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SKY & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

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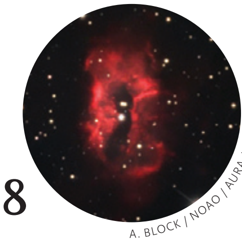
SKY & TELESCOPE

On the cover: Artist Don Davis depicts a very large asteroid slamming into Earth about 600 million years after the planet formed.

August 2011

VOL. 122, NO. 2



A. BLOCK / NOAO / AURA / NSF

FEATURES

THIS MONTH'S SKY

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S&T: DENNIS DI CICCO

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AS TECHNOLOGY rapidly changes, *S&T* is developing new ways to serve its readers. Recently we put out our SkyWeek app, which is free to users of both Apple and Droid mobile devices. We now offer digital subscriptions to *S&T*. Last year we introduced our *S&T* DVD archive, which has been so successful that later this year we'll be offering a DVD archive of *The Sky* and *The Telescope*, the two magazines that merged in 1941 to form *S&T*. We'll also be releasing a DVD archive of *Night Sky* magazine.

As part of this broader effort, we're now producing videos for our website. We have already filmed video profiles of associate editor Tony Flanders, imaging editor Sean Walker, and yours truly. We have also recorded a video tutorial in which senior editor Alan MacRobert explains how to use our center star chart (see page 45).

Jessica Kloss and Shweta Krishnan


Rick Corson

S&T: DENNIS DI CICCO (2)

Jessica Kloss, who has an undergraduate degree in astronomy from Princeton and a graduate degree from Boston University in science journalism, joined our staff in January as an editorial intern. She took on our video projects with considerable enthusiasm, and we're very pleased with the results. Jessica left us at the end of April to take a full-time position at MIT.

Shweta Krishnan, another recent graduate of Boston University's science journalism program, has stepped into Jessica's role and will produce videos through the summer. One of her projects will be to help us create a video to celebrate *S&T's* 70th anniversary. You can watch all of our videos by visiting SkyandTelescope.com/videos.

If you haven't done so already, check out the interviews filmed at this April's Northeast Astronomy Forum. These videos, hosted by senior editor Dennis di Cicco (see pages 35 and 70), allow manufacturers to showcase their latest products and services.

On a final note, I want to extend a fond farewell to Rick Corson, who left our staff in late April to head his family's insurance business. Rick was *S&T's* production director for many years, and was later promoted to VP of production for all of New Track Media's publications. Rick was by far and away the best athlete on our staff, so we'll definitely miss him on the softball field too.

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The Amazing Race

Thanks to Trudy E. Bell and all of you at *Sky & Telescope* for the excellent article in your June issue ("The Great Telescope Race," page 28). By coincidence, I just finished reading *Stargazer: The Life and Times of the Telescope* by Fred Watson (reviewed in *S&T*: November 2005, page 96). For those who might like to put Bell's article in further historical perspective, Watson's book is a fine read!

Dave Talbott
Dennis, Massachusetts

"The Great Telescope Race" described so well by Trudy Bell may have reached farther afield than even she realized.

A fairly large refractor on a Warner & Swasey mount in the observatory at the American University of Beirut is clearly unused and in a poor state of repair. The observatory building itself has now been converted into an office building. In 1980, when I first saw it, most of the controls on the refractor were frozen, but I was able to lower it and climb up on the movable stair used for viewing and look at the objective. It was 12 inches across, and at the edge there was an inscription: "Brashear Pittsburgh 1896." I was told it had been used for serious research at one time, but I don't know any details.

I happened to be in Beirut again in 2001. I took another look at the scope then and discovered that the 12-inch objective had been removed. Nobody admitted knowing when or how the objective was taken. Why someone would take it is also a mystery, although it might have been to protect it from damage. Whoever has it is not talking.

Elmon Coe
Owensboro, Kentucky

I really enjoyed the latest article in *S&T* about the history of telescopes in the U.S., and I especially enjoyed the "reason" for all the telescopes. Although there were lots of great telescopes and a long list of people who would fund them, there weren't enough qualified people to use them.

The civic pride that drove the creation of new telescopes seems to have trumped the scientific need. This was later repeated in the U.S./Soviet space race, so maybe NASA needs to stoke that "button" of the American people! Several people in the Warren Astronomical Society remarked how much they enjoyed that article, especially Ken Bertin, our resident astronomical history buff. Rather than just a bunch of facts listing the makers of telescopes, dates, etc., the article supplied lots of cool information that raised it way above standard history articles.

Bob Berta
Macomb Township, Michigan

Reacting to NASA's Conservatism

Thanks to Daniel N. Baker for raising concerns about an increasingly conservative NASA ("Paralyzing Effects at NASA," June issue, page 86). Given the cost-saving fever in Congress, it's understandable that NASA would want to avoid failure in future robotic missions.

Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send e-mail to letters@SkyandTelescope.com. Please limit your comments to 250 words.

NASA should learn from super-resilient past missions such as Voyager. Use double probes wherever possible and retain creative engineers at the home base. Also, get the word out, in terms the average person can understand. Be creative in the spirit of the late Carl Sagan, who could make the most basic mission seem like another episode of *Star Trek*. Then NASA can continue to be a national treasure!

Earl Finkler
Medford, Wisconsin

Memories of Leif

On behalf of the SuperNova Early Warning System collaboration of neutrino experimenters, we would like to extend condolences for the loss of your former editor Leif J. Robinson.

We met Leif when he attended our first workshop in Boston in 1998. He later helped to explain our network of neutrino detectors with a lively 1999 article in *S&T*. This great communicator will be missed, and he will be in our thoughts when the next nearby stellar core collapses!

Kate Scholberg
Durham, North Carolina
Alec T. Habig
Duluth, Minnesota

Liver Tastes Yummy

"Oh Boy, An F Grade Kills Me," or "Oh Boy, A Fine Girl Kissed Me," are both classic mnemonic devices to help learn the classification of stars, from hottest to coolest. But with the addition of *L*, *T*, and *Y* stars, a new mnemonic device is needed ("Balmy Brown Dwarfs: Spectral Type *Y*?" June issue, page 12). My suggestion: "Onions, Bacon, And Fried Green Kale Make Liver Taste Yummy."

David Schultz
St. Paul, Minnesota

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BLAST Findings

I've always had a thing for very-high-altitude, balloon-borne telescopes with highly specialized instruments aboard. That is why I thoroughly enjoyed the article "Having a BLAST in Antarctica," by Mark Devlin and Mark Halpern (June issue, page 20).

It was gratifying to finally have an answer to the question whether the combined infrared/submillimeter background detected by the Cosmic Background Explorer (COBE) satellite comes from gas in the early universe or many individual galaxies. I had always leaned more towards Ultraluminous Infrared Galaxies (ULIRGs) with high star-formation activity but didn't really know until now. So you can imagine how pleased I was when I saw the images of distant galaxies taken at 500 microns, 350 microns, and 250 microns showing conclusively that starburst galaxies (ULIRGs) accounted for the energy COBE detected but was unable to resolve. It was also good to find out that one of the detectors aboard ESA's Herschel Space Observatory confirmed the findings of BLAST.

Although it was sad to read about the unfortunate demise of BLAST, it was encouraging to read that Mark Devlin and Mark Halpern were able to retrieve the detectors aboard BLAST and went on to build BLAST-pol — almost like the Phoenix rising from its own ashes. It should be interesting to find out with BLAST-pol's polarizing grids if magnetic fields are the reason why young stars support themselves against gravity longer than previous models had predicted.

Eric F. Diaz
Indianapolis, Indiana

50 & 25 Years Ago

Roger W. Sinnott

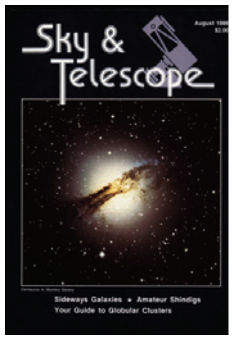
August 1961

Visual Observing of Double Stars "A century ago, nearly all observational astronomy was visual, but today few professional astronomers look through their telescopes except while guiding. . . . Yet in one field of astronomy — the observation of close double stars — visual work is still supreme.

"The eye has two important merits as a light receptor: It perceives a star image very quickly, and hence can react to fleeting moments of good seeing; it is connected to an efficient computer — the brain — which permits a rapid analysis of results. These advantages make the eye superior to photography in the observation of double stars separated by less than about two seconds of arc."

Charles E. Worley headed the U.S. Naval Observatory's double-star program from 1961 until his death in 1997. He personally made 40,000 visual measures with large refractors, then steered the program's switch to interferometric techniques in the mid-1990s.

August 1986



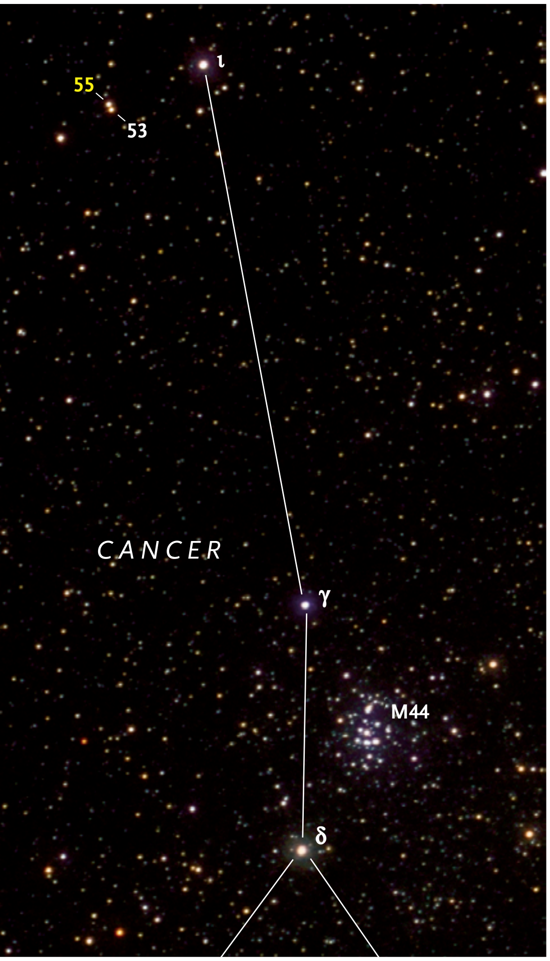
Smaller Milky Way? "A combination of new and old observing techniques has revealed that the Milky Way may be 25 percent smaller than previously thought. . . .

"At a recent seminar, Mark Reid of the Harvard-Smithsonian Center for Astrophysics . . . described how his group used four radio telescopes spanning the United States from California to Massachusetts to observe the molecular cloud Sagittarius B2 North at a wavelength of 1 centimeter [and obtained] a distance to the galactic center of 23,000 ± 4,000 light-years. This value is very much smaller than the traditional 33,000 light-years found in most astronomy textbooks and somewhat less than the official distance of about 28,000 light-years sanctioned by the International Astronomical Union in 1985."

While no doubt on the low side, this value was certainly a move in the right direction. More recent studies by Reid and others, using a variety of techniques, put the galactic center at about 26,000 light-years.

The Hottest, Densest Super-Earth Yet

On a dark night far from city lights you can just make out 55 Cancri, a 6.0-magnitude pinprick in northern Cancer. Shining from 41 light-years away, it's a main-sequence *G*8 star slightly cooler, smaller, and less luminous than the Sun. It's also now the brightest star in the sky known to have a planet crossing its face.



Barely glimmering to the naked eye north of the Beehive Star Cluster, 55 Cancri (Rho[1] Cancri) forms a nice binocular pair with 53 Cancri, an unrelated red giant far in the background. A large fraction of all stars are now thought to have planets of some kind.

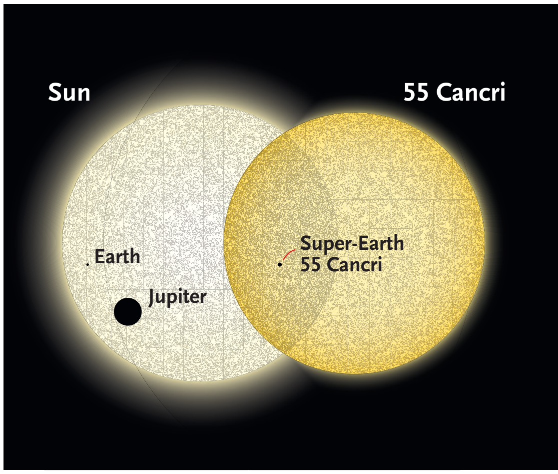
The planet is 55 Cancri e, the closest-in of the star's five known worlds. Astronomers discovered all of them by the radial-velocity wobbles that they induce in 55 Cancri. The weak wobbling due to planet e reveals that it has only 8.6 ± 0.6 Earth masses — a super-Earth.

Astronomers had figured that planet e revolves around the star every 71 hours. But late last year Rebekah Dawson, a graduate student at Harvard, and Dan Fabrycky, now at the University of California, Santa Cruz, followed up on a suggestion that the period might be ambiguous and untangled the star's wobbles differently. They proposed that planet e speeds around with an orbital period four times faster: in just 17 hours 41 minutes. That would put the planet even closer to the star, increasing the likelihood of transits.

Based on this lead, a team led by Joshua Winn (MIT) followed 55 Cancri for two weeks using Canada's MOST (Microvariability and Oscillations of Stars) satellite. MOST is designed to track tiny brightness variations in bright stars for long observing runs. And indeed, MOST recorded weak transits happening like clockwork on the faster schedule.

The amount of dimming during the transits gives the planet's size: it's just 60% wider than Earth. Combined with the planet's known mass, this yields an average density of 11 ± 3 grams per cubic centimeter, significantly greater than Earth's 5.5 grams per cc, implying a large iron core overlaid by rock. The surface gravity on this world must be about 3 gs.

So 55 Cancri e now holds the record not only for transiting a naked-eye star, but also for the fastest orbital period of any known planet. It's even closer to its star than Corot-7b (the "Planet from Hell" of *S&T's* May 2009 cover story) and the similar Kepler-10b (April issue, page 12).



This illustration shows how 55 Cancri e and its host star compare to how Earth and Jupiter would appear transiting the Sun.

Its star-facing side should be as hot as 3000 Kelvins (4900°F), making it also the hottest known planet.

All three of these roasted super-Earths have high densities and seem to form a class of their own. But because it orbits a 6th-magnitude star, 55 Cancri e holds better promise for future investigations. "We can study it in a way Kepler-10b and Corot-7b cannot be studied," says MIT exoplanet expert Sara Seager. Their stars are magnitudes 11.0 and 11.7, respectively.

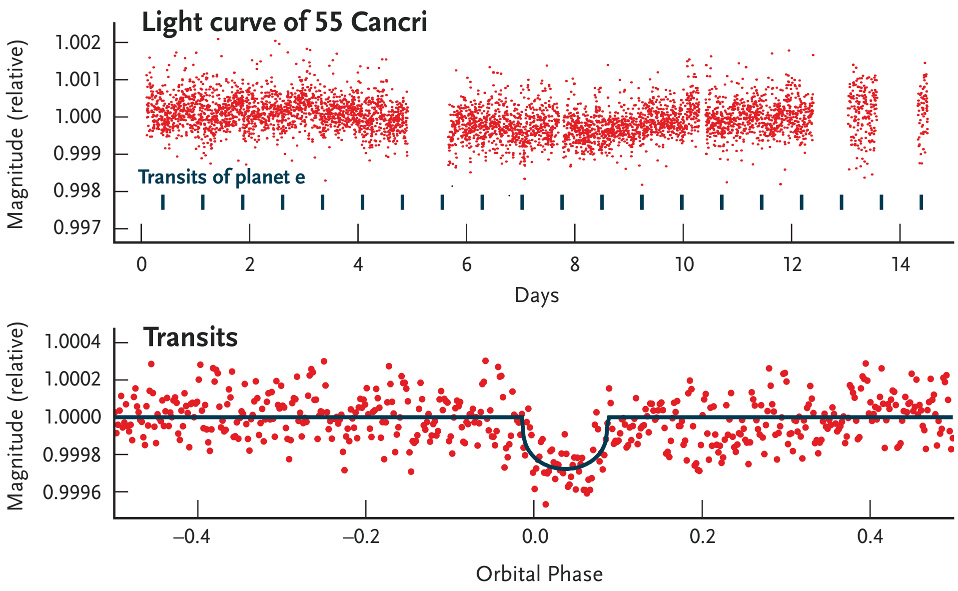
Following up quickly, in January the Spitzer Space Telescope's infrared cameras recorded a single 55 Cancri e transit — and found the planet to be 30% larger than deduced from MOST's observations. The disparity could be due to measurement errors or by thin gas forming a very extended outer atmosphere that blocks infrared but not visible wavelengths.

Could any of 55 Cancri's other four planets transit too? Probably not. The

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

MOST data indicate that planet e's orbit may be inclined as far as 7° from our line of sight. If so, and if the rest of the orbits are coplanar with it, even the next-closest planet would miss the star from Earth's viewpoint. On the other hand, exoplanet hunters have been finding that in some systems, planets orbit in very different planes than their host star's equator — as if they were stirred every which way by early chaotic interactions (presumably the same effect that has left many exoplanets looping in very elongated orbits).

The other worlds of 55 Cancri, named b, c, f, and d in order counting outward, have fairly circular orbits with periods of 15, 44, 261, and 5,200 days. These four planets are more massive; their influences on the star imply that they have at least 260, 54, 45, and 1,200 Earth masses, or 0.82, 0.17, 0.14, and 3.8 Jupiter masses.

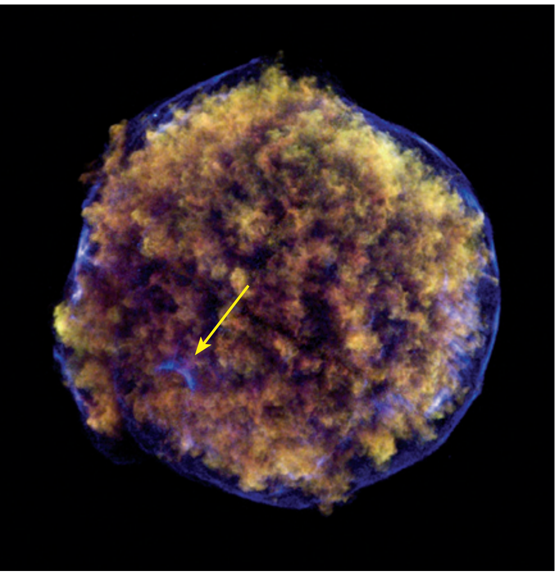


SOURCE: JOSHUA WINN

Top: **MOST recorded the brightness of 55 Cancri almost continuously for 14 days (with a few gaps).** ***Bottom:*** **The transits of planet e are overlaid on one another. The black line shows a best fit. Statistically, the transits clearly stand out from the noise — though individual ones are hardly obvious.**

A Supernova Companion's Strip-Tease?

On the evening of November 11, 1572, the great Danish astronomer Tycho Brahe went out for an after-dinner stroll. "I suddenly and unexpectedly beheld near the zenith an unaccustomed star with a bright radiant light," he later wrote. He described how it rivaled Venus for weeks, how it remained fixed in Cassiopeia, and how sharp-eyed "country folk" could even spot it through the blue daytime sky.



NASA / CXC / CHINESE ACADEMY OF SCIENCES / F. LU, ET AL

In the remnant of Tycho's supernova, does this X-ray-bright arc, or ring, indicate material that was stripped from the sides of a companion star too close to the blast?

More than 400 years later, the supernova's expanding debris cloud appears about 20 light-years wide. NASA's Chandra X-Ray Observatory has imaged it in several X-ray wavelengths, as seen at left. The highest-energy X rays (blue) mostly come from the shocked interface where the blast's leading edge continues to plow into the surrounding interstellar medium at a supersonic speed.

Supernovae have two very different origins. Some result when the core of an aging giant star collapses in on itself gravitationally, releasing more than enough energy to blow the rest of the star apart. The other variety, spectral Type Ia, apparently explodes when a white dwarf collects too much material from a close companion. When the dwarf exceeds 1.4 solar masses, its center becomes hot and dense enough to fuse carbon and set off a runaway thermonuclear reaction that blows apart the entire star.

The Tycho supernova's debris has proved to be rich in the silicon, sulfur, iron, and other elements expected from a Type Ia event. But another uncertainty remains. Do these blasts stem from a white dwarf drawing material off a larger, normal companion star, or from two tiny white dwarfs spiraling together?

In 2004 Maria Pilar Ruiz-Lapuente (University of Barcelona) identified the purported companion star at the center of the remnant. Tycho G, as she called it, is a solar-type star slightly offset from the remnant's center (*S&T:* February 2005, page 22). Tycho G is moving four times faster than the average for stars in its area, as if it were flung off from a tight orbit by its partner's sudden disappearance.

Now Fangjun Lu (Institute of High Energy Physics, Beijing) calls attention to the bright arc arrowed in the X-ray image here. It seems aligned toward Tycho G's position. Lu's team suggests that the arc represents a Jupiter's worth of material that the titanic blast stripped from the sides of the companion star. "We found that it is actually in the interior of the remnant," Lu says, "and is most probably due to the interaction between the stripped companion envelope and the supernova explosion." Other astronomers, however, say the case is far from closed.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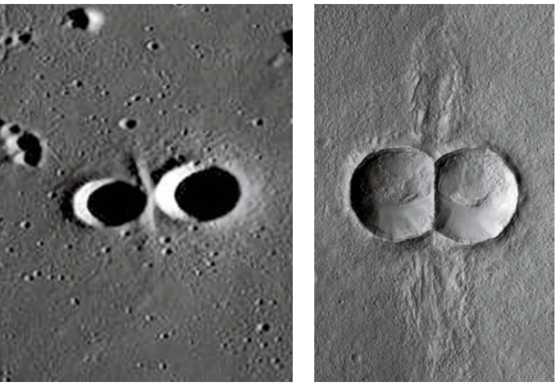


FAR LEFT: NASA / LRO; LEFT: NASA / JPL / UNIV. OF ARIZONA

***Left*: On the Moon's Mare Imbrium near the Alpine Valley is the crater pair Plato K, which appears to be a simultaneous hit. This Lunar Reconnaissance Orbiter image shows ejecta sprays that formed perpendicular to the line between the craters, as if their ejecta collided in flight. *Right*: Twin Martian craters, each about 1 mile (1.6 km) wide, appear in this January 10th image from Mars Reconnaissance Orbiter.**

Double Whammies on Mars and the Moon

NASA's Mars Reconnaissance Orbiter continues to image vast swaths of Mars with resolutions as small as 1 foot (0.3 m) in search of interesting finds. A recent one was the pair of craters above right, in the Icaria Fossae region. They seem to have formed simultaneously, judging by the very straight ridge between them and the ejecta plumes that apparently collided in flight and sprayed toward the top and bottom of the frame.

A similar pair of colliding-ejecta craterlets can be seen on the Moon near the Alpine Valley. Such events no longer seem like impossible coincidences; radar and light-curve studies are showing that many small asteroids are close binary pairs.

Gravity Probe B: Relatively Important?

Perhaps you heard the news when it came out in May: Einstein's general theory of relativity is correct, according to a $750 million NASA satellite designed to test it.

You may have wondered: didn't we already know this?

The Gravity Probe B mission was the child of five decades of planning, lobbying, and execution. First funded in 1963 and launched in 2004, it was designed to test two predictions of general relativity. The first, the "geodetic effect," describes the dent that Earth's mass creates in the fabric of spacetime. The second is "frame-dragging," the twisting of spacetime near Earth caused by our planet's rotation. "Imagine Earth as if it were immersed in honey," says Francis Everitt of Stanford, GP-B's project leader from the beginning. "As the planet rotates, the honey around it would swirl, and it's the same with space and time."

The ultra-precise gyroscopes at the experiment's heart, said Everitt, showed that Earth's warping of space matches Einstein's prediction to within 0.3%, and that a frame-dragging effect was also seen and matches Einstein to within 19%.

That would have been quite a triumph in 1963, though neither result was as good as hoped due to subtle problems in the gyroscopes. But by the time of GP-B's much-delayed launch, other confirmations of these effects were already in hand.

In particular, geodetic precession (the exact effect that GP-B's gyros measured) had been confirmed to a similar 0.3% level by laser-ranging experiments to the retroreflector mirrors that the Apollo astronauts left on the Moon. More significantly, space curvature (the cause of geodetic precession) has been confirmed to 0.002% accuracy, 150 times better than by GP-B, by measuring the delay in radio signals from the Cassini spacecraft as they pass through the Sun's gravitational field.

And "gravitomagnetism," the cause of frame-dragging, has already been confirmed to 0.15% accuracy, or 130 times better than GP-B, by lunar laser ranging.

DON HARLEY

The four gyroscopes of Gravity Probe B were free-spinning spheres coated with superconducting niobium. As they spun they created a magnetic field, whose orientation could be tracked to milliarcsecond precision.

"I won't say there is no value in testing physics in a novel way," says Tom Murphy (UC San Diego), a member of the lunar-ranging project, "but any discrepancy would have been incredibly jarring."

Another Year, Another Observatory Wildfire

McDonald Observatory in West Texas is the latest great astronomy facility to escape destruction by wildfire. For three weeks in April, McDonald was threatened as the Rock House Fire burned 490 square miles of surrounding countryside. When the fire came within a mile of the peak of Mount Locke, firefighters set backfires that succeeded in stopping the advance. Also spared was the Prude Ranch 10 miles away, site of the annual Texas Star Party.

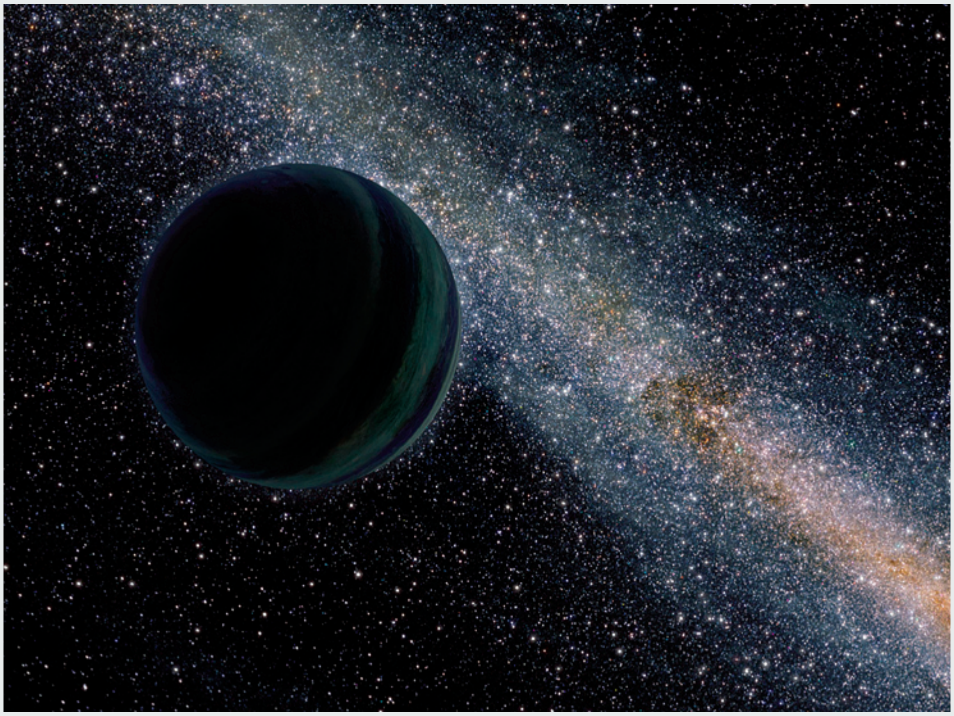
FRANK CIANCIOLO / MCDONALD OBSERVATORY

On April 17th fire raged on Black Mountain, seen behind the dome of McDonald Observatory's Hobby-Eberly Telescope. The bright lines above the dome are the advancing Rock House Fire and a control burn set by firefighters to head it off.

The fire brought back memories of the August 2009 Station Fire near Los Angeles that nearly consumed Mount Wilson Observatory. In November 2007 the Poomacha Fire approached, but did not damage, the Palomar Observatory east of San Diego. The University of Arizona's Steward Observatory had a close call during the Aspen Fire in June 2003. The American West is in a long-term drying trend that has increased the number and severity of fires in wild areas, where major observatories tend to be sited. So is Australia, whose Mount Stromlo Observatory was destroyed by a wildfire in July 2003.

Do Loose Planets Outnumber Stars?

I have seen the dark universe yawning
Where the black planets roll without aim,
Where they roll in their horror unheeded
Without knowledge or luster or name.
— H. P. Lovecraft, *Nemesis* (1918)



An artist's portrayal of a black planet drifting alone through interstellar space, lit only by starlight.

NASA / JPL-CALTECH

Ask an astronomer how many stars populate the Milky Way, and the usual answer is 200 to 400 billion. But new microlensing results suggest that a full census of the big bodies drifting loose in our galaxy may total a trillion — because Jupiter-mass "planets" roaming alone in interstellar space may outnumber the stars themselves.

The evidence comes from two teams of observers: the Microlensing Observations in Astrophysics (MOA) collaboration and the Optical Gravitational Lensing Experiment (OGLE) collaboration.

In 2006–07, the MOA and OGLE teams used telescopes in New Zealand and Chile, respectively, to monitor the brightnesses of 50 million stars in the Milky Way's central bulge. Led by Takahiro Sumi (Osaka University), the two groups recorded the brightness of each star at least once an hour for a large fraction of the time. After boiling down the data, they found that 474 stars temporary surged in brightness in the special way that indicates *gravitational microlensing:* the brightening of a distant star due to an unseen foreground object passing nearly in front of it from our viewpoint. The gravity of the foreground object bends and concentrates the starlight passing by. Such an event is called "microlensing" when it occurs in the case of stars or planets, rather than galaxies or quasars.

Microlensing searches aren't new: they've long been used to search for massive dark or dim objects in the galaxy. But the MOA and OGLE teams found 10 of these events that lasted less than two days — too short to be caused by stars, as usually happens, but just right for Jupiter-mass objects. Based on these statistics, the teams estimate that big planets must be far more common than believed, and in fact must outnumber all the Milky Way's normal stars by about two to one.

During these 10 brief events, there were no corresponding, broader lensing surges to betray the presence of a nearby star. So the teams conclude that these "Jupiters" must either be more than 10 astronomical units from their host stars (more than Saturn's distance from the Sun), or they are orphans drifting freely. They're more likely to be free-floaters, the researchers say, because previous direct-imaging searches have found that giant planets rarely exist in very wide orbits.

The implications of this discovery are profound, say experts, but not unexpected. Theorists have argued for years that the Milky Way should teem with unbound "planets," from two possible sources.

First, some argue that lone brown dwarfs having just a Jupiter mass or two might form the same way that heavier brown dwarfs and stars do: directly from collapsing clouds of interstellar gas and dust. These would be "failed stars" in terms of how they formed, but "giant planets" in terms of their mass. The still-warm planet-mass objects seen accompanying a few young stars at wide separations may be such objects. They're probably much too far away from their stars to have been born inside a protoplantary disk.

The other source of loose dark worlds strikes closer to home. Some 80 to 90 percent of newborn planetary systems (estimates exoplanet expert Geoff Marcy) seem to go through an early period of chaotic interactions. These cause some planets to flip each other's orbits into high inclinations, and cause many planets to end up parked in highly elliptical, looping orbits that they could not have been born with. Such chaos episodes would also fling planets of every description out of the system completely, to roam the cold interstellar dark forever.

The large number of MOA-OGLE discoveries implies that the flung-from-chaos origin is the more important of the two. There seem to be too many loose Jupiters for a miniature version of star formation to make enough of them easily.

This in turn implies that planetary systems are so numerous that most stars have them. This too matches what astronomers have come to think. Marcy estimates that perhaps 80% of all stars are born with planets — "and it's not 100% only because of binary stars" that flung away their planets (or the raw material to make them) completely. ✦

Is There Art on Other Planets?

The author wonders whether other worlds produce creatures who create art.

I'VE RECENTLY SPOKEN at several art museums in conjunction with the current tour of "NASA Art: 50 Years of Exploration." The diverse range of artistic responses provoked by the space age, from Rockwell to Warhol, is both inspiring and dizzying. And as spacecraft continue their reconnaissance, artists will continue to find new ways to help us assimilate the experience.

In Colorado Springs the NASA show was paired with a major exhibition by Monica Aiello, a Denver artist who finds inspiration in the moons of Jupiter, mimicking or riffing their colored surfaces with materials and techniques that do not so much faithfully resemble the landscapes as evoke deep responses to them.

But is there art on other planets? In one sense, obviously yes. Certainly we find artistic qualities in the bursting flowers of Ionian volcanoes and the tangled roots of Europa's cracked, icy surface. But why?

Theories about art are like theories about life. Volumes have been written about the search for life even though nobody can define it well. Of course Earth is beautiful to us and aesthetically evocative; our senses and minds evolved in response to it. But what about planets, where no ancestor of ours has ever laid eyes or set foot, root, or cilia?

***Ionian Garden*, center panel, by Monica Petty Aiello**

I don't think it's a coincidence that the places in our solar system that seem most promising for astrobiology are also the most aesthetically evocative. Mercury and the Moon are dead; they are scientifically important but not as artistically inspiring as Titan and Mars. Energy flow and activity, phase transitions and complexity — these make for the most beautiful places, the most interesting to explore, and the most likely to produce life.

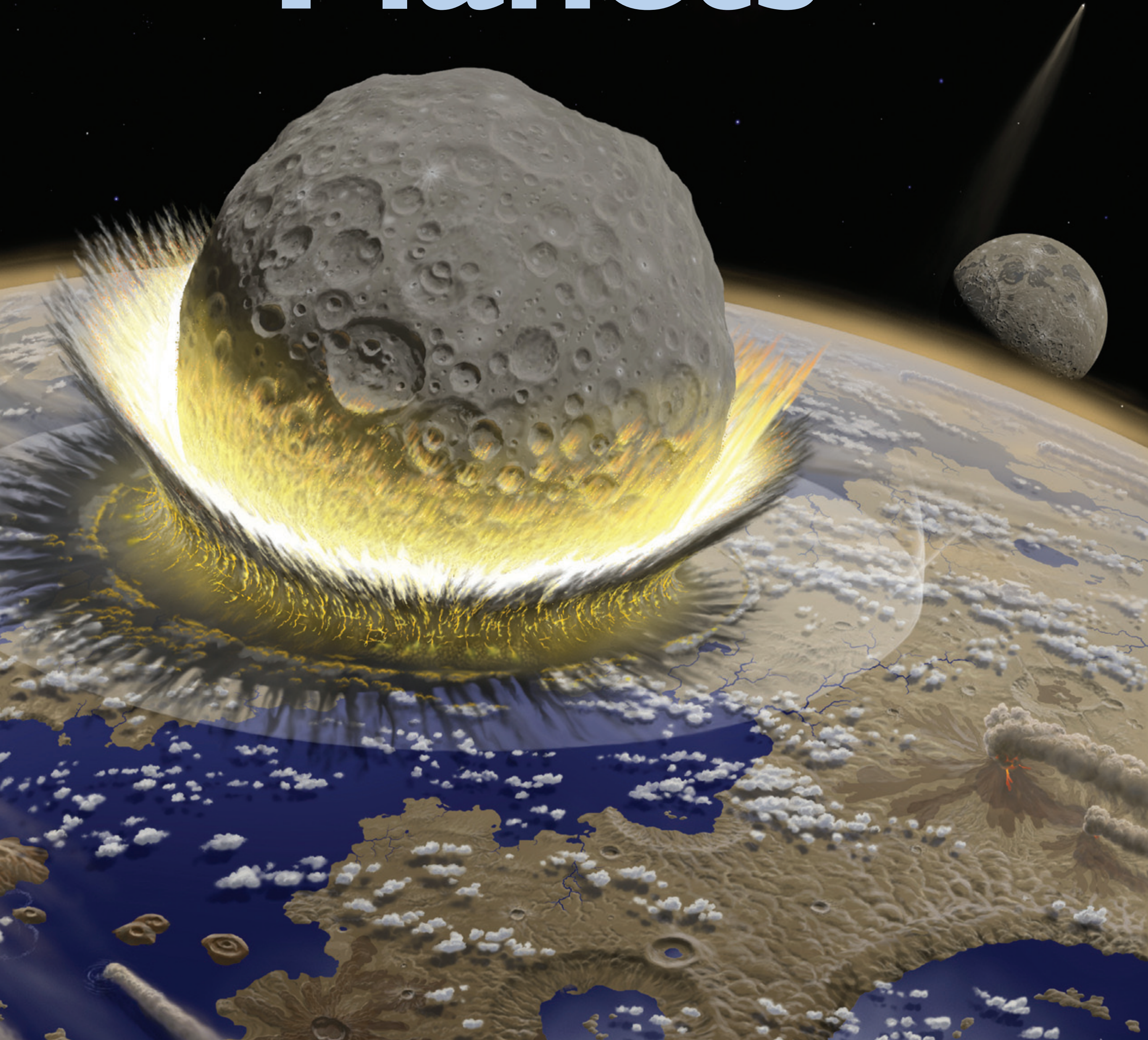
In this vast galaxy, which we now know is well populated with planets, will such active worlds occasionally produce other art makers? Our cultures are born of symbolic languages, including the creating of art in every human society. Now that chimpanzees, crows, and octopi have been found to also use tools, what is unique about us? Archaeologists use the presence of art in ancient sites to distinguish humans from non-human ancestors. Art making seems so widespread, so intertwined with our other unique capacities, that it makes me wonder if it might be universal — inherent in the evolution of curious, communicating civilizations. Or is it some local evolutionary peculiarity of our brains? I'd like to think it's something deeper than that, but as a scientist I'm obligated to be particularly suspicious of any thought that I would like to be true.

We often focus on the ability to build machines, and in particular radio telescopes, as the hallmark of extraterrestrial intelligence. This is pragmatic but perhaps suspect, since this criterion was invented by radio astronomers. We debate whether intelligence inevitably produces science and technology. We cite dolphins, swimming and singing with big brains but too streamlined for opposable thumbs, as an example of intelligence without technology. Dolphins don't create brick-and-mortar art, but do they have something analogous to choral music or poetry?

Perhaps, like life or intelligence, extraterrestrial art is something that we can't define but can still search for and hope to recognize and understand. This leaves room for misunderstandings of cosmic proportions. ✦

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

Pummeling the Planets



Scientists are debating whether the entire solar system suffered a barrage of impacts long after the planets formed.

EMILY LAKDAWALLA

Humans have evolved to appreciate Earth's blue sky, lush green forests, and oceans teeming with life. But our planet's beauty and serenity belies its violent history. The inexorable motions of Earth's tectonic plates, and the slow erosive power of wind and water, erase our planet's distant past. With no craters or rocks dating back more than 4 billion years, scientists must look elsewhere to uncover our solar system's early history.

Fortunately, just 239,000 miles away, the Moon's battered countenance preserves a record of a tumultuous past, when the solar system was not such a tranquil realm. Its overlapping impact basins are the marks left behind from a time when brutally large impacts were common.

The entire solar system must have suffered under the same rain of asteroids and comets. When scientists examine crater densities and measure the ages of rocks returned by the Apollo astronauts, they find that the bombardment may have been even fiercer than they imagined. The rocks showed evidence of alteration by impacts, leading researchers to conclude that nearly all the craters pockmarking the lunar highlands might have formed in a brief period, less than 100 million years long; and this cataclysm may have befallen the Moon and Earth not 4.5 billion, but instead 3.9 billion years ago — 600 million years *after* both worlds formed.

Nearly 2,000 impacts as large as, or larger than, the one that ended the reign of the dinosaurs would have resurfaced 80% of the Moon. Being a much more massive target, Earth would have suffered a cataclysm 10 times worse. The largest impacts would have gouged continent-sized basins, vaporized the oceans and even rocks, superheated the atmosphere, and seared the surface. Paleontologists have searched for evidence of life in Earth's oldest rocks, finding evidence of biologically influenced carbon isotopes 3.85 billion years ago. But with no rocks older than this, scientists can't tell whether nascent life on Earth was destroyed by a cataclysmic rain of debris.

This 4-billion-year-old conflagration has come to be known as the Late Heavy Bombardment (LHB). But was it really an unusual time in the Earth–Moon system, or was it just the tail end of a long history of pummeling? And if there really was a spike in the impact rate, what force of nature sent asteroids and comets cascading into the realm of the planets? The mystery of the LHB remains one of the most intractable and controversial puzzles in planetary science.

WHAM! Artist Don Davis portrays a large asteroid slamming into Earth some 4 billion years ago. If the Late Heavy Bombardment (LHB) occurred, and if lunar cratering rates are extrapolated to Earth, LHB impactors would have gouged about 20,000 craters at least 20 kilometers (12 miles) across, 40 basins with diameters of about 1,000 km, and several basins larger than 5,000 km. Earth would have suffered severe environmental damage about once a century. Complex life could not have survived the pounding.

Clues from the Moon

Everyone agrees that many more and much larger asteroids and comets were hitting the Moon 4 billion years ago than there are today. In 1966 William K. Hartmann (now at the Planetary Science Institute) studied photo maps of the Moon to determine that the battered highlands bore 32 times as many craters as the smoother maria.

Counting maria craters and comparing their density to that on the ancient rocks of northern Canada, Hartmann estimated the maria to be 3.5 billion years old. "I was lucky that it turned out about right," he remarks about this pre-Apollo research. But that ancient maria age implied an astonishing fact about the Moon's early history. "If there are 32 times as many craters, and they had to form in the first 700 or 800 million years, that means the early cratering rate was many hundreds of times higher than the rate we've seen since then."

Hartmann and other geologists assumed that this "early intense bombardment," as he called it, represented the end stages of the solar system's formation, the final days of planetesimals whacking one another to form the planets. By studying the Moon's highland rocks, we could learn about how the Earth and Moon were built. Geologists expected lunar samples to exhibit a wide variety of ages, indicating that rocks that congealed from large impacts formed at different times.

Geologists trained Apollo astronauts to look for "Genesis rocks" that would contain information about the period that has since been obliterated from Earth's geologic record. A dozen moonwalkers dutifully gathered and returned samples that had formed with the Moon's earliest crust, but had been altered in the tremendous heat of the impacts that created the giant basins. When Caltech geologists Fouad Tera, Dimitri Papanastassiou, and Gerald Wasserburg measured the rock ages, they were astonished to find that they all clustered within a relatively narrow window of time around 4 billion years ago, a period they called the "lunar cataclysm."

The combination of Apollo rock ages and careful study of the overlapping relationships between the ejecta deposits of nearside basins led Don Wilhelms (U.S. Geological Survey) to conclude in 1987 that 10 to 12 basin-forming

HISTORICAL ARCHIVE Without wind erosion, water erosion, and crustal plate motions, the Moon preserves a record of the solar system's early battering. The giant basins all date to about 3.9 billion years ago, suggesting a frenzy of impactors 600 million years after the planets formed. But it's also possible that the impact rate remained high long after the planets formed, and the basins preserve the last gasp of the severe rain of large planetesimals that accompanied planet formation.

S&T: SEAN WALKER

impacts, from Nectaris as the oldest to Imbrium as the youngest, occurred within a span of only 70 million years, from about 3.92 to 3.85 billion years ago, supporting the lunar cataclysm.

Not all scientists embraced the lunar cataclysm, to put it mildly. A fundamental problem was that nobody could explain how or why a population of bodies large enough to create the Moon's basins (tens to hundreds of kilometers in diameter) would wait around for 600 million years and then suddenly get flung into orbits that intersected the Earth–Moon system. Moreover, the lunar highlands are saturated with impact craters, meaning each new crater destroys a previous one. Pre-cataclysm lunar basins could have been erased by later impacts. The Moon has an ancient surface, but it might not be old enough to tell us exactly what was going on more than 3.9 billion years ago.

Apollo Samples Aren't Enough

For years, everyone knew that a potential bias lurked in the Apollo age data. To facilitate radio communications, the Apollo landers had to touch down on the Moon's near side, and not far from the equator. As a result, every mission may have sampled the impact that excavated the enormous Imbrium basin. Even Tera and his collaborators recognized this possibility in their original paper.

Arguments that the Apollo samples might be biased

HUMAN SAMPLE RETURN Apollo 17 astronaut and geologist Harrison Schmitt was the only moonwalker who was a trained scientist. In this image, taken by Eugene Cernan, Schmitt is collecting a sample to bring back to Earth. Apollo rocks all date to about the same time, but they came from a chemically anomalous region of the Moon.

NASA / PROJECT APOLLO ARCHIVE

were bolstered by results from a gamma-ray spectrometer on NASA's Lunar Prospector, which orbited the Moon in 1998–99. That instrument measured the abundance of chemical elements with radioactive isotopes. When the Lunar Prospector map was published, lunar scientists were surprised — and chagrined — to discover that the Apollo landing sites clustered in a geochemically anomalous area whose surface appears unusually rich in potassium (K), rare-earth elements (REE), phosphorous (P), and other elements, collectively referred to as KREEP. (Seriously.) The KREEP signal blazed from the area surrounding the Imbrium impact.

Scientists have found more than 150 lunar meteorites from places outside the KREEP terrain, coming from perhaps 60 different spots on the Moon. Unlike the Apollo samples, lunar meteorites should represent a random sampling of rocks from both the Moon's near side and far side. Indeed, the lunar meteorites turned out to be far less KREEPy (a term that's actually in general use!) than the Apollo samples. "We don't know exactly where each meteorite comes from," says planetary scientist Barbara Cohen (NASA/Marshall Space Flight Center), "but they're not from the same sites as Apollo."

In the 1990s, laboratory techniques finally permitted the age dating of the tiny blebs of impact melt preserved in lunar meteorites. "When I was researching my doctoral dissertation," says Cohen, "I naïvely thought for sure I was going to nail this; I was going to find the 4.0-, 4.2-, even 4.4-billion-year-old impact-melt rocks, and I was going to solve the puzzle, and it was going to be awesome."

In fact, Cohen found nothing older than 3.94 billion years of age in any of her samples. She and her University of Arizona colleagues, Tim Swindle and David Kring, published a paper in 2000 announcing that their results supported the lunar-cataclysm hypothesis. But other scientists disagreed.

Hartmann was one of their critics. "When they gave that paper at meetings, I would say, 'Your data don't have a spike in impact ages at 3.9 billion years ago, so I don't understand how you can say it supports a cataclysmic shower of impacts at that time. Lack of samples before 4.0 doesn't prove that a burst of impacts happened at 3.9!'"

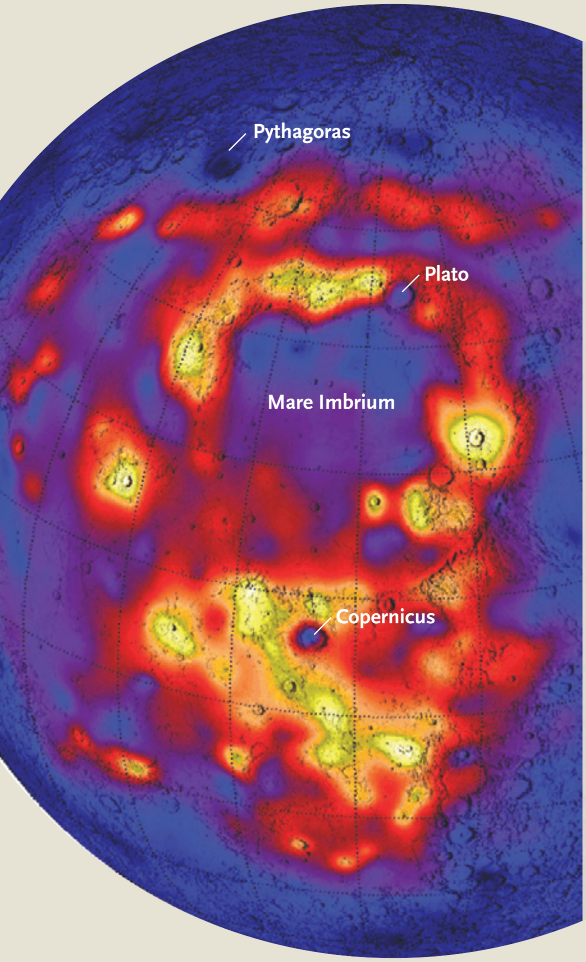
Cohen agrees that the puzzle is not yet solved. "The lunar meteorites show us is that it's not easy to find pre-3.94-billion-year-old impact-melt rock. But what that fact means is still a topic of scientific debate." There may have been a heavy bombardment 3.9 billion years ago, but it might have been just as heavy before then.

Some scientists think that a robotically retrieved lunar sample from the oldest impact site on the Moon, the South Pole-Aitken Basin, might resolve the question of whether there was a lunar cataclysm. Cohen belongs to a team that has proposed MoonRise, a mission in NASA's New Frontiers program, to do just that.

Hartmann remains unconvinced, "I'm really worried whether the returned rocks would actually give the date of the impact of the South Pole-Aitken Basin," he says. After all, explains Hartmann, maybe the samples would simply repeat the Apollo bias problem. The MoonRise team's research suggests such concerns are unfounded. "If we

RANDY KOROTEV (WASHINGTON UNIVERSITY IN ST. LOUIS)

LUNAR METEORITES This rock, known as Yamato 86032, is one of the 150 known lunar meteorites, and it's one of the largest lunar meteorites found in Antarctica. Unlike the Apollo rocks, lunar meteorites come from all over the Moon. Yet most of them show evidence for melting events about 3.94 billion years ago, probably from basin-forming impacts. This particular meteorite is lacking in KREEP elements.



KREEPY SIGNAL The gamma-ray spectrometer aboard NASA's Lunar Prospector orbiter returned data that scientists converted into this map of the near side. The bright area shows an enhanced concentration of thorium. This element is a trace element in the lunar regolith that indicates the presence of potassium (chemical symbol K), rare-Earth elements (REE), and phosphorous (P). The elements are collectively known as KREEP. The Apollo missions all landed in or near the KREEP zone, which means the astronauts returned chemically anomalous rocks. The lunar far side generally lacks the enhanced thorium signatures seen on the near side.

DAVID J. LAWRENCE (JHU / APL), ET AL.

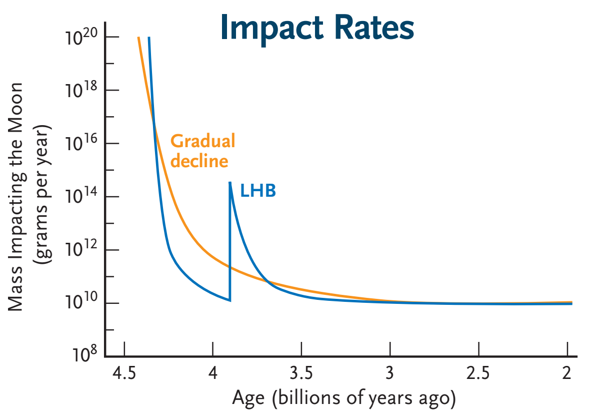
pick an appropriate landing site, we'll get what we need," says Cohen.

It's Neptune's Fault

Meanwhile, other researchers have attempted to explain what could have caused a pulse in impacts long after the planets accreted. For example, perhaps there were enough leftover materials from the accretion process to cause the terminal bombardment. Unfortunately, models of solar-system formation suggest that accretion was essentially complete within 100 million years, much sooner than the time of the cataclysm. Others have suggested that a massive collision in the asteroid belt broke up a Ceres-sized object that resulted in a pulse of impactors being redirected toward the inner solar system. But an object as large as Ceres (about 480 km across) is difficult to disrupt.

Then came the Nice Model (*S&T:* September 2007, page 22). Named for the beautiful French seaside city in which it was developed in 2004 by Hal Levison (Southwest Research Institute) and three coworkers, the Nice Model was motivated by an attempt to explain the orbital eccentricities of Jupiter and Saturn, and then how planets as massive as Uranus and Neptune could have formed so far from the Sun.

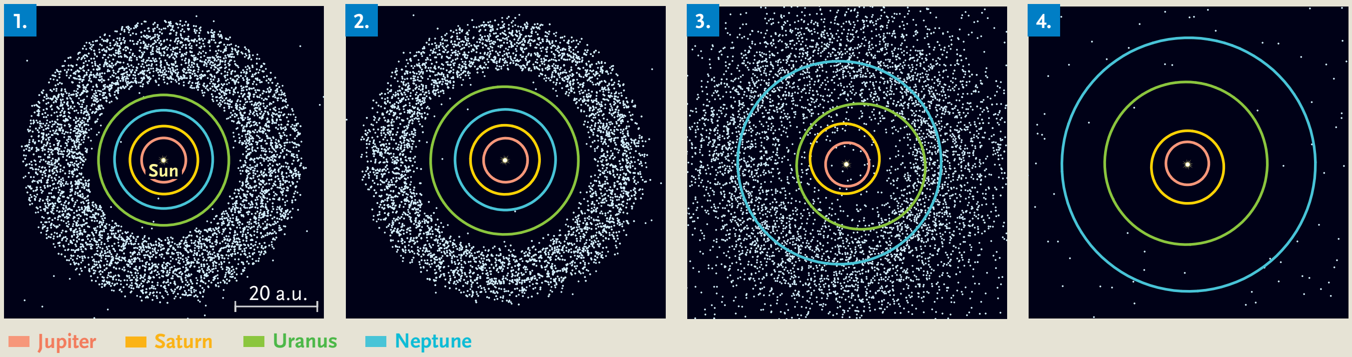
The Nice Model begins with the giant planets in a more compact configuration, surrounded by a cloud of planetesimals (the precursor of today's Kuiper Belt) that had about an Earth mass. Jupiter and Saturn migrated through a 2:1 or other orbital resonance, producing a gravitational chain reaction that sent Neptune plowing into the planetesimal disk (a new version of the Nice Model, to be published in the future, will invoke a different trigger). "That disk goes kaplooey," says Levison. "It scatters bodies all over the solar system, part of it raining down and hit-



IMPACT RATES This graph compares a proposed lunar impact rate with the LHB (blue) and without the LHB (orange). Note the dramatic difference between the two scenarios.

SOURCE: CHRISTIAN KOEBERL (UNIVERSITY OF VIENNA)

The Nice Model



SOURCE: HAL LEVISON (SW RESEARCH INST.), ET AL. (4)

THE NICE MODEL Computer simulations depict a possible chaotic phase in our solar system about 600 million years after it formed. *1.* Jupiter and Saturn start off at 5.5 and 8.2 astronomical units (a.u.). Neptune (at 11.5 a.u.) starts off closer than Uranus (14.2 a.u.). A disk of icy planetesimals, the precursor of today's Kuiper Belt, extends from 15 to 35 a.u. *2.* As the giant planets scatter comets into deep space, Jupiter migrates inward to about 5.2 a.u. The other three planets migrate outward. *3.* Jupiter and Saturn briefly pass through a 2:1 orbital resonance that gravitationally perturbs the orbits of Uranus and Neptune. The two outermost planets exchange position, and their highly elongated orbits carry them into the Kuiper Belt, where they begin scattering enormous numbers of planetesimals, some of which bombard the inner planets. *4.* The outer planets settle into their final orbits, leaving behind a severely depleted Kuiper Belt. Jupiter's inward migration also destabilizes the asteroid belt, sending swarms of bodies into the inner solar system.

ting the Moon, and everything else."

The Moon, being a relatively small target with low gravity, would have been one of the *least* damaged bodies. The wayward comets destabilized the asteroid belt as well; so bodies in the inner solar system, from Mercury to Mars, received a double whammy. The Earth–Moon system (along with Mercury, Venus, and Mars) would have been hammered by roughly equal numbers of comets and asteroids. Because of its proximity to the asteroid belt, Mars would have suffered as badly as more massive Earth; the number of cometary impacts alone could have delivered a volume of water equivalent to 5% that of Earth's oceans.

The hailstorm of comets would have been even more intense in the outer solar system. Ganymede, twice as massive as our Moon and close to gargantuan Jupiter, would have suffered 80 times as many comet crashes as our Moon. So many impacts at such a high rate may have melted Ganymede's upper layers of ice and kick-started its internal geology. Similarly sized Callisto was somewhat spared because being farther from Jupiter, it would have felt "only" 40 times the lunar impact rate, and experienced lower-velocity crashes.

This rain of impactors is really just a byproduct of the Nice Model, which also explains the sizes, shapes, and inclinations of the orbits of the giant planets and all the smaller pieces of the outer solar system. "We explain Jupiter's Trojan asteroids and we make the irregular satellites and we get the right orbital-element distribution in the Kuiper Belt," says Levison. "We get the outer edge of the Kuiper Belt. We get the extended scattered disk. We get the orbits of the giant planets right, too. Before the Nice Model we didn't really have good explanations for any of these things. The Nice Model gives us all of them. And the more we push it, the better it seems to work."

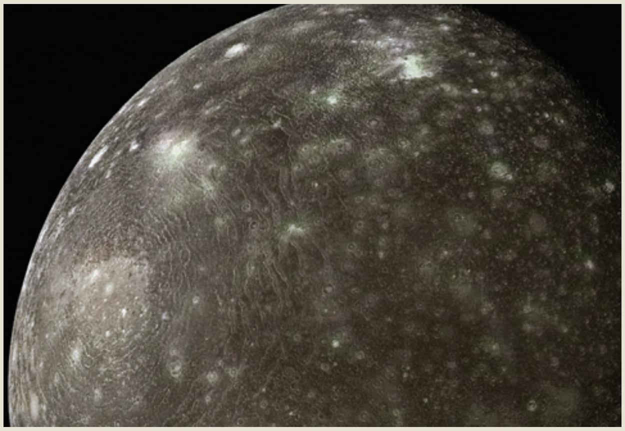
Suddenly there was a mechanism to deliver a late pulse of comets and asteroids to bombard the Moon and every object in the solar system 3.9 billion years ago. According to Cohen, this came as a huge relief to scientists who were trying to justify the LHB. "Even if this specific model is wrong, the fact that they're showing that you could have bodies winging around the solar system hundreds of millions of years after it formed makes it easier for the community to think about the lunar cataclysm as something that could be real."

WHAT ABOUT MARS?

Like the Moon's heavily cratered terrain, Mars's southern highlands preserve a record of a heavy bombardment in the ancient past. But it might be too young to reveal what was happening more than 3.9 billion years ago.

Topography data from the laser altimeter aboard NASA's Mars Global Surveyor orbiter, and model crustal thickness data, revealed about 30 buried and visible impact basins larger than 1,000 kilometers across on the Red Planet. Recent studies by Herbert Frey (NASA/Goddard Space Flight Center) find that these largest basins cluster within a narrow window in time, with no evidence for prior large impacts. The Late Heavy Bombardment predicted by the Nice Model would produce exactly this kind of pattern.

Frey and his colleague Rob Lillis (University of California, Berkeley) have suggested that the LHB played a role in the demise of Mars's global magnetic field, which left the planet's atmosphere unprotected from the ravages of the solar wind. If true, the LHB was a major factor in eroding the Martian atmosphere, turning what had been a warm-and-wet planet into a frigid desert wasteland. — *Robert Naeye*



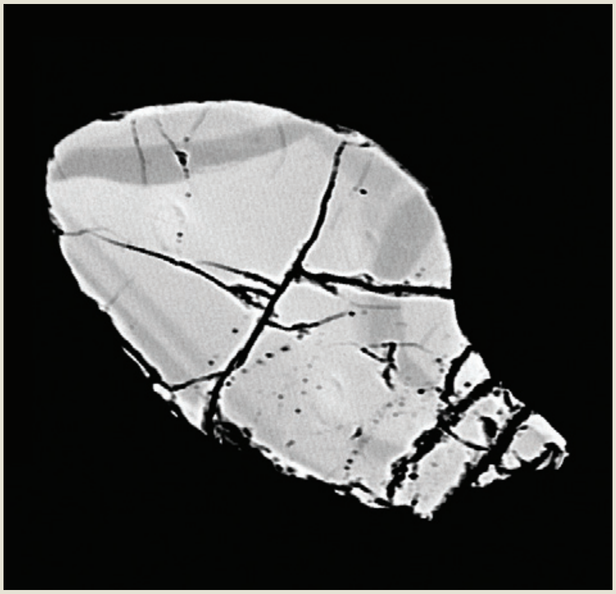
NASA / JPL / DANIEL MACHÁČEK (2)

BATTERED WORLDS The LHB would have profoundly affected the entire solar system, including the outer planets and their moons. Jupiter's gravity would have drawn wayward objects toward it, exposing its moons to a horrendous pounding. *Left:* Ganymede lacks impact craters because geological activity erased many of its ancient scars. *Right:* Callisto has remained inactive for billions of years, so its surface bears numerous impact craters. The outer rings of the Valhalla impact basin (bright region at lower left) extend 1,500 km from the center. Amateur astronomer Daniel Macháček assembled the mosaics from Galileo (Ganymede) and Voyager (Callisto) images.

Even Hartmann, a lunar cataclysm skeptic, acknowledges the beauty of the Nice Model. But he points out that "the model itself does not tell you when this surge of cratering occurred." When the impact spike occurs in the Nice Model depends largely on the choice of the disk's initial mass outside the orbits of the giant planets.

Evidence Under Our Noses

Meanwhile, another line of research is opening a new window into the earliest days of the solar system. Geologists have discovered that a few extremely hardy mineral crystals, notably zircons (zirconium orthosilicate, or $ZrSiO_4$), are practically indestructible. Once they crystallize in magma, they're almost impossible to melt (melting only at temperatures higher than 1000°C). They don't dissolve in hot or acidic fluids, and they only reluctantly give up any elements trapped within them even when heated to near-melting temperatures. As terrestrial rocks have been eroded, reburied, and even partially melted in the roots of ancient mountains, ancient zircons have survived.



STEPHEN MOJZSIS (UNIVERSITY OF COLORADO)

MINI TIME CAPSULE This electron microscope image shows a 200-micrometer-wide zircon from Western Australia. Its core crystallized 4.18 billion years ago. A flash heating event 3.96 billion years ago, possibly from an impact, produced the curved bands near the edge. The heating age matches that of the LHB.

Geochemist Stephen Mojzsis (University of Colorado) and his collaborators have dated 200,000 individual zircon crystals. The oldest zircon comes in at a whopping 4.38 billion years in age, predating Earth's oldest known rocks by more than 300 million years.

The researchers have recently developed a technique by which they use an ion microprobe to burn slowly into single microscopic zircon crystals, analyzing minuscule quantities of uranium, thorium, and lead isotopes to arrive at an age-to-depth profile through the zircon grain. All 10 zircon crystals that Mojzsis has so far depth-profiled — which come from rocks of different ages — contain a region only a few micrometers wide that records a sharp pulse of heating at 3.96 billion years ago. The crystals, and presumably the rocks they resided in, had been heated to temperatures around 1200°C for a period of only months. "This was remarkable," says Mojzsis. "There really isn't any geological condition on Earth that can do that, but impact melt sheets can."

None of the zircons show evidence for any similar pulse of heat earlier than 3.96 billion years ago, going back to 4.3 billion years. "It's not proof of the Late Heavy Bombardment on Earth, but it's compelling," says Mojzsis.

One might conclude that an intense bombardment of the early Earth would have wiped out any nascent life forms, and that all creatures living today descend from microbes that originated after the LHB. But recent mathematical modeling by Mojzsis and his colleague Oleg Abramov have produced surprising results. Even though any individual LHB impact would have sterilized the surrounding crust, there would have been plenty of refugia for unicellular life, especially for microscopic critters that loved the high-temperature fluids that percolate around volcanically active zones. So life could have originated on Earth more than 4 billion years ago and survived the LHB, but evidence for that epic event may be lost forever.

Solving the Puzzle

Hartmann, Cohen, and Mojzsis all agree that garden-variety meteorites from the asteroid belt are an underutilized resource in addressing the LHB mystery. Early data suggest that age dates among meteorites do not show a sharp spike at 3.9 billion years, but the number of analyzed samples remains small.

What about Martian meteorites? Mojzsis says we have one date from a single Martian rock, the famously controversial Allan Hills 84001, which shows that the 4.5 billion-year-old rock suffered a heating event at — guess what? — 3.9 billion years ago.

After five decades of interplanetary missions, we still don't know whether the solar system's violent infancy tapered off gradually into a sedate adulthood, or if there were tempestuous teen years. The maddening puzzle of the Late Heavy Bombardment will motivate researchers for decades to come. ✦

To watch a video of the Nice Model, visit SkyandTelescope.com/LHB.

Planetary Society web editor and S&T *contributing editor* ***Emily Lakdawalla*** *blogs daily at planetary.org/blog. She is the 2011 recipient of the prestigious Jonathan Eberhart Planetary Sciences Journalism Award from the American Astronomical Society's Division for Planetary Sciences.*

Did the Late Heavy Bombardent Flame Out or Fizzle Out?

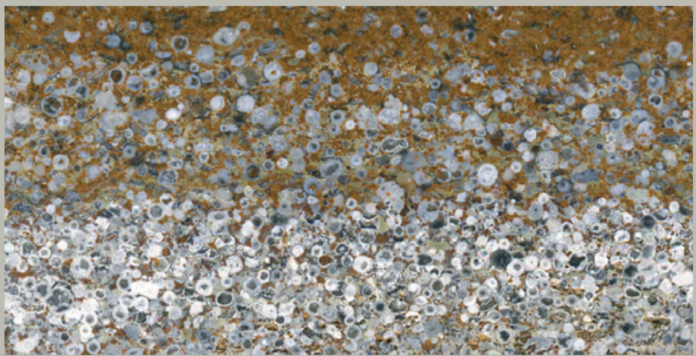
FOR YEARS, planetary scientists assumed that if the LHB was for real, it ended almost as abruptly as it began. But recent geological discoveries suggest it might have tapered off gradually, with Earth continuing to suffer enormous impacts long after the LHB's initial pulse.

The evidence comes from rocks in Western Australia and South Africa, the only known places that preserve sediments from 3.8 to 2.5 billion years ago. Geologists Donald Lowe (Stanford University), Gary Byerly (Louisiana State University), Bruce Simonson (Oberlin College), and others have found numerous well-preserved layers of spherules containing extraterrestrial material embedded in these ancient strata. The thickest layers span several centimeters, much thicker than the 3-millimeter layer found between Cretaceous and Tertiary sediments. These beefier layers suggest that the largest impacting objects were considerably bigger than the 6-mile-wide impactor that hit 65 million years ago and wiped out all dinosaurs except birds. Based on the spacing of the layers, ancient Earth suffered a giant impact every 40 to 50 million years, compared to the modern rate of one every several hundred million years.

A recent dynamical study by Bill Bottke (Southwest Research Institute) and his colleagues suggests that the impactors responsible for the LHB's extended tail originated in the "E-belt," an inner extension of the main asteroid belt that once stretched nearly to Mars. If the Nice Model is correct, E-belt bodies were scattered about 4 billion years ago when the giant planets began their late migration. Some of these asteroids ended up smashing into the Earth and Moon. The few surviving E-belt members make up the Hungaria asteroids, whose members have highly inclined orbits between 1.8 and 2.0 astronomical units.

Bottke points out that the largest LHB impacts ended by 2.5 billion years ago, which coincides with the rapid buildup of oxygen in Earth's atmosphere. Further research may reveal whether this was just a coincidence, or whether our planet had to wait for the LHB to fizzle out before it could start developing the conditions necessary for the evolution of complex, multicellular life.

S&T *editor in chief* ***Robert Naeye*** *is glad he wasn't around to experience the fury of the LHB.*



BRUCE SIMONSON (OBERLIN COLLEGE)

IMPACT SPHERULES This close-up photo of a 2.54-billion-year-old rock from Western Australia shows a 1-cm-thick layer of spherules at the bottom, with the largest spherules being about 1 mm across. The spherules formed during the intense heat of an impact, and consist of target rock and a few percent extraterrestrial material. The spherules flew into space as molten balls and rained back to Earth. The surrounding layers are solidified seafloor mud. Geologists have found at least 10 similar layers in ancient strata from Western Australia and South Africa, suggesting that LHB impactors continued to hit our planet until 2.5 billion years ago.

The Exoplanets that Weren't

Misadventures in planet discovery have continued from 1855 through the present time.

BRANDON TINGLEY

AROUND NOON on January 15, 1992, at the American Astronomical Society meeting in Atlanta, Andrew Lyne of the University of Manchester and Jodrell Bank Observatory stepped to the podium to speak on his epochal discovery the previous July: a planet was orbiting the pulsar PSR 1829–10. He had found it by tracking slight, cyclical changes in the apparent spin period of the pulsar. A low-mass object seemed to be orbiting it, regularly tugging it slightly back and forth. Lyne's remarkable find had been hailed as the first genuine discovery of a planet beyond the solar system after more than a century of highly publicized mistakes. But as Lyne began his presentation he surprised everyone by saying, "The planet just evaporated." The pulsar was not actually wobbling at all. Lyne explained that he and his team had failed to account accurately enough for Earth's orbital motion around the Sun.

Instead of it being the crowning glory of a distinguished career, Lyne's mistaken "discovery" added his name to a different, nearly as prestigious list: astronomers who have announced finding an exoplanet only to be proven wrong.

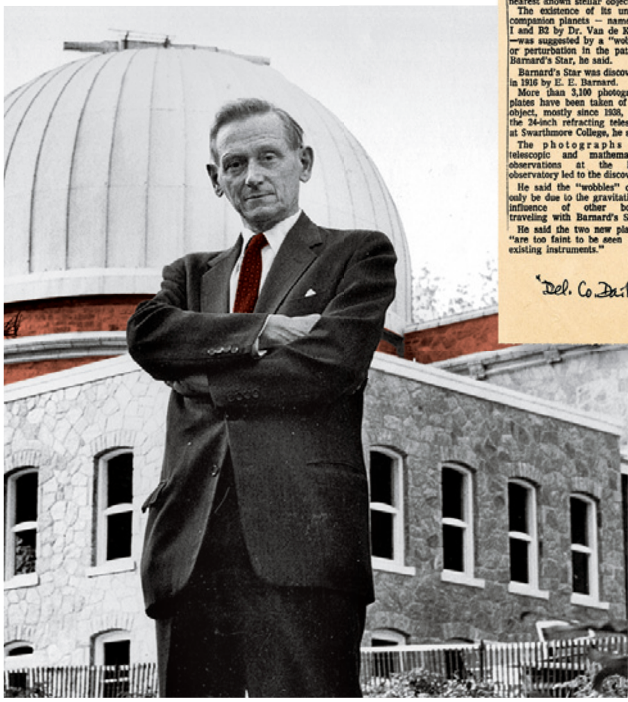
The First "Discovery"

The idea that alien worlds exist, and the excitement that it arouses, go very far back indeed. The first recorded conjectures about the plurality of worlds are credited to the Greeks Leucippus and Democritus in the 5th century BC. With remarkable foresight, they theorized that Earth assembled through the random collisions of tiny, irreducible "atoms," and that this event was unlikely to be unique. Metrodorus of Chios, a member of the school of Democritus (and perhaps his student), said that a singular Earth in an infinite universe would be as improbable as an entire field of millet having but a single kernel.

It would take more than two millennia before astronomers had enough data to dare announce an actual new planet among the stars. But ultimately, dare they did.

The first "discoveries" of exoplanets were based on *astrometry:* the careful measurement of star positions on the sky. Whenever one object orbits another, each moves by an amount proportional to the other's mass. In the case of a distant star being orbited by a much lighter

THE DEFENDER Peter van de Kamp (1901–95) never admitted that he had failed to discover planets orbiting Barnard's Star and 70 Ophiuchi. He directed Swarthmore College's Sproul Observatory (background) from 1937 to 1972.



Area Astronomer Discovers Second Planet-Like Object

A second planet-like object outside our solar system has been discovered by the director of Swarthmore College's Sproul Observatory.

Dr. Peter van de Kamp, who is also head of the college's astronomy department, made the revelation Monday as part of a lecture at Duke University, Durham, N.C.

Dr. van de Kamp's confirmation of the existence of this planet-like object comes six years after he deduced that Barnard's Star had another planet-like companion.

Barnard's Star, six light years from the earth, is the second nearest known stellar object.

The existence of its unseen companion planets — named B I and B2 by Dr. Van de Kamp —was suggested by a "wobble" or perturbation in the path of Barnard's Star, he said.

Barnard's Star was discovered in 1916 by E. E. Barnard.

More than 3,100 photograhic plates have been taken of this object, mostly since 1938, with the 24-inch refracting telescope at Swarthmore College, he said

The photographs and telescopic and mathematical observations at the local observatory led to the discovery.

He said the "wobbles" could only be due to the gravitational influence of other bodies traveling with Barnard's Star.

He said the two new planets "are too faint to be seen with existing instruments."

In a related development, Swarthmore College has announced receipt of a $49,500 grant from the National Science Foundation. It is a continuation of a grant to be used for astronometric research at Sproul Observatory. The research will be under direction of Dr. van de Kamp.

PETER VAN DE KAMP

"Del. Co. Daily Times" 4-16-69

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planet, the star's motion is extraordinary small. Sirius, for instance, wobbles by about 3 arcseconds due to the 50-year orbit of Sirius B, another *star*. That's the width of a human hair seen from 7 feet (2.1 meters) away. A giant planet might have only about a thousandth the mass of Sirius B, causing a side-to-side wobble 1,000 times smaller: the width of a hair seen from 7,000 feet away. And yet Sirius is one of the closest stars in the sky.

Astronomers made the first high-quality astrometric measurements visually, using crosshairs in a telescope's eyepiece. The most precise detections of a star's motion are measured with respect to other stars in the same field of view. Astronomers originally did this visually with a filar micrometer, a device in which the observer could adjust crosshairs to measure the separation of two stars, and rotate the whole thing to measure their orientation. Photographic plates began replacing micrometers about a century ago. Plates were easier to measure under a microscope at a desk and could be archived for rechecking. Even so, the slightest unaccounted glitch — combined perhaps with excitement and wishful thinking — could create ripe opportunities for a false detection.

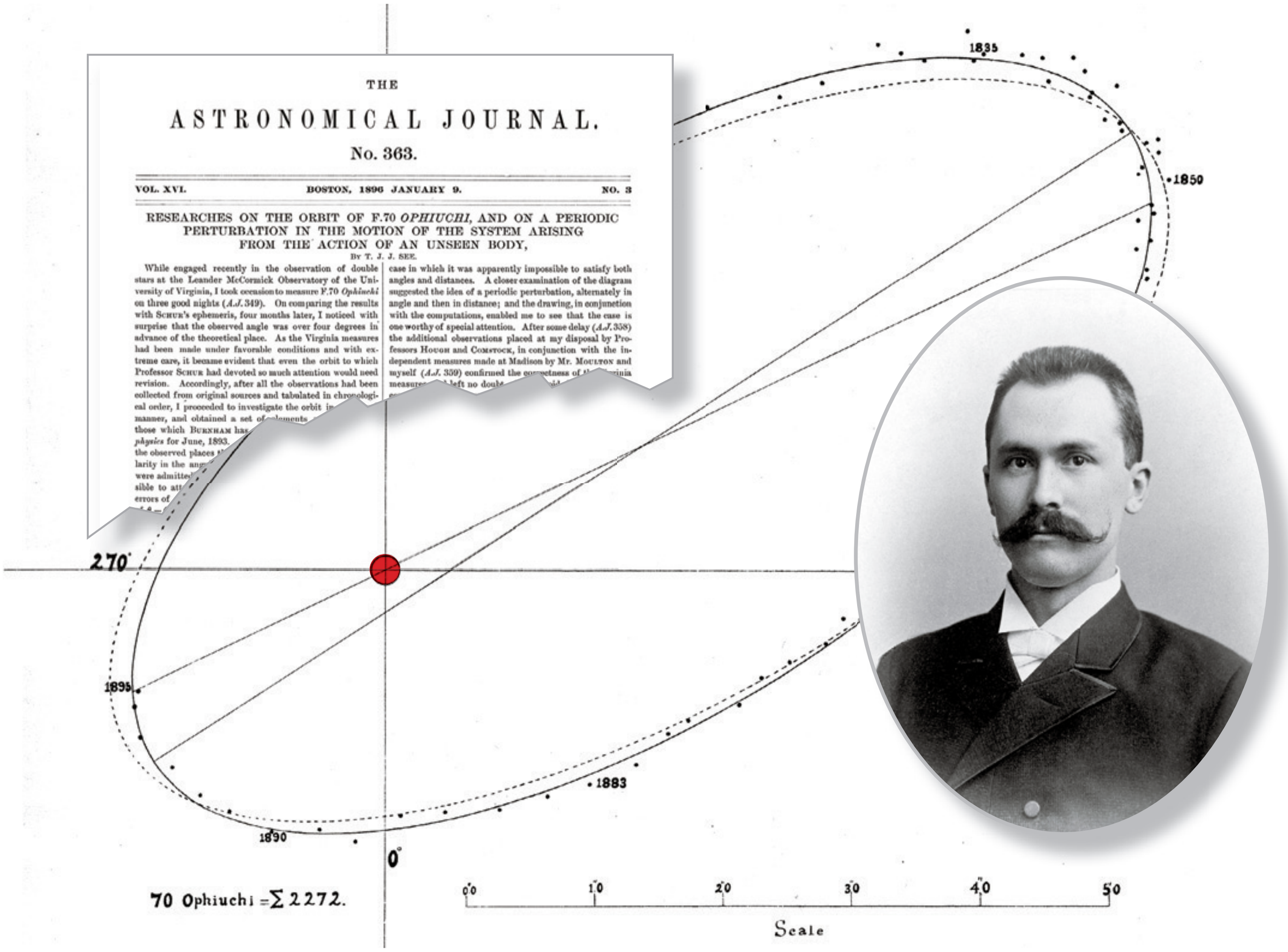
In 1855 Captain William Stephen Jacob of Madras Observatory in Madras (now Chennai), India, probably became the first astronomer to "discover" an exoplanet. He was careful and thorough. Analyzing 35 years of his own measurements of the visual binary star 70 Ophiuchi, along with a handful of measures made earlier by others, he encountered difficulty in fitting an orbit to the positions of the fainter star with respect to the brighter one.

The positions did not quite fit a smooth, proper ellipse. The discrepancies were first in one direction, then another. Jacob, inspired by the recent astrometric discoveries of unseen bodies orbiting Sirius and Procyon (which later turned out to be white dwarfs), tried including a dark body in his calculations for 70 Ophiuchi. The solution he derived surprised him. Given the small size of the unexplained perturbation (0.08 arcsecond, compared to the binary star's 9″-long orbit), he concluded that the third body could only be a planet orbiting the smaller star with a period of about 26 years. Using modern values for the distance and mass of 70 Ophiuchi B (an orange dwarf 16.6 light-years away), the dark object would have a mass of about 40 Jupiters: what we would now call a brown dwarf.

Jacob's "discovery" enthralled astronomers for decades, and they diligently continued measuring 70 Ophiuchi as its stars revolved. In 1896 Thomas Jefferson Jackson See (then at McCormick Observatory at the University of Virginia in Charlottesville) noted that many astronomers had calculated the system's orbital period without any real agreement — and that a strange trend was apparent in the published periods. Early data favored periods around 80 years, those made from 1845 to 1880 favored periods longer than 90 years, and those after 1880 again began to favor periods shorter than 90 years.

See investigated further, using in particular the work of Wilhelm Schur of Göttingen University Observatory in Germany. Schur had compiled about 400 astrometric measures of the pair from the sources he judged to be best. From these he calculated an orbit that he thought would be definitive. But See's own measurements in 1895 demonstrated a significant drift (more than 5 orbital degrees) less than two years after Schur's publication. Observations by other astronomers were showing similarly large deviations. See proposed that the obvious explanation was a low-mass third body tugging one of the stars around with a period of less than 40 years — as Jacob had said.

This solution, however, was unpalatable even to See. The dark object had about half the orbital period of the binary star and would likely be unstable. Forest Ray Moulton soon calculated that such a three-body system could not last; the low-mass object would quickly be flung away by interactions with the more massive revolving pair. Triple systems with at least two massive bodies are only stable when two of the three form a tight pair and the third orbits them at a wide distance — far enough that the pair might as well be a single body, gravitationally speaking.



TEXT PAGE, DIAGRAM: *ASTRONOMICAL JOURNAL*; PORTRAIT: *ASTRONOMICAL SCRAPBOOK*

ORBIT PUZZLE In 1896, T. J. J. See thought he had confirmed the 41-year-old claim that a planet orbits the fainter star of the 70 Ophiuchi binary. The primary star is at the center of the axes; the dots are measurements of the secondary's position with respect to it. See compared the orbit calculated earlier by Wilhelm Schur (dashed line) to his own better fit (solid line). See thought he saw a significant wavering of the secondary star around his orbit line due to an unseen planet.

The orbit of 70 Ophiuchi continued to confound observers until remarkably recently; even the 1984 periastron (when the two stars passed closest to each other in space) occurred much later than expected. Only when their orbit was calculated using nothing but photographic observations was the situation resolved: the earlier, eyeball measures proved to be somewhat less precise than the astronomers had assumed, throwing off the calculations.

After See's announcement, no more exoplanets were forthcoming for several decades — perhaps unsurprisingly, considering the advances in photographic astrometry. But this situation would not last.

When Even the Plates Deceive

The next round of false exoplanet discoveries began during World War II. They all have a common element: Peter van de Kamp of Swarthmore College's Sproul Observatory. Sproul boasts a 24-inch f/18 refractor that was well suited for state-of-the-art astrometric work. In January 1943, Dirk Reuyl (van de Kamp's cousin) and Erik Holberg of McCormick Observatory in Virginia announced a 10-Jupiter-mass dark object in the ever-baffling 70 Ophiuchi system, this time with a 17-year orbit. One month later Kaj Strand, a research associate of van de Kamp's at Sproul, announced the discovery of a 17-Jupiter-mass companion in a 4.9-year orbit around the orange dwarf 61 Cygni A.

These two announcements, made by different astronomers using different telescopes, both had copious photographic evidence to back them up: almost 100 photographic plates of the 70 Ophiuchi pair and 11 plates for 61 Cygni A and B, both spanning decades. In each case, precise measures of the star images seemed to reveal subtle sinusoidal variations with a faster period than that of the visible binary pair.

The scientific world was jubilant: here was clear evidence of the first extrasolar planets. The photographic analyses could be repeated by anyone and were therefore presumably irrefutable.

More astrometric discoveries followed. The next ones looked even better; they did not involve binary stars, whose own large motions complicate the situation; a small error in the analysis of a binary star's orbit could create the illusion of an exoplanet's influence. In 1951 van de Kamp and his research assistant Sarah Lee Lippincott announced that Lalande 21185, a single red dwarf in Ursa Major 8.3 light-years away (the sixth closest star to the Sun), had an unseen object with at least 30 Jupiter masses tugging it around. Then in 1963 van de Kamp reported a planet orbiting Barnard's Star in Ophiuchus, a single red dwarf 6.0 light-years away. This planet had a period of 24 years and a mass of only 1.5 Jupiters.

All these discoveries had ample photographic evidence. The Barnard's Star planet was based on more than 2,400 plates covering nearly 50 years. Moreover, van de Kamp had a reputation as an impeccable scientist. He did everything possible to minimize his errors, going so far as to have 10 different people measure the stars' positions on each plate, then averaging the results.

Other groups were able to reproduce van de Kamp's analysis based on the same data. An analysis by Oliver Jensen and Tadeusz Ulyrch in 1973 even suggested that more planets might be orbiting Barnard's Star. Van de Kamp's historical legacy seemed secure.

The first sign of trouble came in 1973, just after van de Kamp retired and moved back to his homeland of Holland. George Gatewood, a Ph.D. student at the University of Pittsburgh working under Heinrich Eichhorn, analyzed an independent set of observations made with another telescope using new machinery that measured star positions to very high precision automatically. He found no wobble in Barnard's Star at all.

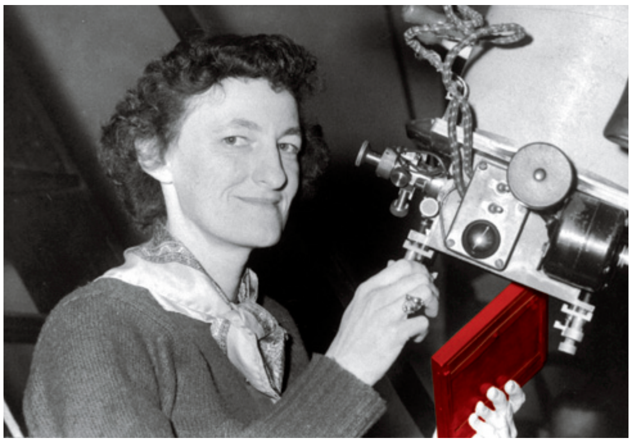
If that weren't enough, even worse news came to light later that year. Measuring old plates taken with Sproul's 24-inch refractor, John Hershey found a wobble in another red dwarf, Gliese 793, very similar to the wobble that van de Kamp had found in Barnard's Star. Both abruptly shifted by 60 milliarcseconds (the width of a hair seen from 900 feet, or 275 meters) in a particular direction in 1949 and then back again over the course of the second half of 1957.

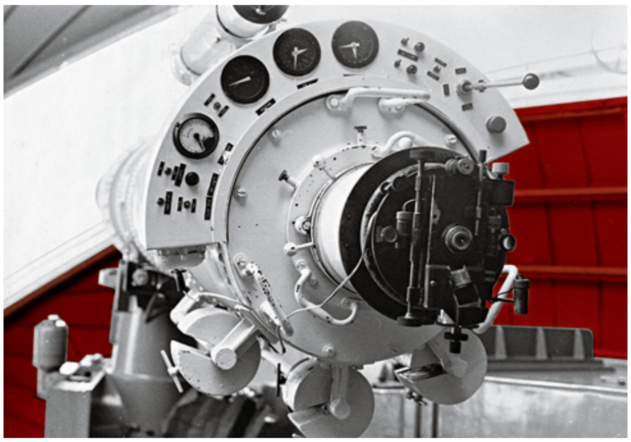
Such a coincidence was extremely unlikely; had some tiny systematic error snuck in? It turned out that the 24-inch had been modified a few times — once in 1949, when the cast-iron cell of the primary lens was replaced and a new emulsion was chosen for the photographic plates, and again in 1957, when the lens was adjusted several times. Van de Kamp knew of these events, of course, but apparently failed to notice how his tiny deviations happened at the same time as changes in his instrument.

Van de Kamp's assistant Wulff Heintz, who succeeded him as observatory director, had privately harbored suspicions about the Barnard's Star planet for some time. When Heintz told van de Kamp that he too was having trouble duplicating the wobble findings even from the Sproul plates, "I was denounced among his friends," Heintz recalled in 2001, "including top administrators, as a nasty character and probably mentally disturbed."

Of course it's devastating to a scientist to have his greatest discovery shown to be a mistake. Naturally he will defend it; challenge and defense are at the heart of the scientific process. But when evidence of a mistake becomes plain to everyone else, the unfortunate discoverer can go several ways. He can acknowledge the error and move on, or he can try to turn up convincing new evidence in the slim hope that he was right after all. Or he may become increasingly dogmatic and rigid.

There's a famous saying that every great new idea is at first ignored, then laughed at, then hotly opposed, and finally everyone says they knew it was right all along. There is a sadder, parallel process that works in reverse. When a scientific idea that everyone thought was right turns out to be untrue, its die-hard defenders are at first hotly debated, then laughed at (however quietly and





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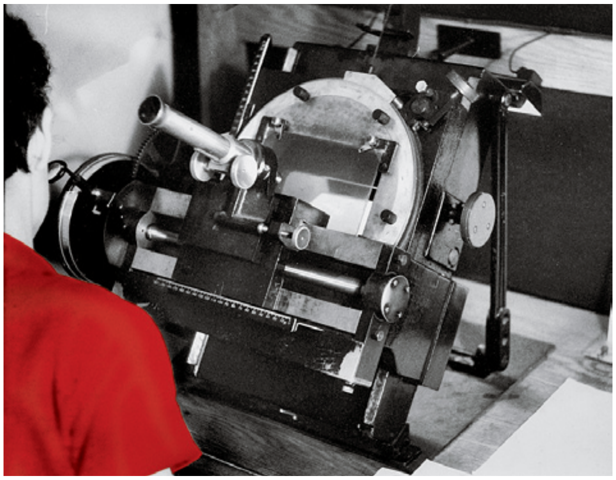
EARLY MEASURER AND EQUIPMENT ***Left:*** **Sarah Lee Lippincott (1920–) worked with van de Kamp from 1945 to 1972; in 1951 they announced signs of a planet orbiting Lalande 21185. Here she prepares to load a plate into the Sproul refractor in 1964.** ***Right:*** **A filar micrometer for measuring double stars visually is attached here to the back end of Sproul's 24-inch refractor.**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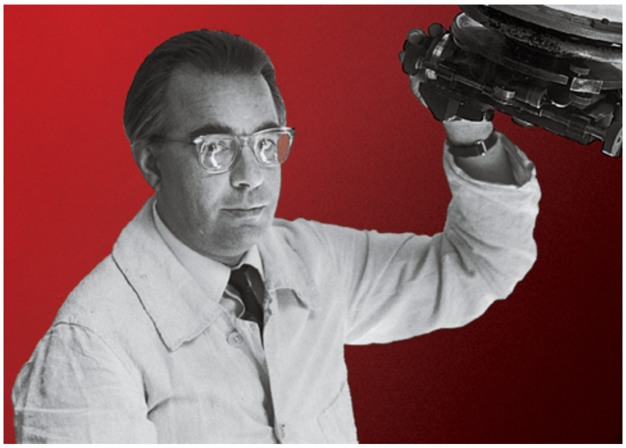
DESKTOP ASTROMETRY Before digitization, photographic plates were measured with a "measuring engine": a microscope riding on massive rails with high-precision analog vernier dials to read out its position.

politely), and then finally ignored. Van de Kamp never gave up and never admitted that he may have made a mistake, unto his dying day at age 93 in 1995.

But even the skeptical Gatewood was not immune from false exoplanet discoveries. In 1996, 23 years after reporting that the Barnard's Star planet was an illusion, Gatewood announced that improved astrometric equipment was revealing that Lalande 21185 had multiple planets. These would have been relatively far from the star — the most distant being 0.8 arcsecond — so they should have been observable with a telescope equipped with an efficient coronagraph to block the central star's light. Efforts to detect them both by direct imaging and by radial-velocity observations have come up empty, casting severe doubts on this claim.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THE SKEPTICAL SUCCESSOR Wulff Heintz took over as director of Sproul after van de Kamp retired. Within a few years he published a detailed refutation of van de Kamp's erroneous Barnard's Star planet claim.

Recent Retractions

Everything finally changed starting in 1992, when Aleksander Wolszczan at Penn State University announced that two planets with about four times Earth's mass are tugging on the pulsar PSR B1257+12 in Virgo. Their motions induce slight wobbles in the arrival times of the spinning neutron star's pulses — this time for real. (Wolszczan announced his discovery in the presentation immediately following Lyne's famous retraction in January 1992, a cruel irony.) Then in 1995, Michel Mayor and Didier Queloz at the Geneva Observatory announced the first planet orbiting a normal star, 51 Pegasi, based on the radial-velocity wobbles that the planet induces in the star's spectrum. Thanks to the planet's fast, 4.2-day orbital period, Geoff Marcy and Paul Butler were able to quickly confirm 51 Pegasi's wobbles after taking spectral data at the Lick Observatory's 3-meter Shane reflector.

Since then nearly all exoplanet discoveries have proved genuine beyond doubt — first a trickle, then a flood. As of this writing many teams of astronomers have announced a total of 552 confirmed exoplanets, mostly by the radial-velocity signatures they induce in their stars' spectra or by slight dimmings as they periodically transit a star's face. Some are seen doing both. In February the team running NASA's Kepler transit-hunting satellite announced 1,235 planet candidates; at least 90% of these are expected to prove real. And the Kepler mission is still young.

But a few false discoveries continue, some of them embarrassingly high profile.

The Geneva Observatory radial-velocity group retracted three of its announced exoplanets after later observations showed strong correlations between the supposed radial-velocity variations and slow brightness variations in the stars themselves. A planet could not cause both effects, but starspots rotating across the star's face certainly could.

Last year the WASP transit-hunting group, headed by Andrew Cameron of the University of St. Andrews in Scotland, had to retract one of its announced planets, WASP-9. In this case the star showed slight, regular dips in brightness just as if a planet were crossing its face. Subsequent measurements of the star's velocity variations seemed to show that the orbiting body had a planetary mass. The group confidently announced its discovery — only to find from further observations that WASP-9 consists of three very similar stars, two of which eclipse each other grazingly. The two eclipsing stars each rotate so fast that their spectral lines are broadened to near-invisibility. With their light blending into the light of the third star, we see tiny, periodic dips in the triple's total brightness that mimic those of a transiting exoplanet.

History appears set to repeat itself as another recent exoplanet claim is being called into question. Stephen Pravdo and Stuart Shaklan of the Jet Propulsion Laboratory announced a low-mass body orbiting VB 10, a tiny, very dim red dwarf just 20 light-years away that's right at the lower mass limit for hydrogen burning. They deduced the planet's presence from side-to-side astrometric wobbles in the star's apparent position, harking back to the bodies once thought to orbit Barnard's Star, Lalande 21185, and the rest. But trouble surfaced quickly. A team led by Jacob Bean (then at Georg-August University, Göttingen, Germany), using a new spectrograph capable of highly precise radial-velocity measurements in the infrared, failed to find the expected radial-velocity wobbles induced by the planet, ruling out its existence.

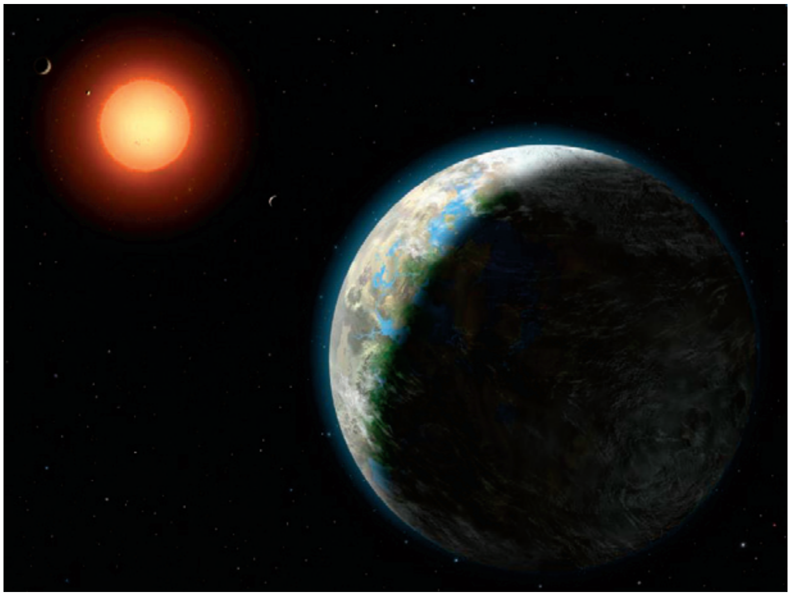
Not even the person who made the first real exoplanet discovery has been immune. Aleksander Wolszczan, who found the first two genuine pulsar planets, added a third in 1994 that has only twice the mass of the Moon. Then in 2005 he announced a fourth, this one orbiting far from the pulsar and with a lower mass still. Although the first three have been thoroughly confirmed, the signal of the fourth turned out to be spurious. It was detected at only one frequency, and a re-tuning of the radio telescope to a shorter wavelength showed no sign of pulse-time perturbations. Wolszczan has since attributed the signal to changes in the interstellar plasma along the line of sight.

Just last September we saw what may turn out to be the most embarrassing false exoplanet since the van de Kamp era. Publicized worldwide as the "Goldilocks Planet," Gliese 581g had only 3 or 4 Earth masses and was orbiting its star, the dim red dwarf Gliese 581 (20 light-years away in Libra), at a distance that would be "just right" for liquid water on its surface. Announced by the Lick-Carnegie Exoplanet Survey led by Paul Butler and Steven Vogt, it seemed to be the first such case clearly known and was trumpeted in the news media (*S&T:* December 2010, page 16).

But the planet quickly came under serious challenge. Its radial-velocity signature amid the star's complex wobbles (caused by at least four other planets) was barely above the noise level — and other radial-velocity measurements showed no sign of it. A re-analysis of the original data called even that into question; the discoverers had assumed that the planet had a circular orbit, and when that assumption was dropped, no evidence for the wobble was apparent. The case of the Goldilocks Planet isn't quite closed yet, but it seems likely to be a classic mistake. Since then the Kepler team has announced 54 planet candidates that orbit in their stars' habitable zones (May issue, page 12), but these have received less public attention.

GEORGE GATEWOOD

SWAPPING NON-PLANETS George Gatewood helped show that the Barnard's Star planet doesn't exist. He went on to see signs of planets around Lalande 21185 — but those too evaporated.



LYNETTE COOK

OOPS! The "Goldilocks Planet," supposedly orbiting in the habitable zone of the red dwarf Gliese 581, was exposed as probably nonexistent soon after the Lick-Carnegie Exoplanet Survey team announced its discovery last year. The team made this painting available with its press release.

Humble Pie

The moral of the story is this: nature is craftier than we give her credit for. Or perhaps that's being too anthropocentric. Rather, even good scientists can be more credulous than they think. Even the best will sometimes overlook, or too readily brush over, a small but crucial detail.

We can also say that more than a century of hard work was most definitely *not* in vain. Efforts to verify the early claims steadily pushed the technology to the point where astronomers began to make real detections. These days, none of the mistaken discoverers are viewed as failures. Instead, we see them as intrepid explorers who, while unable to find their City of Gold, nevertheless blazed trails that others followed, ultimately to success. ✦

***Brandon Tingley** is a researcher specializing in transiting exoplanets. He currently works at the Instituto de Astrofísica de Canarias on the island of Tenerife, on the science team of the Corot exoplanet-hunting spacecraft.*

NEAF turns 20

Photos & Story by Dennis di Cicco & Sean Walker

The annual Northeast Astronomy Forum has something for every amateur astronomer regardless of age, experience, or field of interest.

The Northeast Astronomy Forum (NEAF) has come a long way in the past two decades. What began as a "crazy idea" during a casual conversation among Rockland Astronomy Club members Al and Judi Nagler and the late Allan Green has grown to become one of amateur astronomy's premier events. Thousands of people now make the annual springtime pilgrimage to the campus of Rockland Community College in Suffern, New York, for the two-day extravaganza. They come to hear lectures by prominent amateur and professional astronomers, talk shop with other astronomy

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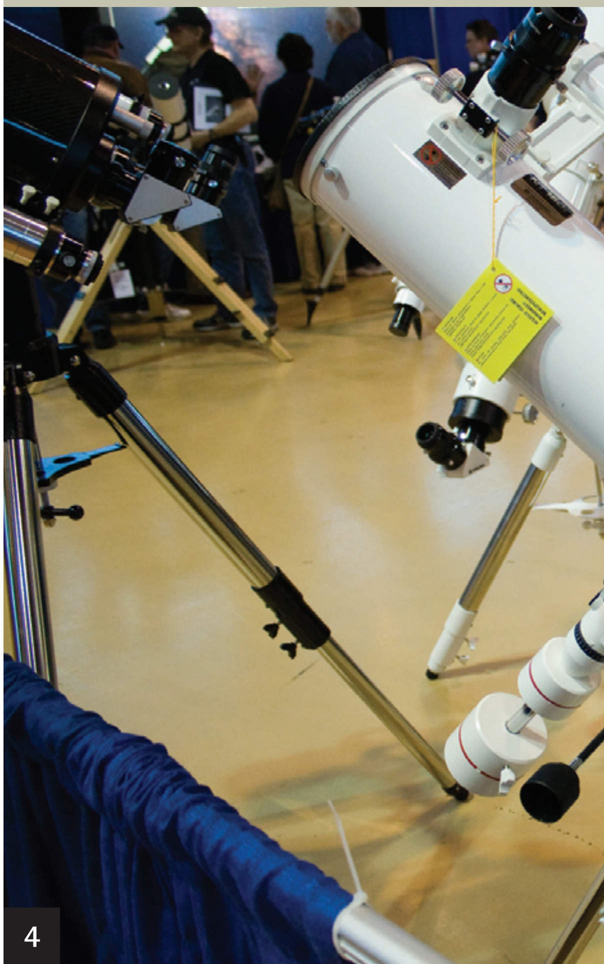
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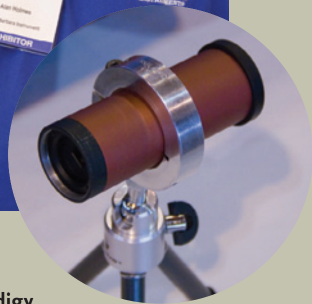


1. Celestron's flagship 14-inch scope shared the spotlight with the company's soon-to-be-released SkyProdigy technological wonder.

2. A prototype 8-inch Schmidt-Cassegrain telescope generated a lot of comments at the Explore Scientific booth.

3. SBIG's new company owner and CEO, Ron Bissinger (left) and Alan Holmes were on hand to talk about their new CCD-based ST-i planetary camera and autoguider (inset), which features 16-bit images.

4. Bresser's new Messier line of reflectors and refractors includes this handsome 6-inch f/8 Newtonian, which attracted lots of attention.

5. Scott Roberts of Explore Scientific showed off an attractively priced 6-inch apo refractor due out this summer and a prototype heavy-duty German equatorial mount now being field tested.

Visit SkyandTelescope.com/neaf2011 to see video interviews with some of the manufacturers exhibiting at NEAF this year.

5

enthusiasts, and renew acquaintances. But most of all they come to see (and purchase) the latest astronomy equipment on display by scores of dealers and manufacturers.

Sky & Telescope, a long-time NEAF sponsor, always has a big turnout, and this year all of our editors were on hand. Pictured in this story (and identified with numbers at the lower left corner of each image) are the people and products that especially piqued our interest. The notes below for selected images expand on the captions that appear with the pictures.

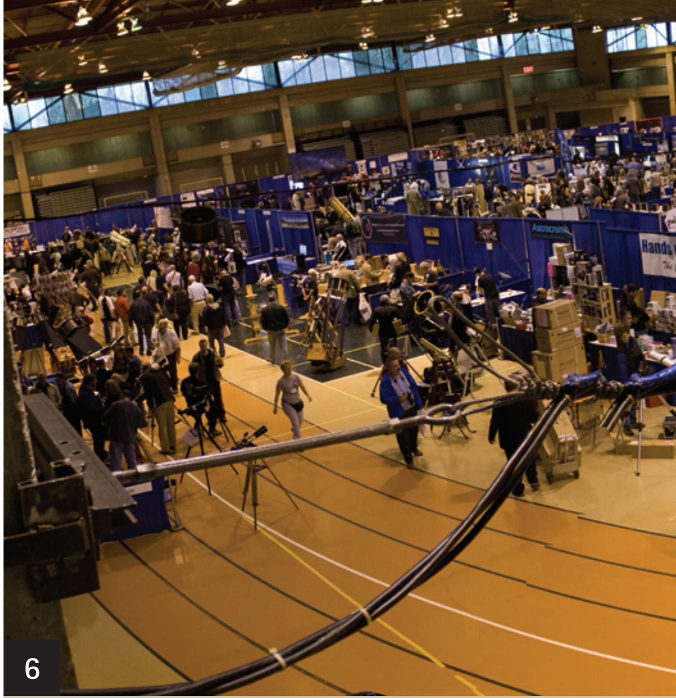
1. Celestron's soon-to-be-released SkyProdigy telescopes, which currently includes a 70-mm refractor, 90-mm Maksutov-Cassegrain, and 130-mm reflector, use onboard "StarSense technology" to automatically identify stars and initialize the scopes' Go To computers. They offer telescopic exploration of the heavens to people with no previous knowledge of the sky.

2. The folks at Explore Scientific were soliciting feedback on a prototype 8-inch Schmidt-Cassegrain telescope fitted with an illuminated 8×50 erect-image finder and 2-inch star diagonal with enhanced coatings.

3. People who stopped by the SBIG booth to check out the new CCD-based ST-i planetary imager and autoguider also got a chance to meet the company's new owner and CEO, Ron Bissinger, who is a long-time amateur astronomer currently involved with pro-am collaborations on observing exoplanet transits.

4. Bresser's new Messier line of refractors and Newtonian reflectors (exclusively distributed in the Americas by Explore Scientific) includes full-feature telescopes for all levels of serious observing from beginning to advanced.

5. Of special interest at Explore Scientific's booth was the upcoming 6-inch apo refractor featuring a carbon-fiber tube, air-spaced triplet objective made with extra-low dispersion Hoya glass, and a 3-inch, dual-speed rack-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6. Approximately 150 exhibitors were spread across NEAF's expansive floor space.

7. The precision-engineered astrographs from Dave Tandy's AG Optical have honeycomb tubes (inset).

8. QSI's new 600 Series cameras have internal 8-position filter wheels.

9. Optec's high-precision FastFOCUS moves the secondary mirror of Celestron's Fastar-compatible scopes.

10. Eyepiece and accessory cases from Wood Wonders combine style with utility.

11. Urban Observatories incorporates boat-building technology in its compact domes.

and-pinion focuser. The right-angle, errect-image 8×50 finder has separate focus adjustments for the eyepiece reticle and the finder.

7. Industry newcomer AG Optical displayed several astrographs with impressive design credentials. Systems based on Newtonian and Dall-Kirkham optics (both equipped with image correctors) are currently available in 12½-, 16-, and 20-inch apertures.

9. Optec's high-precision FastFOCUS system takes advantage of the removable secondary mirror in Celestron's Fastar-compatible Schmidt-Cassegrain scopes. The prototype on display was for the 11-inch EdgeHD scope, but another is in the works for the 14-inch. The FastFOCUS system allows the user to focus the EdgeHD scopes after engaging their highly effective primary mirror locks that eliminate image shift.

12. One of the "must-see" items at the Vixen display was the pocket-sized Polarie tracking mount planned for release later this year. Looking at first glance like an oversized point-and-shoot camera and powered by two internal AA batteries, the Polarie has a bubble "level" calibrated for latitude and a peep-sight for aligning the mount on Polaris. Another noteworthy feature is a half-sidereal drive rate, which is one of the "secret" techniques used to take many of today's outstanding starscape photographs.

14. After making a name for itself with its highly acclaimed tangent-arm tracking systems, AstroTrac is developing an extremely portable German equatorial mount for astrophotographers wanting dual-axis guiding capability.

15. The tiny all-weather, all-sky camera from Moonglow Technologies is made for monitoring sky conditions at remote observatories. An optional "uploader" system converts the camera's video signal for computer display, making it easy to monitor conditions over the internet.

16. MallinCam's new Xtreme model offers shutter speeds from $1/12{,}000$ second to 100 minutes, making the color video camera suitable for everything from high-speed solar and lunar observing to long-exposure deep-sky imaging. The camera also features a built-in title generator, and options include a chip-cooling system and wireless exposure controller. ✦

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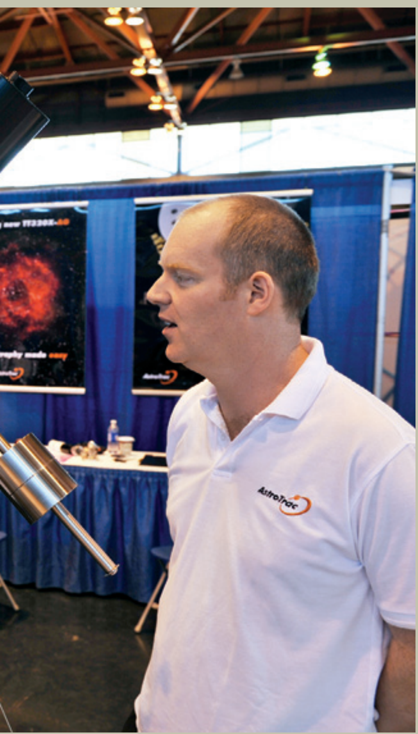

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12. Brian Deis shows off Vixen's upcoming Polarie tracking camera mount powered by internal batteries.

13. Markus Ludes of Lunt Solar Systems exhibited a prototype 230-mm (9-inch) hydrogen-alpha solar telescope.

14. AstroTrac's Richard Taylor (right) talks about his highly portable German equatorial mount with Walter Hildebrand of Astrosysteme Austria.

15. The tiny all-sky camera from Moonglow Technologies can remotely monitor the sky day and night in any weather.

16. MallinCam Xtreme melds the performance needed for deep-sky imaging with video-camera simplicity.

16

Strolling the Milky Way

Take your time exploring the summer sky.

Took an untrodden path once where the swift don't win the race,
It goes to the worthy who can divide the word of truth.
— Bob Dylan, *I and I*

THERE ARE MANY KINDS of untrodden paths. But as I step out on a clear summer night, far from city lights, I see one in the sky. It's the great road of the sky, the Milky Way itself, scanned with the unaided eye or optical aid, evoking in people of all times poignant feelings of connection and longing.

Walking the Milky Way. Our all-sky map on page 44 shows the sky when the constellation Sagittarius is nudging up to the meridian. This Sagittarius Hour features the constellation of the Archer at its highest, though that's not very high for viewers at mid-northern latitudes. But what's most impressive at this time, at least in dark skies, is the Sagittarius Milky Way.

The bright part of the Milky Way band now pours over the shoulder of the sky from high in the east in Cygnus, down the south-southeast mid-sky in Scutum, and into the low south in Sagittarius. Is it a mystic waterfall, frozen by distance? Or the mist of star clouds thrown up from the unseen cataract?

ADAM BLOCK / NOAO / AURA / NSF

Messier 8, the Lagoon Nebula, is one of the glories of the Sagittarius Milky Way.

Some cultures have seen the Milky Way as the backbone of night, others as the river of stars — and others as a mystical path of souls. If it's a path, you certainly can't tread on it, unless you tread with your eyes, admiration, and imagination.

Take your own star walk. You would think that the constellations of summer, the season famous for mild, serene nights and people at leisure, would have been observed as completely as possible by now. Or at least the famed Milky Way regions of these constellations would have been trampled up and down like Broadway.

Why be anxious to explore what's already been explored by others?

Reading about these celestial wonders, or even looking at wondrous images of them, is not the same as seeing them directly with your own eyes. The great 20th-century deep-sky observer and writer Walter Scott Houston joked one night at Stellafane, Vermont's summer meeting of amateur astronomers and telescope makers, that so many people had viewed Messier 13 through the Porter turret telescope that the great globular cluster might be worn out. It's the kind of joke that's all the more potent because we laugh — and then are struck with a shock of recognition. If a great sky wonder can never be worn out by looking, shouldn't it also be true that we can never wear out our own wonder in looking at it?

Where the swift don't win the race. Clear summer nights are peaceful — so calm down and take all the time you need to enjoy the sights along the Milky Way. Try limiting yourself to studying just one constellation per night. In fact, the sights both of Cygnus and Sagittarius are too many and too various to take in even in a whole night. I'll devote the next two months of this column to objects in Cygnus alone.

And what about the Sagittarius region at the Sagittarius Hour? Even our basic all-sky map shows 11 Messier objects in the span from the rich open cluster M11 in Scutum to the big open clusters M6 and M7 at the tail of Scorpius. In between are four fabulous nebulae (M8, M20, M17, and M16), three more open clusters (M11, M23, and M25), and a superb globular cluster (M22). ✦

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

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Dr. J. Rufus Fears is David Ross Boyd Professor of Classics at the University of Oklahoma, where he holds the G.T. and Libby Blankenship Chair in the History of Liberty. An acclaimed scholar with more than 20 teaching awards, he was chosen Professor of the Year on three occasions by students at the University of Oklahoma.

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5. Solon—Democracy Begins (594 B.C.)
6. Marathon—Democracy Triumphant (490 B.C.)
7. Hippocrates Takes an Oath (430 B.C.)
8. Caesar Crosses the Rubicon (49 B.C.)
9. Jesus—The Trial of a Teacher (A.D. 36)
10. Constantine I Wins a Battle (A.D. 312)
11. Muhammad Moves to Medina—The Hegira (A.D. 622)
12. Bologna Gets a University (1088)
13. Dante Sees Beatrice (1283)
14. Black Death—Pandemics and History (1348)
15. Columbus Finds a New World (1492)
16. Michelangelo Accepts a Commission (1508)
17. Erasmus—A Book Sets Europe Ablaze (1516)
18. Luther's New Course Changes History (1517)
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20. The Battle of Vienna (1683)
21. The Battle of Lexington (1775)
22. General Pickett Leads a Charge (1863)
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24. Charles Darwin Takes an Ocean Voyage (1831)
25. Louis Pasteur Cures a Child (1885)
26. Two Brothers Take a Flight (1903)
27. The Archduke Makes a State Visit (1914)
28. One Night in Petrograd (1917)
29. The Day the Stock Market Crashed (1929)
30. Hitler Becomes Chancellor of Germany (1933)
31. Franklin Roosevelt Becomes President (1933)
32. The Atomic Bomb Is Dropped (1945)
33. Mao Zedong Begins His Long March (1934)
34. John F. Kennedy Is Assassinated (1963)
35. Dr. King Leads a March (1963)
36. September 11, 2001

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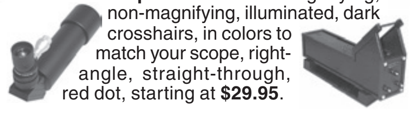

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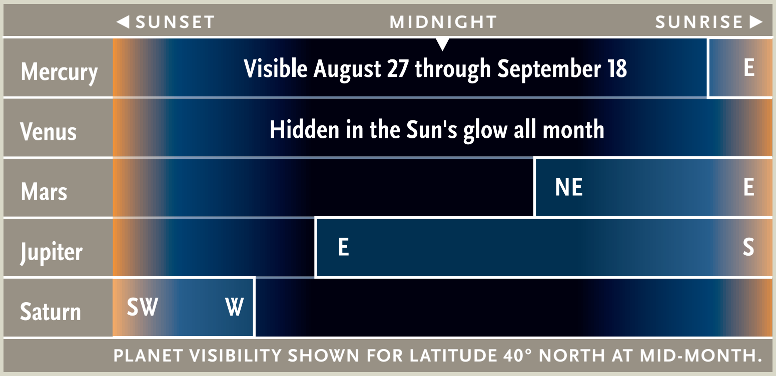
August 2011

MOON PHASES

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

PLANET VISIBILITY



THE PLEIADES rise before midnight by late August, early heralds of the glorious winter sky.

TAD DENTON / ADAM BLOCK / NOAO / AURA / NSF

2–6 **ALL NIGHT:** Vesta shines at magnitude 5.6. This is the brightest asteroid apparition until 2018; see page 53.

3, 4 **DUSK:** The waxing crescent Moon is below Saturn on the 3rd and Spica on the 4th, as shown on page 48.

6 **FIRST-QUARTER MOON** (7:08 a.m. EDT).

6, 7 **PREDAWN:** Mars is less than 1° south of M35, low in the east-northeast.

10 **EVENING:** Binoculars and telescopes show the 2.9-magnitude star Pi Sagittarii disappearing behind the dark edge of the gibbous Moon for the eastern half of North America. See **SkyandTelescope.com/Aug2011Occult** for details.

12–13 **THE PERSEID METEOR SHOWER** peaks late tonight. Unfortunately, the full Moon will hide all but the brightest meteors.

13 **FULL MOON** (2:57 p.m. EDT).

18, 19 **PREDAWN:** Mars is 1½° south of 3.0-magnitude Epsilon Geminorum.

19 **LATE EVENING:** Jupiter rises below the waning gibbous Moon.

21 **LAST-QUARTER MOON** (5:54 p.m. EDT).

LATE EVENING: The Pleiades rise above the Moon.

22–23 **ALL NIGHT:** Neptune is at opposition, opposite the Sun in the sky, rising around sunset and setting around sunrise. See the July issue, page 28.

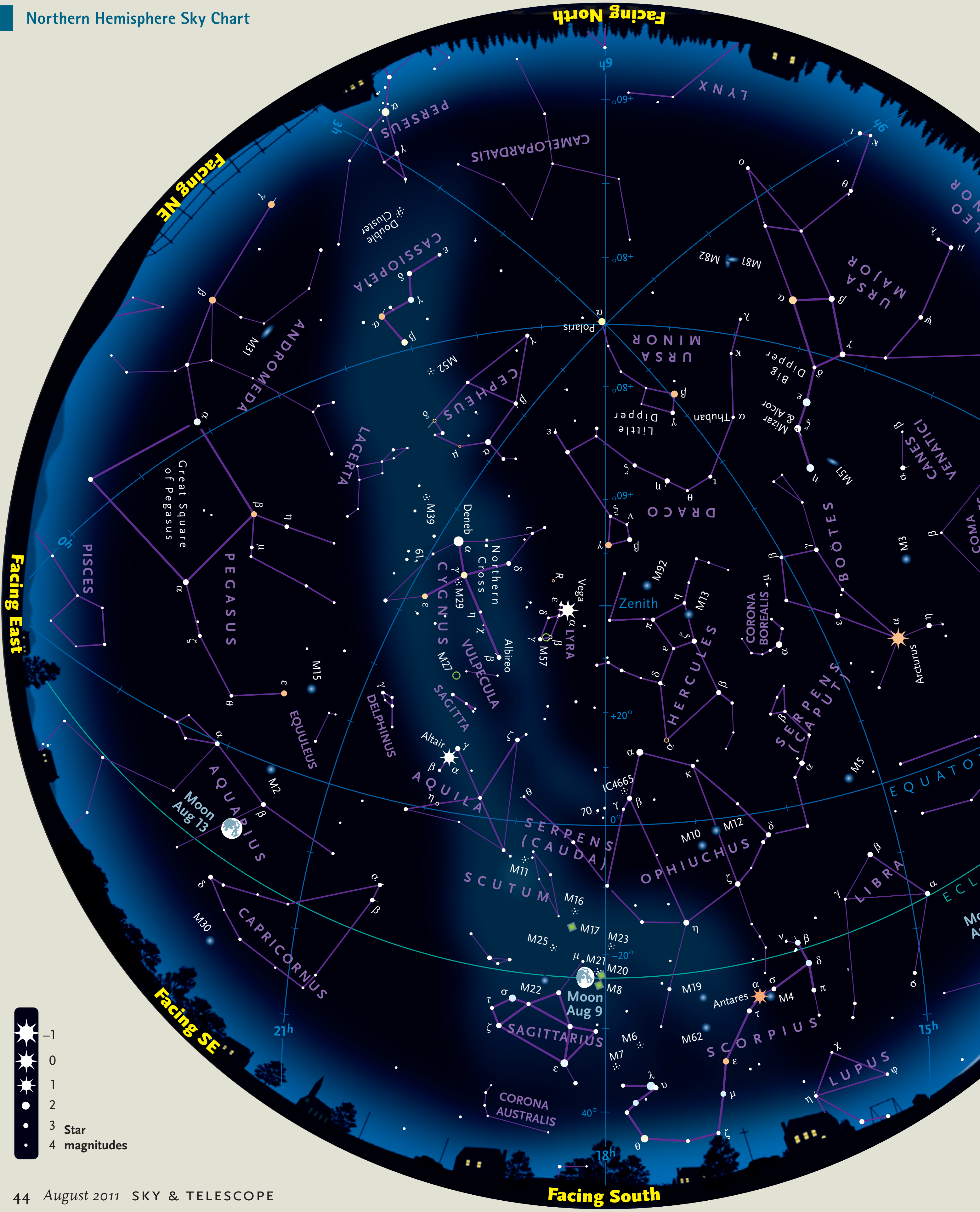
25 **DAWN:** Mars is just left of the thin crescent Moon (for North America) and well to the right of similarly bright Castor and Pollux.

27 **DAWN:** Faint Mercury is far lower left of the thin crescent Moon, as shown on page 49.

28 **NEW MOON** (11:04 p.m. EDT).

31 **DUSK:** Spica is to the upper left of the thin crescent Moon, and Saturn is to the Moon's upper right.

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



Facing North
Facing NE
Facing East
Facing SE
Facing South
Zenith
Polaris
LYNX
CAMELOPARDALIS
PERSEUS
Double Cluster
CASSIOPEIA
ANDROMEDA
M31
M52
CEPHEUS
URSA MINOR
Little Dipper
Thuban
URSA MAJOR
M81
M82
Big Dipper
Mizar & Alcor
M51
CANES VENATICI
DRACO
LACERTA
Great Square of Pegasus
PEGASUS
PISCES
M39
Deneb
Northern Cross
CYGNUS
M29
61
Albireo
Vega
LYRA
M57
M92
M13
HERCULES
CORONA BOREALIS
BOÖTES
Arcturus
M3
COMA
VULPECULA
M27
SAGITTA
DELPHINUS
EQUULEUS
M15
Altair
AQUILA
AQUARIUS
M2
Moon Aug 13
SERPENS (CAPUT)
SERPENS (CAUDA)
IC4665
70
M5
EQUATOR
M10
M12
OPHIUCHUS
SCUTUM
M11
M16
M17
M25
M23
M21
M20
M8
M22
Moon Aug 9
SAGITTARIUS
M19
Antares
M4
M6
M7
M62
SCORPIUS
LIBRA
LUPUS
CAPRICORNUS
M30
CORONA AUSTRALIS
0h
3h
6h
9h
15h
18h
21h
+20°
+40°
+60°
+80°
0°
–20°
–40°
–1
0
1
2
3
4
Star magnitudes

Using the Map

WHEN

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

*Daylight-saving time.

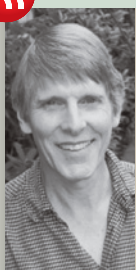
HOW

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 northeast) is at the bottom, right-side up. The curved edge is the horizon, and the stars above it on the map now match the stars in front of you in the sky. The map's center is the zenith, the point overhead. Ignore all parts of the map over horizons you're not facing.

Example: Rotate the map so that "Facing West" is at the bottom. Halfway from there to the map's center is the bright yellow-orange star Arcturus. Go out, face west, 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-August.

Watch a SPECIAL VIDEO



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

Binocular Highlight: Summer Star Cloud

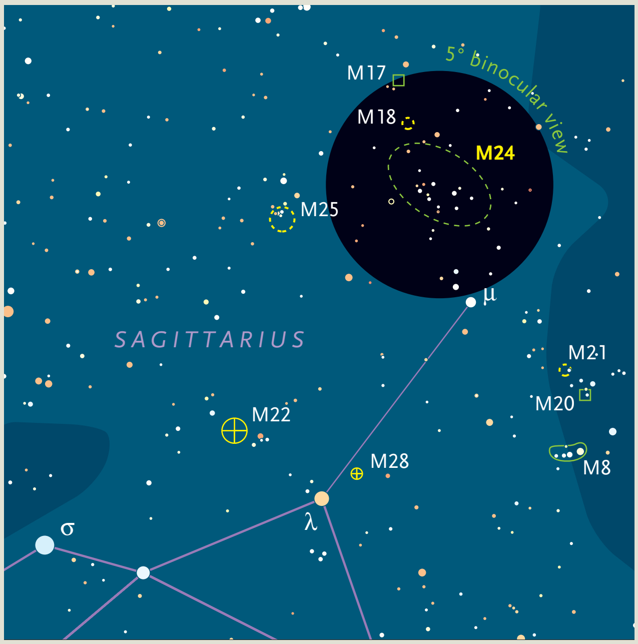
In the entire firmament only a handful of deep-sky wonders look their absolute best in binoculars. Most of these are so large that they're diminished by the restrictive fields of view provided by typical telescopes. One such target is **M24**, otherwise known as the Small Sagittarius Star Cloud. It's a spectacular binocular sight, yet it's unremarkable in most telescopes.

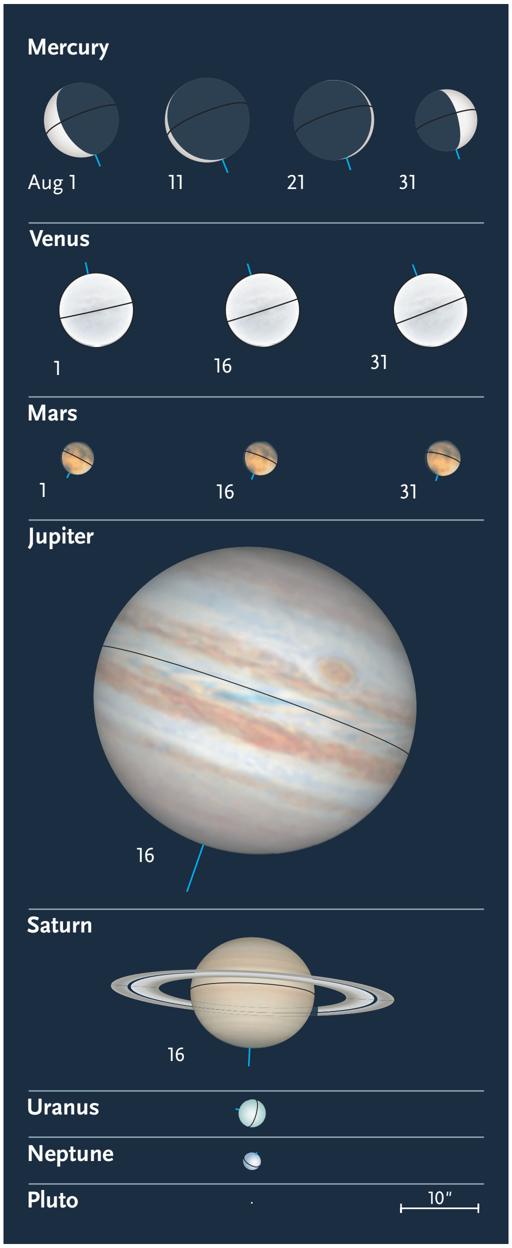
To the unaided eye, M24 looks like a little wisp of steam floating above the Teapot of Sagittarius. And though it's comprised of many, many stars, M24 isn't a cluster but an isolated patch of Milky Way. Indeed, it's regarded as a discrete object primarily because it's bounded on all sides by dark nebulosity. M24 is like a patch of blue sky seen through a hole in the clouds.

In my 10×50s, M24 is a huge, oval-shaped glow oriented roughly northeast by southwest. Superposed on this haze are roughly two dozen individual stars, the brightest of which form a pair of neat little triangles with their apexes nearly touching. Impressive as M24 is, I find the surrounding dark-nebula complexes even more fascinating. Most conspicuous is the finger of darkness that defines M24's southeastern edge.

The extra magnification of my 15×45 image-stabilized binos helps the dark nebulae stand out better, which in turn makes M24 more conspicuous. However, moving up to my 15×70s is a step backward. Although these binos show more stars than the 15×45s, they have a slightly narrower field of view. So they don't include enough of the surrounding star field to show M24 at its best. ✦

— *Gary Seronik*



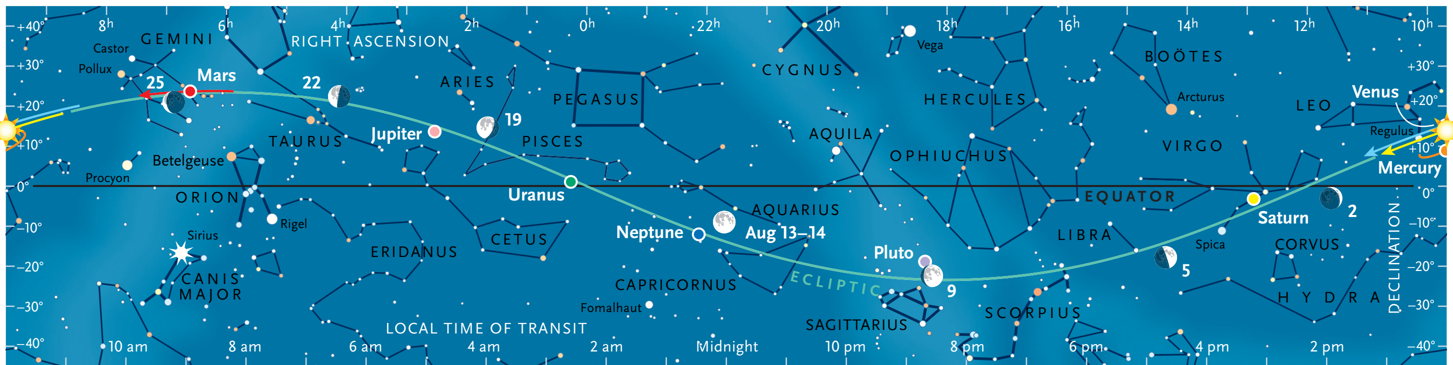


Sun and Planets, August 2011

	August	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$8^h\ 42.8^m$	+18° 12′	—	–26.8	31′ 31″	—	1.015
	31	$10^h\ 35.3^m$	+8° 54′	—	–26.8	31′ 41″	—	1.010
Mercury	1	$10^h\ 06.9^m$	+8° 05′	23° Ev	+1.2	9.7″	24%	0.693
	11	$9^h\ 55.5^m$	+7° 32′	12° Ev	+3.4	11.0″	6%	0.610
	21	$9^h\ 27.1^m$	+10° 56′	8° Mo	+4.1	10.4″	3%	0.646
	31	$9^h\ 27.0^m$	+13° 59′	17° Mo	+0.3	8.0″	31%	0.839
Venus	1	$8^h\ 26.2^m$	+20° 10′	4° Mo	–3.9	9.7″	100%	1.727
	11	$9^h\ 16.6^m$	+17° 05′	2° Mo	–4.0	9.6″	100%	1.731
	21	$10^h\ 05.3^m$	+13° 12′	2° Ev	–4.0	9.6″	100%	1.729
	31	$10^h\ 52.4^m$	+8° 43′	4° Ev	–3.9	9.7″	100%	1.722
Mars	1	$5^h\ 52.3^m$	+23° 43′	40° Mo	+1.4	4.4″	95%	2.129
	16	$6^h\ 35.8^m$	+23° 40′	44° Mo	+1.4	4.5″	94%	2.069
	31	$7^h\ 18.0^m$	+22° 55′	49° Mo	+1.4	4.7″	93%	1.997
Jupiter	1	$2^h\ 27.3^m$	+13° 13′	89° Mo	–2.4	40.6″	99%	4.858
	31	$2^h\ 32.9^m$	+13° 34′	117° Mo	–2.6	44.6″	99%	4.417
Saturn	1	$12^h\ 48.5^m$	–2° 38′	64° Ev	+0.9	16.5″	100%	10.051
	31	$12^h\ 58.5^m$	–3° 46′	38° Ev	+0.9	15.9″	100%	10.434
Uranus	16	$0^h\ 15.4^m$	+0° 50′	139° Mo	+5.8	3.7″	100%	19.309
Neptune	16	$22^h\ 07.4^m$	–12° 09′	173° Mo	+7.8	2.4″	100%	29.001
Pluto	16	$18^h\ 20.9^m$	–18° 59′	132° Ev	+14.0	0.1″	100%	31.390

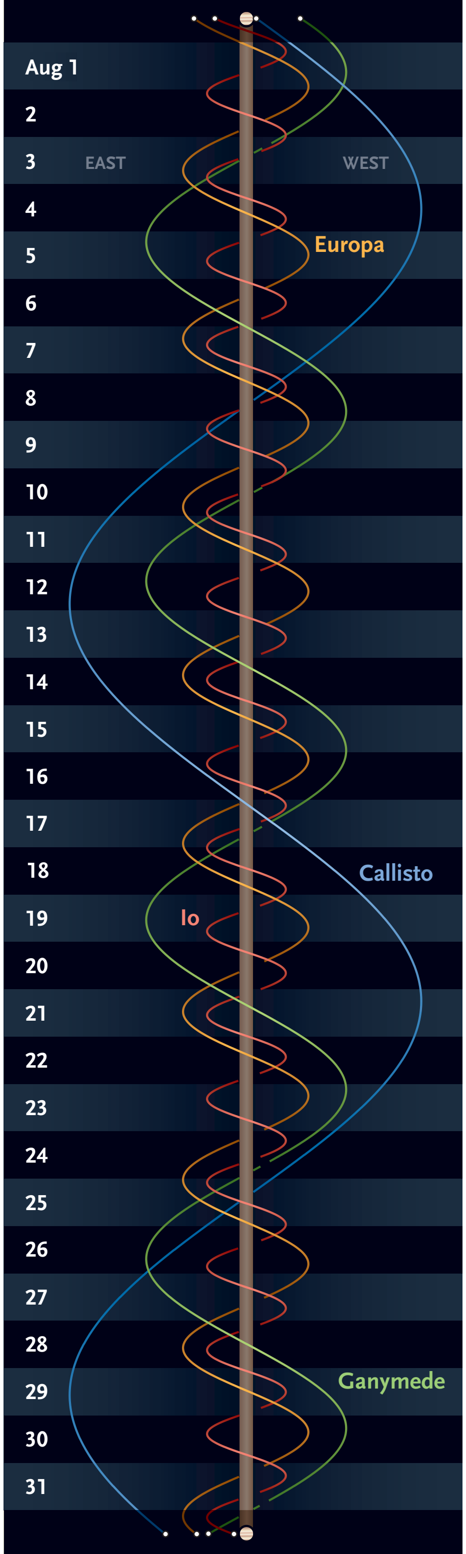
The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial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

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



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

Jupiter's Moons



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

Farewell to the Ringed Planet

August is the last month this year for good evening views of Saturn.

At dusk in August, Saturn is fairly low in the west-southwest. Bright Jupiter rises in late evening, about an hour after Saturn sets. Mars comes up in Gemini well after midnight. By morning twilight Jupiter is high in the south and Mars is well up in the east — with Mercury coming into view far lower left of Mars during the last few days of August.

DUSK AND EVENING

Saturn begins August roughly 25° high in the west-southwest when it first becomes easily visible (about ½ hour after sunset) at latitude 40° north. But by month's end it's less than half that high at the corresponding time of evening, preventing crisp telescopic views.

Saturn, in Virgo, shines at magnitude +0.9 well to the right of almost identically bright Spica. Binoculars show that Saturn continues to move eastward away from 3rd-magnitude Gamma Virginis (Porrima). Telescopes show that Saturn's rings are tilted about 9° from edgewise to Earth.

Pluto, 14th magnitude in Sagittarius, is best observed shortly after the sky grows fully dark. See last month's issue, page 64, for a finder chart.

LATE NIGHT

Jupiter shines around magnitude –2.5 in southwestern Aries. It rises around midnight (daylight-saving time) as August opens and 10 p.m. as the month closes. Jupiter's direct motion (eastward relative to the stars) slows to a halt on August 30th.

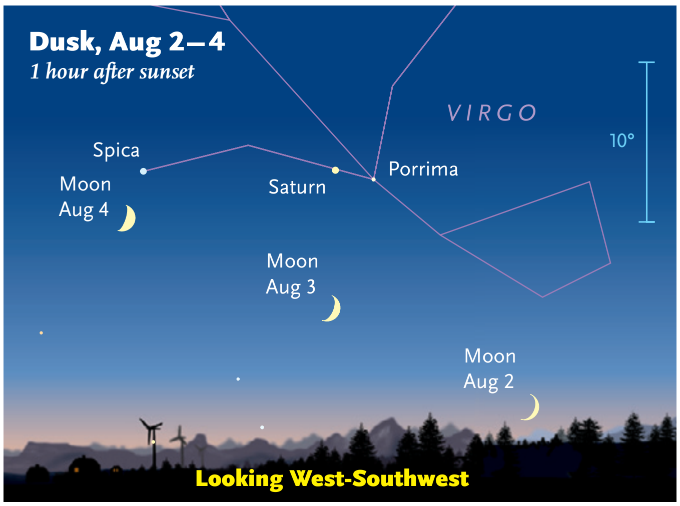
Telescope users will want to view Jupiter at or near the beginning of dawn, when it's quite high in the sky. Jupiter's disk grows from 41″ to 45″ wide in August, and the planet reaches western quadrature (90° west of the Sun) on August 1st. That means Jupiter's moons are at the maximum distance from their shadows as they transit (cross in front of) Jupiter's disk, and the moons spend the maximum amount of time eclipsed in Jupiter's shadow. See the timetable of events on page 54. **SkyandTelescope.com/jupmoons** shows the configuration of Jupiter's moons at any moment.

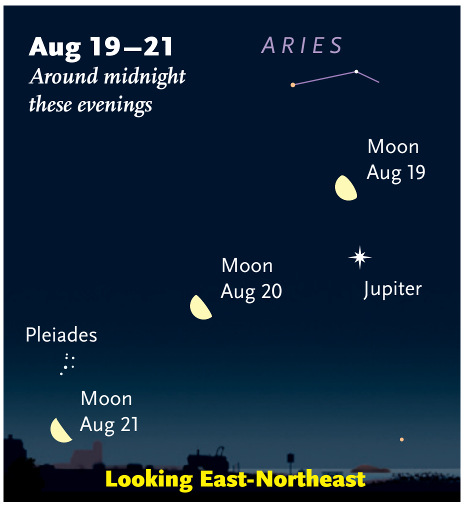
Neptune and the asteroid **Vesta** are at opposition on August 22nd and 5th, respectively, so they're technically visible just about all night long. But it's best to observe them in the middle of the night, when they're highest.

Neptune is in western Aquarius, its 2.4″-wide speck of a disk shining at magnitude 7.8. See page 33 of last month's issue for a finder chart.

Vesta is especially exciting this summer, for two reasons. One is that the Dawn spacecraft should begin its historic orbiting of Vesta in mid-July and reach its lower survey orbit in mid-August. Also, Vesta reaches magnitude 5.6 in the first week of August, its brightest close approach until 2018. That's bright enough to see with the naked eye in a dark sky. Unfortunately for northern observers, Vesta is in Capricornus about 24° south of the celestial equator. See page 53 for more information.

Uranus, shining at magnitude +5.8 near the Circlet of Pisces, rises in the late evening. Its 3.7″-wide disk is best observed when it's highest, not long before





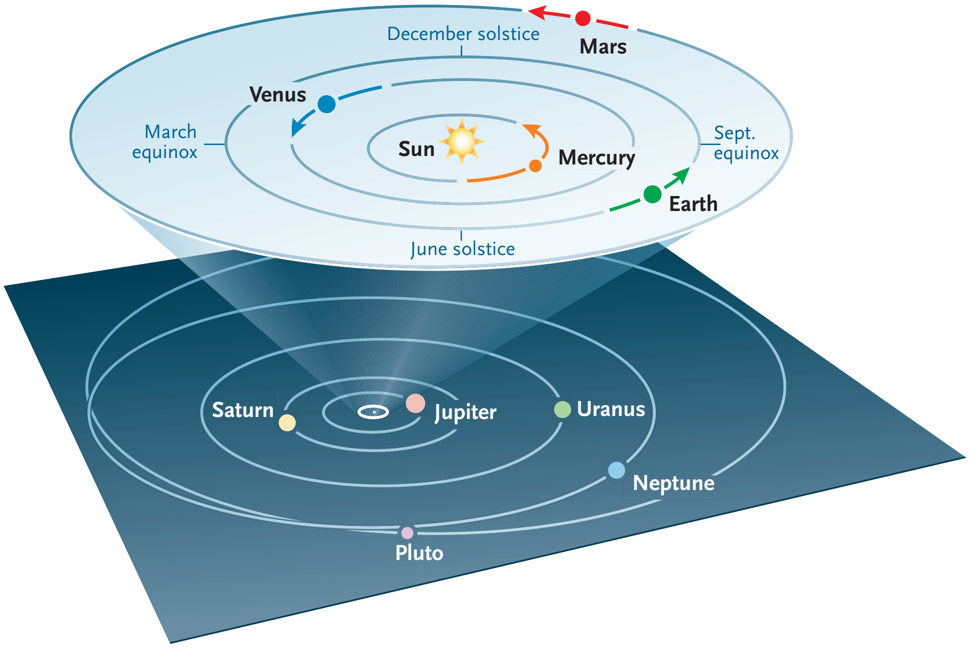
These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist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

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

the onset of morning twilight. See next month's issue or **SkyandTelescope.com/uranus** for a finder chart.

Mars rises around 2 or 3 a.m. in August. Although Mars remains only magnitude +1.4, and its disk appears just 4½″ in diameter, the planet is well worth watching this month as it takes a lovely trek across much of Gemini. Mars appears only about ½° from the big star cluster Messier 35 on August 6th and 7th. On the 18th and 19th Mars is 1½° south of 3.0-magnitude Epsilon Geminorum — Mebsuta, the star it spectacularly occulted for North American viewers 35 years ago. At the end of August the orange-yellow planet shines near 3.5-magnitude Delta Geminorum (Wasat) and forms an elongated triangle with Pollux (distinctly brighter than Mars) and Castor (slightly dimmer than Mars).

By month's end, Mars stands more than 30° above the eastern horizon as the sky grows light.



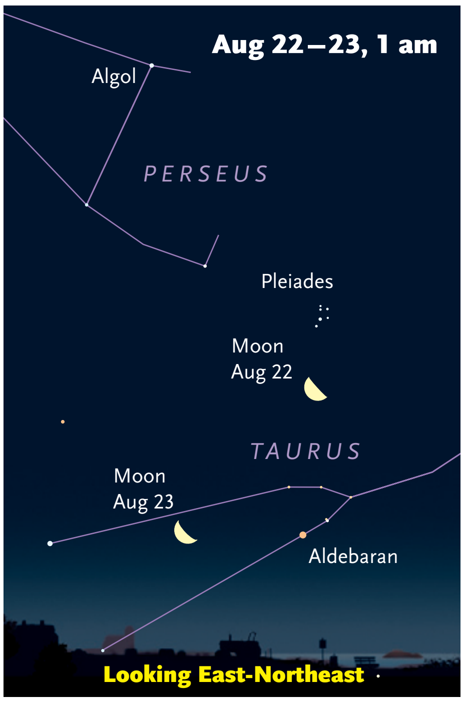
ORBITS OF THE PLANETS

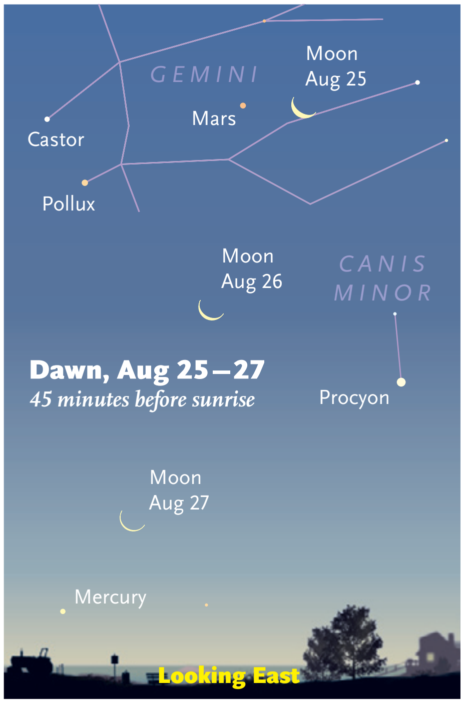
The curved arrows show each planet's movement during August. The outer planets don't change position enough in a month to notice at this scale.

DAWN

Venus is lost from view in August. It leaves the dawn sky, going through superior conjunction (passing behind the Sun), on August 16th. At Venus's next conjunction with the Sun — on June 5–6, 2012 — it will cross the fiery solar face for its second and last transit of the Sun during the 21st century.

Mercury zooms through inferior conjunction on August 17th but is too dim to see in the dawn until the final few days of August. Roughly doubling in brightness every three days, Mercury shines at magnitude +0.3 on August 31st and rises about 1½ hours before the Sun.





MOON PASSAGES

The **Moon** is a waxing crescent well below Saturn on August 3rd and closer below Spica the next evening. The dark edge of the waxing gibbous Moon blots out 2.9-magnitude Pi Sagittarii for the eastern half of North America on the evening of August 10th (see **SkyandTelescope.com/Aug2011Occult**).

The waning gibbous Moon stands not far above Jupiter after they rise late on the evening of August 19th. Just after last-quarter phase, the Moon is straight below the Pleiades around 1 a.m. on August 22nd. The waning lunar crescent floats close to the right of Mars at dawn on August 25th.

On August 31st, the thin waxing crescent is back in the evening sky, forming a triangle with Saturn and Spica. ✦

Large-Scale Lunar Structures

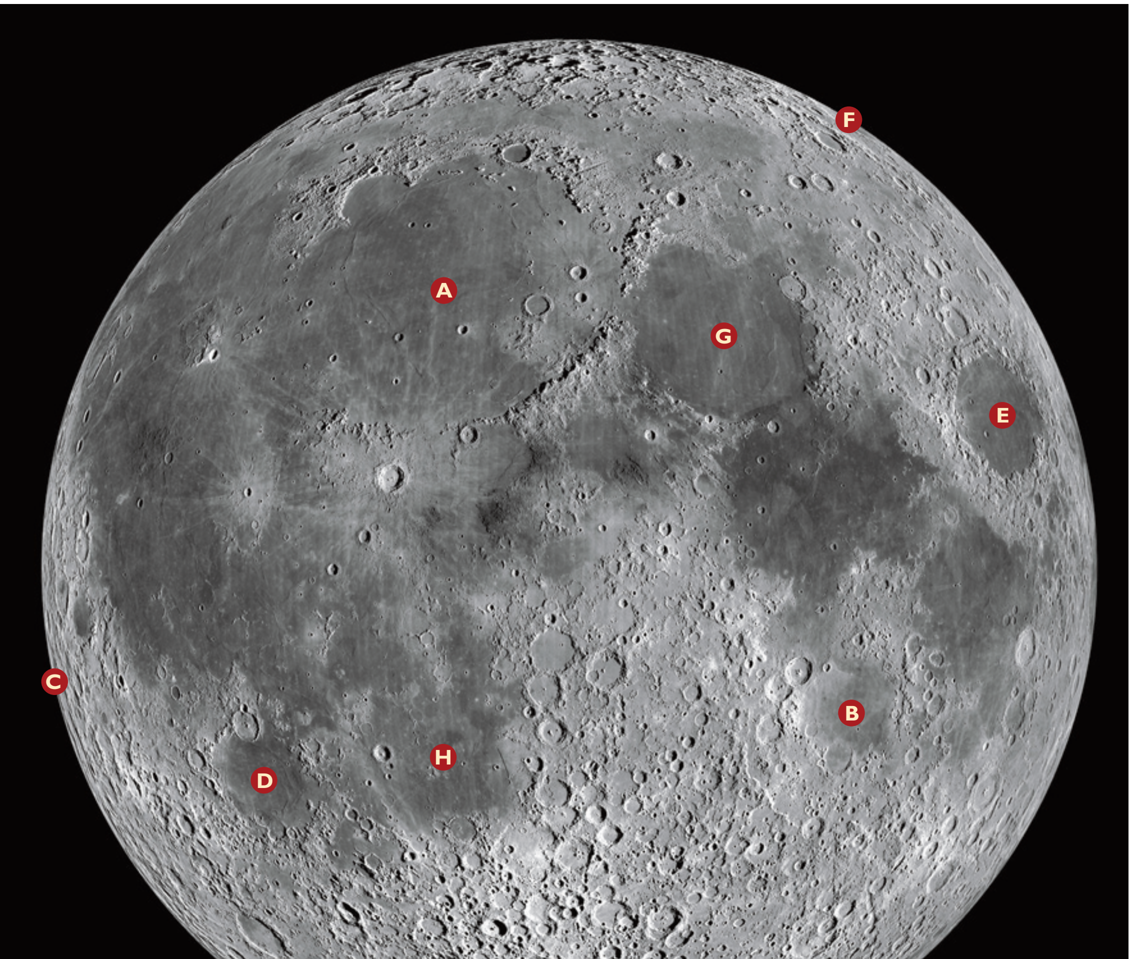
Trace the largest impact basins visible from Earth.

THROUGHOUT ITS EXISTENCE, the Moon has been pummelled by impactors of all sizes. These hypervelocity projectiles gouged pits ranging from microns across all the way up to 1,000-kilometer-wide basins — the very largest craters visible today. The impacts that formed the basins deeply fractured the crust and scattered ejecta across the entire lunar surface. Although basins filled with lava (the maria) are easily visible, the basins themselves were essentially overlooked for centuries. But since 1949, at least eight mare-filled basins have been discovered on the lunar near side.

The Imbrium Basin **(A)**, which includes Mare Imbrium, is the largest observable impact basin. Its most prominent rim segment is Montes Apenninus, one of the most dramatic mountain chains on the Moon, marking the basin's southeast edge. The curved front of these mountains encourages the eye to trace out a bright circular rim that includes Montes Caucasus, Montes Alpes, and the unnamed terrain from Plato past Sinus Iridum. The Apennines also extend to the west as a range of lower and discontinuous peaks known as Montes Carpatus, the Carpathian Mountains.

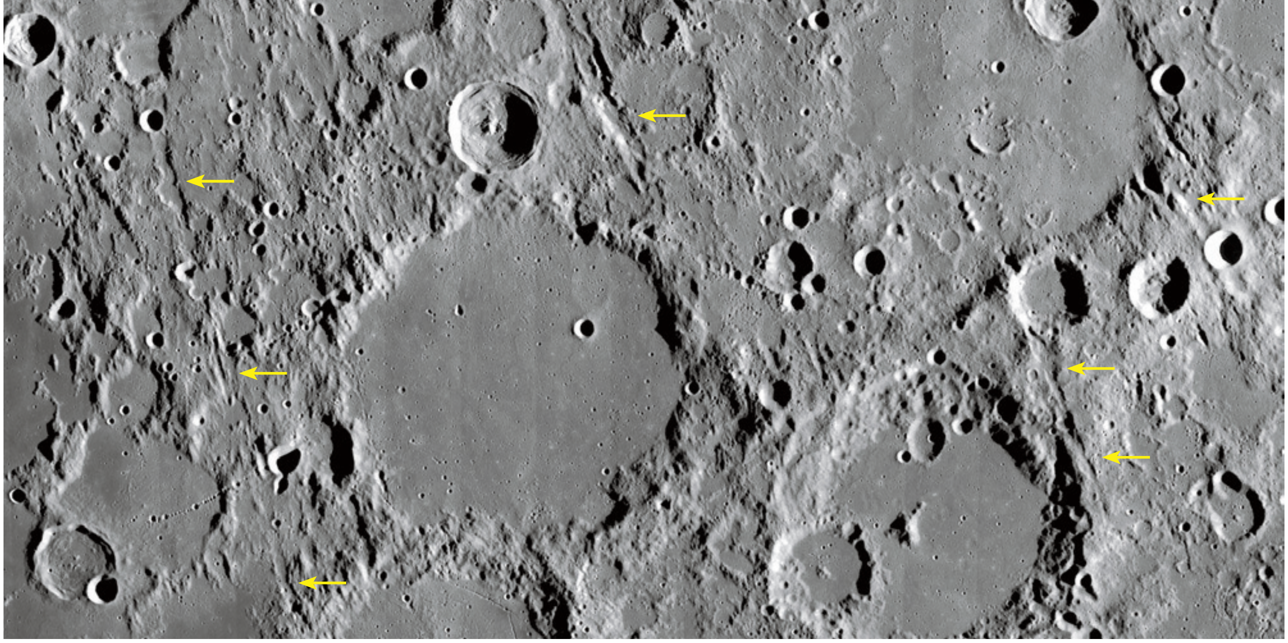
The Moon's second most prominent basin is less inundated with lava than is Imbrium, thus revealing more of its structure. Nectaris Basin **(B)** is bordered by Rupes Altai along its western edge, similar to the Apennines, with a prominent scarp facing the basin's center. The scarp shows that the Altai were either uplifted, or the crust inside subsided. The Altai are much less conspicuous east of crater Piccolomini, with a less-obvious scarp and isolated peaks continuing eastward around crater Colombo. To the north, the basin ring mostly disappears and can only be traced with a dollop of imagination and faith.

Because Nectaris contains just a small patch of mare, two smaller mountainous rings are visible within the larger Altai one. These are best seen on the west side of the basin, particularly when the sunrise terminator is just west of the Altai. The edge of Mare Nectaris is an inner ring, visible as a low scarp from Fracastorius crater bending around toward Bohnenberger on the east. Between this mare edge ring and the Altai Scarp is a broad arc of low hills, made noticeable because of the smoother material on either side of them. Because of the multiple rings that Nectaris and most other basins share, they are often called multi-ring basins.



NASA / GSFC / ARIZONA STATE UNIVERSITY

Overlooked for most of observational history, the rims of the great lunar impact basins are traceable with careful observations and a bit of imagination.



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Deep gouges known collectively as the Imbrium Sculpture are easiest to spot around crater Ptolemaeus. These valleys clearly formed in the cataclysmic impact that created the Imbrium Basin.

The most famous lunar basin is Orientale **(C)**, whose center is located just over the western limb. Recognition of impact basins would have come centuries earlier if this magnificent bull's-eye basin had been centered on the Moon's Earth-facing side. If we had seen it stare down at Earth, perhaps we would have thought we were being spied upon. In any case, Orientale is the Moon's youngest basin, allowing us to see that it has three or four different rings with only slivers of mare inside the main rings and a central puddle of lava known as Mare Orientale.

Having been guided to the ring structures of the three largest basins, you can look for similar multiple rings at Humorum **(D)**, Crisium **(E)**, and along the northeast limb, Humboldtianum **(F)**. It's challenging to identify rings around maria such as Serenitatis **(G)** and Nubium **(H)**, because these basins are older and inundated with mare lavas. If you aren't sure that rings exist there, you're in good company. Professional lunar scientists today differ on the diameters and exact locations of rings for these ill-defined basins.

While observing these basins, recognize that maria and rings are the easiest parts to see. Just as important but harder to notice are the billions of tons of debris that were excavated by the formative impacts and ejected vast distances across the lunar surface. The best-preserved basin ejecta surround the young Orientale Basin. Although its position on the limb makes observing and understanding what we see difficult, massive ejecta flows are just visible southeast of the basin — see Vallis Bouvard — and farther north surrounding and inside the crater Grimaldi.

Great walls of ejecta were also swept away from the Imbrium impact site, scouring walls of pre-existing craters. The resulting ridges and gouges were discovered more than 100 years ago and named the Imbrium Sculpture. These are easiest to see in the area surrounding the crater Ptolemaeus, particularly just to the east of the crater. Pasty flows of ejecta also swept across Montes Haemus and the region near Julius Caesar. In all of these areas, groves and lineations point back accusingly toward their source: the Imbrium Basin. ✦

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

The Moon • August 2011

Phases

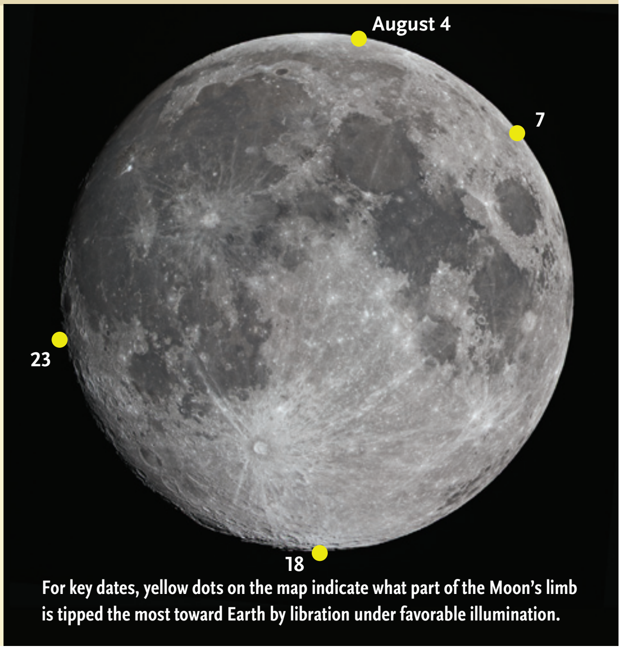
First quarter	August 6, 11:08 UT
Full Moon	August 13, 18:57 UT
Last quarter	August 21, 21:54 UT
New Moon	August 29, 3:04 UT

Distances

Perigee	August 2, 21h UT
225,532 miles	diam. 32′ 55″
Apogee	August 18, 16h UT
249,417 miles	diam. 29′ 46″
Perigee	August 30, 18h UT
226,380 miles	diam. 33′ 12″

Librations

Mare Humboldtianum	August 4
Gauss (crater)	August 7
Cabeus (crater)	August 18
Mare Orientale	August 23



S&T: DENNIS DI CICCO

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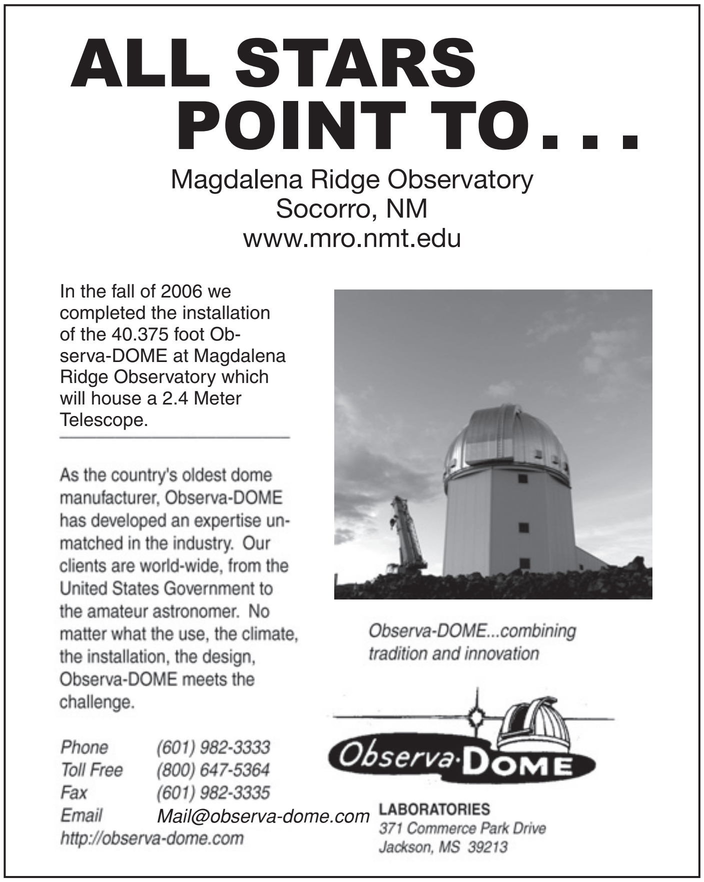
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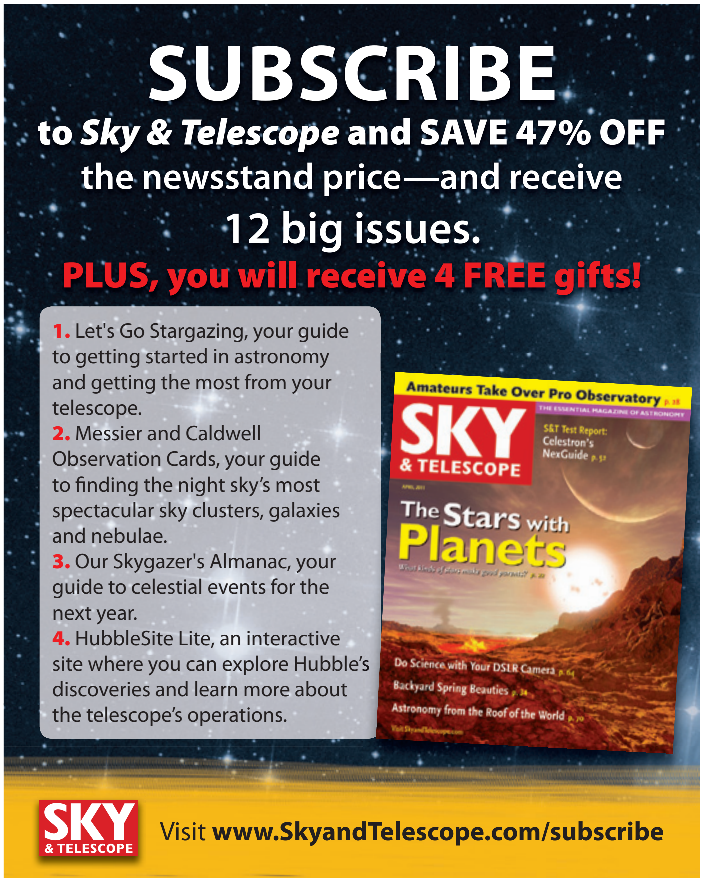
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The Two Brightest Asteroids

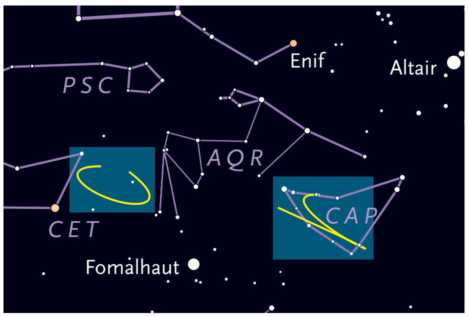
As the Dawn spacecraft images Vesta, with Ceres up next, follow both from your yard.

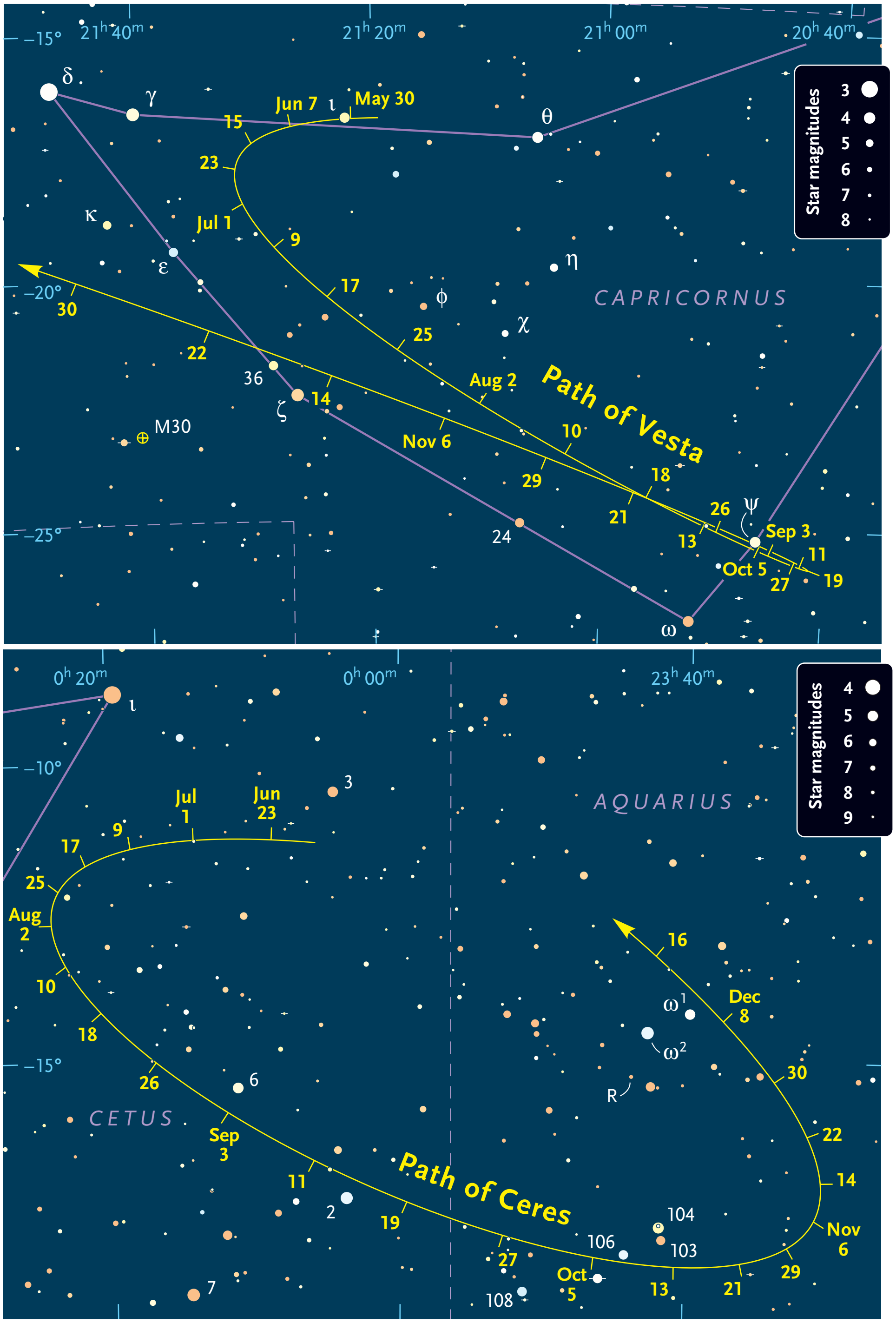
THE TWO BRIGHTEST asteroids inhabit the dim realm south of Pegasus this observing season, when one of them will be making a lot of news. NASA's Dawn spacecraft is set to enter orbit around 4 Vesta in mid-July and begin high-resolution mapping in mid-August. After remaining at Vesta for nearly a year, Dawn will then fly off toward 1 Ceres and take up orbit around it in February 2015.

Both asteroids are visible in binoculars and are easy catches in a low-power, wide-field telescope — if you know where to look.

Vesta is looping through the interior of Capricornus. On July 1st Vesta is magnitude 6.3; on August 1st, 5.7; August 6th (at opposition), 5.6; September 1st, 6.3; October 1st, 7.0; November 1st, 7.5.

Ceres is farther east, looping between the end of Cetus and the water-bucket spills of Aquarius. It's larger than Vesta but fainter, being a little farther from both Earth and Sun and displaying much darker terrain. Its magnitude on July 1st is 8.7; August 1st, 8.4; September 1st, 7.8; September 16th (at opposition), 7.6; October 1st, 7.8; November 1st, 8.4; December 1st, 8.7.

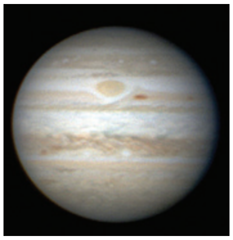




Right: Ticks every 8 days mark the position of Vesta and Ceres at 0:00 Universal Time. (In the time zones of the Americas, this falls on the afternoon or evening of the previous date.) Interpolate between the ticks to put a pencil dot on the track for when you plan to go looking!

Action at Jupiter

EVEN THE SMALLEST TELESCOPE will show Jupiter's four big Galilean moons, and binoculars will usually show at least two or three. Identify them with the diagram on page 47. Listed below are all of their interactions with Jupiter's disk and shadow during August.



The Great Red Spot was at the central meridian when Christopher Go took this stacked-video image on November 9, 2009, with an 11-inch Schmidt-Cass scope.

On Jupiter itself, the dark South Equatorial Belt — which vanished for most of 2011 — had returned as of May as a bicolored pair of bands: red-brown and gray. The North Equatorial Belt was still broad, obvious, and dark red-brown.

Jupiter's most famous marking is its more difficult Great Red Spot. Below are the times and dates (in Universal Time) when the center of the spot should cross Jupiter's central meridian:

August 1, 5:43, 15:38; **2**, 1:34, 11:30, 21:25; **3**, 7:21, 17:17; **4**, 3:13, 13:08, 23:04; **5**, 9:00, 18:55; **6**, 4:51, 14:47; **7**, 0:42, 10:38, 20:34; **8**, 6:29, 16:25; **9**, 2:21, 12:16, 22:12; **10**, 8:08, 18:03; **11**, 3:59, 13:55, 23:50; **12**, 9:46, 19:42; **13**, 5:37, 15:33; **14**, 1:29, 11:24, 21:20; **15**, 7:16, 17:11; **16**, 3:07, 13:03, 22:58; **17**, 8:54, 18:50; **18**, 4:45, 14:41; **19**, 0:37, 10:32, 20:28; **20**, 6:23, 16:19; **21**, 2:15, 12:10, 22:06; **22**, 8:02, 17:57; **23**, 3:53, 13:49, 23:44; **24**, 9:40, 19:36; **25**, 5:31, 15:27; **26**, 1:22, 11:18, 21:14; **27**, 7:09, 17:05; **28**, 3:01, 12:56, 22:52; **29**, 8:48, 18:43; **30**, 4:39, 14:34; **31**, 0:30, 10:26, 20:21. (Assumes the spot is at System II longitude 173°.)

Perseids in the Moonlight

The annual Perseid meteor shower, due to peak on the morning of August 13th, will be mostly mooned out this year. The Moon is full that night, shining as bright as can be from dusk to dawn. Only the brightest meteors will show through the moonlit sky.

Next year will be much better, with the Moon just a waning crescent.

Phenomena of Jupiter's Moons, August 2011

Aug. 1	0:02	II.Tr.I
	2:26	II.Tr.E
	12:51	I.Ec.D
	16:25	I.Oc.R
Aug. 2	10:02	I.Sh.I
	11:25	I.Tr.I
	12:11	I.Sh.E
	13:32	I.Tr.E
	15:25	II.Ec.D
	17:56	II.Ec.R
	18:14	II.Oc.D
	20:39	II.Oc.R
Aug. 3	3:23	III.Ec.D
	5:33	III.Ec.R
	7:19	I.Ec.D
	9:18	III.Oc.D
	10:54	I.Oc.R
	10:57	III.Oc.R
Aug. 4	4:30	I.Sh.I
	5:53	I.Tr.I
	6:39	I.Sh.E
	8:00	I.Tr.E
	10:29	II.Sh.I
	13:00	II.Sh.E
	13:21	II.Tr.I
	15:44	II.Tr.E
Aug. 5	1:48	I.Ec.D
	5:22	I.Oc.R
	22:59	I.Sh.I
Aug. 6	0:21	I.Tr.I
	1:08	I.Sh.E
	2:29	I.Tr.E
	4:42	II.Ec.D
	7:13	II.Ec.R
	7:31	II.Oc.D
	9:56	II.Oc.R
	17:33	III.Sh.I
	19:41	III.Sh.E
	20:16	I.Ec.D
	23:26	III.Tr.I
	23:50	I.Oc.R
Aug. 7	1:00	III.Tr.E
	17:27	I.Sh.I
	18:50	I.Tr.I
	19:36	I.Sh.E
	20:57	I.Tr.E
	23:47	II.Sh.I
Aug. 8	2:18	II.Sh.E
	2:38	II.Tr.I
	5:01	II.Tr.E
	14:45	I.Ec.D
	18:19	I.Oc.R
Aug. 9	11:56	I.Sh.I
	13:18	I.Tr.I
	14:05	I.Sh.E
	15:25	I.Tr.E
	17:59	II.Ec.D
	20:31	II.Ec.R
	20:48	II.Oc.D
	23:12	II.Oc.R
Aug. 10	7:24	III.Ec.D
	9:13	I.Ec.D
	9:33	III.Ec.R
	12:47	I.Oc.R
	13:18	III.Oc.D
	14:51	III.Oc.R
Aug. 11	6:24	I.Sh.I
	7:46	I.Tr.I
	8:33	I.Sh.E
	9:53	I.Tr.E
	13:06	II.Sh.I
	15:36	II.Sh.E
	15:56	II.Tr.I
	18:18	II.Tr.E
Aug. 12	3:42	I.Ec.D
	7:15	I.Oc.R
Aug. 13	0:52	I.Sh.I
	2:14	I.Tr.I
	3:02	I.Sh.E
	4:21	I.Tr.E
	7:17	II.Ec.D
	9:48	II.Ec.R
	10:04	II.Oc.D
	12:28	II.Oc.R
	21:34	III.Sh.I
	22:11	I.Ec.D
	23:40	III.Sh.E
Aug. 14	1:43	I.Oc.R
	3:23	III.Tr.I
	4:52	III.Tr.E
	19:21	I.Sh.I
	20:42	I.Tr.I
	21:30	I.Sh.E
	22:49	I.Tr.E
Aug. 15	2:24	II.Sh.I
	4:54	II.Sh.E
	5:12	II.Tr.I
	7:34	II.Tr.E
	16:39	I.Ec.D
	20:11	I.Oc.R
Aug. 16	13:49	I.Sh.I
	15:10	I.Tr.I
	15:58	I.Sh.E
	17:17	I.Tr.E
	20:34	II.Ec.D
	23:05	II.Ec.R
	23:20	II.Oc.D
Aug. 17	1:43	II.Oc.R
	11:07	I.Ec.D
	11:25	III.Ec.D
	13:33	III.Ec.R
	14:39	I.Oc.R
	17:12	III.Oc.D
	18:41	III.Oc.R
Aug. 18	8:18	I.Sh.I
	9:38	I.Tr.I
	10:27	I.Sh.E
	11:45	I.Tr.E
	15:43	II.Sh.I
	18:13	II.Sh.E
	18:28	II.Tr.I
	20:50	II.Tr.E
Aug. 19	5:36	I.Ec.D
	9:07	I.Oc.R
Aug. 20	2:46	I.Sh.I
	4:05	I.Tr.I
	4:55	I.Sh.E
	6:13	I.Tr.E
	9:52	II.Ec.D
	12:23	II.Ec.R
	12:35	II.Oc.D
	14:58	II.Oc.R
Aug. 21	0:05	I.Ec.D
	1:35	III.Sh.I
	3:34	I.Oc.R
	3:40	III.Sh.E
	7:16	III.Tr.I
	8:40	III.Tr.E
	21:15	I.Sh.I
	22:33	I.Tr.I
	23:24	I.Sh.E
Aug. 22	0:40	I.Tr.E
	5:01	II.Sh.I
	7:31	II.Sh.E
	7:43	II.Tr.I
	10:04	II.Tr.E
	18:33	I.Ec.D
	22:02	I.Oc.R
Aug. 23	15:43	I.Sh.I
	17:01	I.Tr.I
	17:52	I.Sh.E
	19:08	I.Tr.E
	23:10	II.Ec.D
Aug. 24	1:40	II.Ec.R
	1:50	II.Oc.D
	4:12	II.Oc.R
	13:02	I.Ec.D
	15:25	III.Ec.D
	16:30	I.Oc.R
	17:33	III.Ec.R
	21:02	III.Oc.D
	22:27	III.Oc.R
Aug. 25	10:12	I.Sh.I
	11:28	I.Tr.I
	12:21	I.Sh.E
	13:36	I.Tr.E
	18:19	II.Sh.I
	20:49	II.Sh.E
	20:58	II.Tr.I
	23:19	II.Tr.E
Aug. 26	7:30	I.Ec.D
	10:57	I.Oc.R
Aug. 27	4:40	I.Sh.I
	5:56	I.Tr.I
	6:49	I.Sh.E
	8:03	I.Tr.E
	12:27	II.Ec.D
	14:58	II.Ec.R
	15:04	II.Oc.D
	17:26	II.Oc.R
Aug. 28	1:59	I.Ec.D
	5:25	I.Oc.R
	5:36	III.Sh.I
	7:41	III.Sh.E
	11:04	III.Tr.I
	12:25	III.Tr.E
	23:08	I.Sh.I
Aug. 29	0:23	I.Tr.I
	1:18	I.Sh.E
	2:31	I.Tr.E
	7:37	II.Sh.I
	10:07	II.Sh.E
	10:12	II.Tr.I
	12:33	II.Tr.E
	20:27	I.Ec.D
	23:52	I.Oc.R
Aug. 30	17:37	I.Sh.I
	18:51	I.Tr.I
	19:46	I.Sh.E
	20:58	I.Tr.E
Aug. 31	1:45	II.Ec.D
	4:16	II.Ec.R
	4:18	II.Oc.D
	6:39	II.Oc.R
	14:56	I.Ec.D
	18:19	I.Oc.R
	19:26	III.Ec.D
	21:32	III.Ec.R

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 4 hours ahead of Eastern Daylight Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

Today we head out to Australia's astronomy corridor. We'll traverse the UNESCO World Heritage Site Blue Mountains, preserved because of their unique mix of rain forest, blue mists, golden red sandstone escarpments, eucalyptus forest, and canyons. We'll pause in Katoomba to take in the view of The Three Sisters, and head into Central New South Wales for lunch in a country town. Our journey continues through picturesque farmland, arriving at Parkes in late afternoon. We'll have a relaxing dinner and take an informal first look at Southern Hemisphere skies.

Breakfast, lunch, and dinner provided.

DAY 4: Nov. 11

Visit Parkes Observatory

Wake up in Parkes hotel
Breakfast, 7am
Check-out/leave hotel at 8:30am
Arrive Parkes Observatory 9am
Lunch at Parkes Noon to 1pm
Leave Parkes 1:15pm
Arrive hotel in Coonabarabran at 4:30pm
BBQ dinner at Coonabarabran hotel (Matthew Flinders), 5pm
Depart hotel 7:30pm for nighttime observing
Night-time Southern sky observing at 8pm (weather permitting)
Back at hotel in Coonabarabran at 10pm
Spend night in Coonabarabran hotel

This morning we head up the Newell Highway to the Australia Telescope National Facility, Parkes Observatory: The Dish. While we can't enter the observatory building itself, we'll receive exclusive briefings on the radio astronomy work executed with the 64-meter parabolic dish, and learn about Parkes' role in the Apollo 11 Moon landing, and other Apollo missions. Punctuated by the rumbling and whine that signals the movement of the dish, we'll wrap up our visit with lunch at The Dish Cafe (Elvis recommends the scones) and memorable photo ops.

After lunch it's onward to Coonabarabran, Astronomy Capital of Australia. With luck, we'll see emus, and with a lot of luck, we may spy kangaroos and koalas in the landscape. 5pm-ish we'll check in to our classic country motel, and unwind over a poolside barbeque. After dinner, we'll go to a local commercial observatory, and beneath a canopy of stars, tour the southern sky with a Siding Spring astronomer.

Breakfast, lunch, and dinner provided.

DAY 5: Nov. 12

Visit Siding Spring Observatory

Wake up in Coonabarabran
Breakfast, 7am
Check-out/leave hotel at 8:30am
Arrive Siding Spring, 9am
Depart Siding Spring, Noon
Sandwiches on bus
Arrive Tamworth Airport 3:30pm
Depart for Cairns at 5pm
Arrive Cairns 10:30pm
Check into hotel (Shangri-La) at 11:30pm

Wake up in Coonabarabran to the sound of parrots and kookaburras. We'll have a simple country breakfast, and head into Warrumbungle National Park. We head through eucalyptus forests, past the World's Largest Solar System Drive to Siding Spring Observatory, Australia's premier optical astronomy center, atop Mt. Woorut. Get the scoop on cutting-edge tools and exploration at the Australian Astronomical Observatory with an exclusive briefing, and visit some of the dozen other observatories on site.

We're off, then, through New South Wales' "New England" region, headed to Tamworth and our transfer to Cairns, Queensland, and our base at the Shangri-La Hotel.

Breakfast, lunch, and dinner provided.

DAY 6: Nov. 13

The Great Barrier Reef

Breakfast in Shangri-La, 7am

All aboard at 8:30am for a Big Cat Green Island Reef Cruise. On a smooth-sailing catamaran, we head for the Great Barrier Reef World Heritage Area, one of the Seven Natural Wonders of the World. On a 6,000-year-old coral cay, Green Island National Park's tropical vine forest is home to 60 species of birds. Offshore in the surrounding reef live green and hawksbill turtles, clams, fish, stingrays, and a diversity of creatures.

Your cruise includes five hours on Green Island, a semi-sub coral-viewing tour, the choice of a glass-bottom boat tour or snorkelling equipment for the day, a fish feeding display, lunch, and self-guided island walks. The Big Cat cruise ends at 5pm with a transfer back to our hotel in Cairns.

You're on your own for dinner, but our hotel is right on the water, downtown Cairns. Every imaginable food option, and price range, from dozens upon dozens of restaurants, is within a 10-minute walk. For those tuckered out by snorkeling all day at The Reef, either the fancy Aisan Fusion restaurant, or the water front full-service cafe, both on the property of the Shangri-La, are fine choices!

Breakfast and lunch provided.

DAY 7: Nov. 14

ECLIPSE DAY ... at Dawn

Choices choices! Early this morning we leave the Shangri-La for our pre-selected eclipse viewing site options.

Option One: On the Beach
You can settle in at our gorgeous beach selected for weather and viewing prospects, positioned above the high-tide line for the entire eclipse experience, with exclusive use of an ocean-front cafe. We'll have a breakfast buffet going before, during, and after the eclipse ... just a 30-second walk down from the water's edge and equally "distant" to your camera equipment. We have rooms booked right next door in a charming, tropical motel ... a place to store your equipment or recharge your batteries.

Options Two and Three: In The Outback
You can choose to head to the statistically sunniest spot in the Outback, on the dry side of the Great Dividing Range. Once there, you have two options:

- Observe on the ground at a site in the Outback
- Hop into a hot air balloon in Mareeba (guaranteed to the first 45 people who book; any unused by the first 45 will be assigned to people in the order in which they book) optimizing our position for eclipse viewing "on the fly."

Tonight, join us for an eclipse celebration reception, by the sea, followed by a sit-down dinner of regional foods.

Data for our approximate viewing sites:

The Beach
Total duration is 2 minutes and 0.2 seconds.

Event	Local Time	Alt.*
1st contact:	5:44:40.8 AM	1˚
2nd contact:	6:38:26.6 AM	14˚
Mid eclipse:	6:39:26.7 AM	14˚
3rd contact:	6:40:26.8 AM	14˚
4th contact:	7:40:13.5 AM	28˚

The Outback – Balloon launch site:
Total duration is 1 minute and 40.2 seconds.

Event	Local Time	Alt.*
1st contact:	5:44:54.8 AM	1˚
2nd contact:	6:38:44.0 AM	14˚
Mid eclipse:	6:39:34.1 AM	14˚
3rd contact:	6:40:24.2 AM	14˚
4th contact:	7:40:13.1 AM	28˚

For those not ballooning, we'll head north a few clicks:
Total duration is 1 minute and 58.8 seconds.

Event	Local Time	Alt.*
1st contact:	5:44:38.6 AM	1˚
2nd contact:	6:38:15.3 AM	13˚
Mid eclipse:	6:39:14.7 AM	14˚
3rd contact:	6:40:14.1 AM	14˚
4th contact:	7:39:48.1 AM	28˚

*Alt. – Atltitude of the Sun over the horizon

DAY 8: Nov. 15

Fly Home

Check-out/leave Cairns hotel, 10am
Fly home from Cairns; arrive LAX 7pm, Nov. 15

Insight Cruises
THE JOURNEY WITHIN

CST# 2065380-40

The Eagle and the Shield

A rich patch of Milky Way adorns these constellations.

Messier 11 (left center) is prominent near the northeastern corner of the Scutum Star Cloud, as seen in this photograph by *S&T* senior editor Dennis di Cicco.

Often linked in heraldry and emblems of state, the eagle and shield are everlastingly bonded in the starry sky as the neighboring constellations Aquila and Scutum.

Scutum, the Shield, is a small and dim constellation with two great claims to fame: the magnificent Scutum Star Cloud and the stunningly beautiful open cluster Messier 11.

The **Scutum Star Cloud** is a splendid bright patch in the Milky Way roughly 5° across. It's visible to the unaided eye in a dark sky, while binoculars reveal a pointillistic haze draped with brighter loops and chains of stars. The renowned American astronomer Edward Emerson Barnard praised this cloud, calling it "the gem of the Milky Way."

When we gaze at the Scutum Star Cloud, we're looking through an unusually clear window, relatively unsmudged by the obscuring dust lining much of the Milky Way. This window allows us a 20,000-light-year line of sight through the Sagittarius spiral arm and deep into the stars of the great Scutum-Centaurus arm as it leaves our galaxy's thick central bar and curves toward us.

At a distance of 6,100 light-years, **Messier 11** is projected against the northeastern edge of the teeming Scutum Star Cloud. M11 is a beautiful thing to behold in any telescope. Through my 130-mm refractor at 23×, the main mass is a sparkly mix of crystalline specks and powder with a brighter shard embedded in its southeastern edge. In the same direction, a prominent star pair attends the sparse fringes of the cluster. At 102×, gleaming rafts of stars fractured by dark lanes comprise the large, densely settled core, which is sheltered by a bedraggled eastward-pointing V of suns. My 10-inch scope at 68× bares about 100 stars, most in a 5′ core curiously broken into rectilinear bars. The thinly scattered sparks of the halo swell M11 to 11′.

M11's angled core and outlying V inspired William Henry Smyth to write in his 1844 *Bedford Catalogue* that the cluster "somewhat resembles a flight of wild ducks in shape." Thus the group's popular nickname, the Wild Duck Cluster, was born.

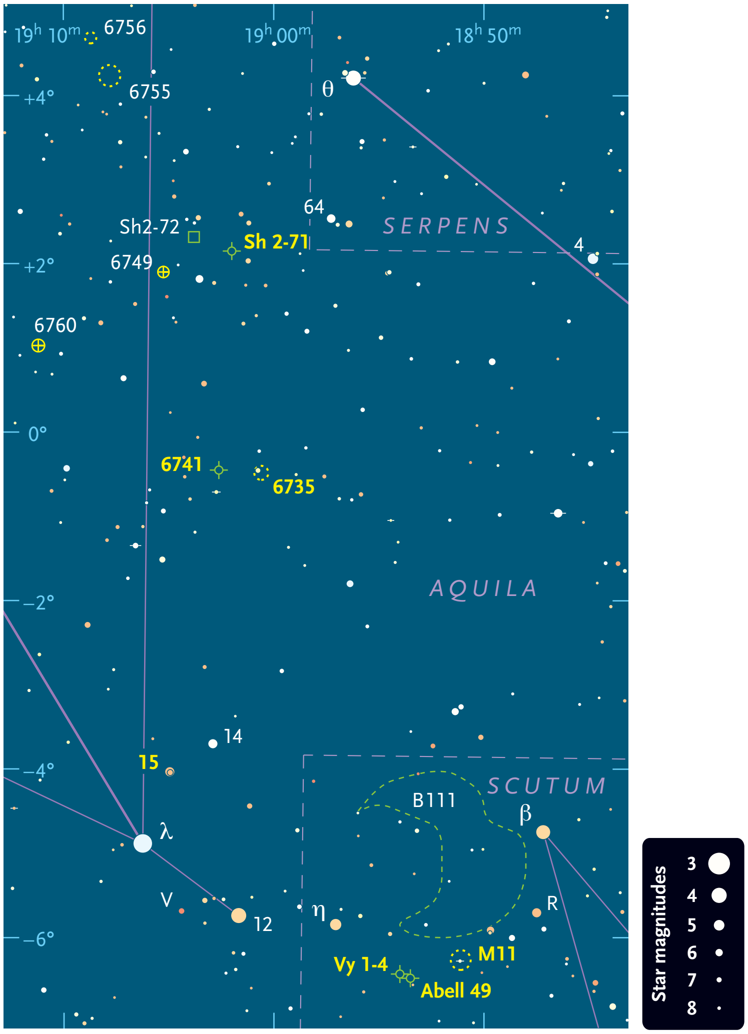
Two obscure planetary nebulae lie east-southeast of M11. The first, **Vyssotsky 1-4** (PK 27-3.2), is 45′ from the cluster's center and visible in my 130-mm scope at 102× as the southern of two close faint "stars." Adding an oxygen III (O III) filter makes the identification certain, as the planetary looks brighter and the star disappears. Vy 1-4 is clearly visible as a 14″ disk through my 10-inch reflector at 299×. In a filterless view it seems brighter in the center, but with an O III filter it exhibits uniform surface brightness. Through my 14.5-inch reflector at 245×, the nebula's central star is intermittently visible. The star's visual magnitude is listed as 15.6, but that value may be in error by as much as a half magnitude.

The second planetary is **Abell 49** (PK 27-3.1), located 8.7′ west-southwest of Vy 1-4 and 2.2′ southeast of a 9th-magnitude star. It's visible only through large telescopes — and even then it's challenging quarry. From my semirural home, I could barely detect it with my biggest scope, a 15-inch reflector. At 192× with an O III filter, the nebula was very elusive even with averted vision. It looks round and is more than twice the diameter of Vy 1-4. Abell 49 sits at the right angle of the triangle it makes with the 9th-magnitude star and an 11th-magnitude star 1.7′ southwest.

Crossing constellation boundaries eastward takes us to the tail of Aquila, the Eagle, where we find the pretty optical double star **15 Aquilae**. This bright, yellow-orange pair is widely split with my 130-mm refractor at 23×. Unlike a *physical* double, an *optical* double is a chance alignment of two independent stars. Different parallaxes for the components of 15 Aquilae indicate that they lie different distances away from us.

Similar in brightness to 15 Aquilae, the white star 14 Aquilae lies 37′ to its west-northwest. From there we can sweep 3.3° north to the planetary nebula NGC 6741 and the open cluster NGC 6735.

NGC 6735 is easier to find because it contains a 7.2-magnitude yellow star, the brightest star within a degree of that spot. Through my 130-mm scope at 37×, 10 very faint stars flock around the bright one, like a frugal version of winter's Tau Canis Majoris Cluster (NGC 2362). At 102×, the cluster expands to include 35 faint to very faint stars spread across 10′, with the topaz gem offset northeast of the group's center.

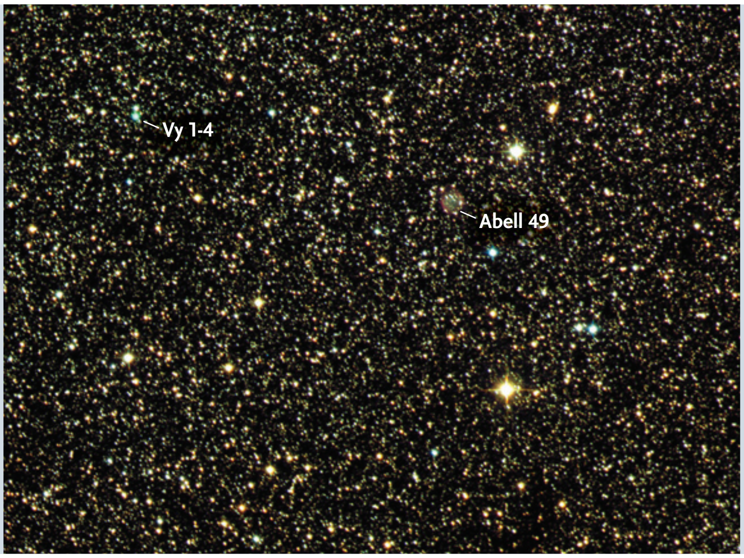


Use this photograph below to track down small, intense Vyssotsky 1-4 and elusive Abell 49. The 8th-magnitude star near the lower-right corner of the photo is plotted on the chart above.

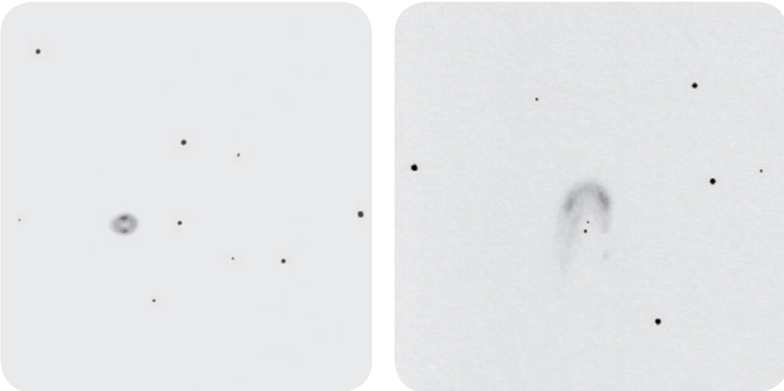
Treasures of Scutum and Aquila

Object	Type	Mag(v)	Size/Sep.	RA	Dec.
Messier 11	Open cluster	5.8	11′	18^h 51.1^m	−6° 16′
Vy 1-4	Planetary nebula	13.6	15″	18^h 54.0^m	−6° 26′
Abell 49	Planetary nebula	16.2	35″	18^h 53.5^m	−6° 29′
15 Aql	Double star	5.5, 7.0	40.5″	19^h 05.0^m	−4° 02′
NGC 6735	Open cluster	—	10′	19^h 00.6^m	−0° 29′
NGC 6741	Planetary nebula	11.4	9″ × 7″	19^h 02.6^m	−0° 27′
Sh 2-71	Planetary nebula	12.3	2.1′ × 1.3′	19^h 02.0^m	+2° 09′

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



STEFAN BINNEWIES / JOSEF PÖPSEL



German stargazer Uwe Glahn sketched NGC 6741 (*left*) as seen at 720× with no filter through his 16-inch Dob, and Sharpless 2-71 as seen at 257× with an O III filter through the same scope.

ADAM BLOCK / NOAO / AURA / NSF

Sharpless 2-71 shows in exquisite detail in this 105-minute exposure through a 20-inch telescope.

NGC 6735 was discovered in 1827 by John Herschel, whose position refers to the bright star rather than the center of the cluster. Although there is certainly a group of stars visible here, NGC 6735 was deemed nonexistent in the *Revised New General Catalogue* (Sulentic and Tifft, 1973) and is absent from many lists of deep-sky objects.

NGC 6741 is 30′ east of NGC 6735 and 2.7′ south of a 10.7-magnitude star. This little planetary is small, round, moderately bright, and bluish through my 130-mm scope at 102×. At 273×, it appears slightly oblong east-west. In my 10-inch scope, the nebula's hue is blue-green, and a faint star guards its western end. At high magnifications, some observers have noticed NGC 6741's brighter northern and southern rims. Can you?

NGC 6741 is sometimes called the Phantom Streak. I was curious about this nickname, which likely originated with John Mallas's article *Visual Atlas of Planetary Nebulae* V (June/July 1963, *Review of Popular Astronomy*). *S&T* senior editor Dennis di Cicco and planetary-nebula guru Kent Wallace came to my rescue with the article's text. Mallas writes:

> The "Phantom Streak." First you see it and then you don't. . . . In the 4-inch after it was located, and using high powers, NGC 6741 looks like a broad silver line. Almost uniform in brightness, the ends appear broken and diffused. . . . My visual impression agrees with H. D. Curtis's description of this object. He states: "It shows some trace of a ring structure, being somewhat fainter along the major axis."

Our final target is the fascinating planetary nebula **Sharpless 2-71** (PK 36-1.1). Drop 1.7° south from the bright U of stars that includes the double Theta (θ) Serpentis to the arc of three stars containing 64 Serpentis. Just 1° eastward you'll find a pair of golden-hued 7th-magnitude stars with a similar star ½° to their south. Sh 2-71 sits 14′ east-northeast of the southern star and is inscribed in the head of a 9′ eastward-pointing arrow of four 9th- to 12th-magnitude stars.

In my 130-mm refractor at 91×, Sh 2-71 is a borderline-visible, north-south glow. Nebula filters make it vanish. The planetary is easier at 117× and appears oblong with a star near the center. At 164× the star stands out better, and the 2′ × 1′ nebula may be slightly darker in the center. Folks with larger telescopes have confirmed the central void and also noted a fading of the nebula at its southern end as well as a dimmer star north-northwest of the one I saw. Deep images show that the dimmer star is actually a very close pair. The star I saw is often given as the planetary nebula's central star, but a recent study indicates that a 19th-magnitude star immediately to its northwest is a better candidate. ✦

Sue French *welcomes questions, comments, and observing reports at scfrench@nycap.rr.com.*

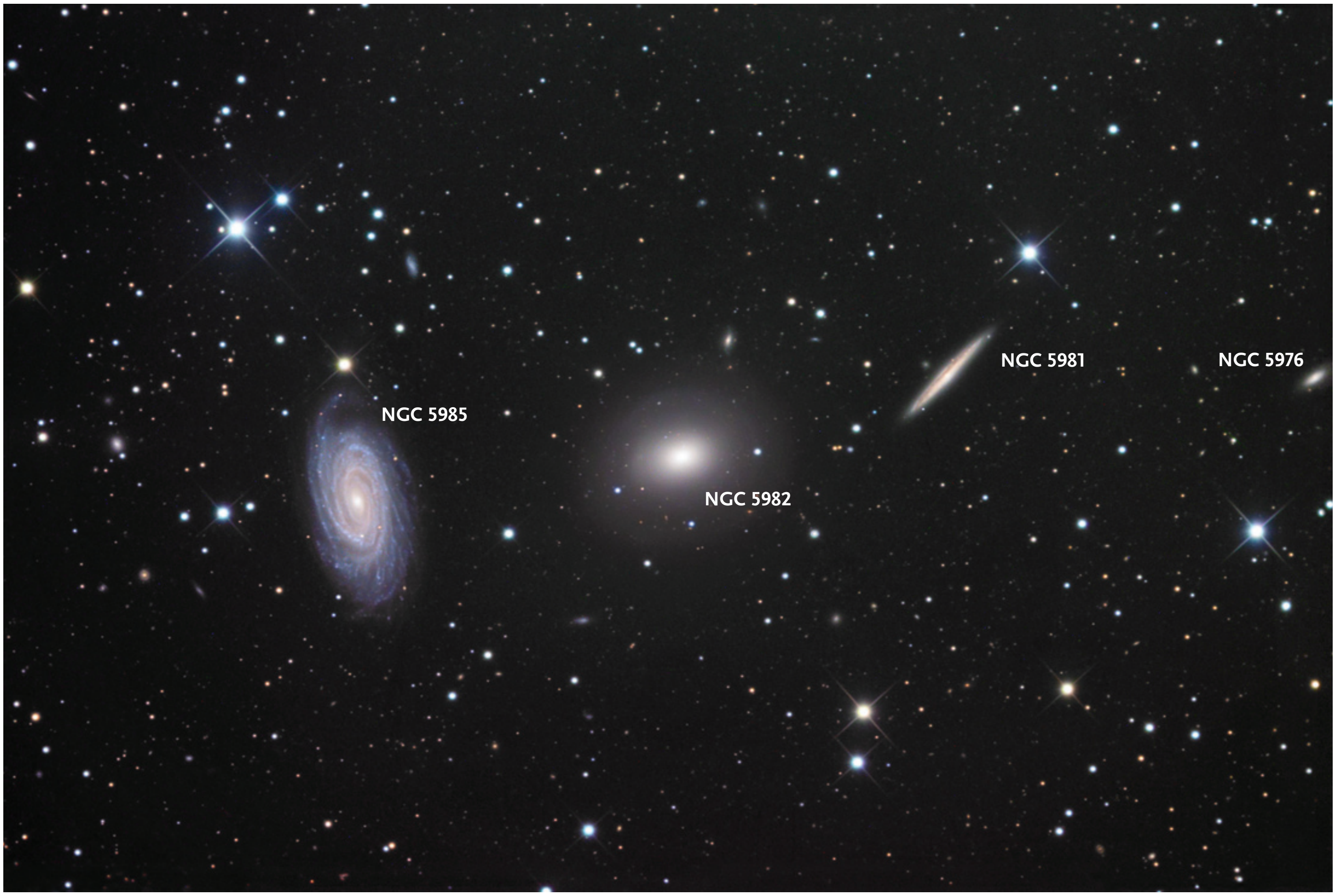
A Galaxy Sampler in Draco

Three strikingly different galaxies line up side by side.

IN HIS REVIEW of George R. Kepple and Glen W. Sanner's *The Night Sky Observer's Guide* (*S&T*: July 1999, page 78), my observing colleague Lee Johnson had space to discuss only a few of this book's thousands of deep-sky entries. He chose one of his favorite groupings as an example: a tiny area in Draco containing a face-on galaxy, an elliptical galaxy, and an edge-on galaxy. Lee noted that his wife called this intriguing trio the Sampler.

You'll find the Sampler less than 2° east-northeast of 3.3-magnitude Iota (ι) Draconis. Arranged in a 15′-long row, oriented east-southeast to west-northwest, the galaxies make an attractive medium-power field. The descriptions below focus on each member of the set, plus a few smaller galaxies nearby. I made the observations at several high-elevation sites in southern British Columbia with my 17.5-inch f/4.5 Dobsonian reflector unless otherwise noted.

The easternmost galaxy, **NGC 5985**, is a tightly wound spiral. About 5.5′ × 3.0′ in extent, NGC 5985 is certainly the largest, if not the most prominent, member of the Sampler. Its magnitude of 11.1 is tempered by a modest surface brightness of magnitude 14 per square arcminute. At 166× I see a diffuse cloud elongated 2:1. Its major axis is essentially perpendicular to the line of galaxies, and

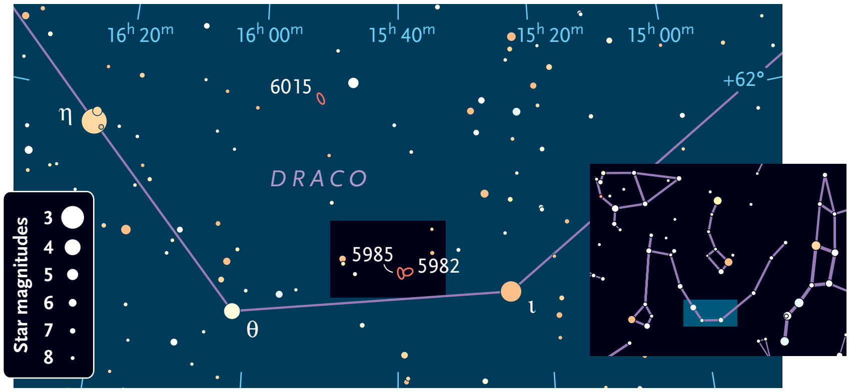


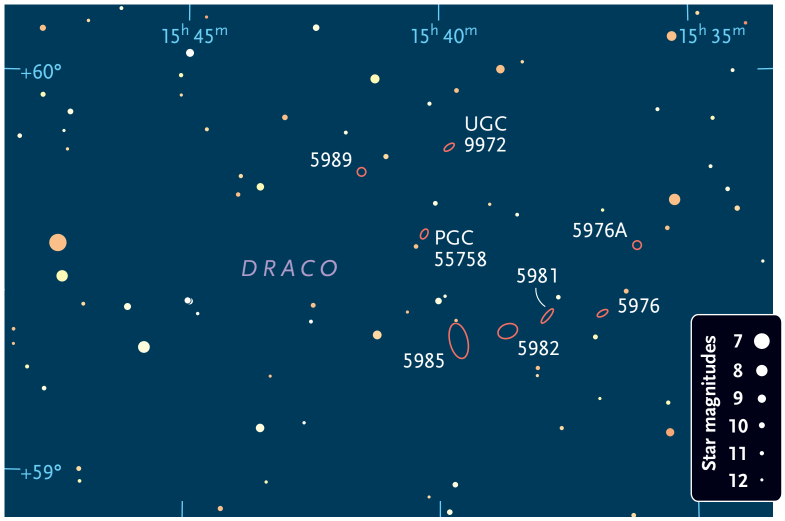
ROBERT GENDLER

it aims at an 11.5-magnitude star immediately north. At 222× the object brightens toward an oblong core less than 1′ in length. A magnification of 285× picks up a vague patchiness north and south of the core. Lee Johnson has glimpsed a portion of two opposing spiral arms with his 17.5-inch scope, but I didn't notice them the night I centered the galaxy in a friend's 20-incher at 400×. My goal next time out is to grab those arms!

The middle object, **NGC 5982**, is a moderately elongated elliptical galaxy. It's 2.6′ × 1.9′ in extent, the long dimension nearly in line with the row. Although it possesses the same total magnitude as its neighbor to the east, NGC 5982 stands out better thanks to a surface brightness of magnitude 12.9 per square arcminute. Other than that, NGC 5982 boasts no unusual features. An eyepiece yielding 222× reveals an oval fuzz that brightens strongly toward a tack-sharp nucleus in the middle. When the sky is very dark and transparent, my averted vision can pick up a tenuous halo all around. This three-part structure reminds me of the popular Cat's Eye Nebula (NGC 6543), also in Draco, whose slightly elliptical disk is accompanied by a bright nucleus (the central star) on the inside and an exceedingly faint halo on the outside.

The western galaxy, **NGC 5981**, is another spiral but viewed essentially edge on. The 13.0-magnitude sliver measures 2.7′ × 0.3′, oriented southeast-northwest, with a 10.8-magnitude star 3′ off its northwest end. Because of its small size, modest total brightness, and low surface brightness, NGC 5981 is the least prominent member of the trio. But this diminutive spindle provides the contrast in shape that makes the Sampler so appealing — and it rewards patient scrutiny. Beginning at around 150× I see wispy, tapered "wings" extending from a broad central bulge. I can't detect the dust lane directly, but at high





power the galaxy's northeast flank seems sharper than the opposite side, indicating that a dark thread runs along that edge. I've confirmed this subtle detail using the 20-incher mentioned earlier.

In his book review, Lee Johnson noted that the *Observer's Guide* neglected to mention three other NGC galaxies near the Sampler. No wonder; the biggest is just 1′ across. **NGC 5976**, a 15th-magnitude smudgy dot 8′ west of NGC 5981, fails to turn the trio into an obvious quartet. A further 12′ northwest is **NGC 5976A** (also called PGC 55561), which I consider a bit easier than NGC 5976. Only ½° northeast of the chain is 13.1-magnitude **NGC 5989**, a round patch with a bright center. Those who enjoy challenges should look almost 14′ west-northwest of **NGC 5989** for tiny **UGC 9972** (also called PGC 55734). Likewise, **PGC 55758** is just northwest of a 10.7-magnitude star halfway between NGC 5989 and NGC 5985.

The Sampler's high declination (+59°) means that it's circumpolar for mid-northern observers. The trio is well placed all summer long, so give it a try sometime soon. ✦

Galaxies in Draco Sampler

Galaxy	Mag. (v)	Size	RA	Dec.
NGC 5985	11.1	5.5′ × 3.0′	$15^h\ 39.6^m$	+59° 20′
NGC 5982	11.1	2.6′ × 1.9′	$15^h\ 38.7^m$	+59° 21′
NGC 5981	13.0	2.7′ × 0.3′	$15^h\ 37.9^m$	+59° 23′
NGC 5976	14.8	0.8′ × 0.4′	$15^h\ 36.8^m$	+59° 24′
NGC 5976A	14.6	1.0′ × 1.0′	$15^h\ 36.1^m$	+59° 34′
NGC 5989	13.1	0.9′ × 0.9′	$15^h\ 41.5^m$	+59° 45′
UGC 9972	14.9	1.0′ × 0.4′	$15^h\ 39.8^m$	+59° 49′
PGC 55758	15.3	0.5′ × 0.3′	$15^h\ 40.3^m$	+59° 36′

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

*Vancouver Canucks fan **Ken Hewitt-White** samples galaxies from the mountains of southern British Columbia.*

A Simple Hinge Tracker

You can make this mount even if you've never built anything more complicated than IKEA furniture.

WOULD YOU BELIEVE that the photograph below was captured with a camera riding on a tracking mount that costs less than $10, takes less than an evening to assemble, and doesn't require batteries? It's true. Meet the hinge tracker.

If you're like most *Sky & Telescope* readers with a DSLR camera, you've considered dipping a toe into the astrophotography waters. But a camera is only part of the equation. Unless you're only interested in shooting star-trail images, a tracking mount is necessary for exposures longer than a few seconds. Most suitable mounts are relatively bulky, or expensive, or both. But not the hinge tracker. And best of all, it's so simple to make that anyone can build one. The most sophisticated tool I used to make mine was an X-ACTO knife.

Parts and Assembly

The heart of my tracker is a heavy-duty, 8-inch strap hinge made by Stanley Hardware. You can use any brand — the crucial parameter is the distance from the *center* of the hinge pin to the *center* of the hole at the far end of the hinge, which should be close to 7 3⁄16 inches (183 mm). You'll also want a hinge that has minimal play, which is why I like the Stanley model. It has nylon bushings between hinge halves, providing a smooth, sturdy assem-

This view of the Milky Way around the tail of Scorpius was captured with a Nikon D200 DSLR camera riding on the hinge mount described here. One of the tracker's great virtues is that it's portable enough to fit into any suitcase. The author took this photo during a trip to Costa Rica.

ALL PHOTOGRAPHS BY THE AUTHOR

bly. When you're at the hardware store, try a few out and pick the one that has the best feel.

The second important part of the hinge tracker is the drive screw. It must have 32 threads per inch, or the mount won't track at the correct rate. I used a 2-inch-long, 10-32 brass screw for my mount, but the material it's made of isn't critical. You'll also need a few other bits of hardware, which are given in the parts list on this page. None of these items are exotic; you should be able to buy everything at your local hardware store and walk out with change from a $10 bill.

The first step in assembling the hinge tracker is to glue one of the 10-32 nuts over the hole farthest from the hinge pin, and the ¼-20 nut to the lower of the two holes nearest the pin. As shown in the accompanying photographs, both of these nuts go on the inside face of the lower hinge wing. The 10-32 nut is for the drive screw, while the other serves as the tripod socket for attaching the mount to your camera tripod. It's important for the drive screw to bear against a flat surface, so you need to glue the large fender washer to the underside of the top hinge wing such that it covers the hole farthest from the hinge pin.

I tested several adhesives for this project, but the one that worked best is a two-part epoxy made by J-B Weld. If you want to assemble the hinge tracker in one sitting, use the version that sets in four minutes (called J-B Kwik). Do your best to make sure that the nuts are centered over the appropriate holes and that no glue ends up on the threads.

The next step is to assemble the drive mechanism with the hardware you purchased and a drive wheel you have to make. The wheel for my tracker is a 6½-inch-diameter plastic lid from a margarine container. I trimmed off the lid's lip with the X-ACTO knife, making the lid relatively floppy, which is a good thing — you don't want to jiggle the mount whenever you touch the drive wheel. Having a flimsy piece of plastic helps ensure that only rotational motion is efficiently transferred to the drive screw.

Use a permanent marker and a protractor to make tick marks on the outer edge of the disk every 6°, with every fifth tick drawn a little longer than the rest. You'll be turning the wheel once every minute, so each tick corresponds to one second. Make a hole in the center of the wheel for the drive screw to fit through.

For the wheel's pointer, I used a scrap of plastic from a margarine container, cut to shape with scissors and bent to form a stretched out Z. I used double-sided tape to attach it to the top wing of the hinge. This placement keeps the spacing between the pointer and the wheel constant as you turn the drive screw.

After the epoxy hardens, you're ready for the tracker's final assembly. Run the 10-32 drive screw through the center of the plastic wheel with a small washer on both sides. Thread on a nut and tighten everything down so that the wheel is firmly clamped between the washers.

The hinge mount is assembled from a handful of common hardware-store items and requires no machining. In addition to the tracker, you'll need a photographic ball head and a regular camera tripod to complete the setup.

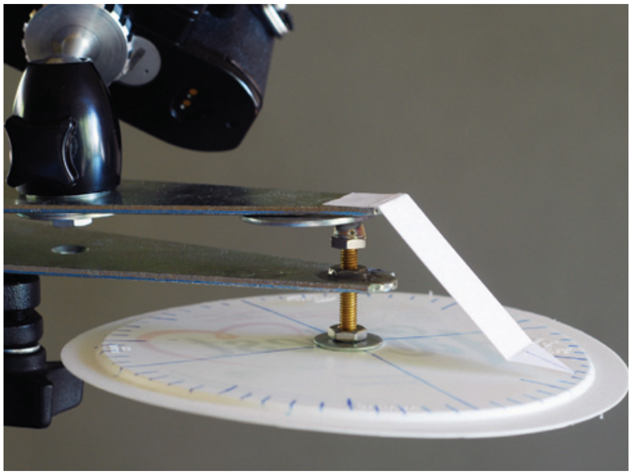
Parts list

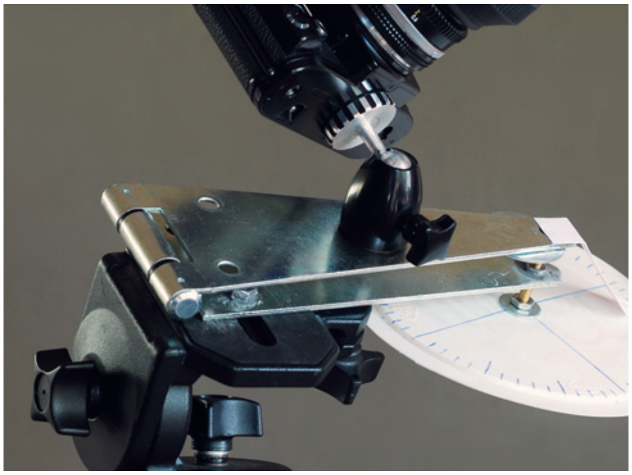
Strap hinge (Stanley model 141620)
10-32 bolt 2 inches long
10-32 nuts (2 needed)
10-32 acorn nut
¼-20 nut
¼-20 bolt ½-inch long
Large fender washer
Small washers for 10-32 bolt (2 needed)
Washer for ¼-20 bolt

Next, thread the drive screw onto the mount from the underside, then screw on the acorn nut. Lastly, run a ½-inch-long ¼-20 bolt through a washer and the top half of the hinge and into the base of a camera ball head.

Polar Alignment

You need to align the hinge tracker with the celestial pole before you start taking pictures. For most purposes, simply sighting along the hinge to aim at Polaris (or Sigma Octantis in the Southern Hemisphere) will provide sufficiently accurate polar alignment. However, if you want to be more precise, use the following procedure:





Left: **The mount's drive mechanism consists of a plastic disk affixed to a 10-32 brass screw, which threads through a nut glued to the lower hinge arm. An acorn nut bearing against the flat surface of a fender washer lifts the hinge arm, resulting in the tracking motion. Index marks on the disk are for monitoring the drive rate.** ***Right:*** **Polar alignment of the tracker is accomplished by eyeballing the hinge pin at Polaris. A more accurate alignment method is detailed in the text.**

1. Set up your mount with the hinge pin on your left when you're facing north and use the tripod's pan/tilt adjustments to aim the hinge pin at Polaris.
2. Center Polaris in the camera's viewfinder by adjusting the *ball head*.
3. Swing the camera through 180° by lifting the top half of the hinge and observe the arc that the stars trace in the camera's viewfinder.
4. Use the ball head to tweak the camera's position until it's pointed at the center of the circle that the stars traced in the viewfinder (this aligns the center of the viewfinder with the rotational axis of the hinge).
5. Now adjust the *tripod* so the camera is centered on Polaris, and repeat steps 2 through 4 until it doesn't appear to move when you perform step 3.

The process takes only a minute once you've done it a couple of times. You can also save time at night if you align the camera's viewfinder with the hinge axis during the day by replacing Polaris with a distant object on the landscape and performing steps 2 to 4. Then at night you simply perform step 5.

Using the Hinge Mount

Once the tracker is polar aligned, aim your camera at your target by adjusting the ball head only. To track the stars, you turn the drive wheel counterclockwise one rotation per minute. You can monitor your progress by watching the second hand of a wristwatch or by listening to the ticks of a short-wave radio tuned to a WWV time signal. I've simply recorded a few minutes of metronome beats onto my iPod, which I listen to with headphones.

In practice, you probably won't have to turn the wheel in 1-second increments. If you're using a lens with a focal length of 50 mm or less, you can move the wheel five tick marks once every five seconds instead. This reduces the chances of jiggling your mount. If you find trailing on pictures taken with longer-focal-length lenses, turn the wheel more frequently.

The mount will track for about 10 minutes before its accuracy starts to decline due to "tangent error" caused by the straight drive screw. One benefit of DSLR cameras for wide-field star photos is that you rarely have to take exposures longer than 2 or 3 minutes. You can achieve the equivalent of longer exposures by taking several short ones and stacking the frames together with software, such as the freeware program *DeepSkyStacker*. I have achieved fine results with the tracker and 135-mm lenses.

Several camera accessories will make your life easier. A remote shutter release (preferably with an interval timer) is a real help. And a right-angle viewer that attaches to your camera's viewfinder saves a lot of neck strain.

The hinge tracker won't take the place of a more sophisticated mount, but for a quick and easy entry into astrophotography, it can't be beat. The version presented here is as basic as it gets and there are plenty of modifications you can make. On my website I've posted information on slightly more complex hinge mounts, including a motorized version and a unit that's even more portable than the one described here.

Finally, if you manage to take some great pictures using a hinge mount, send a few our way — we'd love to see the fruits of your labor. (See this issue's Gallery section for submission details.)

Happy tracking! ✦

Contributing editor ***Gary Seronik*** *has built numerous telescopes and tracking platforms for astrophotography. He can be contacted through his website, www.garyseronik.com.*

Experience the 2012 Transit of Venus in an Otherworldly Setting.

Join *Sky and Telescope's* Editor in Chief Robert Naeye on the Aloha State's astronomy-oriented Big Island for a memorable transit expedition. We'll stay at the four-star Waikoloa Beach Marriott Resort & Spa, home to gracious Hawaiian hospitality, exotic scenery, and classic sunsets. Naeye sets the scene with presentations on transits of Venus and the latest in planetary science. Transit day you'll head up Mauna Kea above the clouds (with excellent prospects for perfect weather) to 9,300 feet, based near the Onizuka Visitor's Center and the viewing sites of Hawaii's astronomy clubs. You can opt to ascend to Mauna Kea's observatory-clustered peak at nearly 14,000 feet, visit the Keck Observatory's telescopes, and take in an unforgettable view of the transit's progress. To ice the cake, June 6 we'll visit Keck Observatory headquarters in Waimea and learn about Keck's current endeavors, plus get a privileged behind-the-scenes look at Keck's command-and-control center.

When it's time for transit viewing, go where the pros go — Mauna Kea, with *Sky & Telescope.* Reserve your adventure now by visiting http://InSightCruises.com/Transit or call InSight Cruises at 650-787-5665. Aloha!

DAY 1: June 3

Arrive Kona

Upon your arrival at Kona, you'll grab a taxi to our hotel and conference center, the luxurious Waikoloa Beach Marriott Resort & Spa. This evening there will be a welcome reception (7pm) where you will enjoy cocktails and light hors d'oeuvres.

DAY 2: June 4

Full Day of Classes Waikoloa Beach Marriott

Learn all about Transits of Venus, past and present, from *Sky & Telescope* Editor Robert Naeye. He and other famous astronomy speakers will be delivering several talks over the next couple of days. In addition to the talk described below, other scheduled talks include:

- The Hubble Space Telescope's Greatest Scientific Achievements
- The Asteroid Impact Threat
- Cassini at Saturn, Part 1: The Planet & Rings
- Cassini at Saturn, Part 2: The Moons

DAY 3: June 5

Transit Day — Welcome to the Keck Observatory

Today we climb Mauna Kea to the summit, to the Keck Observatory (pictured above), at nearly 14,000 feet of elevation, to observe the transit. Above the cloud ceiling we're practically guaranteed to have clear skies and a perfect view. For those sensitive to very high altitude, we will also be observing from the Mauna Kea VIS (aka Onizuka Visitor's Center) at 9,300 feet.

The day's itinerary:
- 10:00am: Depart Waikoloa Beach Marriott
- Noon: Arrive VIS, picnic lunch served
- 12:10pm: Venus first touches the Sun
- 1:00pm: Group departs VIS for the Observatory on Mauna Kea
- 4:00pm: Afternoon snack
- 6:45pm: Transit ends, group departs VIS
- 8:15pm: Return to Marriott
- 8:30pm: Celebration reception and dinner

DAY 4: June 6

Keck Headquarters

This morning we take a 30-minute bus drive to the Keck Observatory headquarters in Waimea. We'll hear two lectures by prominent astronomers, "scope out" the Keck telescopes on the Mauna Kea summit (through a telescope in the lobby of the headquarters), and spend some quality time in the unique gift shop.

The day's itinerary:
- 8:30am: Depart Waikoloa Beach Marriott Resort
- 9:00am: Arrive at Keck Observatory HQ for two 90-minute presentations and tour
- 12:30pm: Depart Keck Observatory HQ
- 1:00pm: Arrive at Waikoloa Beach Marriott Resort
- Relaxed afternoon on the Resort property

DAY 5: June 7

Fly Home

Depart from KOA Airport

Optional Tour to the 'Imiloa Astronomy Center

'Imiloa Astronomy Center of Hawai'i is an astronomy and culture education center located in Hilo, Hawaii. It features exhibits and shows dealing with Hawaiian culture and history, astronomy (particularly at the Mauna Kea Observatories), and the overlap between the two. (June 8)

Itinerary for The 'Imiloa Astronomy Center:
- 8:30am: Depart Waikoloa Beach Marriott Resort
- 10:00am: Arrive at 'Imiloa Astronomy Center for a private "insiders" presentation, a planetarium show, and time to roam the exhibits
- 12:30pm: Lunch in Hilo
- 3:00pm: Depart the 'Imiloa Astronomy Center
- 4:30pm: Arrive at Waikoloa Beach Marriott Resort
- Farewell cocktail party

PRICING: Garden/Mountain View: $1,999 pp; Pool View: $2,199; Ocean View: $2,499; please inquire for Suite pricing. All pricing is per-person based on double occupancy. Single supplement: $700 for Garden/Mountain view; $750 for Pool or Ocean View rooms. Single rates are capacity controlled and subject to change or withdrawal (prior to a confirmed booking) at any time. A $600-per-person advance payment along with a completed reservation form confirms your space. For full terms and conditions please visit: http://InSightCruises.com/top_g/st03_top.html#tabs-8 . For more info, contact us at 650-787-5665 or Concierge@InSightCruises.com .

What's included: ▪ Four hotel nights (including all taxes) ▪ Six educational classes ▪ Round-trip transportation to the summit of Mauna Kea ▪ Round-trip transportation to the Keck Observatory headquarters in Waimea ▪ Lunch and snack on Mauna Kea on June 5 ▪ Arrival cocktail party on June 3 ▪ Celebration cocktail reception and dinner at the Marriott on June 5.

Insight Cruises THE JOURNEY WITHIN

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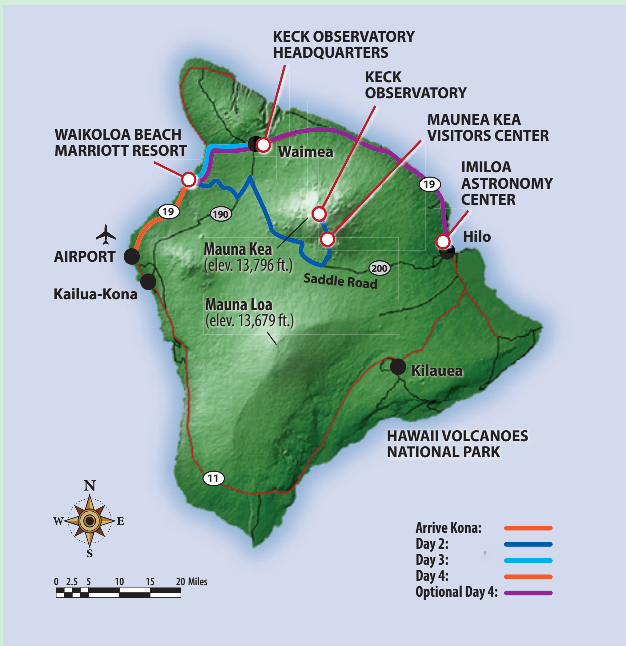


Spectroscopy for Everyone

TOM FIELD

With inexpensive equipment, you can easily reveal the spectral signatures of everything from nearby planets to distant quasars

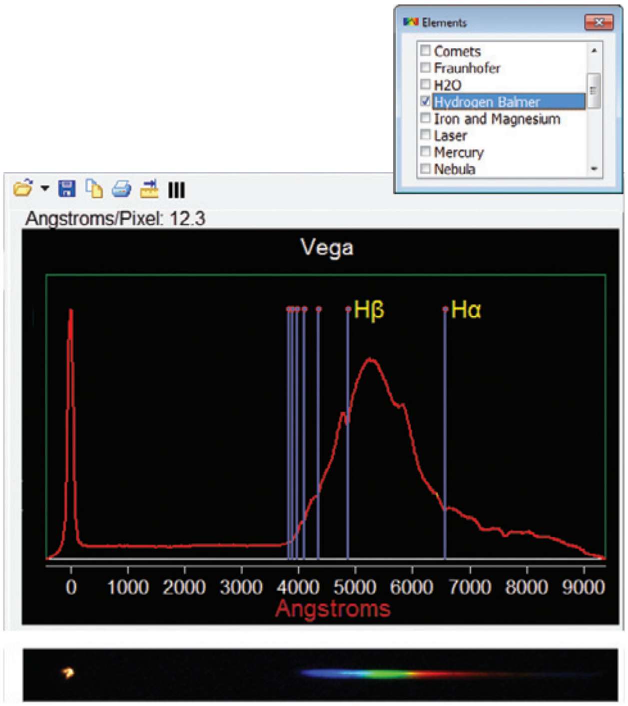
Imagine using a 90-mm telescope in a light-polluted backyard to detect methane in the atmosphere of Uranus. Or how about turning an inexpensive security camera toward a quasar 2 billion light-years away and recording its redshift, seeing firsthand evidence of the expansion of the universe? What if you could aim a simple video camera at a comet and capture the spectroscopic signatures of the complex organic molecules that are thought to be the building blocks of life? Sound exciting? I speak from experience when I say that it is. And in recent years more and more amateurs are discovering this new dimension of observing and imaging.

Although spectroscopy is one of the principal tools of astronomical research, until recently it's been relatively costly and too complicated for most amateurs. But that's changing. With the simple hardware and user-friendly software now available, it's become much easier to get started in spectroscopy. In some ways, it's even easier than astrophotography because it's quantitative — you leave behind the qualitative visual aesthetics demanded by the human eye. But make no mistake: spectroscopic results can be just as captivating as color images of celestial objects.

I've also found that spectroscopy has greatly expanded my understanding of astronomy. It's one thing to have

The spectra appearing with this article were captured with a Star Analyser grating attached to digital cameras such as the Imaging Source video camera shown here. Amateurs have obtained excellent results with everything from simple webcams to advanced astronomical CCD cameras.

S&T: DENNIS DI CICCO



The author's *RSpec* software can create real-time graphs along with reference lines of prominent spectral features for a spectrum captured with a video camera. The webcam image in the window at bottom, obtained with an 8-inch Schmidt-Cassegrain telescope, shows the star Vega as a bright dot (called the zero-order image) at left and its spectrum at right. The window above it shows the spectrum's graph with reference positions for the hydrogen Balmer lines.

passive, theoretical knowledge of a subject, but once I started doing spectroscopy, I found that I was reading astronomical literature much more closely and with a much deeper understanding.

Getting started in spectroscopy can be surprisingly affordable, especially if you already own a camera. Amateurs are doing quality spectroscopic work with DSLRs, video cameras, webcams, and, of course, astronomical CCD cameras. The only additional hardware you need is an inexpensive diffraction grating that splits light into the rainbow-like spectrum we frequently see in publications. A diffraction grating capable of producing the low-resolution spectra accompanying this article costs about $180.

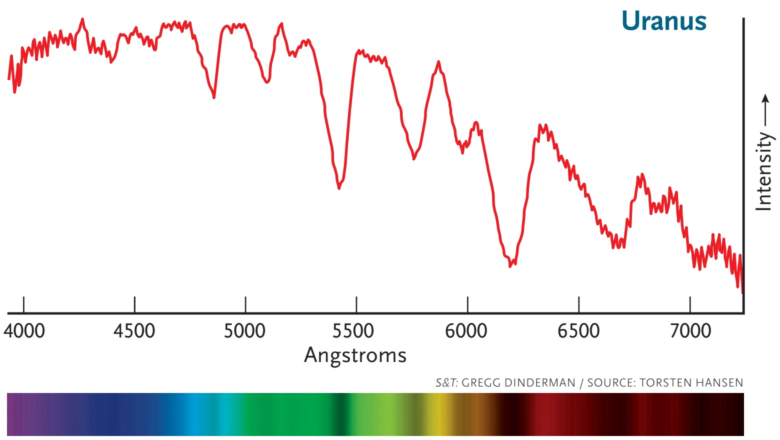
If you live in an urban area you'll be glad to know that, unlike astrophotography, spectroscopy tolerates light pollution very well. For example, one of the pioneers of amateur CCD imaging and spectroscopy, Christian Buil (**http://astrosurf.com/buil**), achieves outstanding results from his light-polluted home in France.

Today's light pollution typically occurs in specific ranges of the visual spectrum. So-called light-pollution filters take advantage of this limited spectral range and transmit only the "important" astronomical wavelengths while filtering out those of artificial light sources. By definition, spectroscopy spreads out light by wavelength, making it easy for us to observe astronomical features at certain wavelengths while ignoring the light pollution occurring at others.

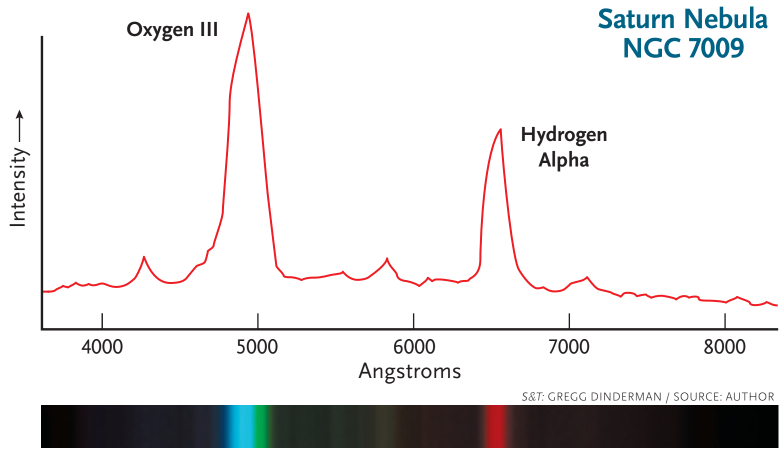
Another advantage of spectroscopy is that you can learn observing techniques with very easy objects such as the bright star Vega. On your first spectroscopic outing, you can shoot an image of the object's spectrum and later analyze the image to produce a profile graph of the spectrum. With bright objects, you can even use modern software to create real-time simultaneous views of the spectrum *and* the profile graph. In addition to being exciting, seeing spectroscopic features in real time, such as dips in the profile due to hydrogen absorption in a star's atmosphere, makes it easy to focus and adjust our equipment for the best results.

There are many interesting objects that we can study with low-resolution spectroscopy. For example, it's easy to detect the atmosphere of Uranus. As seen in the illustration below, deep dips in the long-wavelength (red) portion of the profile graph are due to atmospheric methane that is absorbing sunlight. Reflected sunlight shows as the highest-intensity part of the profile on the left, blue-green end of the graph. This pattern explains why Uranus appears blue-green in a telescope — the sunlight that Uranus reflects is missing most of its red due to methane absorption.

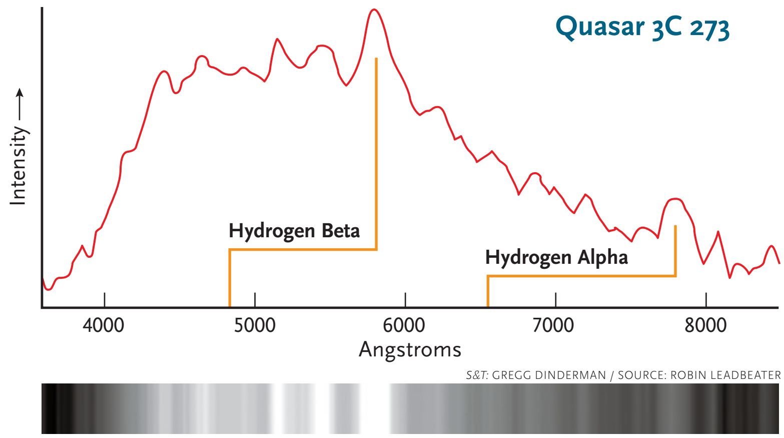
The spectrum of the Saturn Nebula at the top of page 70 illustrates that meaningful spectroscopic data can be recorded in spite of light pollution. This is a typical spectrum for emission nebulae. The bright emission lines are



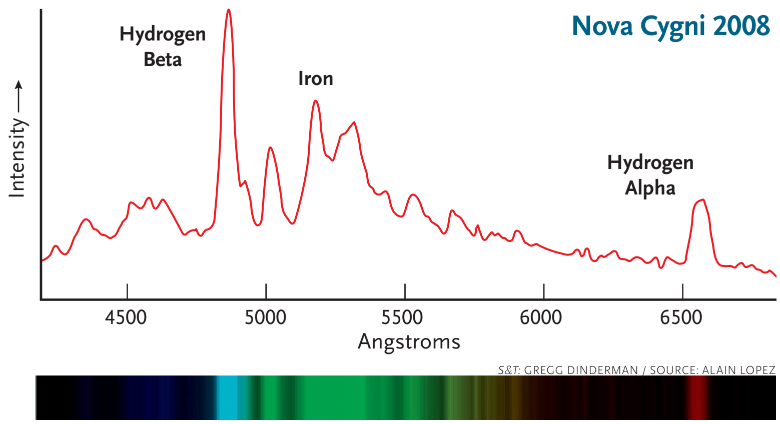
German amateur Torsten Hansen used an 8-inch Newtonian reflector and Imaging Source DMK 21AU04.AS video camera to capture this spectrum of Uranus, which has been corrected for the spectral variations of sunlight and the camera's response. Deep dips in the spectrum are due to absorption by methane in the planet's atmosphere.



The spectra of most emission nebulae show just a few bright lines. The well-known planetary NGC 7009 includes prominent emissions due to oxygen and hydrogen, which can be seen in this spectrum captured with a 9¼-inch Schmidt-Cassegrain telescope and astronomical CCD camera.



Using a 9-inch Cassegrain reflector and modified low-light security camera, English amateur Robin Leadbeater recorded the spectrum of the 13-magnitude quasar 3C 273 in Virgo. Its hydrogen emission lines are shifted toward the red end of the spectrum because cosmic expansion is essentially "stretching" the wavelength of the quasar's emitted light.



Novae and supernovae are often readily identified by their spectral signatures. This spectrum of a nova that appeared in Cygnus in March 2008 (V2468 Cyg) was captured with a DSLR and reveals emissions from hydrogen and iron.

due to ionized gases that have been excited to shine by radiation from the nebula's central star. These lines occur at very specific wavelengths and can be spotted even if there is considerable light pollution at other wavelengths.

One of my favorite examples of a low-resolution spectrum is shown at center left for the 13th-magnitude quasar 3C 273 in Virgo. It was obtained by Robin Leadbeater (**www.threehillsobservatory.co.uk**). Using a modified low-light security camera and a 9-inch telescope, he made a stack of forty 30-second exposures. The quasar's hydrogen emission lines are shifted about 16% toward the red end of the spectrum, because the universe's expansion is "stretching" the wavelength of the quasar's light. A simple calculation shows that this redshift corresponds to a distance of about 2 billion light-years. It's remarkable that backyard equipment can measure such distances!

In the study of variable stars, there's a golden opportunity for spectroscopists to collaborate with photometrists who are making brightness measurements. For example, amateurs are using low-resolution spectroscopy to classify novae. Some types of novae show clear emission lines in the red part of the spectrum due to iron and hydrogen, while other types have a lot of features at the blue end of the spectrum with the rest of the profile virtually featureless. Easily obtainable spectra of these objects enable rapid identification of their types.

Like novae, supernovae also have characteristic spectral features that allow us to determine their type. Every year a few supernovae occur that are brighter than magnitude 14 and can be recorded spectroscopically using modest amateur equipment.

The spectroscopic work mentioned above can be done with an inexpensive, slitless spectrograph. But if you catch the spectroscopy "bug" and want to advance your skills, there is commercial equipment available to do higher-resolution spectroscopy. The European amateur community has done a lot of pioneering work in this field. A high-resolution, slitted spectrograph opens up additional observing opportunities, such as measuring the rotational speed of Saturn's rings, the radial velocities of stars, and detecting spectroscopic-binary stars and exoplanets.

One particularly important high-resolution observing opportunity is a professional/amateur collaboration involving *Be* stars. These are hot *B*-type stars with at least one emission line (usually one of the hydrogen Balmer

During the 2011 Northeast Astronomy Forum last April, *Sky & Telescope*'s senior editor Dennis di Cicco spoke with author Tom Field about amateur spectroscopy. You can watch a video of the interview and see a demonstration of Field's *RSpec* software at www.SkyandTelescope.com/tfield.

S&T: DENNIS DI CICCO

Gratings and Spectrographs

Simple gratings for capturing the low-resolution spectroscopy featured in the accompanying article are available from several sources including:

Paton Hawksley Education Ltd.
European source: www.shelyak.com
U.S. source: www.rspec-astro.com

Rainbow Optics
www.starspectroscope.com

Rigel Systems
www.rigelsys.com

Advanced spectrographs capable of capturing high-resolution spectra are manufactured by:

Baader Planetarium
www.baader-planetarium.com

Santa Barbara Instruments Group (SBIG)
www.sbig.com

Shelyak Instruments
www.shelyak.com

During a recent meeting of the Society for Astronomical Sciences, Olivier Thizy demonstrated the LHiRes spectrograph made by Shelyak Instruments.

lines). The spectra of some *Be* stars can vary over periods from several hours to many years. Scientists don't fully understand the cause of these variations, or the actual structure and characteristics of these stars or their circumstellar disks that give rise to the emission lines. Amateurs are working with professionals to monitor spectroscopic changes of *Be* stars on various timescales and contributing their results to an international database maintained at the l'Observatoire de Paris–Meudon (**http://basebe.obspm.fr/basebe**).

As with visual imaging, successful spectroscopy involves properly post-processing your images. When I started out, I couldn't find any spectroscopy software that would allow me to easily go from the image of a spectrum to a calibrated profile graph. To fill this gap, I wrote a program that I call *RSpec* (**www.rspec-astro.com**). In addition to creating profile graphs from still images, it can make real-time profiles from images obtained with a video camera. It is currently used by observers, teachers, and in outreach programs.

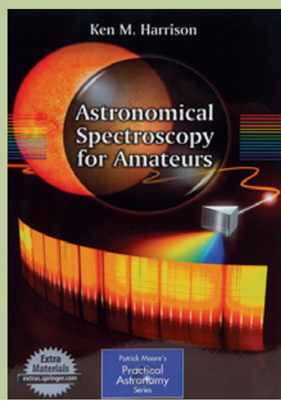
I can't close without mentioning the annual August meeting of spectroscopists at l'Observatoire de Haute Provence (OHP) in southern France. This gathering brings an international collection of amateurs together in a star party/workshop format. Nights are for observing and days are for learning, with lectures and spectrum-processing workshops. All levels of amateur spectroscopists are welcome at OHP, and I learned a tremendous amount at the 2010 meeting. My wife and I were warmly welcomed and we found the language barrier almost nonexistent. We look forward to attending again this year (as well as spending some extra time exploring the beautiful French countryside). If you get involved in spectroscopy, OHP should be on your "must-go" list. You won't regret it.

It's amazingly easy to get started in spectroscopy. With a minimal investment, you can achieve meaningful and compelling results, and I encourage everyone to jump in and give it a try! You'll find that spectroscopy is a challenging and rewarding activity. And I'm sure your appreciation and understanding of the physical science of astronomy will grow by leaps and bounds. ✦

Despite living in rainy Seattle, Washington, ***Tom Field*** *is an enthusiastic observer. He wishes to thank the amateur spectroscopy community for its enormous assistance and patience in coaching him and others as they entered the field.*

Further Reading

Only a handful of books have been written for amateur spectroscopists, but the latest is also one of the best. Ken Harrison's *Astronomical Spectroscopy for Amateurs* (ISBN 978-1-4419-7238-5) is heavily illustrated and packed with valuable information on the design, construction, and use of spectrographs. There's ample background on the science of spectroscopy, and most chapters are accompanied by reading lists and up-to-date links to material on the web. Of special note is a chapter on observing projects for backyard spectroscopists, with sections on the Sun, planets, many types of stars, and deep-sky objects. The $34.95 book is an excellent resource for everyone interested in the subject. See **www.springer.com** for more information.



Trading Techniques

SEAN WALKER

Attending an astrophotography meeting can boost your imaging skills.

I'm not going to lie to you; high-end astrophotography is a complex endeavor. Although modern equipment such as robotic telescope mounts, autoguiders, and remote-controlled observatories have relieved us of the need to spend long, lonely nights at the telescope carefully guiding on a faint star, that is less than half the work needed to produce great astrophotos. The real work is done using a suite of computer software programs to calibrate, combine, and massage data until the efforts bear fruit. Most of these processes cannot be automated. But learning the best techniques doesn't have to be a solitary endeavor.

Specialized imaging conferences have been sprouting up throughout the U.S. and Europe, featuring well-known astrophotographers and scientists sharing their techniques. Are these gatherings worth your time?

Having attended roughly a dozen events, my answer is a resounding yes. And regardless of whether you've just started replacing your eyepieces with digital detectors or are a seasoned pro, these conferences have something to offer for every level of astroimaging expertise.

The Advanced Imaging Conference

The brainchild of Steve Mandel, the Advanced Imaging Conference (**www.aicccd.com**) began in November 2004 and is held annually in or near San Jose, California. Mandel's idea was to host a conference with the best astro-

S&T: SEAN WALKER

photographers in the field giving presentations on their image-processing techniques and imaging projects. Since then, world-famous imagers such as Rob Gendler, Ron Wodaski, Don Goldman, and Adam Block have shared their experiences with attendees from around the world.

Amateurs aren't the only presenters; professional astronomers including Zolt Levay and Lisa Frattare of the Space Telescope Science Institute have revealed their secrets for producing the eye-catching images captured with Hubble and other telescopes.

The growing popularity of imaging conferences is producing a new generation of skilled astrophotographers. Attending these focused gatherings can improve your image-processing knowledge by leaps and bounds. In addition, you can interact face to face with like-minded amateurs and scientists.

AIC concentrates on deep-sky CCD astrophotography capture and processing techniques, with general sessions for overview discussions, and separate workshops on specific software and equipment. Often these workshops cover processing methods that many attendees hadn't considered

KEN CRAWFORD

AIC president Ken Crawford showed attendees how to combine narrowband and broadband color-filtered images to produce breathtaking astrophotos that reap the benefits of both techniques. In this rendition of the Pelican Nebula, IC 5067, Crawford combined a natural-color version of the star field with a deep tri-color narrowband image to avoid the magenta or cyan-colored stars that often occur in narrowband images.

before. Several years ago Adam Block of the Mount Lemmon SkyCenter ran a series of workshops chock full of advanced processing techniques he developed in his years of running the imaging programs at Mount Lemmon and previously at the Kitt Peak Visitor Center.

A vendor area caters to the astrophotography community, where attendees can check out the latest imaging gear. On display is everything from big CCD cameras, astrographs, robotic mounts, remote-observatory-control systems, and premier post-processing software, with knowledgeable staff on hand to explain the nuances of each product. Many of the vendors, such as Software Bisque, Diffraction Limited, and DC-3 Dreams, host workshops that showcase additional features within their products.

The Northeast Astro-Imaging Conference

Another well-established astrophotography get-together is the Northeast Astro-Imaging Conference (**www.rocklandastronomy.com/neaic**) in Suffern, New York, which has preceded the Northeast Astronomy Forum (NEAF) in recent years. NEAIC is organized by Jim Burnell and Bob Moore of the Rockland Astronomy Club. Although similar in many respects to AIC, NEAIC is organized into subsets of special-interest groups. Whether your passion is deep-sky imaging, planetary photography, or DSLR astrophotography, NEAIC presents a well-rounded selection of speakers who cover all levels of interest.

During the past few years, NEAIC lectures have been loosely subdivided into three groups: aesthetic imaging, scientific research, and beginners' workshops. Aesthetic imaging presentations discuss the artistic techniques used to produce the eye-popping images often seen in this magazine and on premier websites such as the Astronomy Picture of the Day (APOD: **http://apod.nasa.gov/apod**).

S&T: DENNIS DI CICCO

One of the major benefits of attending imaging conferences is the opportunity to interact with other imagers face to face. Austrian astrophotographers Johannes Schedler (left) and Wolfgang Promper discuss the finer nuances of printing astrophotos.

S&T: SEAN WALKER, INSET: THIERRY LEGAULT

French astrophotographer Thierry Legault showed off his amazing high-resolution videos of the International Space Station *(inset)* at last April's Northeast Astro-Imaging Conference.

Amateurs recently bitten by the astrophotography bug can quickly get up to speed with inexpensive gear and processes by sitting in on David Snay's introduction to telescopes and astro-imaging workshops. In addition, premier imager Jerry Lodriguss has demonstrated how DSLR cameras can record quality astrophotos, once again proving you don't need to have a small fortune's worth of equipment to produce world-class astronomy images.

Those interested in spectroscopy, astrometry, or any type of survey work can get ideas for their next project by attending NEAIC presentations. Past lecturers included Mike Simonsen of the American Association of Variable Star Observers (AAVSO) and team members of the Herschel Space Observatory.

Although the talks are categorized by subject, it's often beneficial to attend some that aren't within your principal realm of interest. For example, if you already do most of your image processing with a particular software package, try checking out what other programs are available. Each year I make a point to attend the presentations for new programs and often come away with a desire to incorporate them into my own imaging routine. It certainly never hurts to learn something new.

S&T: DENNIS DI CICCO

Presentations at imaging conferences can sometimes be surprising. At the 2008 Advanced Imaging Conference, Chris Ford of Pixar Animation Studios (and an accomplished imager in his own right) gave a presentation on creating 3-D animations of his astrophotos, allowing viewers to "fly by" nebulae and star clusters.

Other Conferences

Besides these major conventions, other imaging workshops have sprouted up recently. Prior to September's Pacific Astronomy and Telescope Show (PATS) in Pasadena, California, the Riverside AstroImaging Workshop (**http://patsimage.org**) features presentations to help you hone your imaging skills, and is conveniently located at the foot of Mount Wilson. In Europe, the biennial Central European Deep-Sky Imaging Conference (**www.cedic.at/en/cedic.php**) was held this past March in Linz, Austria, and featured premier imagers from around the globe. Many of the major star parties worldwide also include astrophotography workshops, so chances are you can get a taste for these events while spending the evenings enjoying the night sky at a dark location.

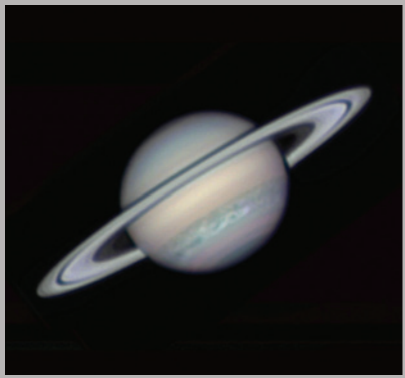
Regardless of which conference you attend, one of the biggest benefits is learning about a fellow imager's processing workflow. No matter how much you use programs such as *Adobe Photoshop* or *MaxIm DL*, chances are you'll find something in a presentation that you hadn't considered before. For example, at the 2005 AIC, I learned how to use a great technique known as high-pass filtering in *Photoshop* while attending a demonstration by Don Goldman. There's nothing like watching a live demonstration to absorb hands-on experience. Afterwards, Goldman answered questions from the audience, which made it a breeze to incorporate this great contrast-enhancing tool into my own workflow.

Expanding Future Networks

Besides the talks, conferences provide a chance to meet and trade ideas with other enthusiasts from around the globe whom you may have only corresponded with over the internet. Some of the best ideas often come from impromptu brainstorming sessions that spontaneously occur over lunch, or between the official sessions. Many times these spirited discussions can lead to new techniques themselves.

Regardless of your astrophotography experience, attending these specialized gatherings can increase your understanding of the latest tools and techniques available in the digital age. And who knows, you might find yourself as a presenter at a future conference. ✦

Sky & Telescope's *imaging editor* Sean Walker *can often be found among the crowds at imaging conferences.*



▼ **DEEP INTO THE LAGOON**

Taha Ghouchkanlu

A showpiece target for observers throughout the world, the Lagoon Nebula, M8, gets its name from the dark band of dust between open cluster NGC 6530 at left, and the brightest region at right known as the Hourglass Nebula.

Details: *Orion Telescopes 190-mm Maksutov-Newtonian telescope with a modified Canon EOS 40D DSLR camera. Total exposure was 28 minutes from Abyaneh, Iran.*

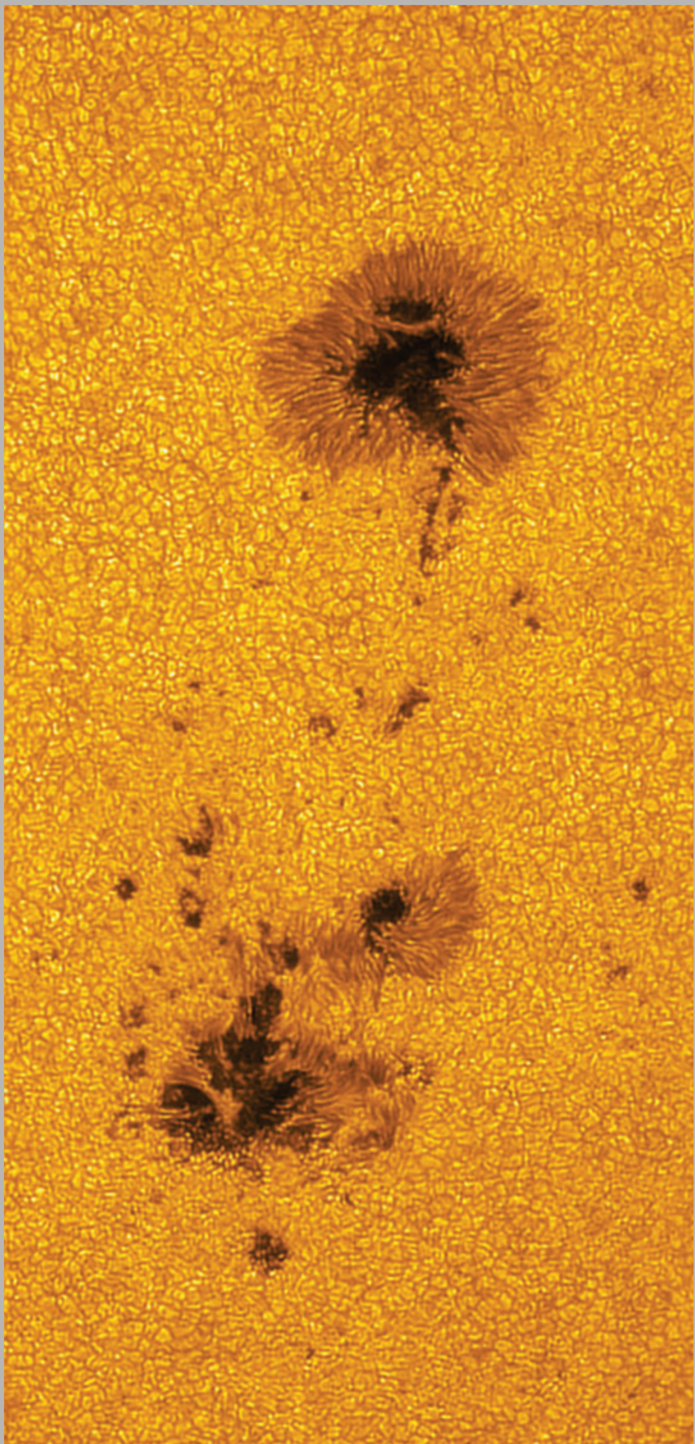
▶ **TUMULTUOUS SATURN**

David Tyler

Since its mid-December 2010 discovery, the massive storm in Saturn's North Tropical Zone continues to spread unabated. Complex swirls of white clouds intermix with darker material dredged up from lower altitudes in the planet's atmosphere.

Details: *Celestron C14 Schmidt-Cassegrain telescope with Lumenera SKYnyx2-0 monochrome CCD video camera. Stacked video frames recorded through color filters.*

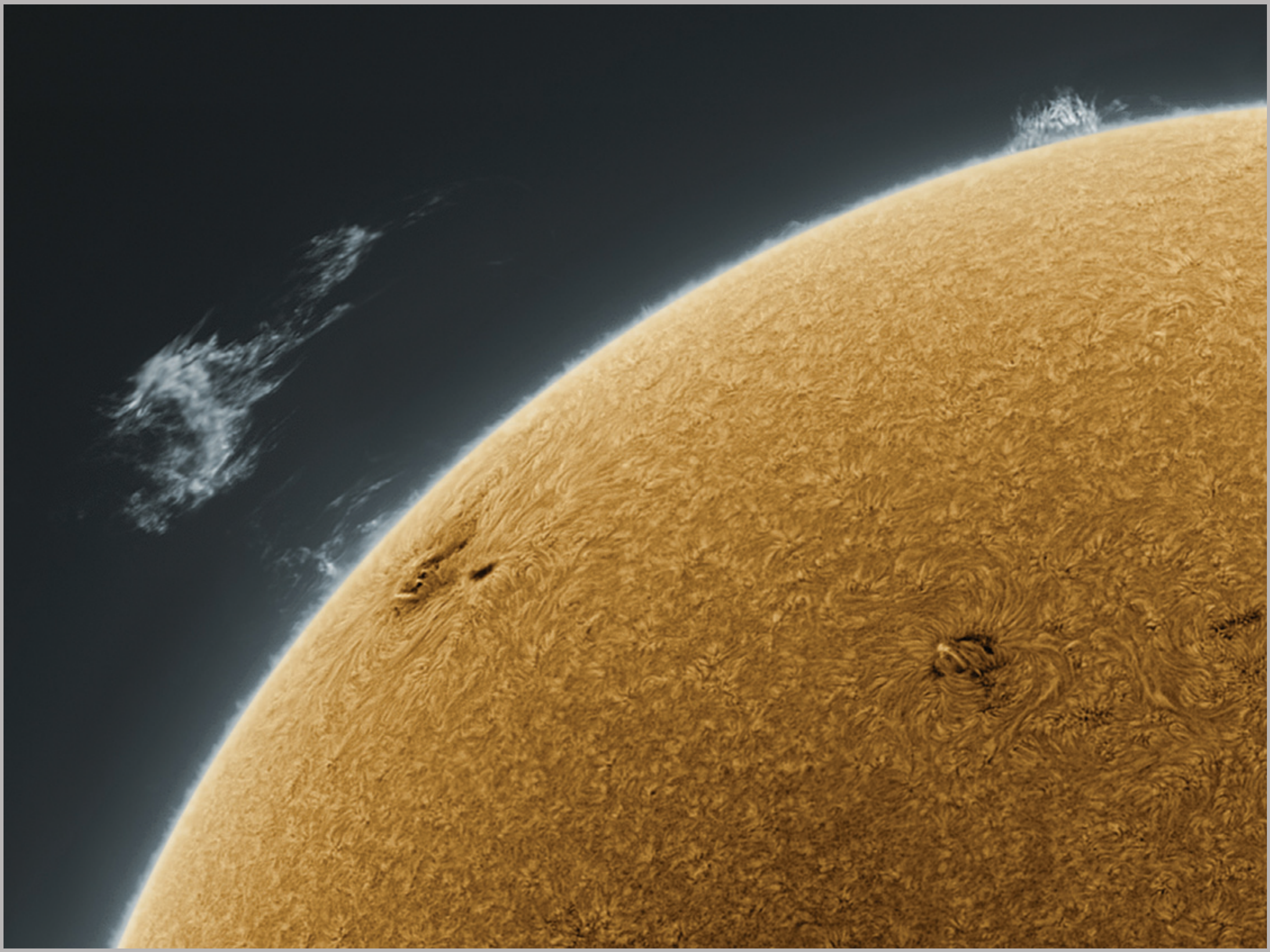
Visit SkyandTelescope.com/gallery for more gallery online.



▲ **THE CHURNING PHOTOSPHERE**
Emil Kraaikamp
This extremely high-resolution view of a sunspot complex last April 23rd reveals solar granules where superheated hydrogen gas rises to the top of the photosphere.
Details: *Meade Starfinder 10-inch Newtonian reflector with Baader Planetarium AstroSolar Safety Film, and a Basler ACE acA640-100gm video camera. Stack of multiple video frames.*

▼ **PERIGEE MOONRISE**
Paco Bellido
The particularly close perigee full Moon last March 19th is seen rising over Castle Espejo in Andalucia, Spain.
Details: *80-mm refractor with Canon EOS 550D DSLR camera.*

▼▼ **SOUTHERN ALL-SKY VIEW**
Tunç Tezel
The Milky Way arcs across the southern sky as seen from Mangaia, a member of the Cook Islands in the South Pacific Ocean. The feeble glow of the zodiacal light is just visible across the top right of the image, with brilliant Venus embedded within.
Details: *Modified Canon EOS 5D DSLR camera with a 17-mm f/2.8 fisheye lens. Total exposure was 5 minutes at ISO 3200.*



▲ **LIFTOFF!**

Alan Friedman

A massive prominence hovered for hours over sunspot 1166 this past March 3rd, as seen from West Summerland Key, Florida.
Details: *Astro-Physics 92-mm Stowaway refractor with 90-mm Coronado SolarMax hydrogen-alpha solar filter, and Point Grey Research Scorpion CCD video camera. Stack of multiple frames.*

► **STARBIRTH IN THE LMC**

Robert Gendler and Ryan Hannahoe

Active starbirth region N11 in the Large Magellanic Cloud surrounds NGC 1760, a cluster of hot, young, blue stars. Many of these stars will end their lives as spectacular supernovae. ✦
Details: *14½-inch RCOS Ritchey-Chrétien with SBIG STL-11000XM CCD camera. Total exposure was 14 hours through color filters.*

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Focal Point

Walt McLaughlin

Galaxy Hunting

A view of the Andromeda Galaxy turned the author into a galaxy fanatic.

I FIRST SPOTTED the Andromeda Galaxy (M31) with my binoculars back in December 2003. I stood along the edge of a farmer's field stomping my feet to stay warm and craning my neck until that ghostly object suddenly appeared. Then my casual interest in astronomy became an obsession bordering upon madness. By the end of the month, I bought a 4.5-inch Newtonian reflector and was on my way deep into space.

Some amateur astronomers are happy enough looking at the Moon, the planets, or any one of the many astronomical curiosities relatively close at hand. Galaxy hunters range much farther out, lured beyond the Milky Way by wild cosmological theories. We're also driven by a profound skepticism. Scientists tell us that "island universes" exist out there, and we feel compelled to see them for ourselves.

In January 2004 I finally viewed M31 through my telescope, leaving no doubt in my mind about what it is. Yet I understood how past astronomers could mistake Andromeda for one of the Milky Way's many nebulae. It took William Herschel's 18.7-inch telescope, built in the 1780s, to suggest that the Andromeda Nebula could be visually resolved into stars. Another 140 years slipped past before Edwin Hubble used Cepheid variable stars to measure its immense distance, thus identifying Andromeda as a galaxy similar to our own.

Chet Raymo once wrote that looking through a telescope is 50% vision and 50% imagination. The Hubble Space Telescope's high-resolution photos show countless galaxies out there, but that doesn't make them any easier to comprehend. No matter how clear the picture may be, it's almost impossible to grasp something 100,000 light-years across, containing a trillion solar masses, and 2.5 million light-years distant.

After Andromeda I found two galaxies above the Big Dipper, about 11 million light-years away. One was the face-on spiral M81, and the other was the elongated M82. Again, they were only smudges of light, but their location agreed with my charts. After those I found the Pinwheel Galaxy (M101) and the Whirlpool Galaxy (M51) even farther out. That was the outermost range of easy galaxies with my telescope. Still I continued hunting. I found, for example, the closer but fainter spiral M33 in Triangulum, and M65 and M66 in Leo.

As a galaxy hunter, I am driven as much by a sense of wonder as a desire to understand. I agree with Chet Raymo's assessment in *The Soul of the Night:* "The night sky is the hunting ground of the mystic and the philosopher, the scientist and the theologian." Deep space is fertile ground for anyone drawn to abstractions. Every galaxy is one more piece of the jigsaw puzzle. Every new object is another clue in the great mystery of the universe.

When Immanuel Kant first wrote of "island universes" in 1755, few people took him seriously. In the 1920s, Edwin Hubble proved him right. Now we revel in the reality of hundreds of billions of galaxies stretching from here to the outermost limits of the visible universe. Deep space is where nature with a capital "N" unfolds in all its glory. And it's all right there for anyone to see. ✦

__Walt McLaughlin__ is a writer, naturalist, and amateur astronomer in Vermont who blogs regularly at woodswanderer.com.

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