came from the breakup of a single giant comet in the 12th century, probably the Great Comet of 1106.

The December flurry fits a longer pattern. "Since SOHO was launched, there has been a trend of increasing numbers of Kreutz sungrazers," says Matthew Knight (Lowell Observatory). "The increase is significant and cannot be accounted for by improvements in SOHO or the increasing skill of comet hunters." Is another giant sungrazer on the way?



SOHO / LASCO CONSORTIUM

An unusually obvious SOHO comet plunged into the Sun (white circle behind occulting disk) on December 23, 1996. This was one of the first noticed, numbered Comet SOHO-6. Most of the 2,000-plus SOHO comets are tiny specks.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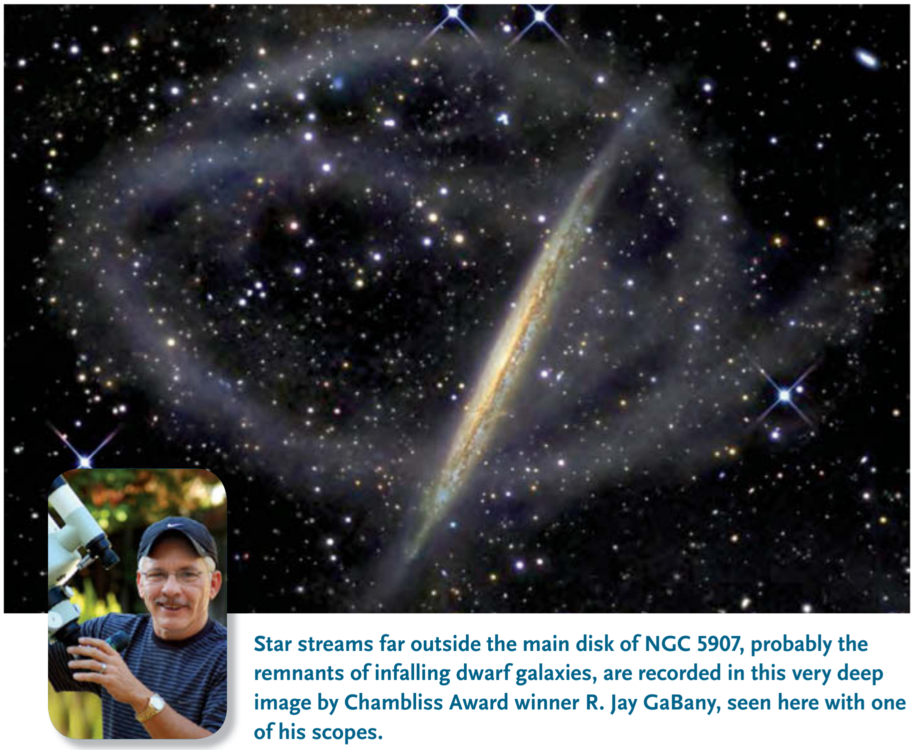


Star streams far outside the main disk of NGC 5907, probably the remnants of infalling dwarf galaxies, are recorded in this very deep image by Chambliss Award winner R. Jay GaBany, seen here with one of his scopes.

sounds like science fiction."

Positrons (antielectrons) were sensed by Fermi's Gamma-ray Burst Monitor (GBM) coming from "terrestrial gamma-ray flashes" that occur above thunderstorms. TGFs, discovered in 1994, are brief, upward sprays of gamma rays that typically last a thousandth of a second. An estimated 500 occur around the world each day, mostly unnoticed.

Fermi has detected 130 TGFs. In four of them, positrons also struck the satellite. Apparently, some of the upward gamma rays are sufficiently energetic to convert into electron-positron pairs, and when this happens near the border of space, the positrons flying onward become trapped along Earth's magnetic field lines to travel in a narrow, curved stream. Occasionally a stream intersects Fermi.

The gamma rays themselves presumably originate when electrons driven by lightning are somehow accelerated to nearly the speed of light before they can strike atoms of air. Cummer pointed out that despite decades of research, scientists still don't know exactly how lightning is produced or propagates in clouds. "This discovery has very important implications for understanding lightning itself," he said in making the announcement. "A new result like this gives us important clues about what's happening."

Lights at Night Worsen Smog

Anyone who has lived in a smoggy city knows that the ugly haze is at its least in early morning and worst in late afternoon. One reason, of course, is that more cars and factories run during the daylight hours. But another factor is sunlight. During nighttime, the nitrate radical NO_3 builds up in the darkened sky and neutralizes some of the other pollutants that foul the air. The rising Sun destroys NO_3, leading to higher levels of the bad stuff.

And so does artificial light in the night sky, according to new research presented at a December meeting of the American Geophysical Union.

Last year Harald Stark of the NOAA's Earth System Research Laboratory conducted a series of flights over Los Angeles to measure light pollution at different altitudes. "My original goal was simply to quantify the intensity of city lights," Stark explains. But it also became clear that the urban glow was affecting nighttime atmospheric chemistry. When Stark and his team plugged the measured illumination into photochemical models, they found that the city lights were destroying up to 7% of the nitrate radicals that would normally be cleaning the nighttime atmosphere. This results in nitrogen-oxide levels some 5% higher than they would otherwise be, making more of these gases available for smog- and ozone-producing reactions each morning. "Ozone production during daytime could be increased by nighttime light sources," Stark concludes.

"Many cities are close to their limits of allowable ozone levels," says Bob Parks, executive director of the International Dark-Sky Association, "so this news is expected to have big implications for outdoor-lighting practices and should be of special interest to the Environmental Protection Agency."

Most light pollution in the sky is unnecessary. It is the wasted light spilled from badly designed or improperly aimed fixtures that send some of their rays uselessly sideways or up, rather than down toward the area that was meant to be illuminated.

Amateur Astronomy Researcher of the Year

R. Jay GaBany of San Jose, California, is the 2011 winner of the American Astronomical Society's Chambliss Amateur Achievement Award. The award is given each year to an amateur astronomer from North America who makes outstanding contributions to scientific research.

Using a 20-inch telescope at the remote Black Bird Observatory in New Mexico, GaBany has been one of the world's leading amateur astrophotographers for the past decade. In recent years he has devoted hundreds of hours to working with a team led by David Martinez-Delgado (Max Planck Institute for Astronomy, Germany) to take extremely deep CCD images of galaxies — revealing faint tidal streams, rings, and arcs in the outer halos of large spirals (*S&T:* January 2009, page 92). These images are helping scientists understand how large galaxies such as the Milky Way build up through the collisions and mergers of many smaller ones. Observing under very dark skies, and using very sensitive cameras, long exposure times, and advanced imaging and processing techniques, GaBany has managed to capture details not seen in professional images. ✦

Requiem for Akatsuki

We're fond of our spacecraft and anxious when we send them on their way. It's hard to lose one.

In July 2009, with a group of European and American scientists, I visited the Japanese Space Agency research center in Sagamihara, outside Tokyo, to meet with the scientists and engineers building the Venus Climate Orbiter, subsequently named Akatsuki. We planned joint observations with the European Space Agency's Venus Express spacecraft, which went into orbit in 2006.

A highlight of this trip was seeing the spacecraft itself under construction. As we donned our slippers, bunny suits, and masks to enter the clean room, there was a feeling of reverence. The innards of the machine were splayed out on three panels, dense with wires, instruments, lenses, and sensors. Behind us was the "spacecraft bus," the solid shell within which all of these elegant instruments and electronics would be folded — high-tech origami. Standing inches from the partly assembled craft, I thought, "This thing is going to Venus!" And it did. Only it didn't get to stay.

In late 2010 I became an official member of the Akatsuki team as the spacecraft was about to enter Venus orbit and begin a multi-year study of the planet's turbulent atmosphere and volcanic surface. I was on a NASA project to use Akatsuki data to study the interaction between volcanoes, clouds, and climate on Venus, and to spread word of the results to the American public.

And then, on December 7th, in a heartbreaking 12 minutes, it was all over. Something went terribly wrong during the critical orbital-insertion rocket burn. Once engineers got a handle on what had happened, it was too late — Akatsuki was receding from Venus on a new orbit around the Sun.

A few images taken while still in close range showed the great promise of the instruments, which magnified our sadness. This was such a wonderful spacecraft, so well equipped to undertake a groundbreaking investigation of our neighboring world, in good health and fully functioning, having made it tens of millions of miles across the void, and now careening helplessly in the wrong direction.

But we may have another opportunity. Akatsuki will swing by Venus again in 5 years. Just maybe — if the problem can be successfully analyzed and corrected for, and if nothing else breaks — the Japanese can try again. Akatsuki is not quite dead. It's a space ghost; its path is precisely known and predictable, but beyond human control.

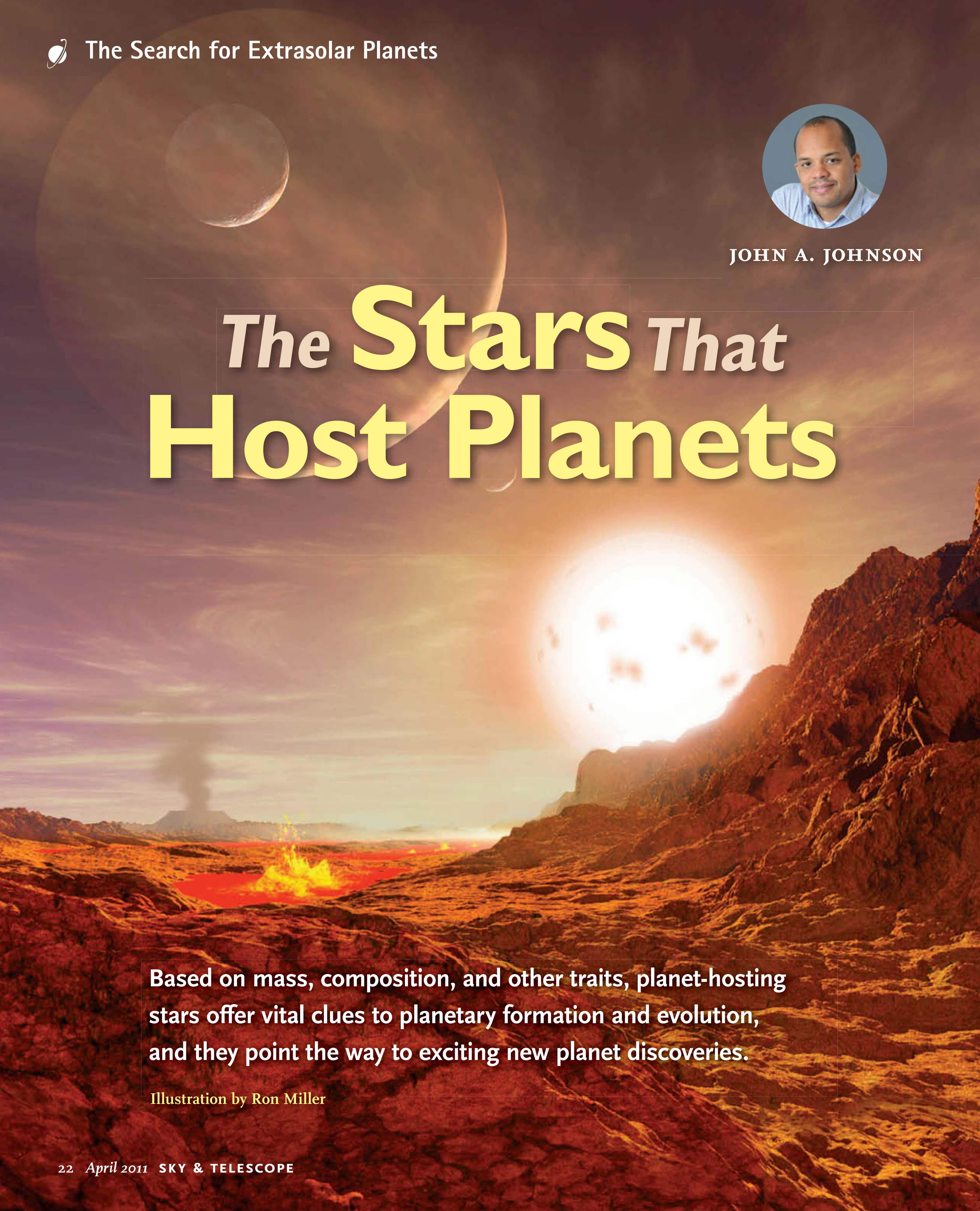
ISAS / JAXA

VENUS FROM AKATSUKI Akatsuki's cameras were working fine two days after the spacecraft flew past Venus. Left to right: These images were taken at ultraviolet, near-infrared, and far-infrared wavelengths, respectively.

What will happen to the team of brilliant scientists and engineers in Japan, some of who have worked for more than a decade on this project? A 6-year cruise phase is not unusual — that's often how long it takes to reach destinations in the more distant outer solar system. But this is an unplanned 6-year hiatus in a project, with uncertain prospects of resurrection. Team members will move on to other things, and perhaps they will reassemble in some form 6 years hence to try again.

What will our world and its space programs look like in 6 years when Akatsuki again approaches Venus? Currently, several proposals are under consideration for new Venus orbiters, landers, or balloons that might arrive at Venus in the 2017 time frame. So Akatsuki may indeed have company, and possibilities for joint observation, if and when it's able to resume its mission. ✦

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



JOHN A. JOHNSON

The Stars That Host Planets

Based on mass, composition, and other traits, planet-hosting stars offer vital clues to planetary formation and evolution, and they point the way to exciting new planet discoveries.

Illustration by Ron Miller

If you're an alien astronomer looking for Jupiter-mass planets, the Sun is hardly the best place to look. Heftier stars rich in heavy elements would provide much higher odds of success. But if you're interested in smaller, rocky planets, then searching around red-dwarf (*M*) stars would be the best strategy. In the search for planets, the type of star matters a lot, and the relationship between the properties of stars and planets provides telltale clues about planet formation.

Planet hunters such as myself have found that the likelihood of finding a Jupiter-mass planet depends strongly on two basic stellar properties: mass and composition. In the search for giant planets, *A*-type stars such as Sirius, with its hefty 2 solar masses, make much better targets than dinky *M* dwarfs such as Barnard's Star, which is only 15% as massive as the Sun. An extremely iron-rich star such as 55 Cancri, which is similar to the Sun except that it has twice the Sun's iron content, is about 20 times more likely to have a giant planet than an anemic star such as Gamma Pavonis, which contains only about 10% of the Sun's iron content.

The high prevalence of giant planets around metal-rich stars has been well established (to astronomers, "metals" refer to elements heavier than hydrogen and helium). In 1997, only two years after astronomers discovered the first planet (51 Pegasi b) around a Sun-like star, they noticed that stars hosting planets tend to contain much more iron than the Sun. Several groups of planet hunters, including Debra Fischer (now at Yale University) and her Next 2000 Stars team, immediately took advantage of this correlation and tilted their target lists toward metal-rich stars. This intentional bias resulted in a spike in the discovery rate of hot Jupiters.

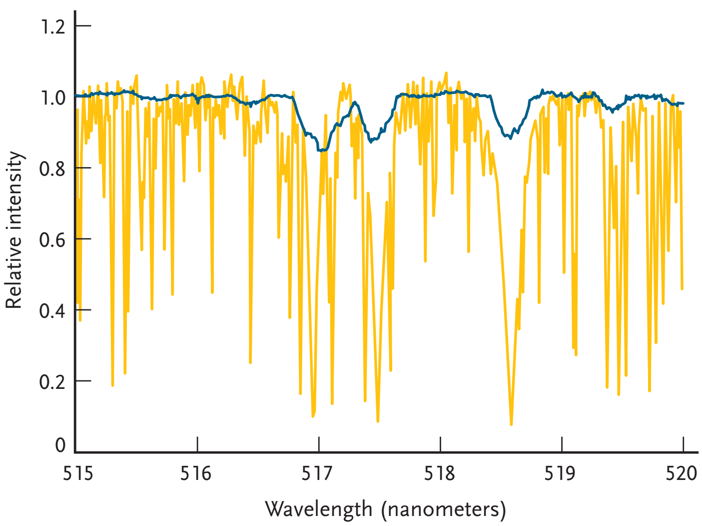
LUIS CALÇADA / ESO

RED DWARF HOST Artist Luis Calçada depicts the super-Earth planet orbiting the *M* dwarf Gliese 1214. The star has only about 16% of the Sun's diameter, 21% of its mass, and 3% of its luminosity.

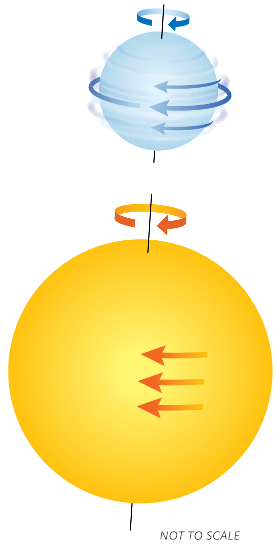
But there are other relationships between planets and their host stars, and they provide clues about the planet-formation process, which informs our understanding of the solar system's origins. A star and its planets form from the same collection of gas and dust, so the stars we see today serve as historical markers of the planet-formation process that operated long ago. By studying correlations between planet properties and the physical characteristics of stars, we can develop better models of how planets form and how planetary orbits evolve.

Stars in Retirement

Though the planet–metallicity relationship has been known for over a decade, the dependence of planet frequency on stellar mass has only recently come under scrutiny. This delay resulted from the fact that massive stars present difficulties owing to their fast rotation speeds. Rapid rotators display very broad spectral lines, making it extremely difficult to measure the small Doppler shifts induced by orbiting planets. But my colleagues and I have recently revealed the population of planets around massive stars thanks in large part to our ability to take advantage of certain beneficial effects of stellar evolution.



EFFECTS OF ROTATION The blue curve is part of a spectrum for a 2-solar-mass main-sequence *A* star that is rotating at 90 km/second. The orange curve is the same part of the spectrum for a 2-solar-mass *K* subgiant that is rotating at only 2 km/second. With the slower rotation and cooler temperature, the *K* subgiant's absorption lines are much deeper and sharper, making it much easier to measure small changes in the star's velocity toward and away from Earth induced by an orbiting planet.



S&T: LEAH TISCIONE
SOURCE: JOHN JOHNSON / CALIFORNIA PLANET SURVEY

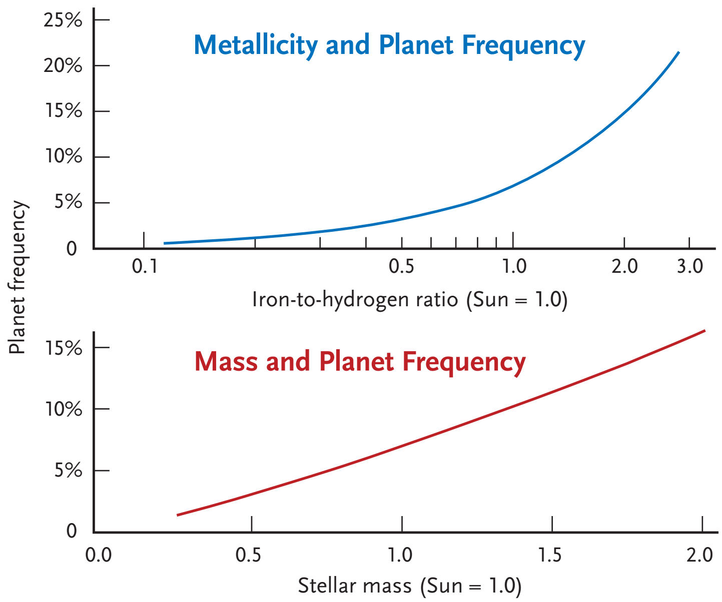
A main-sequence star works around the clock fusing hydrogen into heavier elements. When the star's hydrogen fuel is expended, it passes into "retirement" by turning off of the main sequence. The star expands, cools, and spins down. These changes are vitally important for finding planets because hot stars have sparse spectral lines, and rapid rotation smears those spectral lines. Stellar evolution solves both problems.

Evolved stars also have the advantage of being extremely luminous because their radii have expanded many times, giving them a much larger surface area to radiate light. But when stars become full-fledged red giants, their big, fluffy atmospheres begin to pulsate, making it difficult for planet hunters to discern between stellar motion caused by a planet's gravitational tug and motion in the star's atmosphere. Fortunately, "super-Jupiters" cause their stars to wobble with large amplitudes, so they can stand out above the noise. Bun'ei Sato (Tokyo Institute of Technology), Andrzej Niedzielski (Penn State University), and others have found about 30 super-Jupiters around *K*-giants. Some of the sky's brightest planet hosts are *K*-giants, including Pollux, Gamma Cephei, and Iota Draconis.

Just after stars run out of hydrogen fuel, yet before they become red giants, they spend a brief period in a "Goldilocks" phase. They are cool and slowly rotating, but they're still stable enough for the detection of planets with a wide range of masses. Some of these stars, known as subgiants, have large masses and yet provide the Doppler stability of a Sun-like star. My research is focused on searching for and studying planets around massive subgiants, and we've found dozens of additional giant planets — with masses down to just half a Jupiter — around these "retired *A* stars." Subgiants, together with the more numerous and more massive counterparts on the red-giant branch, have pulled back the veil surrounding massive (*A*-type) stars and revealed a plethora of planets.

PLANETARY MIGRATION

Planets migrate in their orbits through a variety of processes. In some cases, a planet gravitationally interacts with its disk, causing the planet to get dragged inward along with disk material. In other systems, planets will gravitationally interact with other planets or with a binary companion star, causing the planets to be scattered into new orbits. A recent study by author John Johnson and his student Tim Morton suggests that planet-planet scattering is the dominant migration method.



PROPERTIES OF PLANET HOSTS ***Top:*** **This graph plots the observed iron-to-hydrogen ratio in stars versus their likelihood of having giant planets, with the effects of stellar mass removed. Astronomers noticed soon after the first exoplanets were discovered that stars containing larger amounts of heavy elements (such as iron) are more likely to possess planets.** ***Above:*** **This graph shows that massive stars are more likely than lower-mass stars to have planets. In both cases, these relationships are probably due to the fact that massive and metal-rich stars in their formative stages are surrounded by disks richer in planet-forming material.**

JOHN JOHNSON / CALIFORNIA PLANET SURVEY (2)

Clues to Planet Formation

Doppler surveys have provided a nearly complete census of giant planets orbiting within roughly 3 astronomical units around a wide variety of stars. In a recent study, my collaborators and I found that about 1 in 16 stars similar to the Sun (in terms of mass and metallicity) have one or more Jupiter-sized planets. But the odds of finding a gas giant increase to about 1 in 6 around *A* stars, which are twice as massive as the Sun. This crucial finding has important implications for planet formation, and helps point the way toward additional planet discoveries.

There are currently two widely accepted models of giant-planet formation. One, known as the disk-instability theory, posits a "top-down" formation process. Once a portion of a protoplanetary disk exceeds a critical density, it can collapse under its own weight and form a planet rapidly. The other theory, known as core accretion, predicts that planets form in a "bottom-up" process, starting with the slow accumulation of dust and ice grains. Protoplanetary cores eventually begin sweeping up large quantities of gas, resulting in a gas giant with a solid core.

These two theories make very different predictions about the sensitivity of planet formation to the properties of the protoplanetary disk. The core-accretion model predicts a strong dependence on the amount of heavy elements, which serve as planetary building blocks. The abundance of dust and other solids should increase in massive, metal-rich disks, increasing the efficiency of planet formation. But the disk-instability process predicts that disks of all masses should form planets nearly as efficiently because a disk's ability to form overdensities depends primarily on the ratio of the star's mass to the disk's mass. If disk mass increases in lockstep with star mass, then the ratio remains fixed.

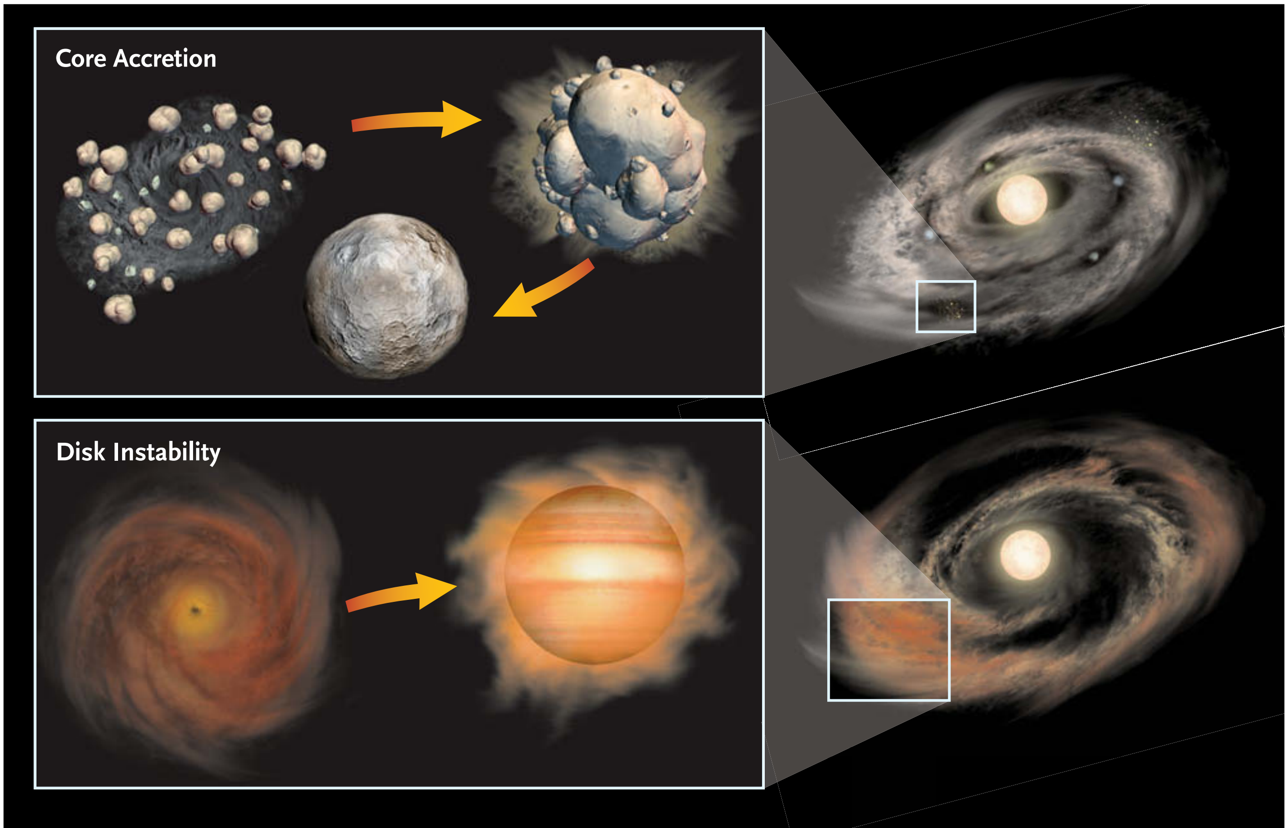
Since a star and its planets form from the same disk material, the present-day properties of stars provide a vital link to their distant planet-building past. Massive stars containing enhanced levels of heavy elements should have possessed massive, dust-rich disks long ago. The observed dependence of planet occurrence on stellar mass and metal content provides strong support that the core-accretion process is the most common way that nature forms the kind of planets we're discovering today.

Hot Stars and Tilted Orbits

The variations of planet properties with stellar mass also provide clues about how planetary orbits evolve. For example, exoplanets often have far more eccentric (elongated) orbits than solar system planets, and there are about 100 examples of giant exoplanets with small orbits, the so-called hot Jupiters. How eccentric planets and hot Jupiters migrated into these orbits remains a mystery. But astronomers are finding important clues, as well as many surprises, by measuring the degree to which exoplanet orbits are tilted with respect to their stars' rotation axis.

Solar system planets orbit in the same direction and in nearly the same plane as the Sun spins, meaning the solar system exhibits a high degree of spin-orbit alignment. When astronomers first started measuring hot-Jupiter spin-orbit angles, they found that the planets were also well aligned with the host stars' equators. This led scientists to conclude that whatever mechanism is responsible for moving planets into tight orbits must preserve spin-orbit alignment.

But this picture of a gentle hot-Jupiter evolution was recently shattered by the discovery of about 15 hot Jupiters with grossly misaligned orbits (*S&T:* July 2010, page 18). Indeed, some of these planets even orbit in a retrograde fashion, in the *opposite direction* of the spin of their host stars! Joshua Winn (MIT), Dan Fabrycky (Harvard-Smithsonian Center for Astrophysics), Simon Albrecht (MIT), and I have since determined that less-massive, cooler stars tend to have well-aligned planets, whereas heftier, hotter stars tend to have planets on tilted orbits.



PLANET FORMATION Theorists have proposed two broad models to explain how planets form. In the core-accretion scenario *(top)*, planets from by the slow accumulation of smaller objects until they form planet-size bodies. In the disk-instability scenario *(above)*, a portion of a protoplanetary disk builds up in density until it gravitationally collapses on a rapid timescale to form a giant planet. Studies of planet-bearing stars suggest that most planets in the modern-day universe formed by core accretion.

S&T: LEAH TISCIONE

The reason for this dichotomy probably has to do with how stellar structure changes with mass, not with how planetary orbits evolve. Close-up views of our Sun reveal a bubbling, boiling surface caused by hotter material rising and cooler material falling — a process called convection. This layer of convective motion sits atop a relatively calm radiative layer. According to our theory, a close-in planet can gravitationally tug the outer convective layer into alignment, independently of the radiative interior. In this way, low-mass stars may be aligned with the orbits of their planets, but the alignment is only skin deep.

Massive stars, on the other hand, have no convective layer; their radiative zone extends all the way to the star's surface. If the majority of hot Jupiters have tilted orbits, then this fact is erased around low-mass stars yet preserved around massive stars. If this theory holds up with further observations, then hot, massive stars may provide us with a clear view of the topsy-turvy nature of planet formation and evolution. Once again, stellar mass matters.

Small Planets Around Small Stars

While about 1 in 6 *A*-type stars has a Jupiter-mass companion, only about 1 in 50 *M* dwarfs has a gas-giant planet. Although red dwarfs are not the best places to search for giant planets like Jupiter and Saturn, they offer favorable hunting grounds in the search for low-mass planets.

Red dwarfs have low masses and thus accelerate more readily when tugged upon by a planet. Unfortunately, they are optically faint, making it time consuming to acquire high-resolution spectra using even the largest optical telescopes. Jacob Bean (Harvard-Smithsonian CfA) and his European collaborators have demonstrated that it's possible to measure high-precision Doppler shifts in the infrared, and they are actively searching for low-mass planets around the Sun's closest and least-massive neighbors.

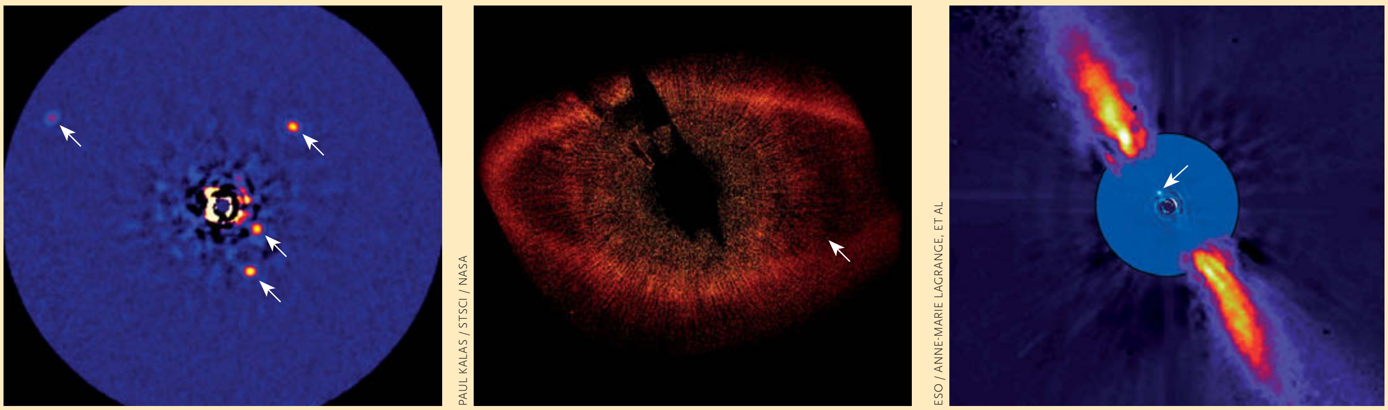
Red dwarfs' small sizes also make them excellent targets for searches using the transit method. The depth of the photometric dip caused by a planet passing in front of its star as viewed from Earth depends on the ratio

Host Stars and Exoplanet Imaging

OBSERVED STAR-PLANET relationships have pointed the way toward planet discoveries using techniques other than the Doppler and transit methods. One such technique is direct imaging. Separating a planet's feeble light from that of its overwhelmingly bright parent star is a very difficult task. But the task is considerably easier for massive young planets. Planets start out very hot and then cool with time. The younger the planet, the brighter it will appear and the easier it will be for astronomers to image.

Massive stars have shorter lifetimes than Sun-like stars or red (*M*) dwarfs, so any *A* star we see is younger than our Sun. But there are far more *M* stars in the galaxy than there are *A* stars; 70% of the stars closest to the Sun are *M* dwarfs. To study how these competing effects determine what types of stars should harbor the most "photogenic" planets, Justin Crepp (Caltech) has recently performed simulations of planet surveys. He predicts that future imaged planets will most likely reside around massive *A*-type stars, owing in large part to their youth, brightness, and odds of having a giant planet.

Crepp's prediction accords well with observations. The first three relatively nearby main-sequence stars with imaged planets all belong to spectral type *A*: HR 8799, Fomalhaut, and Beta Pictoris. Based on model predictions and the early returns from high-contrast imaging surveys, astronomers are tilting their target lists, this time taking advantage of the natural youth of *A*-type stars and their propensity to host young, bright planets. Astronomers now see high stellar mass as an easily observed flag waving at us to indicate the presence of detectable giant planets.



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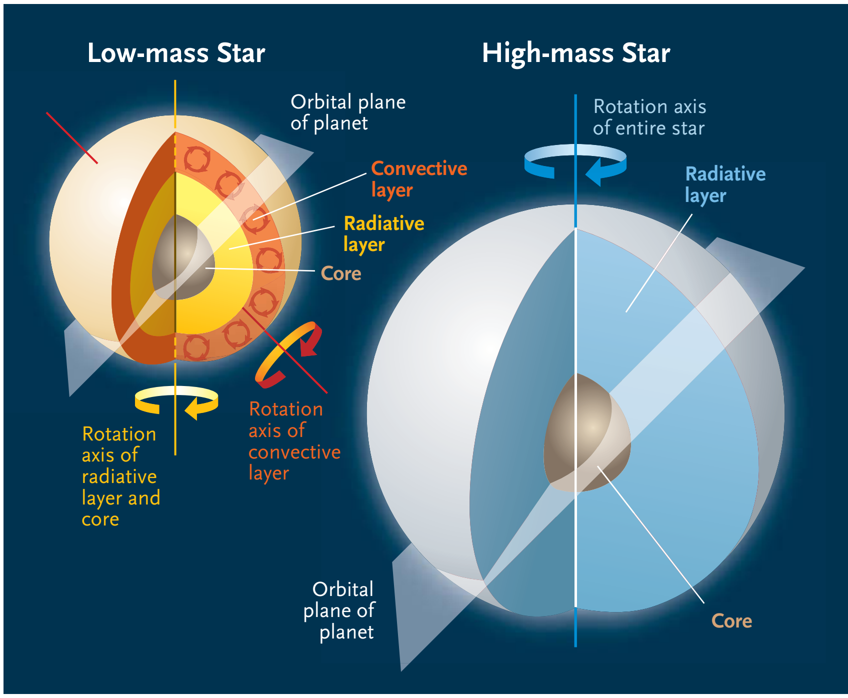
PAUL KALAS / STSCI / NASA

ESO / ANNE-MARIE LAGRANGE, ET AL

PICTURED PLANETS As predicted, the easiest sites for direct exoplanet images come around young *A*-type stars. All currently imaged exoplanets around main-sequence stars orbit young *A* stars: four planets (the innermost planet was recently discovered) around HR 8799 *(left)*, a planet around Fomalhaut *(center)*, and a planet around Beta Pictoris *(right)*. The stars themselves are blotted out by occulting disks.

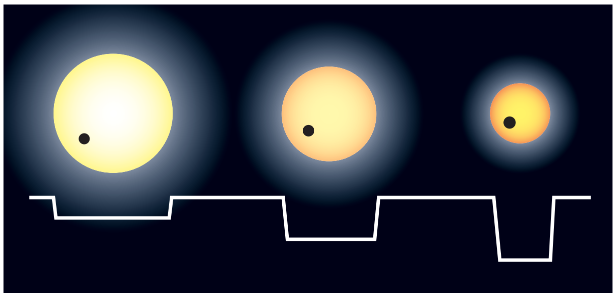


S&T: LEAH TISCIONE

SPIN-ORBIT ALIGNMENT Astronomers have recently found that transiting hot Jupiters around cooler, lower-mass stars tend to have orbits that are well aligned (perpendicular) to their host star's spin axis. But for hotter, higher-mass stars, the planetary orbits are usually highly inclined to the star's rotation axis. The author and his colleagues have developed a model in which the seeming "good" alignment in low-mass stars is only skin deep. If a planet is massive enough, it can torque the star's outer convective layer into alignment, but deeper layers remain highly inclined. This model suggests that chaotic processes cause planets to migrate into tight orbits, and that close-in planets around cool stars can torque their stars' convective layers into alignment with their orbital plane.

of the projected areas of the planet and the star. Stars with smaller radii thus dim more when a planet passes in front of them, making smaller planets much more detectable around *M* dwarfs than Sun-size stars. Using this method, David Charbonneau (Harvard-Smithsonian CfA) and his colleagues discovered the transiting super-Earth Gliese 1214b.

Another planet-hunting method takes advantage of Einstein's general theory of relativity. Massive bodies bend space around them, and this bending can act like a lens to magnify the light of a background star. Just as stars can bend light, planets can, too. Gravitational microlensing requires a very precise alignment of a foreground and background star. Since they constitute roughly 85% of all stars in our galaxy, *M* dwarfs and their planets are the most likely types of stars to serve as lenses. Microlensing surveys are most sensitive to low-mass planets orbiting several astronomical units from their stars. Micro-



S&T: LEAH TISCIONE

HOW TO FIND EXO-EARTHS If you want to find a transiting Earth-size planet, you're more likely to find one orbiting a small star, such as a red (*M*) dwarf. A 1-Earth-diameter planet orbiting a red dwarf (right) will produce a deeper and easier-to-detect transit signal than an identical planet orbiting a larger star.

lensing planet hunters such as Andrew Gould (Ohio State University) and Subo Dong (Institute for Advanced Study) have found that long-period, Neptune-mass planets are found around about 1 in 3 *M* dwarfs.

Stellar Mass Matters

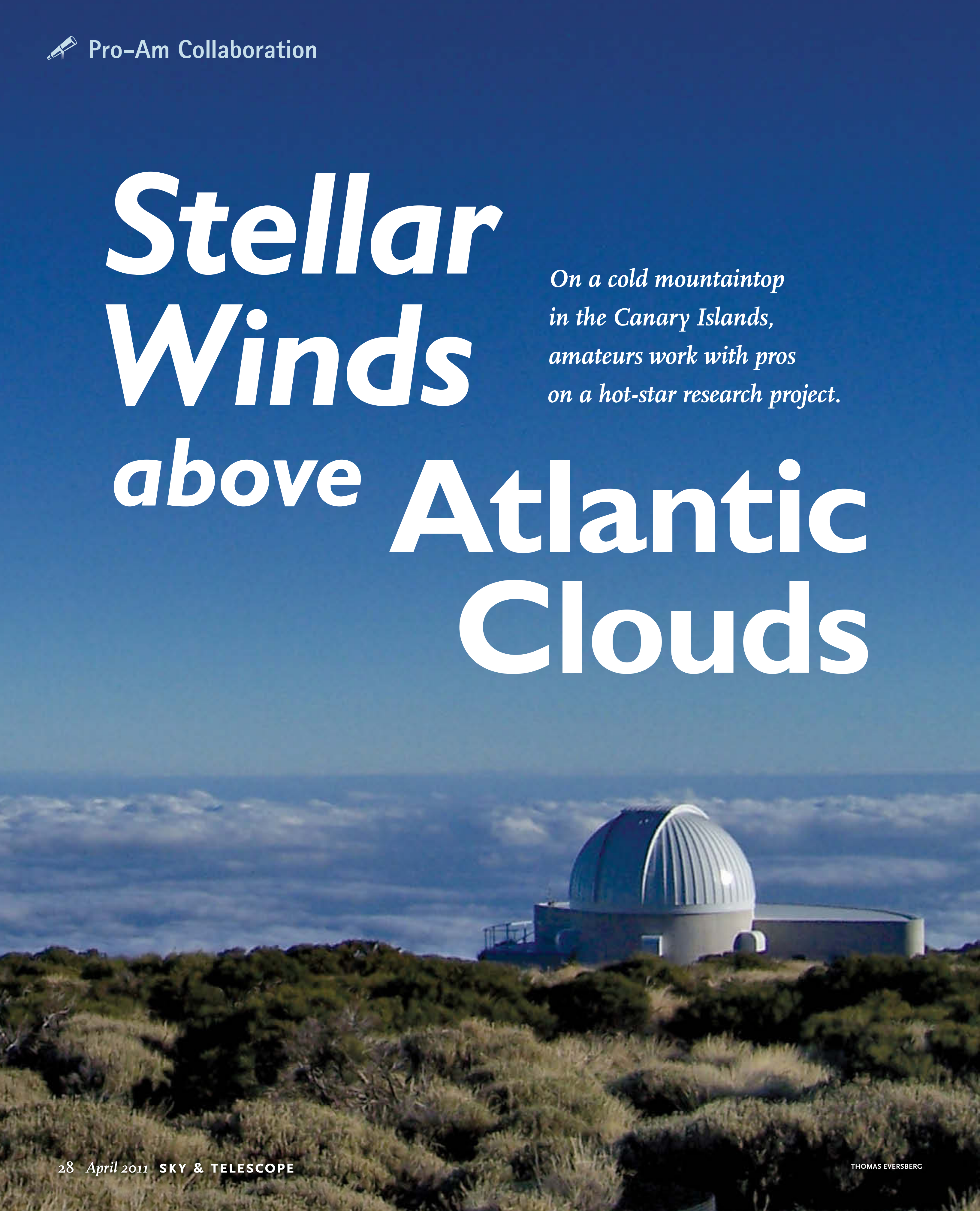
The study of planets is intimately linked to the study of stars. The stars in the night sky are the potential suns of other planetary systems, and the properties of stars can either help or hinder us in the discovery and characterization of exoplanets. But there is no one-size-fits-all strategy. Different stars provide different opportunities for discovery. The process of finding planets requires an in-depth understanding of what kinds of stars make the best targets for the scientific question at hand.

Finally, the relationships between stars and planets give us perspective. Compared to its neighboring stars, the Sun is not particularly exceptional in either mass or metallicity. So the next time you look up into the night sky and see Jupiter shining brightly, remember how lucky you are to see such a massive planet up close. ✦

John A. Johnson is an assistant professor of astronomy and astrophysics at the California Institute of Technology. His research is focused on the detection and characterization of planets around other stars.

Stellar Winds above Atlantic Clouds

On a cold mountaintop in the Canary Islands, amateurs work with pros on a hot-star research project.



THOMAS EVERSBERG

AMATEUR ASTRONOMERS have always admired professionals for their awesome telescopes and equipment, their access to the world's best observing sites, and also for their detailed, methodical planning to do the most productive possible projects. Compared to what most of us do, professional astronomy is in a different league.

This is a story of how some of us went there and played on the same field.

Backyard amateurs have always contributed to astronomy research, but digital imaging and data collection have broadened their range enormously. One new field for amateurs is taking spectra of bright, massive stars to monitor variable emission lines and other stellar activity. Skilled amateurs today can build, or buy off-the-shelf, small, high-quality spectrographs that meet professional requirements for such projects.

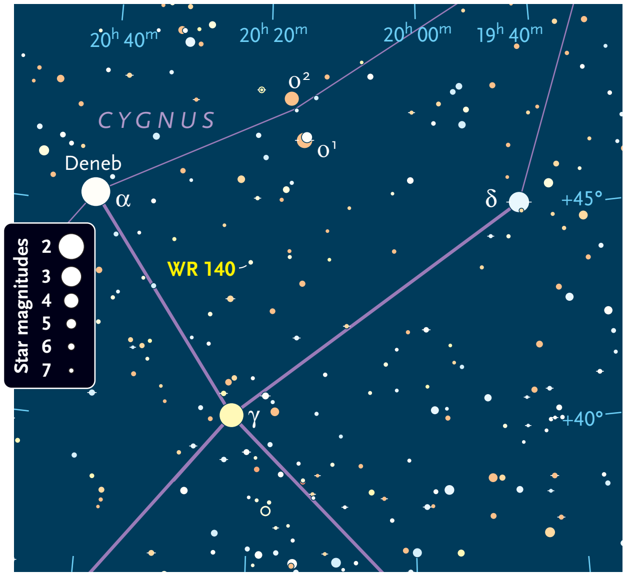
THOMAS EVERSBERG

BY THOMAS EVERSBERG

Professional spectrographs, meanwhile, are usually found on heavily oversubscribed telescopes that emphasize "fashionable" research and projects that can be accomplished with the fewest possible telescope hours granted by a time-allocation committee. It's hard to get large amounts of time for an extended observing campaign. So we created an unusual pro-am collaboration in order to bypass this problem.

The Idea

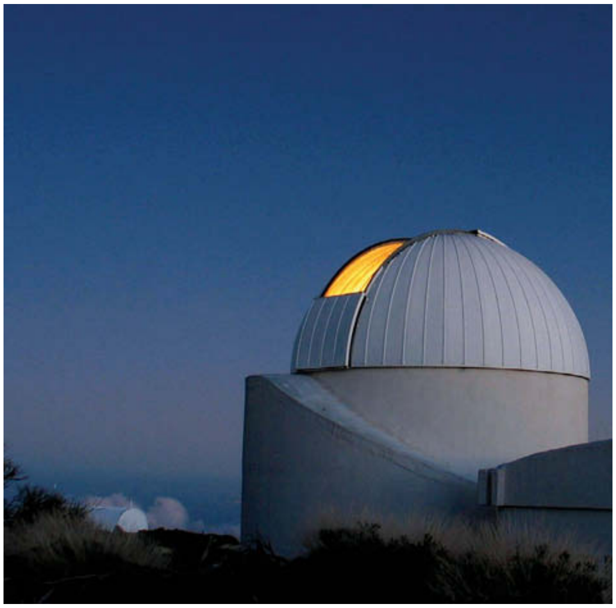
In 2006 I had a discussion with my mentor and friend Anthony Moffat at the University of Montreal, who for many years has been a specialist in massive hot stars. Our topic was how to mount an observing campaign for the ultra-hot binary star WR 140 in Cygnus, the best known of the "colliding-wind" binaries. WR 140, at a distance of about 6,000 light-years, appears as a single, unassuming, magnitude-7.1 point of light in a telescope (or binoculars). But there's a lot going on here. The pair consists of a carbon-rich Wolf-Rayet star and a more massive, type-*O*5 star swinging around each other every 7.9 years. Their orbit is highly elliptical; at the far end of the ellipse the two stars are 30 astronomical units apart, but around periastron they rapidly dip to within about 2 a.u. of each other. At each such swing-by, the system creates a thick burst of carbon-rich dust, goes through a series of spectral changes at visible wavelengths, and displays a sequence of X-ray and radio changes as well. From observations of many kinds, astronomers have figured out that most of these phenomena arise where the two stars' powerful winds collide. In fact WR 140 has become the archetypal colliding-wind binary. But some of the geometry and physics has remained obscure.



HIDDEN IN PLAIN SIGHT In one of the summer Milky Way's most familiar rich fields for binoculars, the colliding-wind binary star WR 140 (also known as HD 193793 and V1687 Cygni) is almost lost among other 7th-magnitude specks.

JOSÉ RIBEIRO

WORKHORSE The Mons Telescope, a 1972-era 20-inch Cassegrain, poses above the project's second Portuguese team: Luis Carreira, Filipe Alves, José Ribeiro, and Alberto Fernando (left to right).



FILIPE DIAS

LOOKING UP **Twilight falls on the Mons Telescope as preparations wrap up for its nightly rendezvous with a very interesting 7th-magnitude speck.**

The two stars were next due to swing close by each other in January 2009. If we wanted to learn more, this was when the whole sequence of events ought to play itself out again.

The *WR* star is a bare, carbon-rich stellar interior that has already blown off its hydrogen layers and is on its way to going supernova. As such it emits about 10 times as intense a wind as the hot *O* star, which still retains its hydrogen mantle. Because of this imbalance of power, the wind of the *WR* star wraps around and blows back the wind of the *O* star. The interface where the two winds collide forms a "shock cone" of dense, highly ionized, X-ray-hot material, vaguely comet shaped. We see the *O* star through the wall of the cone for most of the 7.9-year orbit.

Despite astronomers' successes in working out this picture, some important aspects of the system — such as the opening angle of the shock cone and even the tilt of the stars' orbit to our line of sight — remained poorly constrained.

As Tony Moffat and I discussed the possibilities, we knew that observing for just a few nights around the stars' periastron passage would not be enough. We needed an extended run of several months. This meant we would have to use relatively small telescopes with few demands on their time. And if amateurs were going to help fill this need, a big team would be essential: who wants to spend four months doing non-stop observing?

Another solution would be to use robotic telescopes instead of human observers. But then where's the hands-on fun?

After Tony and I met, I announced the idea on the forum of the Spectroscopy section of the German ama-

JOSÉ RIBEIRO

PRIME SITE **On the island of Tenerife, 7,840 feet (2,390 meters) high in the steady air flowing across the Atlantic, Teide Observatory is home to 12 telescopes of up to 60 inches (1.52 meters) aperture. Much larger scopes grace the neighboring island of La Palma.**

teur society *Vereinigung der Sternenfreunde* (spektroskopie.fg-vds.de) — and also, to recruit from other countries, on the forum of the Astronomical Ring for Access to Spectroscopy (ARAS: astrosurf.com/aras). I also designed a webpage for the project: www.stsci.de/wr140/index_e.htm. We let everyone know that WR 140's periastron passage should be observable with medium-resolution spectrographs on small telescopes.

Sure enough, experienced amateurs in Germany, France, England, Portugal, and Spain took notice. It became clear that amateur spectroscopists could indeed help investigate this binary. Furthermore, we realized that a campaign would connect amateurs from different countries for exciting work in a field they love.

Within about two weeks almost 20 amateur spectroscopists announced their interest in joining a coordinated campaign. Professionals too were planning their own specialized campaigns, to be done in France, Finland, India, Canada, and the U.S., as well as in space by NASA's Rossi X-Ray Timing Explorer (RXTE) and Chandra X-ray Observatory. Continuous, long-term monitoring of the star, such as we intended, would be vital to tying everything together.

A few weeks later I flew to the island of Tenerife, in the Canary Islands off Morocco, to visit my longtime friend Johan Knapen, now a professor at the Instituto de Astrofíscia de Canarias (IAC), which runs the major observatories on Tenerife and La Palma. While approaching the island, I peered through the airplane window at the top of Teide Mountain high above the clouds and immediately recognized the telescopes of Teide Observatory in the Izaña district of the island. The site has first-class atmospheric conditions. I began to think. . . it obviously would be better for our group to have its own private telescope and run the WR 140 campaign here on the mountaintop rather from the cloudy mess of Europe. That's what I told Johan one evening over a beer in a local pub. Johan calmly replied: "We have such a telescope up at Izaña, and I believe you can use it."

FILIPE DIAS

CHANGING OF THE GUARD The observing team of Filipe Dias and Thomas Bergmann arrive on the mountain to take over from Lothar Schanne and Berthold Stober (left to right).

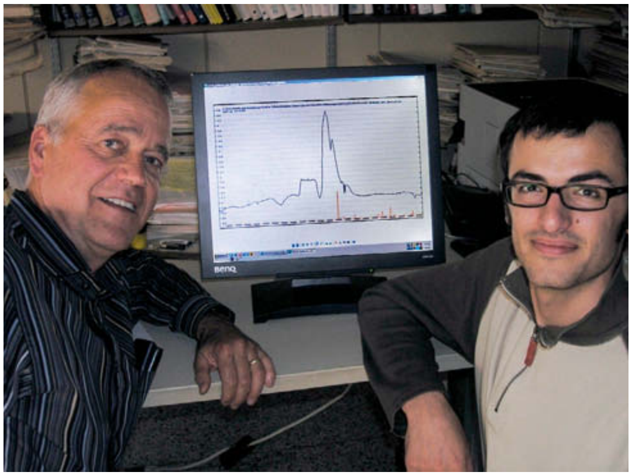
LOTHAR SCHANNE

MOMENT OF TRUTH Johan Knapen (left), Berthold Stober (right), and John Morrison attach the team's custom-built spectrograph and guiding-eyepiece assembly to the telescope.

The next weekend we visited the mountaintop and, off to the side of the many larger domes, the Mons Telescope: a 50-cm (20-inch) f/15 Cassegrain built in 1972 by Belgium's University of Mons. What we found was no match for some advanced amateur observatories. The telescope had electronic guiding but no go-to pointing. It had no spectrograph. Other things needed work. But it would serve.

Johan became as excited as me and promised local support. We did a quick cost calculation for a campaign of 3.5 months, with eight teams of two to four observers at the telescope for two weeks each, and came up with 700 Euros (roughly $1,000) per person including travel and accommodation at the observatory. We knew that many qualified amateurs would jump at the chance.

Tony became our main scientific partner. His Ph.D. student Rémi Fahed came on as well. Back in Europe I spoke to Gregor Rauw and Thierry Morel at the Université de Liège in Belgium about including additional target stars. They chose some hot *Oe* and *B* stars where we could investigate periodic phenomena in their winds. I announced the idea again in the spectroscopy discussion forums. Fifteen amateur astronomers, from a high-school

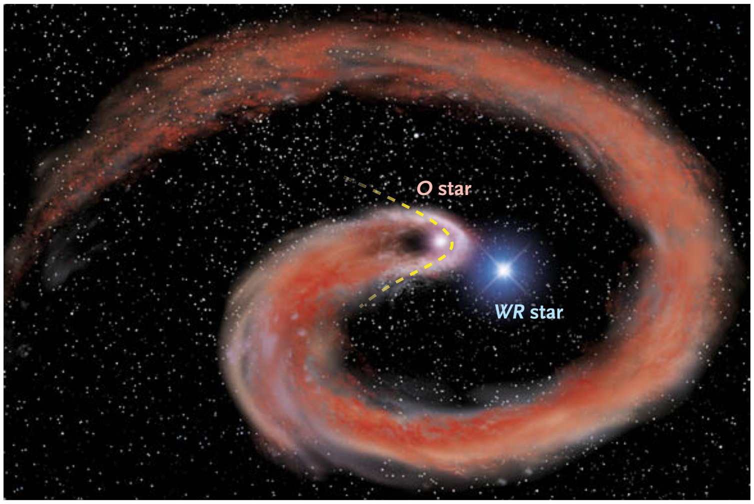


THOMAS EVERSBERG

THE HUNTERS AND THEIR QUARRY Hot-star expert Anthony Moffat (left) and graduate student Rémy Fahed display part of a spectrum of WR 140. The flat-topped bump just left of center is the critical CIII emission line.

student to a physician, asked to join the campaign and work on the mountain.

One problem was that during the months around WR 140's periastron, Cygnus would be near the horizon and setting soon after sunset or, later, rising soon before dawn. So we planned to observe our other *O*e and *B* stars during the rest of the night. Our proposed run would start on December 1, 2008, and end March 23, 2009. In addition, other amateurs and professionals agreed to participate by making their own observations elsewhere. Everyone's data would be reduced and published together, and all participants would be coauthors for the three peer-reviewed papers that we hoped would result.



S&T: LEAH TISCIONE

DUST TAIL Each time the two stars come closest and the shock cone grows most intense, some process creates billows of carbon-rich dust on or near the cone's head. The hot dust later spirals away as the stars orbit, creating a complex infrared signature for the whole system.

With Johan's help we worked up a formal proposal and submitted it to the IAC's time-allocation panel — which assigned us 16 weeks, all to ourselves, on the 20-inch telescope at Izaña.

Getting Ready

We decided to use all our own equipment on the Mons Telescope, since it lacked most of the things we would need and we learned quickly that the local technical staff gave low priority to support. But we loved the challenge!

German amateurs Berthold Stober and Lothar Schanne, experienced in mechanics and instrument design, handled many aspects of getting everything set up. They fixed up and adapted a spectrograph donated by German amateur Wolfgang Arnold, and a CCD loaned by the German manufacturer Gerhard Fischer. They built a flip-mirror arrangement for guiding and implemented a Shapley lens as a focal reducer. It became clear that they would have the most difficult part of the project: making the entire system work.

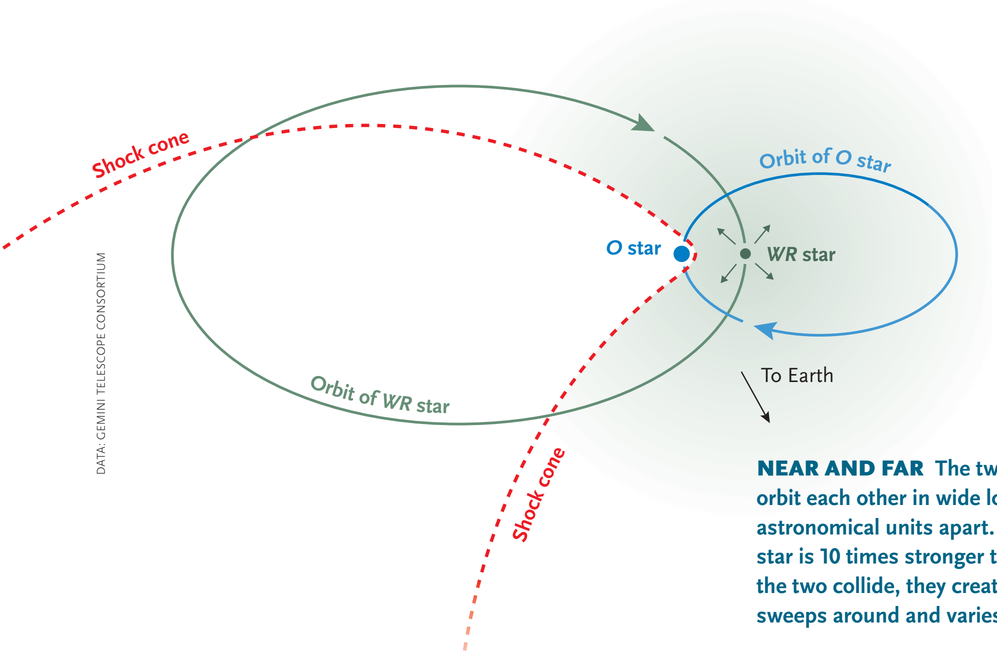
To start the ball rolling well in advance, we organized two workshops for participants, believing that the best ideas come in person, over coffee. We discussed finding charts, refraction, guiding problems, telluric lines, bias-, flatfield- and dark-correction images, shock fronts, excitation levels, ftp servers, USB extenders, FITS formats, and, and... it was wonderful!

I again visited Montreal, where Tony informed me about the other ground-based WR 140 activities worldwide. We resolved the crucial issues of the best spectral resolution and wavebands to observe in. Back in Germany, we shipped off our equipment four weeks before our allotted time began.

The first observers, Berthold and Lothar, spent much of the first two weeks just setting up. As is typical at telescopes small and large, they had problems, such as with the CCD camera and the optical system. We also had to define a standard routine on the mountain and be able to transfer it to the teams that followed. But we eventually solved everything with patience, commitment, and support from the colleagues in Europe and North America. Berthold and Lothar established the whole setup in a very professional manner.

The second team, high-school student Thomas Bergmann and engineer Filipe Dias, ran the project over Christmas. The third team had bad luck — they were clouded out for a week and had an ice storm. Even so, we acquired data right through periastron in January, as spectra were taken by others on clear nights in Germany and England when clouds covered Teide — an unexpected switch!

We reduced all our spectra within just a few days, so that we were always informed about the ongoing status of WR 140. In the shock cone around the *O* star, carbon atoms are heated to the point of losing two electrons



NEAR AND FAR The two brilliant, massive stars of WR 140 orbit each other in wide loops, dipping from about 30 to 2 astronomical units apart. The stellar wind from the type-*WR* star is 10 times stronger than the wind from the *O* star. Where the two collide, they create an X-ray-bright shock cone that sweeps around and varies in intensity as the stars orbit.

— becoming CIII ions, which shine with a yellow emission at a wavelength of 569.6 nanometers. We saw extra, blueshifted CIII emission appear just before the stars' periastron passage, modifying the overall broad emission line around this wavelength. This new emission quickly moved to the redshifted side of the line just after periastron, then disappeared.

All the teams performed in perfect routine. As a member of the final team, I benefited from the extraordinary achievements of those before us. Our planning paid off; the harmony between software, telescope, and spectrograph was perfect, and we finished without untoward problems. After closing up on the last night, we had only to dismantle our equipment and ship it back to Germany.

Results

In May we held a wrap-up meeting in Portugal to discuss our first results and possible future campaigns. Among our conclusions:

- We published an updated value for the binary's orbital period, 2,896.5 ± 0.7 days, and we found the orbit to have a higher eccentricity than was previously known: 0.896 ± 0.002. This is important because all other parameters deduced for the system depend on knowing the orbit accurately.
- Our new value for the orbital inclination, 52° ± 8°, gives the following values for the two stars' masses: 16 ± 3 solar masses for the *WR* star, and 41 ± 6 for the *O* star.
- We fitted both the changing radial velocity and the changing width of the excess CIII emission to a simple geometric model that includes the opening angle of the shock cone, the velocity of the shocked material moving along the cone's surface, the binary's orbital inclination, and an angular shift due to Coriolis forces.
- Meanwhile, satellite X-ray observations showed that the system's X-ray flux dropped when we saw the excess CIII emission appear. This could be a sign of material cooling, but the effect has to be investigated in more detail. We're still reducing and analyzing our data in Canada and Belgium for a further, final publication.

But we did more than analyze stars. We showed that amateur spectroscopists have the engineering and technical skills, scientific knowledge, and collaboration abilities to carry out very fruitful pro-am spectroscopy at a professional observatory even across continents. As far as I know, ours was the first pro-am collaboration on this scale. As a result of this project, we expect that amateurs will be seen with new respect in future applications to other observatories.

And we have more plans brewing. Another outcome of this project has been the formation of the ConVento Group, a platform to establish future professional-amateur campaigns in photometry and spectroscopy (see www.stsci.de/convento). We've started something that we hope will have no end. ✦

Thomas Eversberg *was educated as a professional astronomer, co-founded the Schnörringen Telescope Science Institute in Germany (www.stsci.de), and in his day job now works for the German Space Agency in Bonn.*

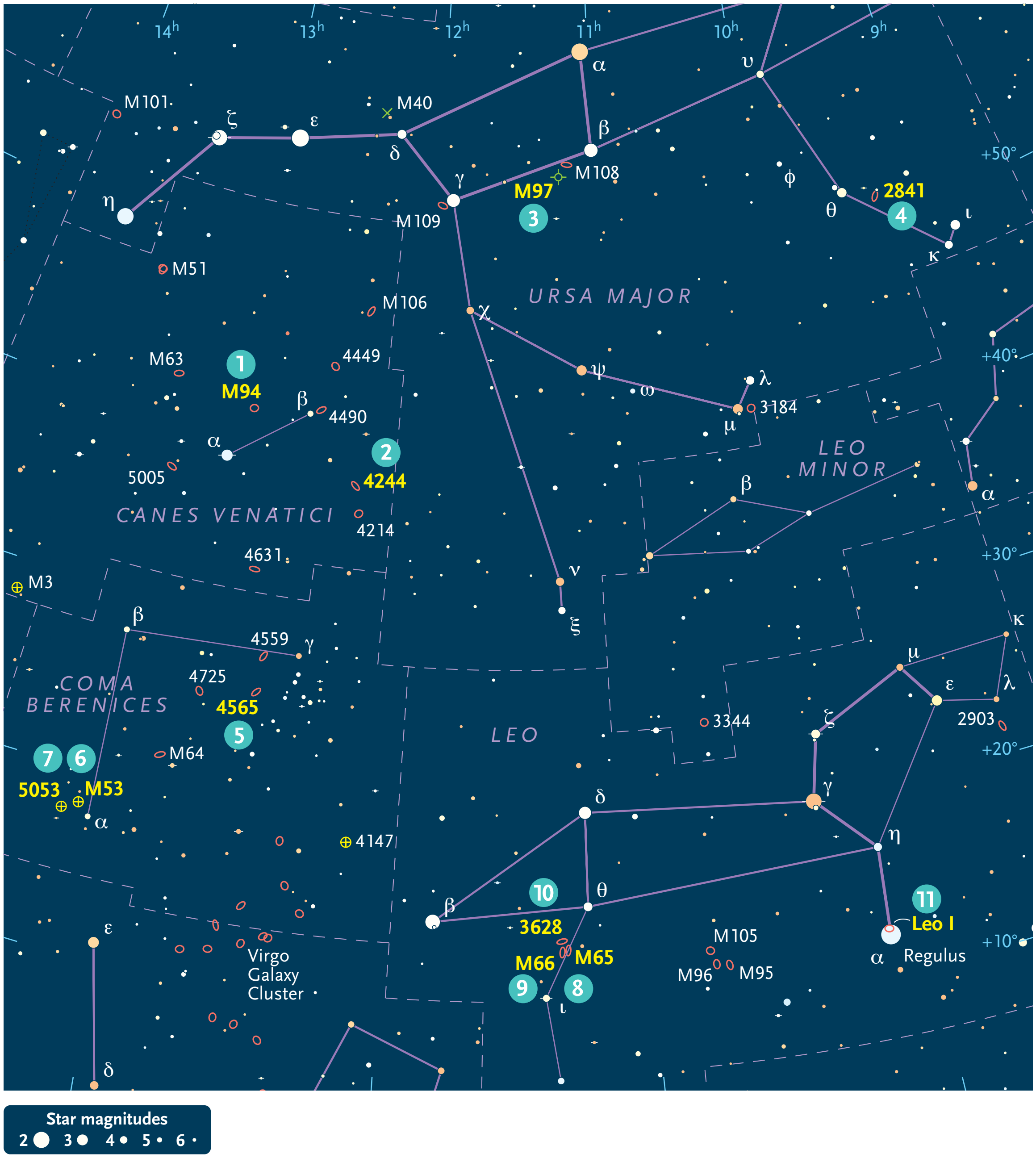
Acknowledgements: I want to thank all the project participants for their skills, enthusiasm, and trust in this unique campaign. They made it work. They include Filipe Alves, Wolfgang Arnold, Thomas Bergmann, Luis Carreira, Rémi Fahed, Alberto Fernando, Gerhard Fischer, José Sánchez Gallego, Filipe Dias, Thomas Hunger, Robin Leadbeater, Tony Moffat, Thierry Morel, Gregor Rauw, Norbert Reinecke, José Ribeiro, Nando Romeo, Eva Santos, Lothar Schanne, Otmar Stahl, Barbara und Berthold Stober, Nelson Viegas, Klaus Vollmann and Udo Zlender.

I want to thank Professor Francisco Sánchez, Director of the Instituto de Astrofísica de Canarias, and Miquel Serra for their assistance and the generous allotment of telescope time. My special thanks go to Johan Knapen, my friend and colleague at the IAC.

The Backyard Sky: SPRING

Explore the season's well-known and lesser-known deep-sky showpieces.

Rod Mollise



I've learned to keep an eye on new members of my astronomy club. I want them to succeed, but many novices barely make it through their first year under the stars. An enthusiastic beginner joins the club, buys a telescope, and begins happily exploring the deep sky. At first it's easy to decide what to observe: M13, M42, and the other brightest Messier objects. But even the Great Globular Cluster in Hercules and the Great Nebula in Orion become boring if they're all you look at. I'm convinced this is the main reason novices drop out: they get tired of seeing the same old objects night after night.

You'd think it would be easy to figure out what to look at in this day of computerized Go To telescopes. Just punch in an object and away you go. Unfortunately, most newcomers have no idea what to punch in. Or if they have a list of good stuff beyond the best Messiers, they assume these less-prominent objects are only visible from their club's dark site. But once-a-month observing with the club isn't good enough. If you only played a musical instrument once a month, how good would you get at it? How long would you remain interested in music?

What follows is a sampling of deep-sky objects beyond the best-of-the-best. Most are visible from average suburban backyards in telescopes with apertures of 4 inches or more. These beauties aren't merely *visible* from the suburbs; many of them look downright spectacular. I have seen and marveled at all of these from my semi-urban home near the center of a city of 250,000.

HILLARY MATHIS / NIGEL SHARP / NOAO / AURA / NSF

The spring constellations aren't as flashy as those of winter and summer, but they have one thing those prettier constellations lack: lots of galaxies. In the springtime, we in the Northern Hemisphere are looking up and out of the disk of the Milky Way. That means the main course tonight will be galaxies, the great cloud of galaxies that stretches from northernmost Ursa Major through Virgo to Hydra and points south. Let's get started.

1 Our first stop is the galaxy for people who don't think you can see galaxies from the backyard: **M94**, the Croc's Eye. It lies in the little constellation Canes Venatici, the Hunting Dogs, south of the Big Dipper's handle. You will find the galaxy 1½° northeast of the middle of the line connecting the constellation's two brightest stars.

Backyard Deep-Sky Treats for Spring

	Object	Constellation	Type	Magnitude (v)	Size	RA	Dec.
1	Messier 94	CVn	Face-on spiral galaxy	8.0	11′ × 9.1′	12^h 50.9^m	+41° 07′
2	NGC 4244	CVn	Edge-on spiral galaxy	10.0	17′ × 1.9′	12^h 17.5^m	+37° 48′
3	Messier 97	UMa	Planetary nebula	9.9	3.4′ × 3.3′	11^h 14.8^m	+55° 01′
4	NGC 2841	UMa	Inclined spiral galaxy	9.5	8.1′ × 3.5′	9^h 22.0^m	+50° 59′
5	NGC 4565	CBr	Edge-on spiral galaxy	9.5	16′ × 2.1′	12^h 36.3^m	+25° 59′
6	Messier 53	CBr	Globular cluster	7.7	13′	13^h 12.9^m	+18° 10′
7	NGC 5053	CBr	Globular cluster	9.0	11′	13^h 16.5^m	+17° 42′
8	Messier 65	Leo	Inclined spiral galaxy	9.3	9.8′ × 2.9′	11^h 18.9^m	+13° 06′
9	Messier 66	Leo	Inclined spiral galaxy	9.0	9.1′ × 4.2′	11^h 20.3^m	+12° 59′
10	NGC 3628	Leo	Edge-on spiral galaxy	9.8	15′ × 3.0′	11^h 20.3^m	+13° 35′
11	Leo I	Leo	Dwarf elliptical galaxy	10.2	9.8′ × 7.4′	10^h 08.5^m	+12° 18′
12	NGC 3242	Hya	Planetary nebula	7.7	45″ × 36″	10^h 24.8^m	–18° 39′
13	Messier 83	Hya	Face-on spiral galaxy	7.8	15′ × 13′	13^h 37.0^m	–29° 52′

Angular sizes are from recent catalogs. Visually, an object's size is often smaller than the cataloged value. Celestial coordinates are for equinox 2000.0.

M94 is a large, bright face-on spiral, and it's almost impossible to miss. In my 4-inch Newtonian reflector at 90×, it appears as a slightly fuzzy star. Bumping up the magnification to 150× brings out a little more of the nebulous haze surrounding the galaxy's intense core, making it look similar to an unresolved globular star cluster. M94's center is bright because something unusual is going on there; likely a massive black hole is feeding on gas and unlucky stars. Why is M94 called the "Croc's Eye Galaxy?" In long-exposure images its glowing center, surrounded by a wreath of tightly-wrapped spiral arms, looks amazingly like the baleful eye of a crocodile.

❷ What's my favorite type of galaxy? I love graceful face-on spiral galaxies such as M101 and M51, but what really pleases my eye are thin edge-on spirals such as **NGC 4244**, the Silver Needle galaxy. It's one of the premier edge-on galaxies in the sky, and I've never failed to get at least a glimpse of this 10th-magnitude spiral on any but the worst nights. Not that I see all of it. Catalogs list it as 17′ long, but I'm often lucky to trace it for a third that distance. In my 8-inch telescope, it usually appears as a skinny ray maybe 5′ to 10′ in length. On an especially good evening, my 11-inch Schmidt-Cassegrain telescope shows hints of bright patches and irregularities along the Needle's length.

❸ Let's head back north to the Big Dipper for our next prize: the Owl Nebula, **M97**, a planetary nebula, the corpse of a dead star. It's conveniently located 2¼° east-southeast of the bright bowl star Merak, Beta (β) Ursae Majoris, so it's easy to locate even without Go To. The Owl is famous but isn't often visited by backyard astronomers, since it's reputed to be one of the toughest Messiers. Fortunately, a nebula filter makes it relatively easy; I've seen the Owl from a heavily light-polluted site using just a 60-mm refractor equipped with an O III filter.

The hard part is seeing the two dark patches that form the Owl's eyes. I have been able to see them from suburbia, but never with a telescope smaller than 12 inches, and only occasionally then. In smaller instruments, M97 is a featureless gray spot of dim light.

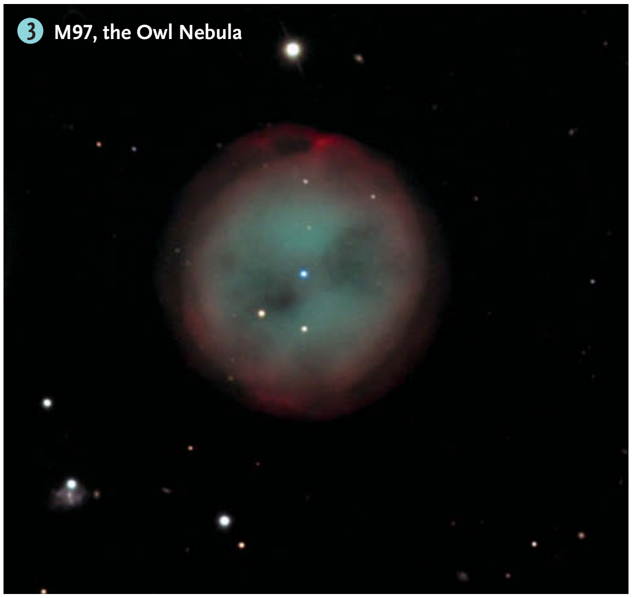
❹ Now let's detour far to the west of the Dipper to the Great Bear's frontmost leg, where we'll find **NGC 2841**. This galaxy is so good that I'm surprised it doesn't have a common name — so I've given it one: "Sunflower Junior." In my 8-inch reflector, this 9.5-magnitude spiral first appears as a dim, oval smudge. As I continue to stare, however, I see hints of multiple patchy spiral arms that make this seldom-visited fuzzy look a lot like the better known Sunflower Galaxy, M63.

The Great Bear is full of targets for the backyard astronomer, galaxies by the bushel basket, but we'll leave those for another night. Our next stop is Coma Berenices, to the south of Canes Venatici.

❺ The Silver Needle is a beautiful edge-on, but for many stargazers, the Flying Saucer Galaxy, **NGC 4565**, is the most beautiful edge-on galaxy of all. What you'll see of it, though, depends on your telescope and your sky. On a superior night I can see as much as 10′ of the Saucer's 16′ length in my 11-inch scope. On a poor evening I'm lucky to make out its bright core. When conditions are right, NGC 4565 looks exactly like Michael Rennie's spaceship in the classic 1951 science-fiction movie *The Day the Earth Stood Still*, with a bulging central section that blends into a flat, thin saucer.

❷ NGC 4244

J. NAUGHTON / S.STAFFORD / A. BLOCK / NOAO / AURA / NSF



❸ M97, the Owl Nebula

GARY WHITE / VERLENNE MONROE / ADAM BLOCK / NOAO / AURA / NSF

❹ NGC 2841

PETER KUKOL / ADAM BLOCK / NOAO / AURA / NSF

6 Are your eyes bleeding from straining to make out detail in dim galaxies? Let's take a break with something closer to home: **M53**, one of the Milky Way's globular star clusters. Finding M53 is easy even without computers; it's less than 1° northeast of Coma's second-brightest star: Diadem, Alpha (α) Comae Berenices.

This 7.7-magnitude, 11′ ball of ancient stars is not the brightest or largest globular in the sky, but its presence among the dim galaxies of Coma makes it a standout. It's easy to see as a dim spot in a 3-inch refractor, and it begins to resolve in my 5-inch Maksutov-Cassegrain at high power, showing a small, bright core and tangled chains of stars. If you can't see any of M53's suns, kick up your magnification to 150× or more. Low power is not always best for the deep sky; high power spreads out the background skyglow and can sometimes make dim objects easier to see.

7 When you're done admiring M53, how about a challenge? I find that stretching for difficult objects in the backyard helps improve my observing skills and allows me to see more when I get to a dark site. And there's no doubt that **NGC 5053** is a challenge. This globular cluster is easy to locate, since it resides 1° east-southeast of M53, but it's very difficult to see.

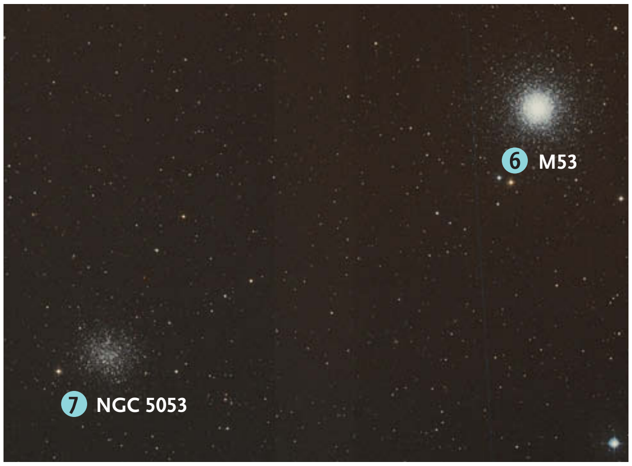
NGC 5053 is a very loose globular the same size as M53 but only 1/4 as bright. It's so loose, in fact, that there's hardly anything there. Not sure you are on the correct field? Work your way over from M53 matching star patterns with the photograph at right, step by step. When I can see NGC 5053 at all in my 12-inch reflector, it's nothing more than a faint mist of starlight. The only time I've gotten a good look at it has been from the dark skies of the Texas Star Party.

There are two ways to proceed from Coma: southeast to Virgo or southwest to Leo. This evening let's visit Leo, the Lion. He's not as rich in galaxies as Virgo but he's higher in the sky and better placed for observing. Next month Virgo will be up and out of the horizon murk, and there'll be an article in *Sky & Telescope* to guide you through her wonders.

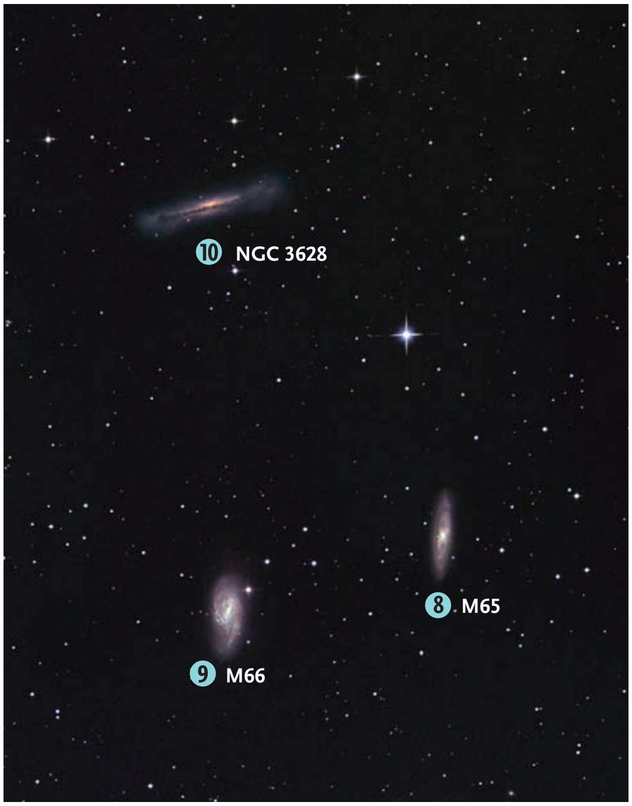
8 – 9 Two of Leo's galaxies, **M65** and **M66**, are so bright that I've seen them on nights when I wasn't sure that Jupiter would be visible. Both galaxies are south of the Lion's hindquarters, 2¾° south-southeast of 3.3-magnitude Theta (θ) Leonis.

Although they're fellow travelers in the sky, only a little over 20′ apart, the two galaxies look quite different even in a small telescope. M66 is the larger and brighter of the two, and from the backyard this big, dusty spiral gives up a little detail for 8-inch and larger telescopes. In addition to a bright core and an extensive oval haze, M66 displays subtle hints of texture and mottling when I use averted vision — when I look off to the side of the object instead

BRUCE HUGO / LESLIE GAUL / ADAM BLOCK / NOAO / AURA / NSF



POSS-II / CALTECH / PALOMAR OBSERVATORY



ROBERT GENDLER

of directly at it, allowing the dim light receptors of my eye, the rods, to come into play.

M65 is a slightly smaller, dimmer prize. This galaxy, a featureless gray oval, is easy to see, and looks great paired with M66 in a wide-field eyepiece. But it's blander than its pal, not revealing any detail to my backyard telescope.

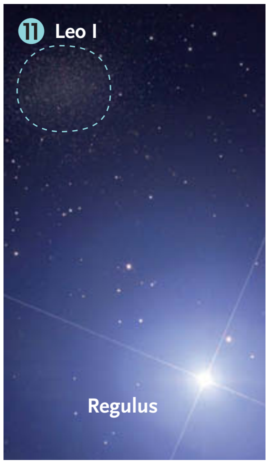
⑩ Ready for another hard one? Don't worry, **NGC 3628** isn't as difficult as fiendish NGC 5053. It's a galaxy, only ½° north of M65 and M66, and the reason amateurs refer to the group as the "Leo Trio." Although NGC 3628 is nominally almost as bright as Coma's NGC 4565, it looks a lot dimmer in the eyepiece. If you glimpse this spiral's beautiful equatorial dust lane, though, you may agree with me that it's even more lovely than the Flying Saucer.

⑪ NGC 3628 was easy? Here's one that's a real problem, and not just because it's dim and so large that its light is spread over a wide area. **Leo I** (also known as UGC 5470 or the Leo Dwarf) is both those things, but the real difficulty is that it's just 20′ north of dazzling, 1.3-magnitude Regulus, Leo's brightest star. The blue glow of Regulus practically extinguishes this dwarf elliptical galaxy. Can you do Leo I from the backyard? I have, but only with the Lion nearly overhead. On the best evenings with my 12-inch, it's a large oval glow just on the edge of perception.

⑫ After dipping toes in Leo's deep ocean, it's time to move southward again — to sprawling Hydra, the water snake, and **NGC 3242**, the Ghost of Jupiter. Like all planetary nebulae this object has nothing to do with planets, being the remains of a dead star.

In the eyepiece of my 4-inch telescope at 150×, this small, bright nebula looks much like a dim Jupiter

ADAM BLOCK / NOAO / AURA / NSF



RUSSELL CROMAN

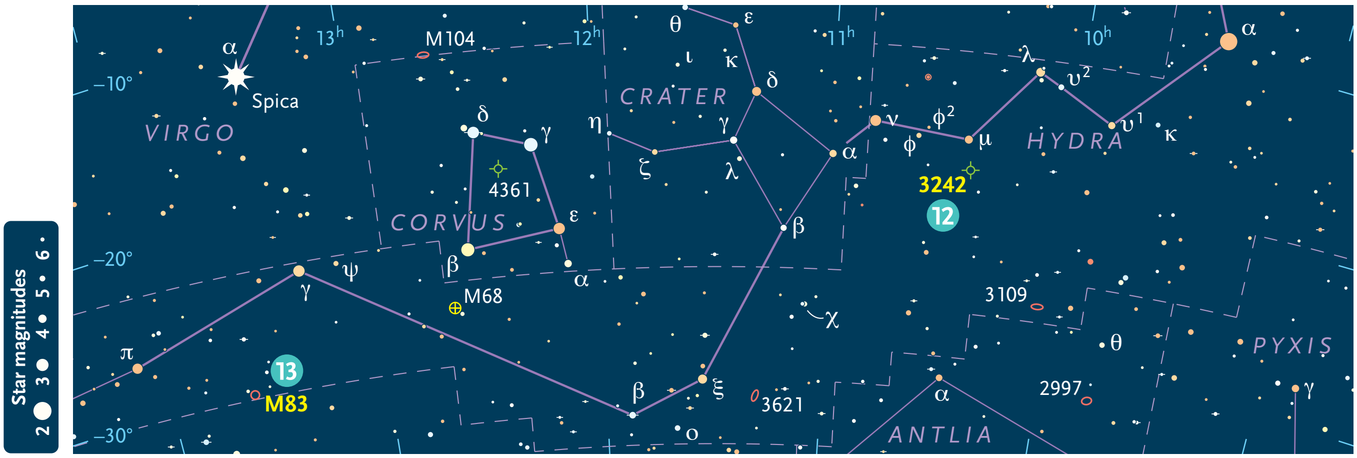
ESO

minus his cloud belts: a sharp-edged, slightly flattened, bluish disk. Since it's almost the size of the real Jupiter, NGC 3242 is unmistakable even in a low-power eyepiece.

⑬ There's one more magnificent galaxy to see tonight: **M83**, the Southern Pinwheel. From dark sites it's amazing, looking like a huge catherine-wheel firework. From my backyard? Sometimes I can't see anything beyond the galaxy's elongated core. On excellent nights, especially if I wait for this part of Hydra to rise as high in my sky as it can, I begin to see a little of the galaxy's form. After letting my eyes become as dark adapted as possible, I begin to make out a subtle, oval haze that is this wonder's arms.

We've come a long way tonight, not just across the spring constellations but away from the too-familiar. I've barely scratched the surface of the dozens of beautiful dimmer objects available to you, though. There are enough marvels visible from the humble backyard to keep anyone — novice or old hand — occupied and amazed for a lifetime. ✦

Rod Mollise keeps an astronomy blog at uncle-rods.blogspot.com and is author of several books, including The Urban Astronomer's Guide *(Springer-Verlag, 2006).*



New Product Showcase

S&T: SEAN WALKER

Hands On Optics
26437 Ridge Rd., Damascus, MD 20872
301-482-0000; http://handsonoptics.com

▲ **4-INCH PLANET KILLER** Hands On Optics has introduced a 4-inch scope to its Astro Telescopes line of refractors. The new 102-mm (4-inch) f/11 refractor ($499) features a hand-corrected, long-focal-length doublet objective in an aluminum tube with three knife-edge baffles to ensure high-contrast views in the eyepiece. The scope tips the scale at 12 pounds (5.4 kg) and includes a two-speed 2-inch Crayford-style focuser with 1¼-inch adapter, a retractable dew shield, hinged tube rings, and a Vixen-style dovetail mounting bar.

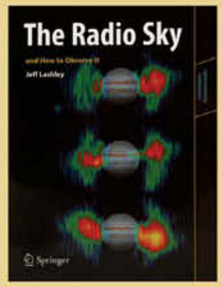
MEADE INSTRUMENTS

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

◀ **ASTRONOMER INSIDE** Expanding on a concept first introduced with the groundbreaking LightSwitch self-aligning telescope series, Meade now includes an AudioStar hand controller with its popular LX90, LT, and LXD75 telescope lines. The AudioStar controller features Meade's patented Astronomer Inside with more than four hours of audio descriptions of celestial objects. Now you can view planets, constellations, nebulae, galaxies, and star clusters while listening to facts and historical information about them. Astronomer Inside will present custom guided tours of the best objects visible from your location. The AudioStar handbox has an extensive database of nearly 40,000 celestial objects, including the Messier and Caldwell catalogs, more than 5,000 IC objects, and 50 Earth-orbiting satellites. See the company's website for additional information and a list of dealers.

BACKYARD RADIO ASTRONOMY
Springer, 236 pages, ISBN 978-1-4419-0882-7

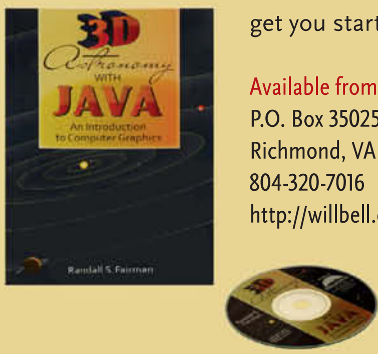
Jeff Lashley's new book *The Radio Sky and How to Observe It* ($34.95) opens up the possibilities of radio astronomy to amateurs. Lashley provides background material needed to appreciate and understand the major radio sources within reach of modest observing equipment. He also includes easy step-by-step instructions to help you build your own low-cost radio telescopes. Learn how to detect the radio emissions of the Sun and Jupiter, "hear" meteors as they flash through our atmosphere, and catch many more objects beyond our solar system.



Available from Springer
233 Spring St.
New York, NY 10013
212-460-1500
www.springer.com

ASTRONOMICAL PROGRAMING
Willmann-Bell, 374 pages, ISBN 978-0-943396-93-4

Interested in developing your own astronomical software program? The new book *3D Astronomy with JAVA: An Introduction to Computer Graphics* by Randall S. Fairman ($29.95) will teach you the basics of JAVA programming, the foundation on which many popular 3-D video games and computer animations are based. Learn how to apply complex mathematical computations to depict astronomical phenomena such as precession in easy-to-understand animations. The book walks you through projects based on data from the Jet Propulsion Laboratory, culminating in a project that displays an animation showing what an observer would see in the sky from any given time and place on Earth. *3D Astronomy with JAVA* also includes a CD-ROM with source code and executable files to help get you started.



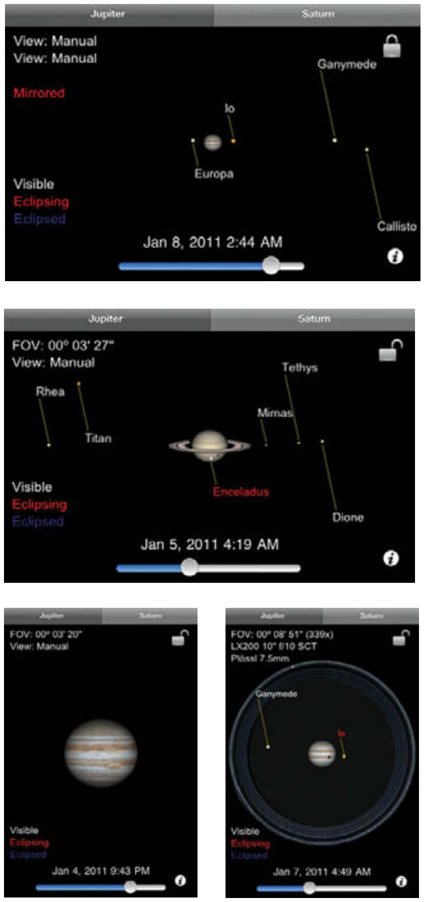
S&T: SEAN WALKER (2)

Available from Willmann-Bell
P.O. Box 35025
Richmond, VA, 23235
804-320-7016
http://willbell.com

▼ PRODIGAL SCOPE Celestron unveiled its series of fully self-aligning telescopes at the Consumer Electronics Show last January. The SkyProdigy 130 ($799) features a 5.1-inch (130-mm) f/5 Newtonian Reflector coupled to the company's most technologically advanced Go To Altazimuth mount to date. Simply turn on the power, push a button, and the SkyProdigy aligns itself using a built-in digital camera and Celestron's StarSense technology. The entire process takes only about three minutes. The mount's internal database includes more than 4,000 celestial objects and there are customized sky tours for any time of the year. The SkyProdigy 130 includes a unit-power red-dot finder, 25- and 9-mm 1¼-inch eyepieces, and a CD-ROM of *The SkyX* Light Edition. It is powered by eight D-cell batteries.

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

CELESTRON



SOFTWARE BISQUE (4)

▲ GAS GIANTS ON THE GO
Software Bisque takes its first foray into the Apple App market with *Gas Giants* ($2.99), an app that lets you accurately display the positions of Jupiter's and Saturn's moons at any time. It also accurately predicts the transit times of moons, their shadows, and Jupiter's Great Red Spot. And you can use *Gas Giants* to simulate the view through virtually any telescope at any magnification. The app requires an iPad, a third-generation iPod touch or later, or an iPhone 3GS or later. Available for download via the iPhone App Store.

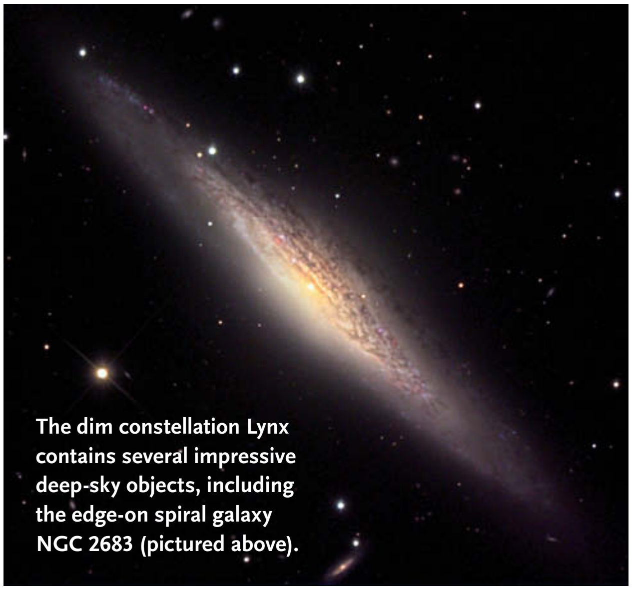
Software Bisque
912 12th St., Golden, CO 80401
303-278-4478; www.bisque.com

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

Two Dim Beasts of Spring

These little-known constellations are full of surprises.

THREE VAST constellation beasts glide in a slow race with one another across the sky on spring evenings. Two of them — Ursa Major the Great Bear and Hydra the Sea Serpent — touch their snouts to the sky's north-south meridian at the same time. The third beast, Leo the Lion, noses the meridian almost an hour later. And a half hour after that, the 10^h line of right ascension reaches the meridian, marking 10 hours sidereal time — a time we can call the Leo Hour.



The dim constellation Lynx contains several impressive deep-sky objects, including the edge-on spiral galaxy NGC 2683 (pictured above).

DOUG MATTHEWS / ADAM BLOCK / NOAO / AURA / NSF

Ancient Ursa Major, Leo, and Hydra are worth all the attention they get from amateur astronomers. But let's now discuss two underappreciated beasts near them that were invented in the 17th century by the Polish astronomer Johannes Hevelius.

Lynx the long. It's said that Hevelius named a constellation Lynx because its stars are so dim that you would need the eyes of a lynx to see them. Modern constellation maps, however, show Lynx's main stars clearly, connected in the form of a long zigzag line. The constellation fills the space between Auriga and Gemini on one side and Ursa Major on the other.

Lynx is sometimes listed as a northern circumpolar constellation, but this is misleading. Most of its stars are south of declination +50°, the point at which stars remain visible all night every night from latitude 40° north. And 3.1-magnitude Alpha Lyncis, the constellation's brightest star, lies at declination +34°, close to Lynx's southern boundary .

Lynx has only five other stars brighter than magnitude 4.5. But it's home to two well-known 10th-magnitude deep-sky objects: the globular cluster NGC 2419 and the spindle-shaped galaxy NGC 2683. NGC 2419 is so far from our Galaxy's core that it's sometimes (misleadingly) called the Intergalactic Wanderer. Lynx is also noted for its lovely double stars — especially 12, 19, and 38 Lyncis.

The last of these doubles happens to be paired fairly closely to Alpha Lyncis. This duo helps the naked-eye observer find the start of Lynx. The three star pairs that form the paws of Ursa Major were known in a medieval Arabic tale as the Three Leaps of the Gazelle. So perhaps we could consider the Alpha-38 Lyncis pair, which greatly resembles the star-pair paws of Ursa Major, as an unofficial fourth hoof print of the gazelle.

The little lion. In most constellations the brightest star is designated Alpha. But the dim constellation that Hevelius invented between Ursa Major and Leo — Leo Minor the Little Lion — has a 4.2-magnitude Beta star and no Alpha. The 3.8-magnitude star that should be Alpha Leo Minoris is actually called 46 Leo Minoris — or Praecipua. But Praecipua only means "principal," an attempt to make up for the missing Alpha label.

The other three constellations without an Alpha star are all southern ones: Puppis, Vela, and Norma — and two of those have a good excuse. The huge constellation Argo Navis, the ship Argo, was divided in 1763 into three pieces — Carina the Keel, Vela the Sails, and Puppis the Poop — but Argo's Greek letters were retained. Canopus, the sky's second-brightest star, was renamed from Alpha Argûs Navis to Alpha Carinae. Carina also inherited Argo's Beta star, leaving Gamma Velorum and Zeta Puppis as the brightest stars in their respective constellations.

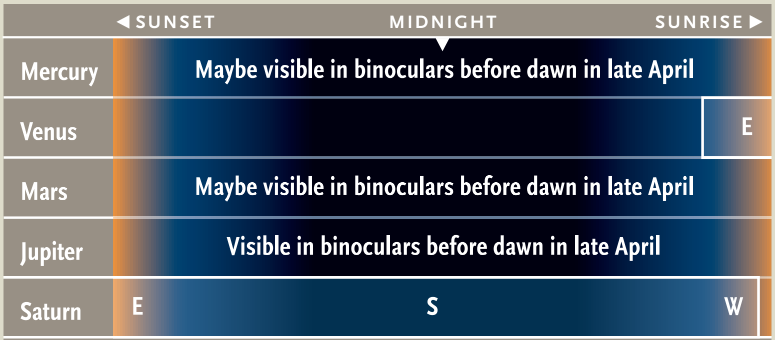
Leo Minor offers no showpiece objects, but it contains a wealth of faint galaxies. The best is probably the 10th-magnitude face-on spiral NGC 3344, located on a sort of peninsula of Leo Minor that extends south into Leo. ✦

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

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



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

IMAGE BY NASA / STSCI / AURA / HUBBLE HERITAGE TEAM

SATURN'S RINGS are finally beginning to open up after being nearly edge-on to Earth for the past two years.

April 2011

1 DAWN: North Americans can see the thin crescent Moon 13° or 14° left of Venus low in the east before sunrise, as shown on page 49.

3 NEW MOON (10:32 a.m. EDT).

3–4 ALL NIGHT: Saturn is at opposition: opposite the Sun in the sky, rising around sunset, setting around sunrise, and near its brightest and biggest (through a telescope) for 2011.

6, 7 EVENING: The Moon is below the Pleiades on the 6th and right of Aldebaran and the Hyades on the 7th.

9 EVENING: Binoculars show the star cluster Messier 35 about 2° upper right of the Moon.

11 FIRST-QUARTER MOON (8:05 a.m. EDT).

13 EVENING: Regulus is about 6° above or upper left of the Moon.

16, 17 EVENING: The Moon is lower right of Saturn on the 16th and below Spica when full on the 17th, as shown on page 48.

17 FULL MOON (10:44 p.m. EDT).

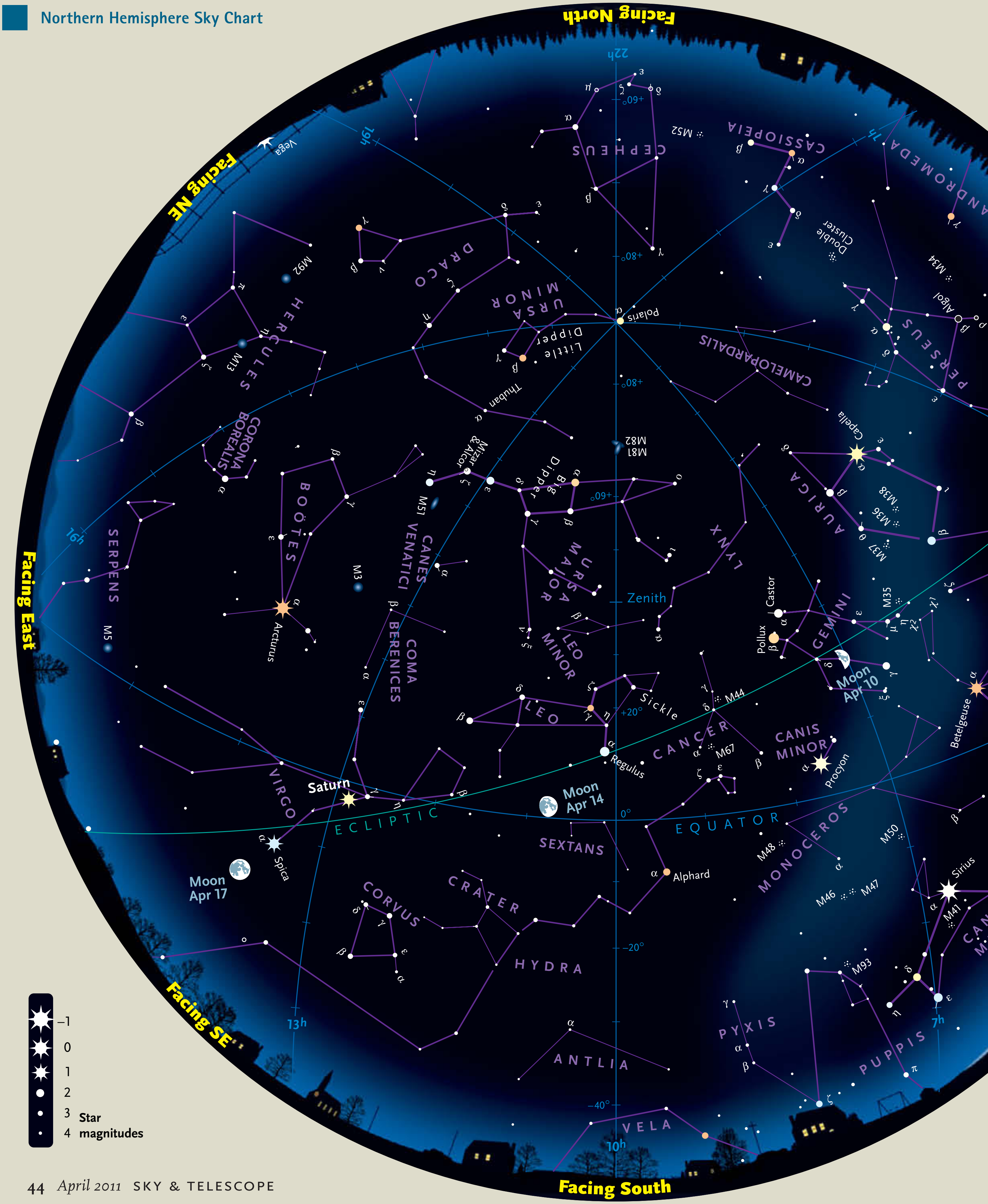
19 DAWN: Telescopes may show Mercury less than 1° upper left of Mars extremely low in the east 15 minutes before the Sun rises — a very difficult observation. Scan the horizon 15° lower left of bright Venus.

22–23 NIGHT: The weak Lyrid meteor shower peaks tonight. Best observed around midnight daylight-saving time, when Lyra is fairly high and the Moon hasn't risen. See page 57.

24 LAST-QUARTER MOON (10:47 p.m. EDT).

30 DAWN: Four planets are clustered below and lower left of the thin crescent Moon just above the eastern horizon shortly before sunrise, as shown on page 49. Bring binoculars or a telescope.

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


Facing North
Facing NE
Facing East
Facing SE
Facing South
Zenith
ECLIPTIC
EQUATOR
Saturn
Moon Apr 17
Moon Apr 14
Moon Apr 10
Vega
Polaris
Thuban
Arcturus
Spica
Regulus
Alphard
Procyon
Sirius
Betelgeuse
Castor
Pollux
Capella
Algol
Double Cluster
Mizar & Alcor
Big Dipper
Little Dipper
Sickle
CEPHEUS
CASSIOPEIA
ANDROMEDA
DRACO
URSA MINOR
URSA MAJOR
HERCULES
CORONA BOREALIS
BOÖTES
SERPENS
CANES VENATICI
COMA BERENICES
LEO MINOR
LEO
LYNX
CAMELOPARDALIS
PERSEUS
AURIGA
GEMINI
CANCER
CANIS MINOR
MONOCEROS
VIRGO
CORVUS
CRATER
SEXTANS
HYDRA
ANTLIA
PYXIS
PUPPIS
VELA
M52
M34
M92
M13
M82
M81
M51
M3
M5
M35
M36
M37
M38
M44
M67
M48
M50
M46
M47
M41
M93
22h
19h
16h
13h
10h
7h
4h
+60°
+80°
+20°
0°
–20°
–40°
–1
0
1
2
3
4
Star magnitudes

Using the Map

WHEN

Late February	Midnight
Early March	11 p.m.
Late March	11 p.m.*
Early April	10 p.m.*
Late April	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 a little so that "Facing East" is at the bottom. Nearly halfway from there to the map's center is the bright, yellow-orange Arcturus. Go out, face east, and look halfway up the sky. There's Arcturus!

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-April.

You can make a sky chart customized for your location at any time at **SkyandTelescope.com/skychart**.

Binocular Highlight:
Belly of the Beast

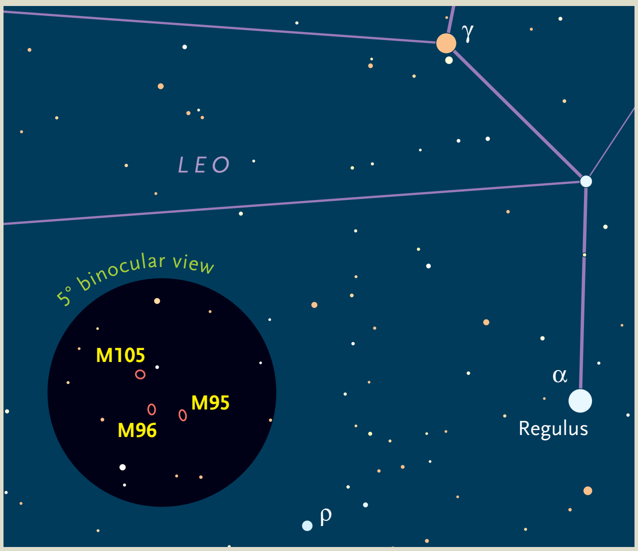
ALTHOUGH GALAXIES dominate the list of deep-sky objects in the Messier catalog, they're also the most difficult to observe. This goes double if binoculars are your instrument of choice. However, it's worth remembering that seeking faint targets with binos is very similar to searching out dim quarry with a telescope — the thrill of the hunt is the same, as is the gratification that success provides.

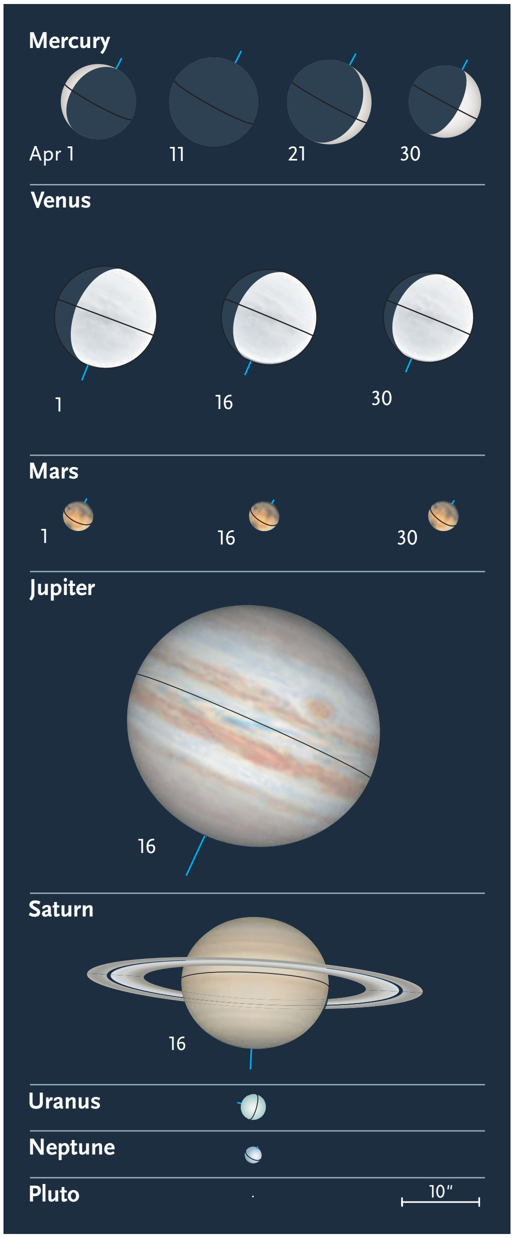
Situated near the belly of Leo the Lion are three challenging Messier galaxies: **M95**, **M96**, and **M105**. These are distant objects lying some 38 million light-years away. They're the brightest members of the M96 galaxy group, which also includes a half-dozen fainter members.

Begin your journey at 3.8-magnitude Rho (ρ) Leonis. Place Rho at the 4 o'clock position and the galaxies will enter the field at 10 o'clock. You're probably going to notice M96 first. Glowing at magnitude 9.3, it's the brightest of the threesome, though that isn't saying much — even this galaxy is a tough find. Under reasonably dark skies I can see M96 in my 10×50s, but only just. Thankfully, the extra magnification and light-gathering power of my 15×70s make the task considerably easier. In the bigger binos, M96 looks like a dim, out-of-focus star.

If you succeed with M96, try for its companions, M95 and M105. M95 is the faintest of the trio, listed at magnitude 10.0, though M105 isn't much brighter at magnitude 9.4. In 15×70s, M105 has a nearly star-like nucleus, while M95 is just a faint blip, visible only half the time. Under dark skies, I can glimpse all three galaxies simultaneously in the 15×70s and in 15×50 image-stabilized binoculars. No doubt about it though — these are difficult objects that will test your observing skills and the quality of your skies. ✦

— *Gary Seronik*



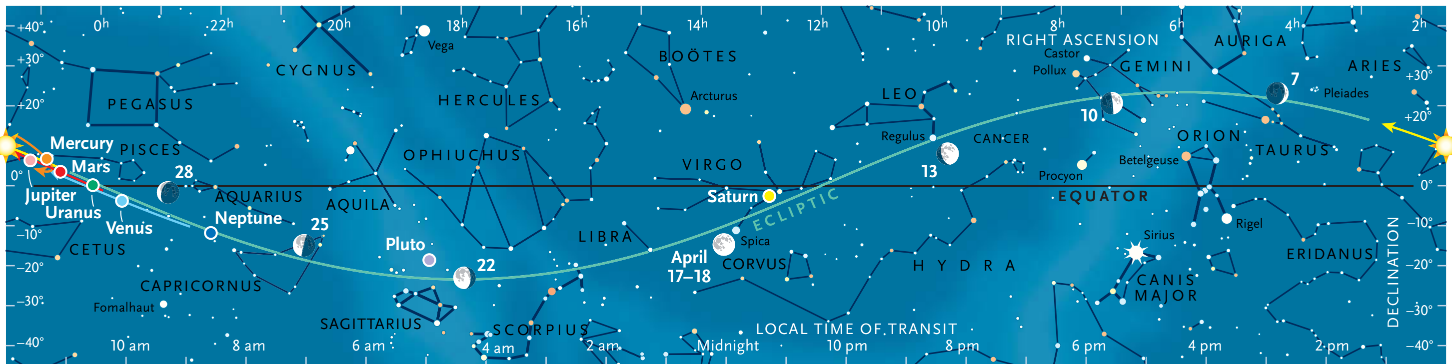


Sun and Planets, April 2011

	April	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$0^h\ 39.6^m$	+4° 16′	—	–26.8	32′ 01″	—	0.999
	30	$2^h\ 27.1^m$	+14° 33′	—	–26.8	31′ 46″	—	1.007
Mercury	1	$1^h\ 24.3^m$	+12° 27′	14° Ev	+2.1	9.7″	12%	0.690
	11	$1^h\ 05.1^m$	+9° 14′	3° Mo	—	11.5″	0%	0.582
	21	$0^h\ 48.6^m$	+4° 38′	17° Mo	+2.2	10.9″	12%	0.615
	30	$0^h\ 56.9^m$	+3° 32′	25° Mo	+0.9	9.4″	29%	0.716
Venus	1	$22^h\ 30.6^m$	–10° 18′	35° Mo	–3.9	13.2″	80%	1.259
	11	$23^h\ 16.2^m$	–6° 05′	33° Mo	–3.9	12.6″	83%	1.320
	21	$0^h\ 01.1^m$	–1° 33′	31° Mo	–3.9	12.1″	85%	1.379
	30	$0^h\ 41.3^m$	+2° 39′	29° Mo	–3.8	11.7″	87%	1.428
Mars	1	$23^h\ 57.5^m$	–1° 18′	12° Mo	+1.2	4.0″	99%	2.347
	16	$0^h\ 40.1^m$	+3° 24′	15° Mo	+1.2	4.0″	99%	2.336
	30	$1^h\ 19.8^m$	+7° 37′	18° Mo	+1.2	4.0″	99%	2.324
Jupiter	1	$0^h\ 56.7^m$	+4° 53′	4° Ev	–2.1	33.2″	100%	5.944
	30	$1^h\ 22.6^m$	+7° 32′	17° Mo	–2.1	33.4″	100%	5.902
Saturn	1	$12^h\ 55.6^m$	–2° 59′	176° Mo	+0.4	19.3″	100%	8.615
	30	$12^h\ 47.7^m$	–2° 10′	153° Ev	+0.5	19.1″	100%	8.716
Uranus	16	$0^h\ 07.8^m$	+0° 04′	24° Mo	+5.9	3.4″	100%	21.001
Neptune	16	$22^h\ 09.7^m$	–11° 53′	55° Mo	+7.9	2.2″	100%	30.570
Pluto	16	$18^h\ 30.9^m$	–18° 44′	108° Mo	+14.0	0.1″	100%	31.686

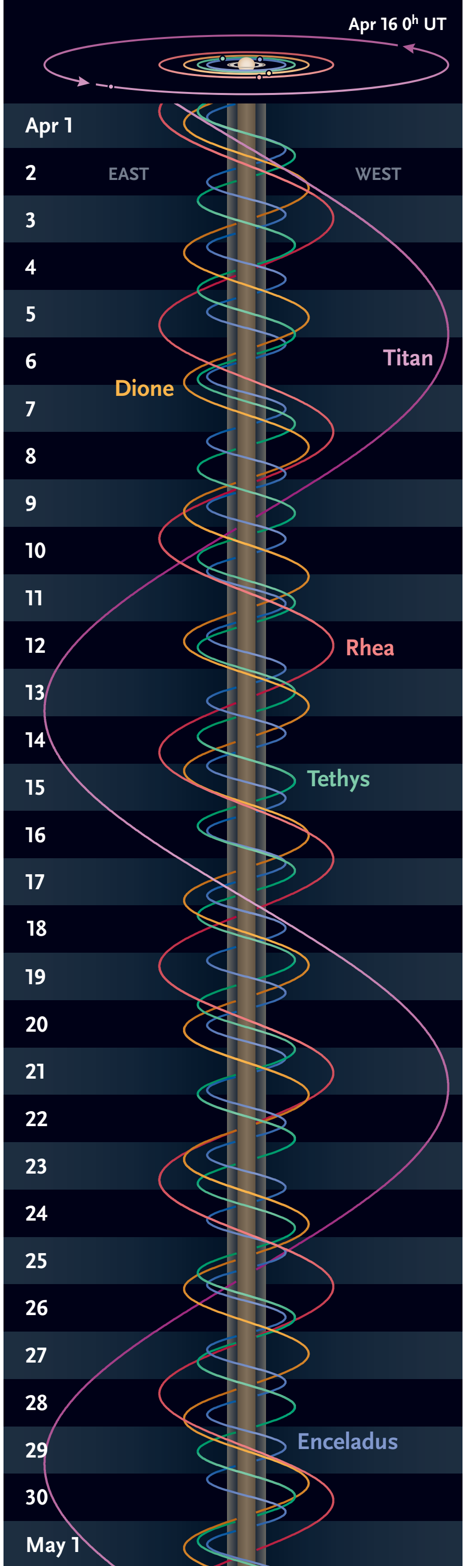
The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of a planet's disk illuminated by the Sun and the distance from Earth in astronomical units. (Based on the mean Earth–Sun distance, 1 a.u. is 149,597,871 kilometers, or 92,955,807 international miles.) For other dates, see SkyandTelescope.com/almanac.

Planet disks at left have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.



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

Saturn's Moons



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

Saturn Rules the Night

The ringed planet soars in solitary splendor from dusk almost to dawn.

THE GREAT DAWN gathering of planets that climaxes in May begins to assemble in April. Saturn is the only planet visible at dusk this month — and for that matter, the only planet visible all night until the sky starts to get light. Even then the only easy dawn planet is Venus, low in the east-southeast. But during the course of the month, no fewer than three other bright planets — Mercury, Jupiter and Mars — begin poking out of the solar glare just before sunrise.

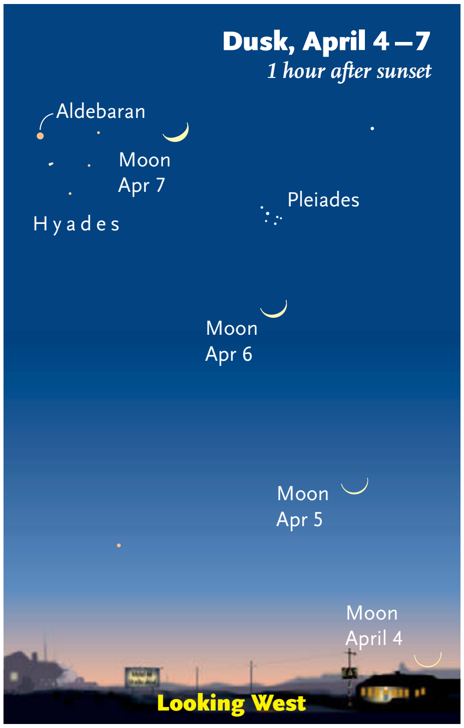
ALL NIGHT

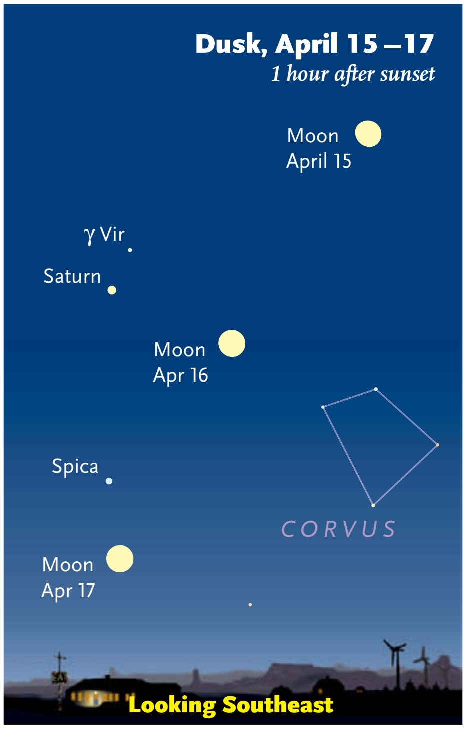
Saturn arrives at opposition to the Sun on the night of April 3–4. By the time the sky starts to darken, Saturn is already above the horizon. As it begins to ascend the eastern sky it lies about 30° right of zero-magnitude Arcturus. Saturn itself shines at magnitude +0.4 now, its brightest for 2011, and the brightest it has been for three years.

Saturn's increased brilliance is due to the fact that its rings are tilted wider than they've been since 2008. But this spring their angle temporarily decreases — from 8.8° to 7.8° during April. At opposition the rings have an apparent span of 44″, with a minor axis of 6.6″. The equatorial width of Saturn's disk then is 19″. Saturn is the most oblate (flattened) of all planets. Its diameter from north to south pole is only 17″ — enough different from the equatorial diameter to be noticeable.

Telescopic observations of Saturn this month will typically be best when the planet is highest, in the middle of the night. But the view will be nearly as good a few hours after sunset. By then, Saturn is partway up the southeast sky with 1.0-magnitude Spica below it and 2.7-magnitude Porrima (Gamma Virginis) to its upper right. The gap between Saturn and Spica grows from 11° to 13° in April, while the separation between Saturn and Porrima dwindles from 3½° to 1½°. Porrima is a famous telescopic double star, now widening; see page 56.

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





PREDAWN

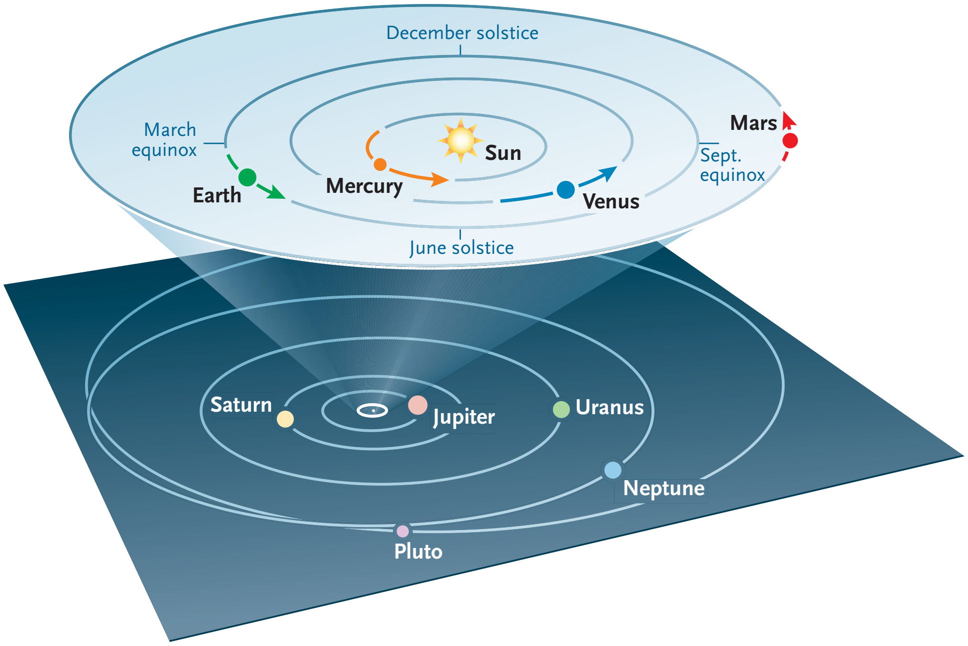
Pluto is in Sagittarius. It's fairly high as the sky begins to grow light, if you want to try viewing its faint flicker. **Neptune**, in Aquarius, is visible through telescopes just before dawn, but it will be much better placed in coming months.

DAWN

Venus rises roughly 80 minutes before the Sun on April 1st and an hour before the Sun on April 30th. The planet is so bright (magnitude –3.9) that it's still prominent low in east-southeast in the growing morning twilight.

Uranus lies about 1° above Venus as viewed from North America on the morning of April 23rd, but the 6th-magnitude planet may be difficult to detect in the dawn glow even with a telescope.

Mercury, **Jupiter**, and **Mars** are all above the eastern horizon by sunrise in mid-April, but they're so low for observers at mid-northern latitudes that they're difficult to view even with optical aid. By late in the month, however, bright Jupiter should be readily visible with binoculars,



ORBITS OF THE PLANETS

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

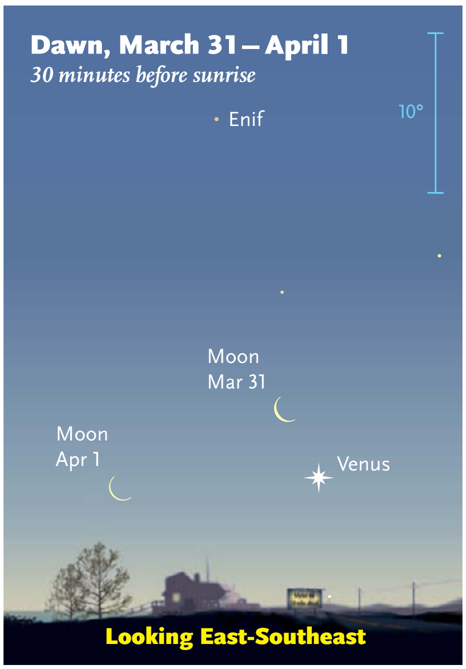
and binoculars may also show Mercury and Mars if the sky conditions are good.

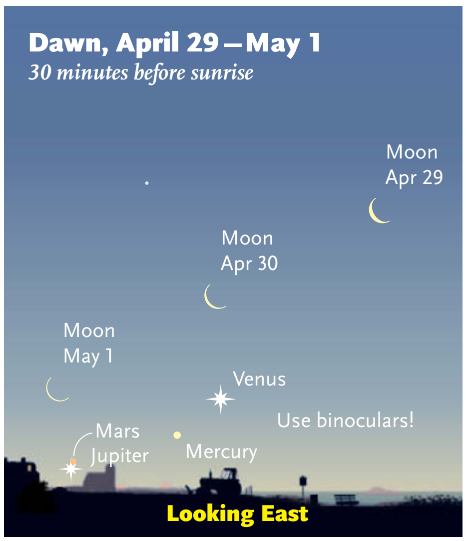
Jupiter passes through conjunction on the far side of the Sun on April 6th and Mercury through conjunction on the near side of the Sun (*inferior conjunction*) on April 9th. Mercury then races out to catch Mars, and at the East Coast dawn of April 19th the two are only ¾° apart. They may be visible in telescopes just above the eastern horizon 15 minutes before sunrise. But it will be a challenging observation because the sky will be very bright and the planets quite dim — especially Mercury, which then shines at only magnitude +2.5.

Observers at mid-northern latitudes will have a much better chance by month's end — especially on April 30th, when the Moon joins the group of four bright planets, as shown at bottom right. That morning viewers in the U.S. and southern Canada see Venus about 6° below the thin lunar crescent. Get out your binoculars. Mercury, now brightened to magnitude 0.9, is less than 4° lower left of Venus, and their separation is decreasing. A little closer to sunrise, scan with binoculars 11° lower left of Venus to find Jupiter shining at magnitude –2.1, with Mars ½° to its upper right. (You may need a telescope to spot Mars's low, dim glow at magnitude +1.2.) Jupiter and Mars will be even closer together the next morning, May 1st.

MOON PASSAGES

The lunar crescent is below the Pleiades after dusk on April 6th and is close to the right of the Hyades on April 7th. The nearly full Moon is well lower right of Saturn on the evening of April 16th. Then, on April 30th, comes the waning lunar crescent Moon's first dawn of joining with Venus, Mercury, Jupiter and Mars (as described above). But the Moon and all these planets will be very low for observers at mid-northern latitudes. ✦





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

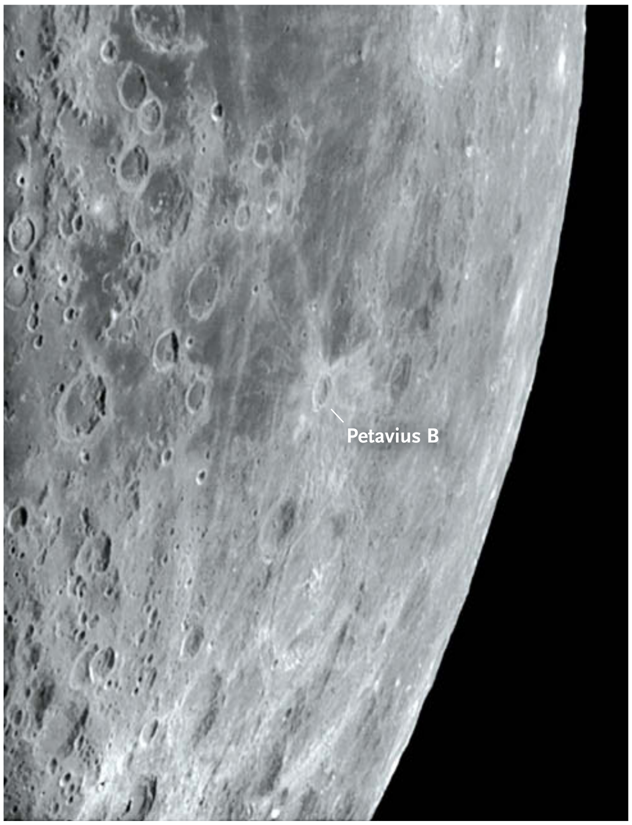
Charles A. Wood
Exploring the Moon

Coming in at an Angle

Low-angle impacts create some of the more interesting lunar craters.

WHEN CONTEMPLATING the origin of lunar craters, we often imagine projectiles coming from high in the sky, striking the Moon's surface nearly vertically, and excavating a perfectly round impact crater. While this occasionally happened, more often projectiles hit the lunar surface at a 45° angle, though many came in at increasingly shallower trajectories.

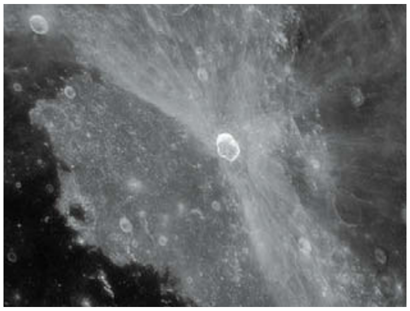
During the 1960s, Don Gault and his colleagues at NASA's Ames Research Center fired small projectiles at hypervelocity speeds to demonstrate that there was little detectable effect on the resulting craters until impact angles became less than about 30°. As impact angles decreased, progressively more exotic craters resulted. Craters become elongated in the direction of projectile motion, and rim collapses often occurred on the uprange side, cutting a bite out of the normally round rim.



HOWARD ESKILDSEN

Crater rays reveal clues about the direction and angle of an impactor when it hit the Moon. The triangular "zone of avoidance" north of (above) Petavius B clearly reveals the impactor's trajectory.

For the April Lunar Libration diagram, go to SkyandTelescope.com/skytel/beyondthepage.



BOB PILZ

The lack of rays to the west of Proclus tells us the impactor approached from that direction, striking the lunar surface at a low angle.

With impact angles shallower than about 20°, really interesting things happen to crater ejecta. The excavated material creates rays and secondary craters. Because of the projectile's momentum, rays formed in the downrange direction are longer than in the uprange direction. Additionally, a triangle-shaped zone of avoidance occurs uprange, where no ray material is deposited. Rays form in a "butterfly wing" pattern perpendicular to the projectile's direction during extremely oblique impacts of 5° or less, with a long ray forming downrange.

The most remarkable effect of very oblique impacts is that the projectile breaks apart, sending fragments farther along the flight path that create smaller, overlapping craters. In the extreme case of a near-grazing impact, a ricochet occurs, and the impactor (or parts of it) skips back above the surface before landing downrange. In some cases, the ricocheting projectile and some of the entrained surface rock escapes the Moon's gravity, entering orbit around Earth.

Gault's laboratory experiments are fascinating, but did anything like this happen on the Moon? The answer is yes! Evidence of oblique impacts is easiest to see during full Moon when rays stand out prominently. Start with a conspicuous example, such as the ray system of the crater **Proclus**, just west of Mare Crisium. Proclus is a 28-kilometer-wide (16-mile) bright walled crater. Its rays extend roughly north and south, with longer rays spilling eastward into Mare Crisium. But there are no rays to the west and southwest — this zone of avoidance marks the direction the projectile came from. In fact, this zone looks especially dark because it's not blanketed by ray material. The region is so strikingly different than the surrounding

S&T: SEAN WALKER

Perhaps the strangest oblique impact on the Moon is within Mare Fecunditatis, and involves the elongated crater Messier (upper right) and Messier A to its immediate lower left.

terrain that early Moon mappers gave it a name: Palus Somni.

Tycho is another crater with rays that reveal it was formed by an oblique impact. Note the dearth of rays to its southwest, and the broad swath in the opposite direction. **Kepler** is a little less certain, but it has a likely zone of avoidance to its west. Harder to find is **Thales**, a fresh crater poleward from the eastern end of Mare Frigoris. Its rays splay toward the west and southeast, with almost none going toward the pole. If the incoming object had approached from the opposite direction, the rays would pass over the lunar limb and would be harder to see; we might not realize Thales was a ray crater, and an oblique one at that.

One more rayed crater that is noteworthy because of its zone of avoidance is **Petavius B**. This 33-km-diameter crater was formed by a projectile that came from the north, smashing into the lunar surface just at the southeast end of Mare Fecunditatis at an angle of about 10°. Its rays are strongest to the sides, with some streamers to the south and an easily seen zone of avoidance to the north.

The lowest-angle impact we know of also formed the oddest ray craters on the Moon. In northeastern Fecunditatis, the peculiar pair **Messier** and **Messier A** look weird under any lighting. Messier is elongated east to west, and to its west, Messier A looks like one crater sitting inside an older one. Continuing west from A are two nearly parallel rays, and extending perpendicular to Messier are radiating swaths of faint rays. This is the best-known example of a very-low-angle impact — perhaps 5°. The grazing projectile came over the horizon from the east, hit the surface and formed Messier and its rays, and ricocheted farther downrange, forming the crater complex Messier A. The impactor's forward momentum kicked ejecta westward, forming the long twin rays.

Gault referred to the rays from Messier as butterfly wings, but they are too narrow for that insect. Considering the rays splayed out to the side and the long parallel ones, it's obvious that this is a dragonfly, albeit with only one pair of wings. ✦

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

 Alan Dyer

AUTOGUIDING BREAKTHROUGH:
Celestron's NexGuide

A stand-alone autoguider for $300 that really works! Can it be true?

THIS MUST BE the golden age of autoguiding. Driven by the current booming interest in astrophotography, never before have manufacturers offered so many choices for the most important component in any astrophotography rig, the autoguider.

Celestron's new NexGuide breaks the price barrier for a stand-alone autoguider, the type that doesn't require a separate computer and software to control your telescope mount. At $300, the price tag seems too good to be true, and I ventured into this review with some trepidation. The last thing I wanted to do was spend precious clear nights fighting an autoguider that refused to guide. But after a couple of nights of virtually flawless performance, the Celestron NexGuide earned the highest accolade I can give to a reviewed product — I forgot about testing it and simply started using it.

Getting it Guiding

The key selling point of the NexGuide is that it promises autoguiding at half to one-third the price of previous stand-alone autoguiders. Yet, it seems to give up nothing in the way of guiding accuracy. Dozens of test images I took with the NexGuide at its factory-default or automatic settings showed virtually perfect guiding. I rarely touched any of the unit's settings other than exposure time.

The author used the NexGuide for many deep-sky shots in late 2010, including this one of the North America Nebula. It's a stack of five 15-minute exposures with a Canon 5D MkII camera and an A&M (now Officina Stellare) 105-mm refractor on a Celestron CGEM mount. The guider worked so well that images exhibited no more than a pixel or two shift in right ascension from frame to frame.

ALL PHOTOS BY THE AUTHOR.

WHAT WE LIKE:

Simple, reliable, accurate guiding

Light weight

Low power consumption

WHAT WE DON'T LIKE:

Requires a moderately bright guide star

Does not resume guiding if clouds interfere

No battery level indicator

Celestron NexGuide Autoguider

U.S. price: $300

Celestron, www.celestron.com

Celestron's new NexGuide includes the autoguider head with a built-in display, a hand paddle, four-D-cell battery pack, parfocal locking ring, and barrel extension tube. Cables are included for connecting the guider to a mount's ST-4-style autoguider jack, and for connecting it to a computer's serial port for possible future firmware updates.

I was also impressed with how reliable the NexGuide was. Once I gave it a suitable guidestar (more about this in a moment), it consistently locked onto the star, calibrated, and began guiding without complaint or any dreaded "Calibration Failed" or "Star Lost" error messages. Even turning the guider's field of view at a 45° angle to the telescope's right ascension and declination (RA and Dec) motions did not faze it. Although the NexGuide menu offers a function to reduce its electronic noise, I never needed it — the NexGuide never mistakenly guided on a hot pixel or image artifact.

The quick calibration process that the NexGuide goes

Our test rig was typical of many setups: a good GoTo mount (here a Celestron CGEM), the telescope and camera for imaging, piggybacked with a smaller guidescope and autoguider.

Autoguiding 101

Like any modern autoguider, the NexGuide is built around a small CCD camera. But its 510-by-492-pixel sensor is not for taking pictures. Its job is to watch a single guide star. If the star wanders even a fraction of a pixel off its starting position, the NexGuide sends commands to the mount's motors to jog the mount in the direction that will bring the star back to its initial position. By doing this tirelessly every 1 to 4 seconds, stars in your photo record as pinpoints, not streaks.

Even the best telescope mounts require guiding during long-exposure photographs. Mechanical gear errors, misalignment on the pole, atmospheric refraction, and a host of other demons conspire to make a telescopic image wander around on a camera's sensor by a few pixels this way and that. For deep-sky imaging, whether with DSLR cameras or dedicated astronomical CCD cameras, autoguiding is essential for long exposures.

Some high-end CCD cameras made by SBIG come with built-in autoguider sensors that monitor a guide star just outside the field of the main imaging sensor. But entry-level astronomical cameras and all DSLRs pressed into service for astrophotography require a separate autoguider, plus associated optics and mounting hardware.

Guiding prevents this embarrassing result: a field of stars that all look like little Saturns. Without guiding, stars will inevitably trail east-west (in right ascension) and maybe north-south (in declination) too.

Left: **While the NexGuide can be screwed directly onto any adapter having standard T threads, it's best to use the included 1¼-inch nosepiece as this will allow you to easily swap the NexGuide for an eyepiece. *Right:* The NexGuide requires three cable connections for power, the guiding cable, and the hand controller.**

through automatically picks "Aggressiveness" values, which determine how large a correction to issue to the telescope mount. If aggressiveness is set too high, the guider can chase random guide star movements due to seeing conditions. While it is possible to adjust the unit's aggressiveness on the fly, the automatic settings usually worked fine. But you really don't know this until you see the photograph you're guiding.

During guiding, the NexGuide flashes + or – briefly to indicate when it has issued a correction to the mount. Another pair of numbers show the longer-term drift in RA and Dec. While these provide reassuring feedback on how well the unit is doing, a running graph of the last few minutes of guiding corrections would be welcome. Such a graphical display could reveal guiding problems that tweaking the aggressiveness can sometimes alleviate.

Finding a Guide Star

To work well, the NexGuide requires a moderately bright guide star. And finding one usually means that you have to swap the NexGuide for an eyepiece (not supplied) so that you can see a wider field and choose a suitable star.

The first thing you do when using the NexGuide is focus it (and this need be done only once). The unit focused about 1 centimeter (roughly ½ inch) in from the point where my 17-mm Plössl eyepiece reached focus. So if a generic Plössl-style eyepiece can reach focus, the NexGuide should too. If you plan on using one of today's popular short-tube refractors as a guidescope and you use a "straight through" arrangement, you may need an extension tube to reach focus, since most of these scopes were designed for use with a star diagonal.

The NexGuide can be set to take exposures in doubling increments from 1 to 4,096 milliseconds (1/1,000 to 4 seconds). If your guide star is initially way out of focus, a long exposure might be needed just to get it to show up on NexGuide's screen. As you adjust the focus, the star image will shrink and its brightness value goes up. Short millisecond exposures yield fast screen updates and aid in homing in on the best focus point when you get close.

Once it's focused, you can replace the NexGuide with an eyepiece, sliding it into focus and fixing its position with a "parfocal ring" that comes with the NexGuide and fits around the eyepiece barrel. Also included is a short extension tube for the eyepiece barrel so there's more for the focuser drawtube to grab onto if, as was the case for me, the eyepiece has to be pulled out a bit to be parfocal with the guider.

Once this initial setup is done, finding a suitable

A Guide to Using the NexGuide

Once you focus the camera, find a suitable guide star, and position the star on the sensor, getting the NexGuide guiding is relatively quick and easy:

STEP 1 – PREVIEW

The NexGuide's PREVIEW screen shows stars as black dots of varying intensity. Numbers indicate the guider's exposure time, star brightness, and the star's X and Y positions on the sensor.

STEP 2
LOCK ON A STAR

You can LOCK on a star by selecting it manually with moving crosshairs, or you can have the NexGuide automatically lock onto the brightest star in the field.

STEP 3
CALIBRATE

Entering GUIDE starts AUTO CAL, a brief automatic process during which the NexGuide exercises the mount's motors through each of the four directions.

STEP 4
GUIDING UNDERWAY

During guiding, you can adjust the aggressiveness of the right ascension and declination corrections (the top two numbers) on the fly by using the hand controller.

guide star in the future is simply a matter of inserting the parfocalized eyepiece and adjusting the guide scope to center and focus a bright star in the field. Swap in the NexGuide and you should see a lone dark speck appear on the screen. It need not be centered (though it should not be near the edge) for the NexGuide to work.

But the star does have to be reasonably bright. With a 66-mm f/6 guidescope and 2- to 4-second exposures, I needed a star of at least 7th magnitude. This is in agreement with the advertised specs for the camera. I shot several dozen objects and never had a problem getting a good guide star, but it always required hunting. There was never a suitable star that, by chance, happened to be in the field of the NexGuide's small 5.6-by-4.7-mm sensor.

NexGuide Caveats

While Celestron has a nifty autoguider in the NexGuide, buyers are left to assemble a complete guidescope system on their own, since the company doesn't offer the required mounting plates and guidescope rings. Suppliers such as ADM, Astro-Tech, Losmandy, and Orion offer the right bits, but knowing what to buy can be a daunting task, especially for beginners. What plates will fit your imaging scope? And what rings will work with your guidescope? Considering the popularity of astrophotography, it is surprising that assembling a good rig still remains a do-it-yourself affair involving many brands of gear.

Previous stand-alone autoguiders have been rather power hungry, but not so the NexGuide. The supplied four D-cell power pack ran the NexGuide for about 5 or 6 frosty autumn nights worth of guiding, at 2 to 3 hours of shooting per night. If the power drops too low, the NexGuide refuses to advance beyond its initial "splash" screen. But it doesn't provide any way to check the battery level, or sound a low-battery warning. It just stops working. So take spare batteries! The battery pack supplies 6 volts, but the NexGuide works fine with any source of clean 6- to 12-volt DC power.

My only real issue with the NexGuide is that, unlike some autoguiders, it does not resume guiding after losing sight of the guide star (perhaps due to intermittent clouds). After the star returns, the NexGuide still registers "Star Lost." You have to resume autoguiding manually. Nor does it beep when it loses a guide star. Walk away after starting your automated shooting sequence and you might find that a brief, passing cloud caused subsequent shots to be unguided, despite the sky clearing up.

Nevertheless, when coupled with a solidly mounted but adjustable guidescope, the NexGuide represents a breakthrough in autoguider price and performance. I highly recommend it. ✦

Coauthor with Terence Dickinson of The Backyard Astronomer's Guide *(Firefly Books, 2008),* ***Alan Dyer*** *frequently reviews products for* Sky & Telescope.

Autoguiding Options

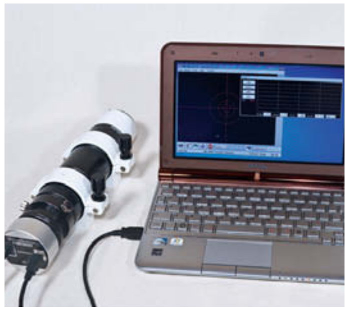
The first commercially successful autoguiders were stand-alone black boxes manufactured by Santa Barbara Instrument Group (SBIG). The company's pioneering ST-4 and STV units from the 1990s have long been discontinued.

During the last decade, most autoguiding solutions required a laptop computer running specialized software that analyzed images from a separate autoguider camera and issued commands to the mount. This is still a popular way to go. My favorite software for this type of setup, *PHD Guiding* from Stark Labs (stark-labs.com), works great when coupled to a sensitive autoguider camera such as Orion's StarShoot Autoguider.

One disadvantage to a laptop-based guiding system is the need to power the laptop in the field. Today, however, small Windows netbooks with 7- to 10-hour battery lives make this less of an issue than with the power-hungry laptops of yesteryear.

Nevertheless, it's even nicer to have an autoguider that does it all on its own, with a minimum of paraphernalia and drawing so little power that it will run for several nights on a set of flashlight batteries. A new generation of stand-alone autoguiders provides attractive choices at a wide range of price points.

AUTOGUIDE OPTION #1
NETBOOK BASED
An advantage of computer-based autoguiding is the ability to see the image the autoguider is taking, and to pick any star in the field to be your guidestar. Cameras such as Orion's $280 StarShoot are so sensitive there's always a star bright enough in the field of a small guidescope (this one is a Borg with a 50-mm aperture).



AUTOGUIDE OPTION #2
STAND-ALONE (HIGH-END)
SBIG's new SG-4 autoguider (reviewed in the September 2010 issue, page 38) offers the ideal combination of one-button operation, stand-alone convenience, low power needs, and the sensitivity to find and guide on a star in any field you aim it at, even when using its tiny eFinder guidescope. But it costs $1,000.

AUTOGUIDE OPTION #3
STAND-ALONE (ENTRY-LEVEL)
The Celestron NexGuide offers the stand-alone operation of the SG-4, with the added value of screen readouts and a $300 cost. The trade-off is the camera's lower sensitivity, demanding a larger guidescope (like this William Optics 66-mm), adjustable mounting rings, and the extra effort required to find a suitably bright guide star.

Porrima's Grand Opening

The binary star Gamma Virginis, "single" a few years ago, is again double.

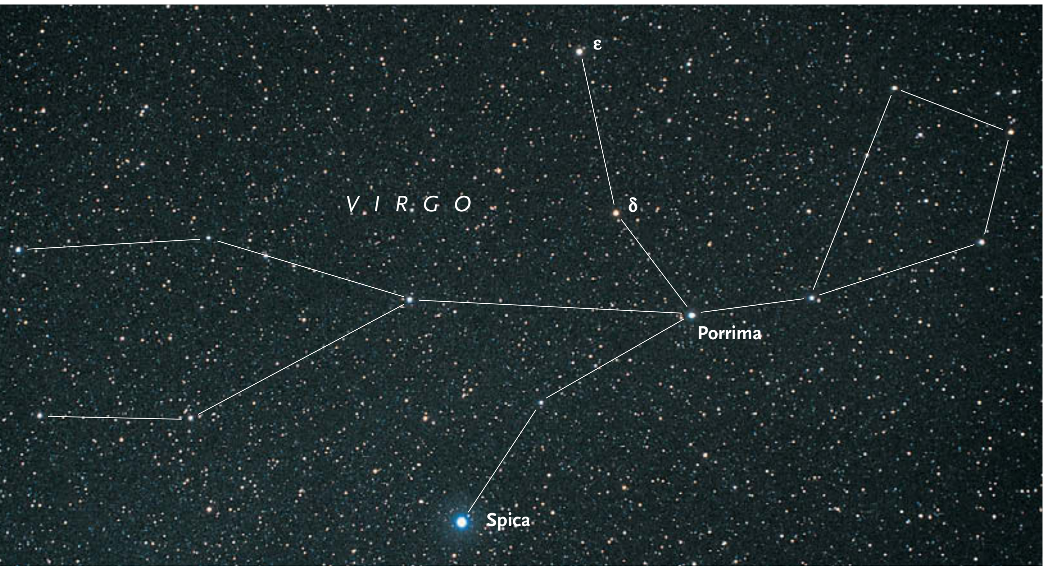
Saturn will be the top evening attraction for small telescopes this spring and summer, but right near it is a very special naked-eye star that you should be sure to examine also. Gamma (γ) Virginis, or Porrima, is the best-known star in Virgo after Spica: it's a telescopic binary that all the classical observing handbooks called one of the finest doubles for small telescopes.

Porrima's two identical stars, each magnitude 3.5, displayed an easy maximum separation of 6.0 arcseconds around 1919, then closed in on each over the decades — very gradually at first, then faster. By the late 1990s the pair had become surprisingly difficult in amateur telescopes — surprising to observers who didn't know what was happening. Then Porrima turned *single* in most scopes from about 2003 to 2007. Now it's widening again, becoming splittable in smaller and smaller telescopes.

This spring Porrima should display a separation of 1.7″. That will make it a good test object for a 3-inch scope at high power during excellent, steady seeing. This prediction comes from "definitive" new orbital elements for the binary published in 2007, based partly on speckle-interferometry measurements made during the critical time around the 2005 periastron and closest separation (0.4″).

Some visual measurements made around then diverged from predictions, raising excitement that the assumed orbit might be seriously wrong. But now those only seem to show how hard it is to measure a very close double star accurately at the eyepiece. The orbit had been revised substantially before. But William I. Hartkopf, a double-star specialist at the U.S. Naval Observatory, says that any further

Using a 6-inch reflector at 200×, Jeremy Perez of Flagstaff, Arizona, sketched Porrima emerging from its 2005 periastron. Few visual binaries change so fast!



AKIRA FUJII

Shining close to Saturn this year with a combined brightness of magnitude 2.7, the binary star Porrima, or Gamma Virginis, is the second brightest star in Virgo. This portrait of the constellation was taken when Saturn was elsewhere.

Asteroid Occultation

On the night of April 29–30, the 10.3-magnitude asteroid 7 Iris occults an identically bright star in Cancer as seen from a track crossing from northern Idaho through Iowa and Illinois to Virginia and North Carolina. The asteroid is a generous 120 miles wide, and the uncertainty in the location of its shadow path is less than the path's width.

Start watching at least 20 minutes early to see this evenly matched "double star" narrow and merge into a single point. The occultation, if it occurs at your site, will cause the combined light to suddenly drop by half, meaning 0.8 magnitude. This is less obvious than you might think; watch carefully! The occultation may last for up to 10 seconds.

For finder charts, path maps, and further information, see www.asteroidoccultation.com/IndexAll.htm. Here you'll also find many more asteroid-occultation predictions worldwide.

For lots more about observing and timing these events, see www.asteroidoccultation.com/asteroid_help.htm.

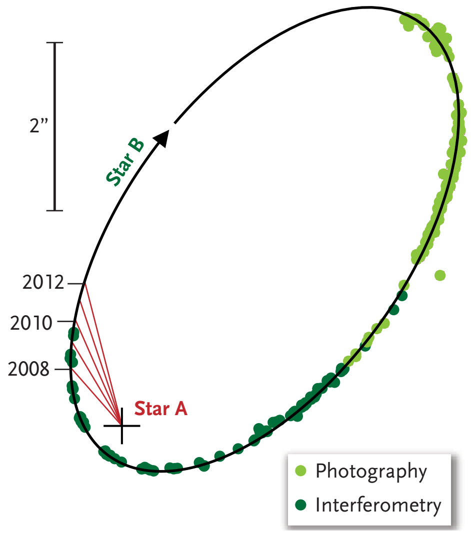
refinements to Porrima's orbit will, at last, be extremely slight forevermore.

The stars take 169 years to swing around each other in a very elongated path. The orbital eccentricity is 0.882, meaning the stars are 17 times farther apart at one end of their orbit than at the other. Their physical separation ranges from 4.8 to 81 astronomical units. Both are main-sequence *F*0 stars with 6 times the Sun's luminosity and 1.4 times the Sun's mass. They'll continue becoming easier for springtime telescope users until they reach maximum separation again in 2088.

How easy, or hard, is Porrima for you to resolve in 2011?

The pair is currently oriented north-northeast to south-southwest. Knowing directions in your eyepiece accurately helps for checking whether you're really resolving a difficult double star or seeing a lopsided effect of atmospheric distortion or miscollimated optics. Turn off the scope's drive; stars will drift exactly westward. North is 90° counterclockwise from west if your scope gives a correct image. North is 90° *clockwise* from west in a mirror image (as is usually seen when using a right-angle diagonal at the eyepiece).

Orbit of Gamma Virginis



The most recent "definitive" orbit of Porrima, as seen projected on the plane of the sky, includes accurate measurements of the star pair made since their periastron (closest physical approach) occurred in 2005. The light green dots are the best photographic measurements of star B's position with respect to star A since 1910. The darker dots are more recent speckle-interferometric measurements, a more precise modern technique for close pairs. North is up and east is to the left.

S&T: LEAH TISCIONE, SOURCE: WILLIAM HARTKOPF / U.S. NAVAL OBSERVATORY

Two Lunar Occultations

As the waxing crescent Moon passes north of the Hyades in the western sky on **Thursday evening April 7th,** the Moon's earthlit dark limb will cover up Kappa (κ) and/or Upsilon (υ) Tauri for observers in much of western North America. Both stars are magnitude 4.3, in the tail of the Davis's Dog asterism (*S&T:* December 2010, page 39). Kappa also has a 5.3-magnitude companion 0.1° to its south. Some times of disappearances: Edmonton, 10:50 p.m. MDT; Vancouver, 10:16 p.m. PDT; Los Angeles, 10:23 p.m. PDT.

It's easterners' turn three days later, when on **Sunday evening April 10th** the dark limb of the first-quarter Moon snaps up Zeta (ζ) Geminorum, magnitude 3.8. Some times: Toronto, 9:10 p.m. EDT; Washington, DC, 9:17 p.m. EDT; Atlanta, 9:09 p.m. EDT; Miami, 9:29 p.m. EDT.

Maps and timetables for these and other lunar occultations are at www.lunar-occultations.com/iota/bstar/bstar.htm. Once there, scroll to the UT date and click on the star name.

The Fickle Lyrid Meteors

The mornings around April 22nd and 23rd bring the annual, but highly variable, Lyrid meteor shower. Outbursts of Lyrids have been seen since at least 687 B.C., when Chinese records say "stars dropped down like rain," though in most years meteor watchers count only 10 to 20 visible per hour under ideal conditions. At intervals of about 12 years the Lyrids occasionally perform more than ten times as well. But the 12-year cycle itself is very spotty.

Why does this cycle happen at all? The orbital periods of the meteoroids and of their source, Comet 1861/G1 Thatcher, are much longer: about 400 years. Complex perturbations by Jupiter (which has a 12-year period) seem to be acting on separate, narrow substreams within the overall Lyrid meteoroid stream. Each substream was shed by Comet Thatcher during a particular past return to the inner solar system. According to this model, the next Lyrid outburst won't come until 2040. But no one knows for sure what's going on, and if past outbursts have been missed (they tend to last only about 6 hours), the model may be incorrect. So observers are needed to keep the Lyrids under watch.

This year the light of the waning gibbous Moon will interfere, but at least you can determine whether or not an outburst is in progress at the times you're looking. Watch in the hours before dawn, when the shower's radiant (near Vega) is high in the sky. For more on making a meteor count, see SkyandTelescope.com/meteors. ✦

Minima of Algol

Mar.	UT	Apr.	UT
2	5:03	2	18:06
5	1:53	5	14:55
7	22:42	8	11:45
10	19:32	11	8:34
13	16:21	14	5:23
16	13:10	17	2:12
19	10:00	19	23:01
22	6:49	22	19:51
25	3:38	25	16:40
28	0:27	28	13:29
30	21:17		

The eclipsing binary star Algol is sinking in the northwest on March and April evenings. It remains near its minimum brightness, magnitude 3.4 instead of its usual 2.1, for about two hours. It takes several additional hours to fade and to rebrighten.

Sextans Uraniae

This obscure constellation is swarming with galaxies.

IN 1679 A DISASTROUS fire swept through the estate of renowned Danzig astronomer Johannes Hevelius. His home and observatory, Stellaburgum, burned to the ground. Most of his books and records were consumed by flames, and none of his fine instruments survived — including his prized six-foot brass sextant for measuring the angular separation between stars. Hevelius immortalized his lost sextant by creating the constellation Sextans Uraniae between astrologically fiery Leo and Hydra. It endures today under the shortened name Sextans.

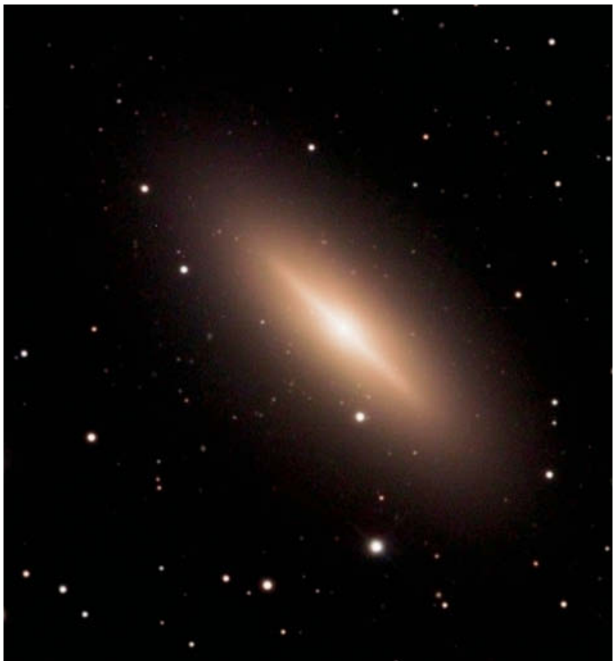
Sextans plays host to many galaxies, and we're going to visit a sample of them, limiting ourselves to galaxies brighter than visual magnitude 12.0. If you think that means they'll all be easy, you're mistaken. You'll soon find that a galaxy's magnitude doesn't tell the whole story.

We'll start with **NGC 3115**, a large lenticular (lens-shaped) galaxy about 34 million light-years away with a black hole a billion times the mass of our Sun lurking in its heart. It's the brightest galaxy in Sextans at magnitude 8.9.

NGC 3115 sits halfway between the 5th-magnitude stars Gamma (γ) and Epsilon (ε) Sextantis and 22′ north of an imaginary line connecting them. Even at 23× through my 130-mm (5.1-inch) refractor, the galaxy is a bright oval that greatly intensifies toward the center. Three times longer than wide, it lives up to its nickname, the Spindle Galaxy. The size is easier to estimate at 117×, appearing approximately 4½′ × 1½′ to my eye. It leans northeast and holds a small round nucleus. In my 10-inch reflector at 171×, NGC 3115 is 5′ long with its tips gradually blending into the background. A thin core about 2′ long brightens toward the nucleus, and the halo has a faint star superposed south of the galaxy's center.

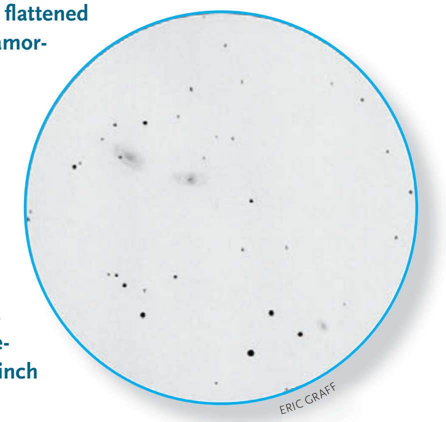
The interacting spirals **NGC 3169** and **NGC 3166** are twice as distant as the Spindle and weigh in at magnitudes 10.2 and 10.4. To locate them, aim for a 25′ asterism of several 7th- to 12th-magnitude stars (pictured below) that makes an isosceles triangle with Alpha (α) and Beta (β) Sextantis. To me, the group resembles the lower-case Greek letter nu (ν) with a tipped capital delta (Δ) to its west. The galaxies float 12′ north of the ν.

The asterism is mirror reversed in my 130-mm refractor, but still quite distinctive. Both galaxies are small ovals with bright cores at 23×. NGC 3169 leans northeast, and NGC 3166 reclines east-west. At 117×, an 11th-magnitude star hugs the flank of NGC 3169, east of center. The galaxy appears roughly 3½′ × 1½′, and its core is oval. NGC 3166 is similar in size, but has a rounder and brighter core. My 10-inch scope at 171× bestows a stellar nucleus.



DANIEL VERSCHATSE / OBSERVATORIO ANTILHUE / CHILE

Left: NGC 3115 is a classic example of a lenticular galaxy — flattened like a spiral galaxy but amorphous like an elliptical.



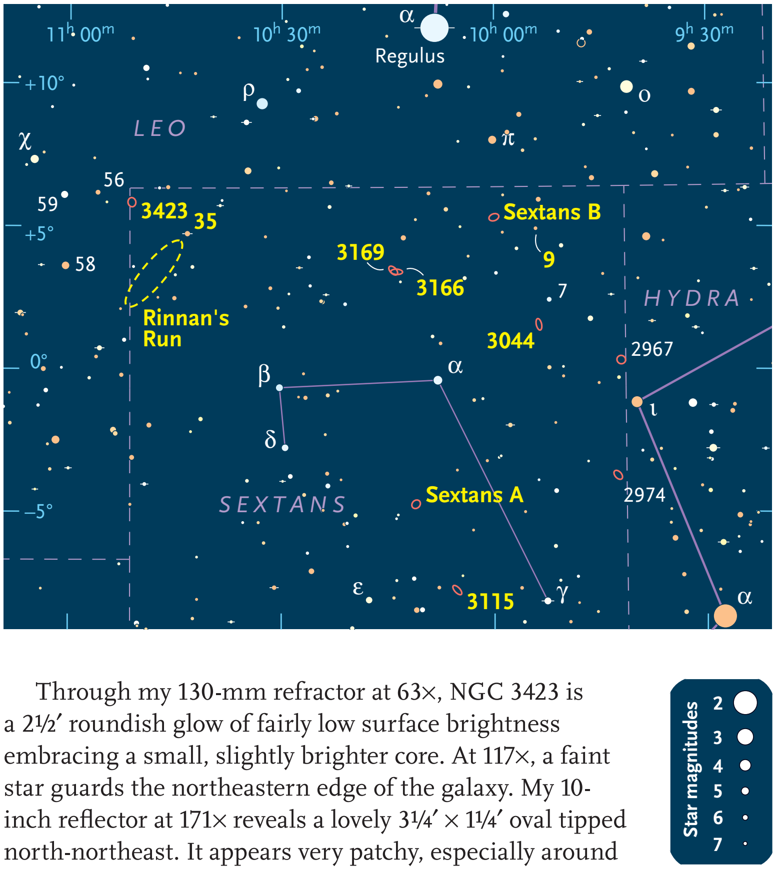
Right: At 60×, the galaxies NGC 3166 and 3169 are easily located north of a prominent asterism. Fainter NGC 3156 lies just west of the asterism's brightest stars. All sketches represent views through a 6-inch reflecting telescope.

ERIC GRAFF

On the way to our next galaxy, let's stop to admire **35 Sextantis**. Through my 130-mm scope at 37×, it's a lovely double with a yellow-orange 6th-magnitude star nuzzling a deep-yellow companion to the west-southwest. They occupy the northeastern corner of an 8′ trapezoid formed with three field stars. A recent spectroscopic study indicates that the companion is composed of two stars in such close embrace that they cannot be seen separately through a telescope.

35 Sextantis heads a remarkable line of stars that has caught the attention of various people over the years. With a slight kink in the top, the sparkling cascade tumbles south-southeast from 35 Sextantis for 3°. Eugene (Oregon) Astronomical Society members call this "beautiful little starfall" **Rinnan's Run** after Dan Rinnan, who chanced upon it during one of their 2009 observing sessions while perusing the sky with image-stabilized binoculars. Tomm Lorenzin zeroed in on the southern end of the line, where the stars are fainter but more densely packed. He dubbed that section The Scar in his 1997 online *2000+ Catalog*. With 11×80 binoculars in 1980, California's Dana Patchick saw a wide V made up of The Scar and a second starry line reaching northeast from its southern end. I've always called it Dana's V.

Now that you're acquainted with the area, look for the galaxy **NGC 3423** two-thirds of the way from 35 Sextantis to the reddish orange star 56 Leonis. It's stored on the attic floor of a skinny, Cepheus-like, stick-figure house of five stars. The house is ½° tall with its sharply peaked roof aimed south-southwest. NGC 3423 is magnitude 11.1 and as distant as the Spindle Galaxy.

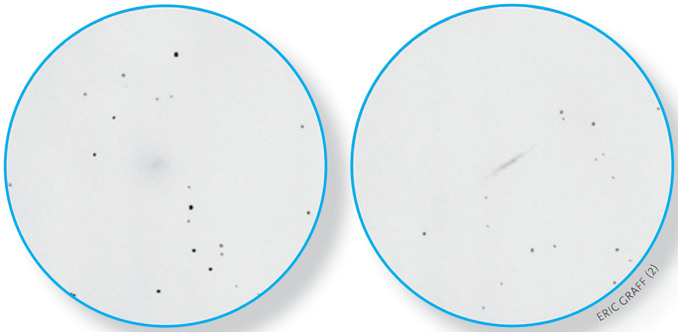


Through my 130-mm refractor at 63×, NGC 3423 is a 2½′ roundish glow of fairly low surface brightness embracing a small, slightly brighter core. At 117×, a faint star guards the northeastern edge of the galaxy. My 10-inch reflector at 171× reveals a lovely 3¼′ × 1¼′ oval tipped north-northeast. It appears very patchy, especially around the outer edges, giving the impression of weakly defined spiral arms wrapping clockwise outward. The core is round and spans 40″.

Our next two galaxies are nearly the same magnitude

NGC 3169 (left) and 3166 are distorted by each other's gravitational pulls. The author also spotted little NGC 3165 (far right) but did not include it in the article because it's below the 12.0-magnitude cutoff.

KEN CRAWFORD



ERIC GRAFF (2)

Left: **Faint Sextans B sits in a pretty star field at 60×.**
Right: **NGC 3044 is a long, thin sliver at 120×.**

as NGC 3423, but they're much harder to see. Sextans B (UGC 5373) is magnitude 11.3, and Sextans A (MCG–1-26-30) is 11.5. At 5 million light-years, these dwarf galaxies dwell just beyond the boundaries of our Local Group.

Sextans B sits 1½° east-northeast of the pretty, wide, orange-and-gold double **9 Sextantis**. In my 10-inch scope at 171×, Sextans B is a very faint glow that covers about 3′ × 2′ and leans west-northwest. A 14th-magnitude star is pinned to its northern edge, and 13th-magnitude stars rest 2½′ north and east-northeast of the galaxy's center.

Sextans A is located 4.4° south and a bit east of Alpha Sextantis. With my 10-inch reflector at 187×, I could only pick out its brightest patch, which lies in the western side of a faint star pattern that's a lopsided version of the 5-spots on dice. The patch is very grainy, less than 1′ long, and wider at its southwestern end. Through my 15-inch reflector at 79×, this little scrap of the galaxy is embedded in the eastern side of a ghostly 3′ glow.

Our final galaxy is the faintest of all, yet I can glimpse it in a small telescope. **NGC 3044** shines at magnitude 11.9, and it's about the same distance away from us as NGC 3166 and NGC 3169. We find it dangling 57′ south-southeast of 7 Sextantis.

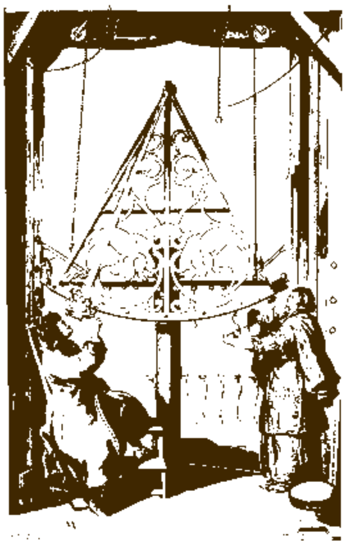
Through my 105-mm scope at 122×, NGC 3044 is a very faint slash about 3′ long with a brighter, elongated core. The galaxy points toward an 11.7-magnitude star 6′ away from its west-northwestern tip. The view through my 10-inch scope increases the length of this slender streak to about 4′.

Why are Sextans A and B so difficult to see if their magnitudes are only a little dimmer than NGC 3423's and brighter than NGC 3044's? The answer lies largely in their apparent size.

In our table, the listed magnitude for NGC 3423 is 11.1. In other words, if all the galaxy's light were gathered into a single point, it would look like an 11.1-magnitude star. But that light is actually smeared across an oval 3.8′ × 3.2′ in size, making each square arcminute of the galaxy, on average, magnitude 13.7. This value is known as surface brightness (SB), and a quick glance at size and SB columns in the table will tell you why Sextans A and B are tough to see. Their light is attenuated by being spread over a larger area than the other two galaxies.

These four galaxies are challenging to find, and a good star atlas can be a helpful tool for tracking them down. All the objects in this sky tour are plotted on the second edition of *Sky Atlas 2000.0*. ✦

__Sue French__ welcomes comments at scfrench@nycap.rr.com.



WIKIMEDIA COMMONS

Johannes Hevelius and his wife Elisabetha measured star positions with extraordinary accuracy using their giant sextant, now immortalized as one of the 88 constellations.

Exploring Hevelius's Sextant

Object	Type	Magnitude	Size/Sep	SB	RA	Dec.
NGC 3115	Galaxy	8.9	7.2′ × 2.4′	11.9	$10^h\ 05.2^m$	–7° 43′
NGC 3169	Galaxy	10.2	4.4′ × 2.8′	12.8	$10^h\ 14.2^m$	+3° 28′
NGC 3166	Galaxy	10.4	4.8′ × 2.3′	12.8	$10^h\ 13.8^m$	+3° 26′
35 Sextantis	Double star	6.2, 7.1	6.8″	—	$10^h\ 43.3^m$	+4° 45′
Rinnan's Run	Asterism	—	3°	—	$10^h\ 46.3^m$	+3° 26′
NGC 3423	Galaxy	11.1	3.8′ × 3.2′	13.7	$10^h\ 51.2^m$	+5° 50′
Sextans B	Galaxy	11.3	5.5′ × 3.7′	14.5	$10^h\ 00.0^m$	+5° 20′
9 Sextantis	Double star	6.9, 8.4	52.5″	—	$9^h\ 54.1^m$	+4° 57′
Sextans A	Galaxy	11.5	5.5′ × 4.5′	14.8	$10^h\ 11.0^m$	–4° 42′
NGC 3044	Galaxy	11.9	4.9′ × 0.7′	13.1	$9^h\ 53.7^m$	+1° 35′

Surface brightness (SB) is in magnitude per square arcminute. 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.

The Moon's Four Librations

We took these photos of the lunar eclipses in 2004 and 2010 from the same location in Colorado. Why is there an apparent rotation of the Moon between them?
— Darien & Patrick O'Brien, Lakewood, CO

December 21, 2010 October 17, 2004

Darien and Patrick O'Brien used the same telescope, camera, and exposure settings for these two total lunar eclipses six years apart — when the Moon displayed different librations.

The changing positions of the Moon's features (notice especially Mare Crisium on the right and dark little Grimaldi on the left) are caused by the Moon's *librations:* the slight, back-and-forth nodding of the Moon's visible face in roughly monthly cycles. "Libration" refers to a tipping like that of a *libra,* Latin for a pair of scales.

The Moon has four separate kinds of libration, each with a different cause:

Libration in longitude. The Moon's orbit is slightly elliptical; the Moon runs a little faster along the part of its orbit nearest Earth, and slower along the far part. But the Moon's rotation rate is tidally locked to the Moon's *average* orbital motion. So the Moon doesn't always present us quite the same face. Because the Moon speeds up and slows down around its orbit while its rotation rate stays nearly the same (the Moon is too big and heavy to change spin easily), we see a little way around first one side, then the other.

Libration in longitude tilts the Moon as much as 7.7° east or west from the average.

Libration in latitude. We also see a little farther around the Moon's north and south edges during each month, because the Moon's axis is tilted with respect to its orbit around Earth. This is exactly like the effect that causes the seasons on Earth as Earth goes around the Sun. If you were standing on the Sun you would see the Earth's Northern Hemisphere tipped toward you when Earth was on one side of its orbit, and tipping away from you when Earth was on the opposite side of its orbit.

Libration in latitude lets us see as much as 6.7° beyond the Moon's north and south poles.

Diurnal libration. You get a slightly different viewpoint toward the Moon depending on where you are on Earth's Moon-facing side. When the Moon appears near your horizon, you see about 1° over its top edge compared to when the Moon rises to your zenith.

Physical librations. The above are just optical effects due to your own changing viewpoint. The Moon itself doesn't feel them. But the Moon does have several slight "physical librations" whereby, even with its great inertia, it tries to change rotation to keep up with the changing tidal torques exerted by the Earth and Sun. But these actual turnings are tiny: less than about 0.05° from the Moon's average. ✦

Collimation Warning

How often should I collimate my scope? What are the signs I should?
— Dave Meunier, North Attleboro, MA

Miscollimation, like many other optical problems, can easily be diagnosed with the *star test.*

Aim at a moderately bright star at very high power. Polaris is a good choice because it doesn't move. Center the star and focus it.

Now turn the focuser knob slightly one way, then slightly the other way, from best focus. Compare the out-of-focus diffraction patterns (little bull's-eyes) just a touch on each side of best focus.

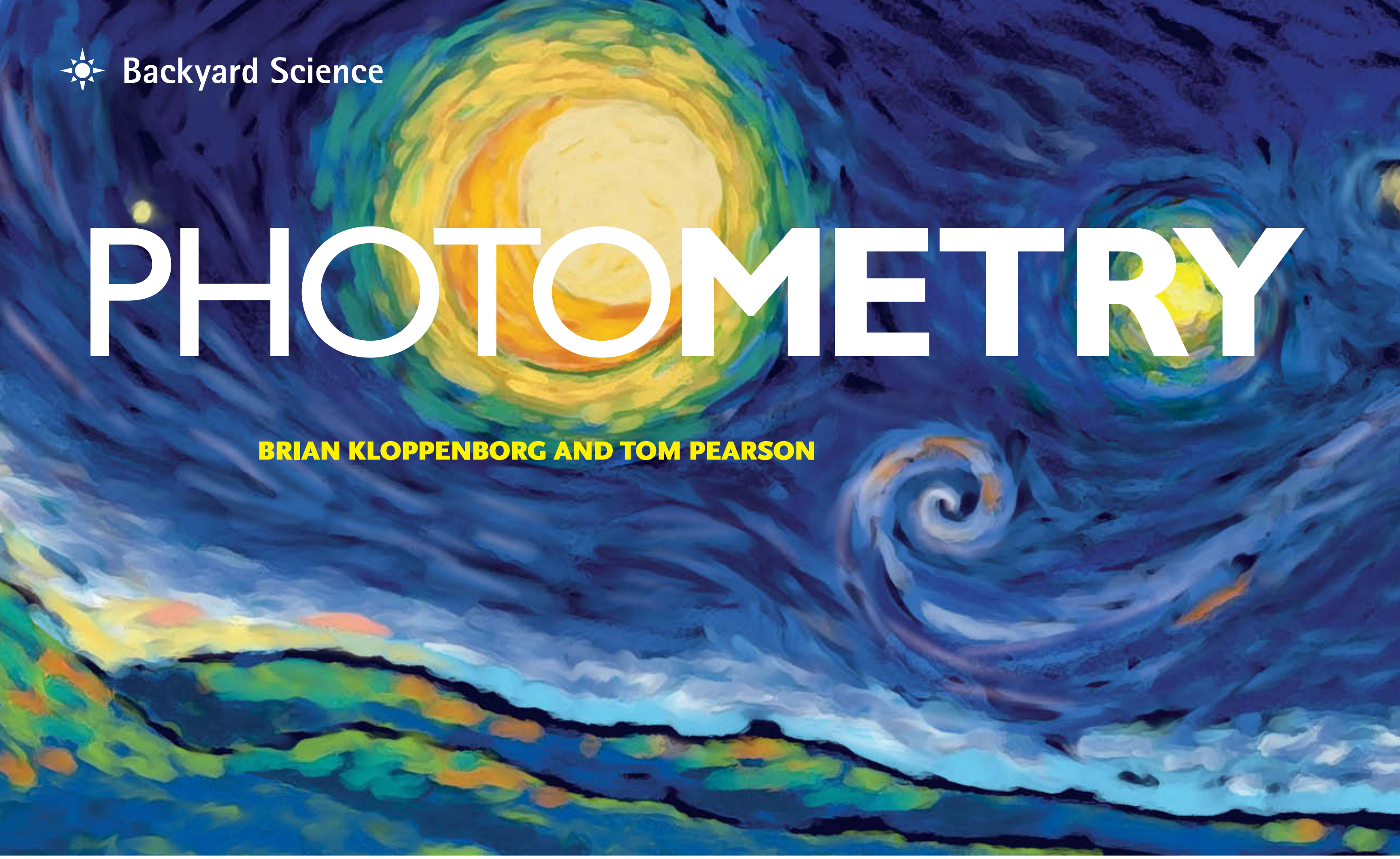
In a perfect telescope they will be identical. This test is so sensitive to all sorts of aberrations that few telescopes pass it perfectly. A little difference has no appreciable effect. But the inside- and outside-of-focus patterns should not be different by a lot.

Miscollimation shows an effect all its own. If the star becomes lopsided or flary *in the same direction* on both the inside and outside of best focus, breathe a sigh of relief; a collimation tweak should fix it. (Aberrations in the optics themselves will cause the star to switch appearance, or switch the orientation of its out-of-roundness, on either side of focus).

Collimating a scope is easiest with two people. One turns a collimation screw; the other watches in the eyepiece, recenters the star after the tweak, and says whether that made it better or worse. Go around from one of the three collimation screws to the next until no further improvement can be made.

For more, see SkyandTelescope.com/collimation.

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



PHOTOMETRY

BRIAN KLOPPENBORG AND TOM PEARSON

You can make valuable scientific contributions to astronomy with just your

IF YOU HAVE EVER YEARNED to make tangible contributions to the science of astronomy, digital-camera photometry may be for you. Photometry, the measurement of light intensity from stars and other celestial objects, is one of the most fundamental tools of modern astronomy. Much of our knowledge of variable stars, supernovae, asteroids, and even extrasolar planets is derived from photometry.

BRIAN KLOPPENBORG

TOM PEARSON

Estimating the brightness of stars dates back to the second century BC, when the Greek astronomer Hipparchus devised a magnitude system that's still in use today. He visually compared the brightness of stars and assigned numbers from one, for the most brilliant, through six, for the dimmest. This comparison method of determining magnitude is a form of what we call differential photometry, which is also still used today.

Refinements made to the estimation of visual magnitudes in the 1800s and the advent of photography later in the 19th century greatly improved magnitude measurements, but photometry continued to rely on taxing visual comparisons. In the 1940s photomultiplier tubes were able to convert starlight into a measurable electric current, largely removing observer bias from the process of determining brightnesses. The advent of CCDs in the 1970s further revolutionized photometry. These digital sensors (and their CMOS cousins) are highly sensitive and can produce a linear response to variations in light

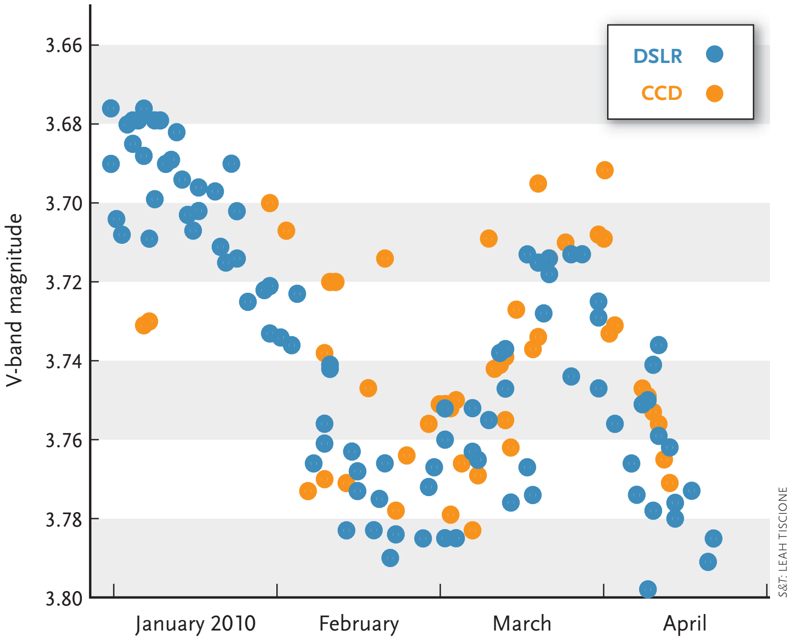
for All *in the* Digital Age

S&T Illustration by Patricia Gillis-Coppola

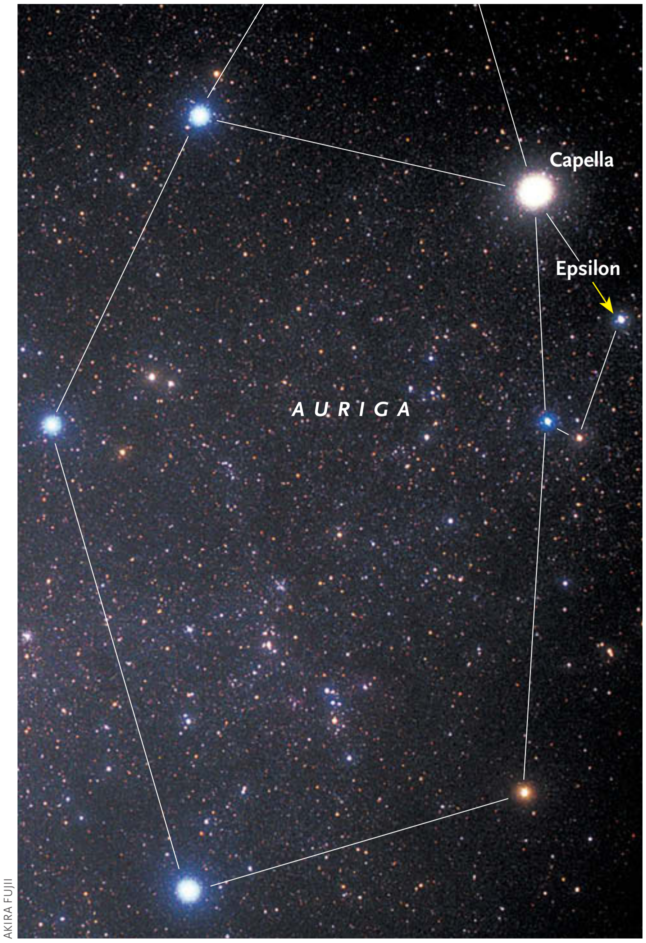
off-the-shelf digital camera and appropriate computer software.

intensity. Both of these characteristics are very important for photometric detectors.

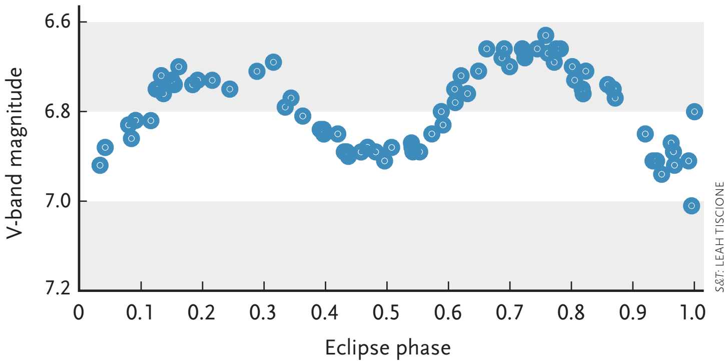
During the past decade, digital imaging has revolutionized amateur astrophotography. While admiring today's beautiful photos, it's easy for us to forget that these images are made by assigning numbers to millions of pixels on the camera's sensor. The number, or "count," assigned to a pixel is directly related to the number of photons striking the pixel. It's this quantitative side of digital imaging that we use in CCD photometry. With the proper software we can analyze a photograph and compare the photon counts of a target object with those



Amateur Jeff Hopkins has been coordinating observations for the International Epsilon Aurigae Campaign (see page 66). This graph plotting the brightness measurements contributed by eight observers shows that data gathered with DSLR cameras (blue dots) compares well with traditional photometry done with astronomical CCD cameras (orange dots).



As explained in the accompanying story, the current eclipse involving the "Mystery Star," Epsilon Aurigae, helped inspire the creation of the AAVSO's Citizen Sky program and a worldwide effort to monitor the star's changing brightness with digital cameras. After spending more than a year at minimum light, Epsilon should begin returning to normal brightness in March 2011.



Specializing in photometry of bright stars with low-amplitude brightness variations, amateur Des Loughney produced this light curve of the variable AW Ursae Majoris using images made with a Canon 450D DSLR and processed with *AIP4WIN* software.

of comparison stars of known brightness, and thus determine an accurate magnitude for the target. This is the modern application of differential photometry.

Until recently, most people interested in doing CCD photometry had to make a sizable investment in equipment and software. Now, however, amateurs can use standard digital cameras, especially DSLRs, to do valuable wide-field photometry. Images from these cameras can be evaluated with popular software packages (some available for free) to make brightness estimates with accuracies approaching ±0.01 magnitude.

Potential targets run the gamut of celestial bodies. They include flare stars, Cepheid variables, eclipsing binaries, extrasolar planetary transits, and even stars with spots. And if targets a little closer to home appeal to you, then you can apply your skills to asteroids, planets, comets, and even the Moon.

The long awaited eclipse of the "Mystery Star," Epsilon Aurigae (*S&T:* May 2009, page 58), has sparked a resurgence of interest in observing variable stars among professional and amateur astronomers. In support of this interest, the American Association of Variable Star Observers (AAVSO) launched Citizen Sky (www.citizensky.org), a program designed to organize and educate participants on how to make and analyze observations and publish the results in peer-reviewed journals.

One component of Citizen Sky is the establishment of scientific teams made up of individuals with complementary skills working toward a common goal. One of us (Brian Kloppenborg) spearheaded the DSLR Documentation and Reduction Team, with the goal of collecting and disseminating the growing knowledge base being developed around DSLR photometry.

An example of the tangible results possible with DSLR Photometry is shown in the graph on page 65. Amateur Jeff Hopkins, a renowned observer of Epsilon Aurigae, organized nearly 60 amateur and professional astronomers in a worldwide observing campaign for the current eclipse (www.hposoft.com/Campaign09.html). The graph of V-band magnitude estimates from eight observers illustrates that results obtained with DSLRs compare favorably with data from traditional photometry.

Another avid amateur, Des Loughney of Edinburgh, Scotland, has been perfecting DSLR methods for several years. He's particularly interested in bright variable stars with amplitudes of 0.5 magnitude or less, and his light curve (at left) for the eclipsing binary AW Ursa Major demonstrates the accuracy that can be achieved with off-the-shelf digital cameras.

Placed on a simple photographic tripod and pointed at the starry sky, a DSLR makes an excellent photon collector. The individual stars captured in a series of short exposures can be analyzed to determine accurate visual, or "V," magnitudes. The camera's relatively wide field of view is a particularly desirable feature. It makes pointing at target stars easier and provides a single image that includes an array of comparison stars of known brightness. Ease of use is an added plus. A typical observing session takes only 10 to 20 minutes. Setting up the equipment is no more complicated than taking a family photo — and you don't have to get the kids to stand still!

If you want to give photometry a try, check out the Citizen Sky website at www.citizensky.org/content/dslr-documentation-and-reduction, where you'll find tutorials prepared by the Citizen Sky DSLR Team. These will guide you through ways to make and analyze observations and submit the results to the AAVSO. All it takes is:

❶ A digital camera (preferably a DSLR) with manual focus and exposure control that can record images in a so-called RAW format.

❷ A simple photographic tripod. (A cable release and a right-angle viewfinder are very helpful, but not required.)

❸ Analysis software. Citizen Sky tutorials show you how to use free (*IRIS*), and commercial (*AIP4WIN* and *MaxIm DL*) software packages.


COURTESY THE AUTHORS

This Canon 20D with cable release and right-angle viewfinder on a simple tripod is a typical photometry rig. The 2.5× viewfinder makes aiming a camera skyward more comfortable, but it's not required.

While it may come as a surprise to many, what isn't needed is a dark-sky location. Photometry can be done from most suburban backyards under moderate light pollution. All you need is a clear view of the sky and a few bright "guide" stars to help point your camera in the direction of your target star. Severe light pollution does make photometry of faint stars nearly impossible, but you can still do meaningful photometry of bright stars even from a city location.

The bottom line is this: with only modest equipment and effort, amateur astronomers can head out into their backyards and collect scientific-quality photometry data. And, as digital-camera photometry grows in popularity, so too will the quantity and quality of accurate magnitude data. Such an increased database may well provide new insights into the nature of many variable stars, deep-sky, and planetary objects. ✦

__Brian Kloppenborg__ is doing his doctoral dissertation on Epsilon Aurigae at the University of Denver. He became interested in astronomy while working at the Sachtleben Observatory of Hastings College and the J.M. McDonald Planetarium, in Hastings, Nebraska. __Tom Pearson__ is a retired U.S. Navy oceanographer and a member of the Back Bay Amateur Astronomers in Virginia Beach, Virginia.

S&T: CRAIG MICHAEL UTTER (2)

In addition to a digital camera, you'll need appropriate software to calibrate and analyze images. Two popular commercial packages that include tools for measuring star brightnesses are *MaxIm DL* (cyanogen.com) and *AIP4WIN* (willbell.com).

A Classic Wooden Tube

TIM PARKER

This easy-to-build tube will give your scope a touch of 18th-century class.

WHEN I READ ABOUT the Delmarva Stargazers's Mid-Atlantic Mirror Making Seminar in Gary Seronik's March 2010 Telescope Workshop column, I immediately signed up to try my hand at grinding a 10-inch mirror. The class was a success, and when my newly completed mirror returned from the coater, it was time to start building the rest of the scope, starting with the tube.

Rather than use cardboard tubing or some kind of truss design, I opted for a classic wooden tube similar to those I'd made previously for my 8-inch Springfield reflector (pictured in this magazine's August 1981 issue, page 123) and 12½-inch f/23 Cassegrain. I feel such tubes offer an ideal combination of functionality and classic good looks. They're also a lot less work than those made from fiberglass, and much cheaper than aluminum.

To keep construction simple, I opted to make a nine-sided tube (a *nonagon*) using scrap ¼-inch-thick mahogany plywood leftover from a bookcase project. The plywood remnant was 5 feet long — perfect for a tube to house my mirror's 60-inch focal length. To determine the width of the individual pieces, I simply made a scale diagram with a protractor and compass.

The next step was to cut the plywood into nine strips. I began by setting the angle of my table saw's blade to 20° (half of 40°, which is one-ninth of 360°). The saw's fence was positioned to yield a strip slightly wider than the required 4¼ inches. I cut one edge of all nine slats, and then I set the saw fence to the required width, and cut the remaining angled edge of each strip. If you're building a tube with a sheet of wood that has a distinctive pattern or grain, take a moment to number each slat when you cut it. This makes it easier to match the pieces when you

ALL PHOTOGRAPHS BY THE AUTHOR

Left: The individual wooden slats are taped together, glued, and then rolled into a tube. After the glue sets, the tape is removed. (This photograph shows the tube for Tim Parker's 4¼-inch scope under construction.) *Right:* Small triangles of ¾-inch-thick plywood glued to the front and back ends of the tube provided extra rigidity and give the instrument a finished appearance. A nine-sided tube does not have opposing sides that are parallel, making it impractical for designs that have side bearings attached to the tube.

Parker poses with his newly completed 10-inch f/6 Newtonian, featuring a beautifully finished wooden tube. The scope rides on a Takahashi equatorial mount and utilizes a rotating ring assembly that he built himself.

assemble the tube, keeping the grain detail contiguous across the join seams.

Once I had the wooden strips in hand, I laid them on my "workbench" (a 1960 Volkswagen pickup bed, which is just the right height for this task) with the inside surfaces facing down. The slats were taped together with painter's masking tape, running the tape perpendicular to the joints and pulling each slat tight against its neighbor as it was taped. I use painter's masking tape because its mild adhesive won't damage the wood surface when it's removed. After the parts were taped together into a single sheet, I ran more tape lengthwise over each seam, ensuring that no air bubbles appeared under the tape.

Now it was time to glue the parts together. I use yellow carpenter's glue, and I recommend it rather than waterproof adhesives, which make cleaning up the excess glue difficult. I began by carefully turning the taped sheet over so that the tube's inside was facing up, exposing the V-shaped grooves where the slats abut. Then I squeezed a line of glue down the length of each V, and along the edge of the first slat.

Next comes the messy part: folding the glued slats into a tube. I carefully lifted one edge of the sheet and rolled it until the sides met, adding strips of tape across this joint and forcing the parts together as before. These proved good enough to hold the tube together without applying additional strips of tape lengthwise along the joint. Most of the seams will ooze glue on the inside, which is an indication that you've applied sufficient adhesive. If you're worried about neatness, you can use a damp rag to wipe off the excess glue before it sets.

I stood the tube up on end while the glue dried, making sure that the tube was as "round" as possible by measuring several diameters across opposite corners, and gently squeezing the tube until they were all equal. By standing the tube on its end, I didn't have to worry about it sagging out of round while the glue dried. Altogether, cutting the wood and gluing the tube together took only an hour.

After the glue dried, the tube needed reinforcement to achieve the desired rigidity. I accomplished this by gluing wooden triangles (cut from ¾-inch plywood) into each corner at both ends of the tube, as shown in the photograph on the opposite page. A little epoxy putty filled the gaps and gave the tube a tidy finished look. To protect and beautify the tube exterior, I chose a dark Brazilian rosewood water-based polyurethane gel stain. I applied two coats to get a nice dark color and fill in the grain. Finally, I gave the tube several additional coats of clear polyurethane, sanding between applications.

I made a plywood cell for the mirror, based on instructions on Gary's website (www.GarySeronik.com). The cell's back plate is cut to match the outline of the tube, and it stands out from the end of the tube on blocks of ¾-inch plywood, which are also shaped to match the tube's corners. This gap improves airflow, speeding the mirror's cool down for optimal performance.

I built this 10-inch for high-resolution planetary viewing and imaging, and it certainly delivers the goods. During first light last July, I could easily make out subtle shading in Venus's cloudtops. Later, when the seeing steadied, I trained the scope on Saturn and was rewarded with a high-contrast view of the planet showing the shadow of its rings as a razor-sharp black line etched on the pastel globe. I was pleased. ✦

__Tim Parker__ is a planetary geologist at the Jet Propulsion Laboratory. A noted planetary imager, he's been an amateur astronomer since receiving a 50-mm refractor for Christmas 50 years ago. Readers can contact him at tjp314@pacbell.net.

Star Trails from th

TWAN ambassadors photograph the night sky from the base of the Himalayan Mountains.

Babak A. Tafreshi

We were walking in the heavens. There was nothing but thick fog around us and the sound of the roaring river below in the valley. After three days of trekking and searching for a suitable location, we had reached an altitude of about 4,000 meters (12,000 feet) and were waiting for the fabled Himalayan sky to darken. This was the spectacular view that brought us to Nepal.

I was there on an imaging sortie for The World at Night (TWAN, www.twanight.org), together with my colleague Oshin Zakarian. It was our first night in the Everest region, far above Namche Bazaar, the gateway village to the high Himalayas. The temperature was quickly falling below freezing, and we were exhausted from hiking throughout the day without stopping to allow our bodies to acclimate to this low-oxygen environment. Suddenly, the appearance of a bright yellow-red star through the dancing mist reinvigorated our excitement. I quickly recognized it as the red giant Betelgeuse in Orion's shoulder. Moments later, a mysterious white glow appeared through the fog about 40° above our eastern horizon. It was a snow-covered Himalayan peak shining under the light of the first-quarter Moon. I could hardly believe my eyes.

Within a few minutes the fog dissipated, and we found ourselves surrounded by the world's highest mountains

e Top of the World

Orion rises above the Himalayan Mountains shortly after a cold mountain fog retreated into the valley below author Babak Tafreshi's location. The snow-covered peak of Ama Dablam catches moonlight in the distance at lower left, while majestic Thamserku dominates the view at right. Unless otherwise noted, all photographs are courtesy of the author.

reaching more than 8,000 meters toward the crystal-clear starry sky. Our northeastern view was dominated by Mount Everest, the highest mountain on Earth, and its spectacular neighboring peak Lhotse to its right, marking the border of Nepal and Tibet. Soon, Epsilon Aurigae blinked into view above Everest. This mysterious eclipsing variable was in the midst of its 2-year-long eclipse that occurs every 27 years (see page 64). To our east, the Pleiades rose above the most scenic and iconic mountain of the region, 6,812-meter Ama Dablam — a favorite challenge for mountaineers who visit the World Heritage site of the Sagarmatha National Park.

Though we weren't half as high as Everest, the altitude of our observing site was approaching those of the highest observatories on Earth. Furthermore, we were far from any urban areas, and the sky was amazingly clear and sharp. The closest major source of light pollution was the country's capital, Kathmandu, 140 km away. While I've experienced darker environments in places such as the heart of the African Sahara in Southern Algeria, here in the Himalayas there were no light domes in any direction. Although there are many small villages throughout the southern valley along the main trekking trail to Everest, besides my red flashlight, the next noteworthy source of artificial light was easily more than 100 km away.

The altitude, sky transparency, and spectacular mountain scenery made for a unique observing experience. Using a small pair of binoculars, I was surprised how easily I could spot deep-sky objects, and easily skipped from one to another. The patchy light of the nearby galaxy M33 was an easy catch without optical aid, and I didn't have to use averted vision.

For astrophotography we had several digital SLR cameras and a few medium-format film cameras, as well as a portable tracking mount. Using a fast 50-mm lens and a modified DSLR, I was shocked to clearly record Barnard's Loop and the Horsehead Nebula in Orion above the majestic Himalayan peaks with only a 20-second exposure. This was something I had never experienced before in nearly two decades of landscape astrophotography.

On the next night we stayed beside a stupa (a Buddhist monument) along the main trail to the Everest Base Camp. As the Moon set

OSHIN D. ZAKARIAN

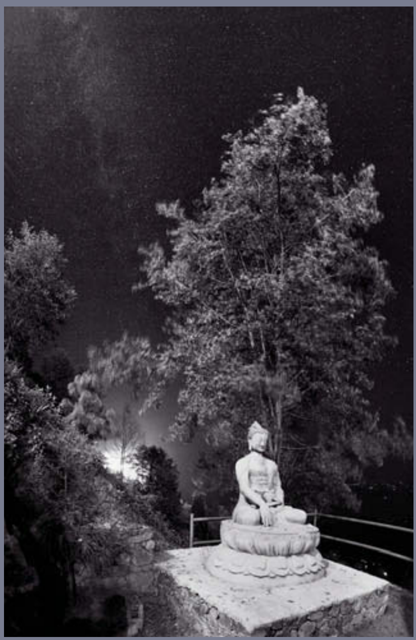
Author Babak A. Tafreshi (second from right) and fellow TWAN photographer Oshin D. Zakarian (third from right) pose with members of the Nepal Astronomical Society.

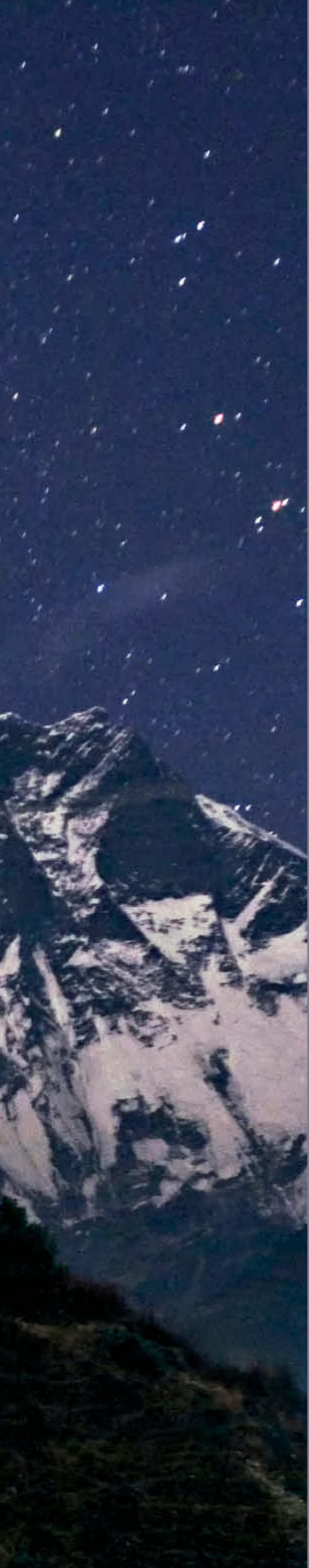
Above: Morning twilight paints the clouds in vivid hues as the waning crescent Moon peeks above temple spires surrounding Durbar square in Kathmandu, Nepal.

• *Facing page*
Middle left: TWAN photographer Oshin Zakarian captured one of the many statues of the Buddha. This one appears to host the Milky Way above the village of Nagarkot.

Middle right: Stars wheel around the North celestial pole above the town of Panauti in this hour-long image. In the foreground, the Indreshwar Mahadev temple is the oldest pagoda-style structure in the country, originally built in 1294.

Bottom: The bright star Capella rises above distant Mount Everest at the lower left in this panoramic view. The pentagon of Auriga streches from Capella to bluish Elnath just left of the tooth-shaped peak Ama Dablam. To the left of center, the Hyades cluster with the orange star Aldebaran rears above the left shoulder of snow-capped Thamserku. High above Aldebaran, the Pleiades cluster (Messier 45) shines bluish; hints of the cluster's surrounding nebulosity are just barely visible.





Capella shines dazzlingly bright over Mount Everest, with Lhotse to its right. The brightest star to the upper right of Capella is Epsilon Aurigae.

Hundreds of attendees line up to peek through a Sky-Watcher 8-inch Dobsonian telescope at the star party in Durbar Square, Bhaktapur.

around midnight, the limiting visual magnitude became fainter than 7. Dazzling Sirius high in the south was rivaled only by Canopus near the horizon, which was briefly visible during the night from our latitude of 28°. As the morning twilight approached, the zodiacal light extended nearly to the zenith.

More than a Starry Sky

Our visit to Nepal in November 2009 wasn't just focused on night-sky photography above the Himalayas. The Nepal Astronomical Society (http://astronomy-nepal.blogspot.com) invited TWAN to hold an astrophotography workshop in Kathmandu, and to attend a major public star party near the capital. The society's highly motivated young amateur astronomers are the driving force behind astronomy outreach activities in Nepal. Most are physics students, and they potentially represent the future generation of Nepalese professional astronomers. In a country with a rich, long-standing culture of astrology and religious mythology, popularizing the science of astronomy in Nepal is not an easy task. There are few telescopes available for the growing amateur community. As of 2010, there were less than 10 telescopes in the country with apertures larger than 4 inches. The largest is a 16-inch Schmidt-Cassegrain at the National Observatory of Nepal near the mountainous village of Nagarkot.

Despite the lack of equipment, amateur astronomy activities in the country grew exponentially throughout 2009, the International Year of Astronomy. I was quite surprised by the number of budding amateur astronomers who participated in our workshop and later attended an observing event to watch the Leonid meteor shower. Most amateur activities in Nepal are based on naked-eye observations.

Another highlight of our visit was a star party at the World Heritage Site of Bhaktapur. Walking in the streets of this town, I felt as if I had traveled backward in time — the town must have changed very little during the last 500 years. There are very few places left on Earth that give the same feeling. Bhaktapur was founded in the 12th century and was capital of much of Nepal until the Greater Malla Kingdom was divided in 1482.

On the night of our star party, the young crescent Moon shone above Durbar Square, opposite of the old royal palace, where hundreds of locals gathered. The Nepal Astronomical Society arranged with officials to switch off all the lights in the square, enabling better views of the night sky for the attendees. The scene was amazing; the joy and excitement of hundreds of people having their first view through a telescope, gazing for the first time at craters on the Moon. An 8-inch motorized Dobsonian telescope we brought along generated the longest line I have ever seen behind a telescope, reaching all the way to the other side of the square.

The beauty of the Himalayas and the starry sky above the roof of the world that brought us to Nepal also resulted in long-lasting friendships with the country's amateur astronomers. Following the idea behind Astronomers Without Borders (www.astrowb.org), I'm confident the night sky works as a bridge between people from different cultures. We truly are one people, one sky! ✦

Babak A. Tafreshi *(btafreshi@twanight.org) received the 2009 Lennart Nilsson Award for his night-sky photography and contributions to public awareness of the beauty of the night sky.*

▲ **CALIFORNIA BOW SHOCK**
Stuart Heggie
North of the bluish 4th-magnitude star Menkib lies the large hydrogen-rich cloud NGC 1499, popularly known as the California Nebula. This deep image reveals faint wisps of nebulosity that extend beyond the picture frame at lower left.
Details: *Takahashi FSQ-106N astrograph with Apogee Alta U16M CCD camera. Total exposure was 4½ hours through Astrodon color and hydrogen-alpha filters.*

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▲ **MEANDERING STORM**
Don Parker
This detailed image taken last January 2nd reveals a complex storm spanning half of the Saturn's northern hemisphere.
Details: *16-inch Newtonian reflector with Lumenera SKYnyx 2-0 video camera. Stacked video frames recorded through Astrodon color filters.*

▼ **SOLSTICE ECLIPSE**
Brian Kimball
The December 21st solstice last year was accompanied by a colorful total lunar eclipse widely seen in North America.
Details: *10-inch Ritchey-Chrétien telescope at f/6 with a Canon EOS Rebel T2i digital SLR camera. Montage of exposures ranging from 1⁄60 second to 10 seconds.*

▲ **CRESCENT SUNRISE**
Sebastian Voltmer
Two weeks after the lunar eclipse, the partially eclipsed Sun rose over the Mont Blanc massif, as seen in this spectacular view from La Rosiére, France, on the morning of January 4th.
Details: *Composite of exposures made with a Canon EOS 500D camera and 70-mm lens.*

NORTH AMERICA MOSAIC

Larry Van Vleet

In this colorful narrowband image, the well-known North America Nebula (NGC 7000) at left and the Pelican Nebula (IC 5070) at right have the visual appearance of a convex hollow surrounding a dark lane that divides the two.

Details: *Takahashi BRC-250 astrograph with a Finger Lakes Instrumentation PL16803 CCD camera. Four-frame mosaic totaling 116 hours of exposure through Astrodon narrowband and color filters.* ✦

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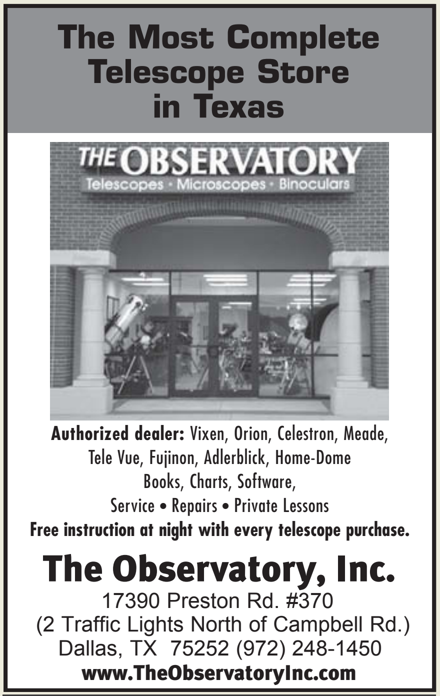

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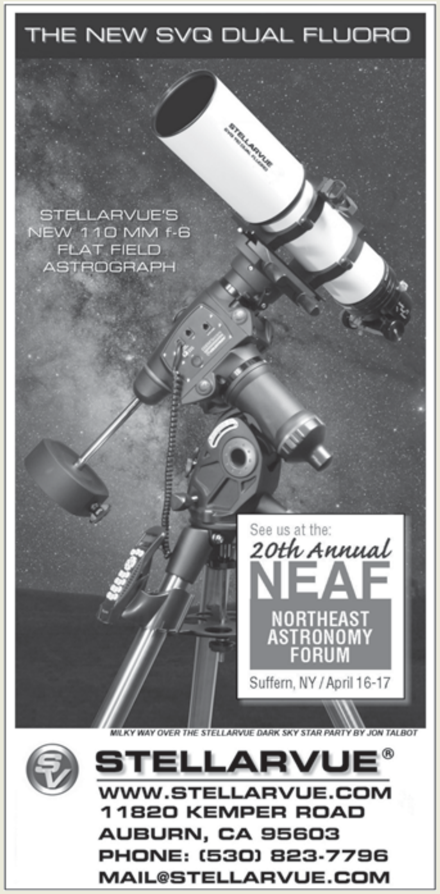

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Focal Point Dale E. Lehman

Science as Human Nature

Humans have practiced science since the earliest of times.

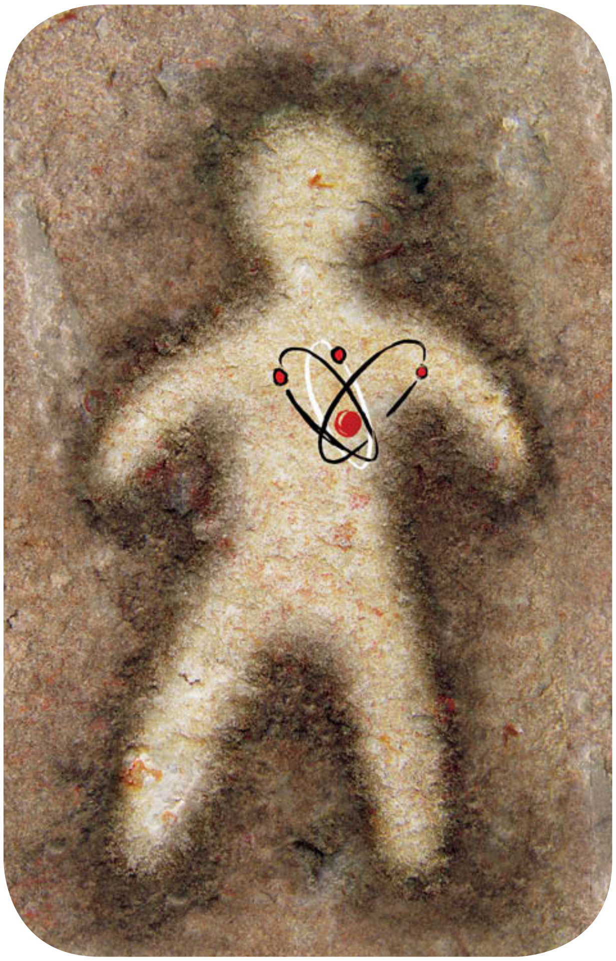
In an article on Galileo's astronomical observations of the Moon in the February 2009 issue, page 28, a statement is made that science is "foreign to human nature." What a strange assertion! Science is demonstrably inherent in human nature, a faculty we have exercised from our earliest times.

Although modern science, characterized by systematic observation and experimentation, is relatively new in the grand scheme of history, the fundamental question that underlies all science is an ancient one: What works? This is not a question answered by "internal whims, conceits, and made-up stories," but by observational evidence. An imaginary Paleolithic hunter we'll call Thag uses pointy rocks on the end of his stick to bring down game. Thag's people eat better than others. Maybe Thag is onto something.

The Ptolemaic model of the solar system wasn't in vogue because it was a good fairy tale that satisfied some inner need for human beings to be at the center of all things. It was accepted because, based on the available evidence, we *were* at the center of all things. It predicted the motions of the Sun, Moon, and planets well enough to give the appearance of being right. In a later age, the Copernican model, refined by Kepler, predicted those motions well enough to give the appearance of being more right. In a still later age, Einstein's general theory of relativity predicted the motion of Mercury well enough to give the appearance of being even more right. But as Albert Einstein once said, "Reality is merely an illusion, albeit a very persistent one."

Both Thag and Ptolemy did science in the sense that they found out, based on available evidence, what worked. George Sarton, in his three-volume work *Introduction to the History of Science*, wrote that while ancient science was "a very poor science, very imperfect, yet perfectible," our science today is certainly the same: imperfect, yet perfectible. Then, as now, science was rooted in that most human of qualities, curiosity. We are not content to go through life merely surviving and reproducing. We want to know how and why, and are always seeking ways to make our lives better, richer, more productive.

These drives, part and parcel of human nature, underlie all science. I'm quite sure that when Eratosthenes heard of that well in Alexandria, gathered the numbers, and calculated Earth's circumference, he didn't think he was doing anything contrary to human nature. When Galileo turned his telescope on the Moon and saw the unexpected, I'm sure he didn't feel it contrary to human nature to map what he saw or to go planet hopping in search of even more wonders.



S&T: LEAH TISCIONE

What distinguishes modern science from ancient is methodology. It's still that age-old question being asked: what works? Modern scientific methodologies have proven extraordinarily effective in answering it, so much so that our success has come close to endangering our survival and engulfing us in what astronomer Alan Dressler called "the nightmare of existential nihilism." But we need not go down that path. Science is part of our nature, always has been, always will be. Yet it is not the sum total of our nature. Other aspects of our humanity have value, too. So long as we remember to seek a balance, we'll do fine. ✦

Dale E. Lehman *is a veteran software developer and president of One Voice Press, a newly formed publisher of books with Bahá'í themes.*

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