Fireball Fragments Pepper Town p. 24

SKY & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

100 Years of Citizen Star Science p. 30

Chilean Astronomical Odyssey p. 72

OCTOBER 2011

Super-charged Supernovae

New types of exploding stars need new explanations. p. 18

How To

See Stationary Satellites p. 66

Observe Autumn's Best Double Stars p. 38

Spot Clusters in the Swan p. 56

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SKY & TELESCOPE

October 2011

VOL. 122, NO. 4

NASA / ESA / J. HESTER / A. LOLL

On the cover: The Hubble Space Telescope images the Crab Nebula, which is the remnant of a core-collapse supernova.

FEATURES

THIS MONTH'S SKY

S&T TEST REPORT

ALSO IN THIS ISSUE

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LOCKHEED MARTIN

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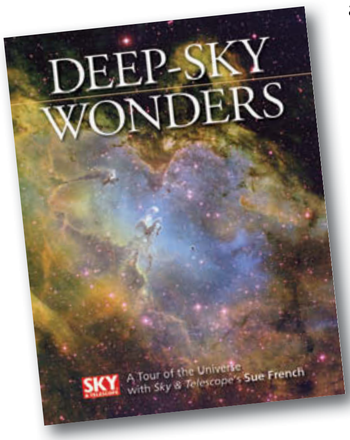
New Digital Archives & Sue French Book

IT'S HARD TO BELIEVE that *S&T*'s 70th anniversary issue is just one month away. How many U.S.-based magazines that were being published in 1941 are still around today? I have no idea of the exact number, but you wouldn't need a supercomputer to add them up. Thousands of magazines have come and gone over the past 70 years, including magazines that reached much larger circulations than *S&T* could have ever hoped to attain. There are still a few magazines around from before World War 2, such as *S&T, National Geographic*, and *Scientific American*. They still exist because of a sustained commitment to quality and integrity that inspires reader loyalty across generations.

As global internet and economic forces change the media world in which *S&T* operates, we continue to expand the ways we serve our readers. As I foreshadowed two months ago in Spectrum, we have now released our DVD archive of the two magazines that merged in November 1941 to become *S&T*. What better time than just before our 70th anniversary to put out DVDs of *The Sky* and *The Telescope*?

And for those of you wanting to complete your DVD archives of *S&T* publications, we have released *Night Sky* magazine in digital format. This is the bimonthly magazine we published from 2004 to 2007 specifically for beginning skygazers. Almost every article in *Night Sky* is still highly relevant today. A CD containing all of *S&T*'s 2010 issues is also now available.

For those of you who want a specific article or back issue of *S&T*, but don't want to purchase the entire DVD archive, individual back issues of *S&T* (1941 to the present day) are now available for purchase in PDF format from our website. Visit ShopatSky.com to order any of our exciting array of products.



And last but certainly not least, my *S&T* colleagues and I are grateful to Firefly Books for being a terrific publishing partner in a new book by our monthly columnist Sue French. Due for release in late September, *Deep-Sky Wonders* is a collection of Sue's 100 favorite sky tours (25 per season) from the past 11 years of *S&T*. Besides the usual charts and maps, it's spiced up with gorgeous images from amateur and professional astronomers. We know you'll love it!

Robert Naeye

Editor in Chief

SKY & TELESCOPE

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

The Essential Magazine of Astronomy

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S&T's August issue (and yogurt) enabled reader Carl Christensen to capture Scorpius on a clear night in July.

Building Your Own Hinge Tracker

The August issue with your Hinge Tracker article (page 64) arrived just in time. I had just purchased a new Canon T3i and had spent a few evenings in the backyard taking pictures of the sky. It appeared that the star images began to trail after about 10 or 15 seconds. I was going to move on to using a "piggy-back" method on my telescope when I read Gary Seronik's article. The magazine arrived at noon, and after lunch I made a trip to the hardware store and local camera shop for the photographic ball head. I built the Hinge Tracker in less than an hour, and that evening I was back outside with my camera mounted on the Tracker.

I'm a musician, so I used my pocket battery-powered metronome to time the rotations of the wheel which I had marked in 5 second increments. Turning the wheel one mark every 5 seconds produced good results, and I am very pleased with my 2-minute exposure of Scorpius (pictured above).

I used a plastic top from a yogurt container as the wheel — an homage to John Dobson, who I believe remarked that his mounts tracked under yogurt power due to his diet in the monastery!

Carl Christensen
Salinas, California

Charting Pluto

I'm glad that you again published the finder charts for Pluto, and I hope that you consider continuing to do so. I (along with several other members of our group) used last year's chart to find Pluto using our 24-inch reflector at the Amateur Astronomers Association of Pittsburgh's Mingo Creek Observatory in Washington County, Pennsylvania, while it was traversing a dark nebula. Based on the success of this endeavor and the peculiar alignment of the planets last year, a number of us went on to observe all nine of the eight planets on three different occasions during our later public star parties.

Without the possibility of easily identifying Pluto with your charts, it is doubtful that we would have had the unique pleasure of observing all of the planets in only one night (it took about four hours each time). Keep up the good work, as you never know where an inspiration will lead! By the way, all of our observations of Earth were done with the naked eye; all others were telescopic.

Ken Kobus
AAAP
Bethel Park, Pennsylvania

Where Were the Women?

I was struck by the pictures of NEAF and the imaging conference in the August 2011 issue: in neither was there even one woman ("NEAF Turns 20," page 34). While I don't attend either expos or conferences myself, surely there must be a few female amateur astronomers out there who might?

Sharon I. Smith
Copper Harbor, Michigan

Editor's note: *Many hundreds of women attended and actively participated in NEAF. Because our article focused on new equipment, our close-up people photos showed vendors, who are predominantly male.*

Scooped?

As both C. Renée James and William Sheehan point out in their delightful article "Neptune Comes Full Circle," priority of discovery is a big deal in science (July issue, page 28). But their example regarding the first measurement of stellar parallax might inadvertently leave readers with

the impression that Friedrich Bessel, who measured the parallax of 61 Cygni in 1838, was scooped by both Thomas Henderson and Wilhelm Struve, who had previously measured the parallaxes of Alpha Centauri and Vega, respectively.

The issue was analyzed in depth in the pages of *Sky & Telescope* (November and December 1956) by none other than Otto Struve, Wilhelm's great-grandson and a frequent contributor to this magazine. His conclusion: Bessel justly receives credit for the first determination of stellar parallax. After presenting the scientific case with lawyerly precision, Otto Struve explains, "The important thing, however, is not . . . which parallax was determined first but which parallax actually dispelled all doubts of the contemporary astronomers that the long-searched-for effect had finally been found. . . . I believe it is important to distinguish the result that appeared convincing to the contemporaries of Bessel, Struve, and Henderson, from what we, with more than a century of hindsight, can recognize as the first successful [measurement.]" Establishing priority of discovery can be complicated, as we all know. First is not always first.

Alan Hirshfeld
Professor of Physics, University of Massachusetts Dartmouth
North Dartmouth, Massachusetts

For the Record

The photo of M27 and M71 on page 77 in the September issue is a stack of 8 exposures, for a total of about 19 minutes.

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.

50 & 25 Years Ago

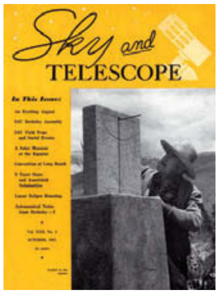
Roger W. Sinnott

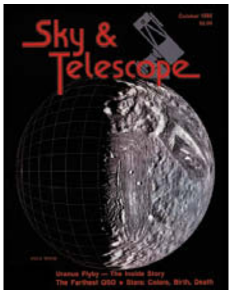
October 1961

Novae are Binaries "A striking hypothesis as to the origin of the U Geminorum variable stars was given at a session of IAU Commission 27 (Variable Stars) by Robert P. Kraft. These stars, of which over 100 are known, spend most of their time at minimum brightness, but at irregular intervals become several magnitudes brighter for a few days or weeks. . . .

"Dr. Kraft reported that at least four stars of this type were short-period spectroscopic binaries, in addition to SS Cygni, which was already known to be one. Thus the suspicion that all U Geminorum variables may be binaries is strengthened."

Kraft's announcement about U Gem stars, now often called dwarf novae, fell in line with studies of classical novae. In a remarkably short time, starting in the mid-1950s, astronomers came to realize that both types are close binaries rather than isolated stars, and that the transfer of matter from the primary to its white-dwarf companion produces (by different mechanisms) the sudden brightening.





October 1986

Farthest Thing Seen "Last August the limit of the known universe was pushed back once again. The new distance champion is a 20th-magnitude quasar in Sculptor that has been found to have a redshift of 4.01. This means it appears to be flying away from us at 93 percent the speed of light, and that it was alive and kicking when the universe was less than 10 percent of its present age.

". . . This puts the quasar some 10 to 20 billion light-years away. The exact value depends on just how old the universe is and how space itself curves along such enormous lines of sight. The find was made by Stephen Warren and Paul Hewitt of Cambridge University in England."

A quarter century has passed since Ann Finkbeiner's article, but Warren and Hewitt are still at it. They are both members of the European team that, in June this year, announced a new most-distant quasar. It lies in Leo and has a redshift of 7.085.

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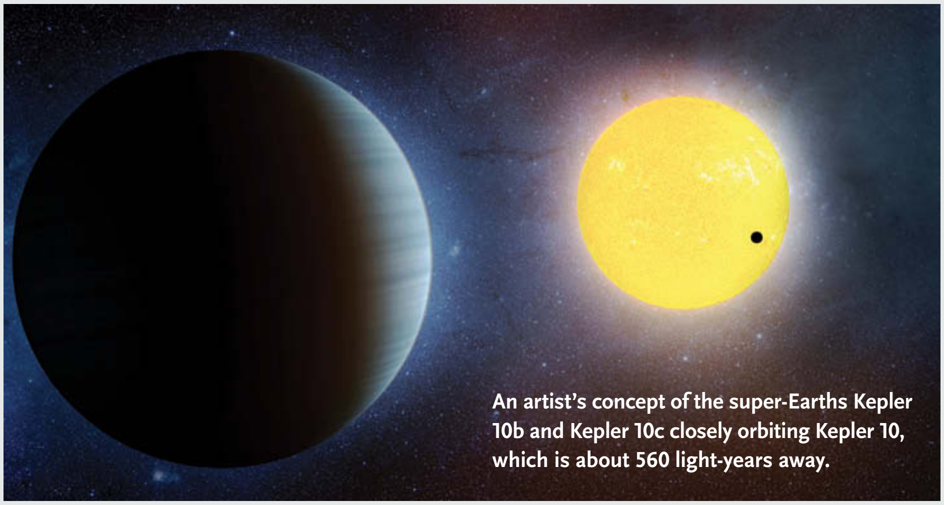
For astronomy news as it breaks, see SkyandTelescope.com/newsblog.

Trouble for the Kepler Mission



NASA-AMES / JPL-CALTECH

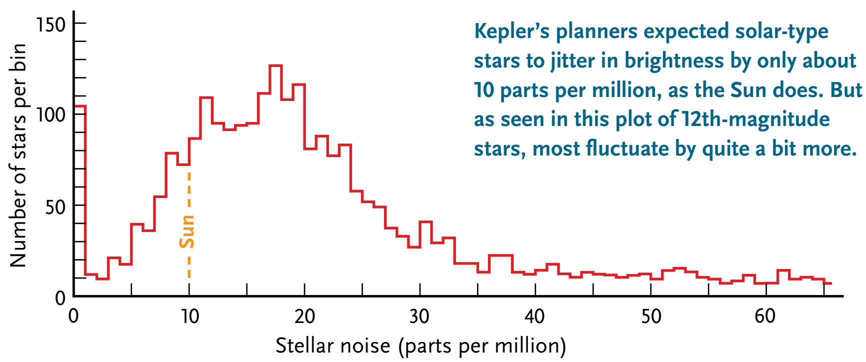
An artist's concept of the super-Earths Kepler 10b and Kepler 10c closely orbiting Kepler 10, which is about 560 light-years away.

By all accounts, NASA's Kepler exoplanet-hunting spacecraft has been an unabashed success since its launch 2½ years ago. Mission scientists announced in February that they had found an astounding 1,235 planet candidates in just the first four months of Kepler's data. Beyond its planet-hunting prowess, Kepler has returned paradigm-changing data on the nature of stars themselves, opening what some call a "golden age for stellar physics."

But project managers have become quietly concerned that Kepler's top priority — finding Earth-size worlds in wide, temperate orbits — cannot be achieved by the time the spacecraft completes its planned 3½-year mission in November 2012.

Kepler is staring at a patch of sky about 10° wide in Cygnus and Lyra, continually recording the brightness of more than 145,000 stars to very high precision. It's designed to detect the tiny dip in a star's brightness when a planet crosses in front. Spotting giant planets this way is a snap for Kepler's 37-inch (95-cm) telescope and superprecise detector array. But it's much more challenging to pick out the tiny dips from Earth-size bodies, which cause dimmings of roughly 100 parts per million.

"We've always believed that there are more small planets than big ones," says Sara Seager, an MIT exoplanet specialist.



R. GILLILAND ET AL. / APJ

Kepler's planners expected solar-type stars to jitter in brightness by only about 10 parts per million, as the Sun does. But as seen in this plot of 12th-magnitude stars, most fluctuate by quite a bit more.

Yet among Kepler's 1,235 announced candidates, only 68 are Earth-size — a tally far short of the anticipated windfall.

The reason is not that exo-Earths are proving to be rare, or that something is wrong with the spacecraft. The problem is in the planets' host stars themselves.

Noisy Stars

The first signs of trouble appeared early. "We weren't getting anywhere near the precision we should," recalls principal investigator William Borucki (NASA/Ames Research Center). An end-to-end check showed that the craft itself was fine. But Kepler scientists had assumed that most main-sequence stars like the Sun would behave as the Sun does. Up-and-down churning of gas in the solar photosphere causes the Sun's brightness to vary by about 10 parts per million (ppm) over timescales of a few hours. But most of the stars Kepler is watching turned out to fluctuate more than that (see graph at lower left). This intrinsic noise makes their light curves messier, so identifying transits by small bodies is unexpectedly difficult.

A planet like ours, crossing a star like ours, would dim it by about 85 ppm. "That's going to be a fairly subtle signature in the data," explains Ron Gilliland (Space Telescope Science Institute).

The main reason Kepler has identified any Earth-size candidates so far is that a planet in a tight orbit will cross its star's face many times in just a few months. So a distinct repetitive signal will eventually emerge even if the individual dips are nearly buried in noise.

But these close-in worlds are much too hot to be habitable. Kepler's core mission is to identify true analogs of Earth — small planets orbiting far enough from their stars to maintain water-friendly temperatures. Mission scientists knew all along that these prize candidates would take the most time to spot, both because they cross in front of their host stars only about once per year (for 13 hours at most for an Earth-and-Sun clone), and also because their much larger orbits have only a 1-in-200 chance of appearing so nearly edge-on that they cross the star's face.

That's why Kepler is staring at so many stars, and that's why the basic mission is 3½ years long. Over that stretch a candidate planet circling roughly 100 million miles from its star (as we do) will complete three transits — the minimum to be considered statistically robust. But throw in the added difficulty of noisy stars, and the chance of finding true Earth analogs plummets.

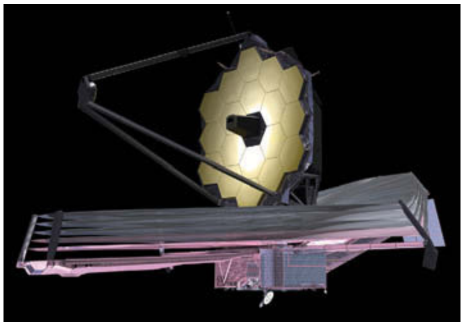
More Time Needed

There's only one way around this unexpected setback. The longer Kepler can stare, the more long-period transits it can record, so the better they will stand out from the noise. According to a comprehensive analysis by Gilliland and 16 colleagues, the spacecraft would need to amass at least 7 or 8 years of observations — double the planned mission length — to identify all the Earths passing in front of solar-type stars in its field of view.

Ordinarily, getting NASA managers to extend Kepler's operations for a few more years would be nearly automatic. Although the total mission cost is roughly $600 million, it would take no more than $17 million per year to keep it going. The spacecraft is healthy, with enough consumables to last through most of this decade.

But these are turbulent budgetary times. NASA's astrophysics funds are shrinking, and major cost and schedule overruns by the James Webb Space Telescope threaten to swallow ever more of them (see next story). Worse, Congressional budgeteers proposed in July to slash more than $1.9 billion from the Obama administration's NASA budget for 2012.

Borucki remains hopeful that an extension will be approved. "I think this is the greatest mission that NASA has ever flown," he says. "I can't imagine any other mission being more important." But, says Jon Morse, director of NASA's astrophysics division, "One of the hardest things we do is to plan our next year's activities in uncertain times."



NASA

An engineering drawing of the James Webb Space Telescope in space. Its optics are above and its instrument package is below the wide sunshade. The Sun is below the frame.

Will the James Webb Space Telescope Be Canceled?

NASA's James Webb Space Telescope, the intended successor to Hubble, has had a rocky road toward the launch pad. Last year a blue-ribbon review panel found that the project was rife with bad management and poor cost control. Now there's fear that the huge space observatory's 6.5-meter primary mirror — recently completed — will never see starlight at all.

In July the House Appropriations Committee unveiled its spending plan for the coming fiscal year. The Republican-controlled committee proposed to provide NASA only $16.8 billion in fiscal 2012, $1.6 billion less than in fiscal 2011 and $1.9 billion below President Obama's request. And the committee called for JWST to be cancelled outright, despite the $3 billion already spent on it.

The committee is looking to make such deep reductions, in part, because Congress favors having NASA develop a new heavy-lift Space Launch System capable of sending crews beyond Earth orbit. The fiscal 2012 plan contains $1.9 billion to keep that program rolling.

Meanwhile, construction on JWST continues. More than 75% of the hardware is either in production or finished, NASA says.

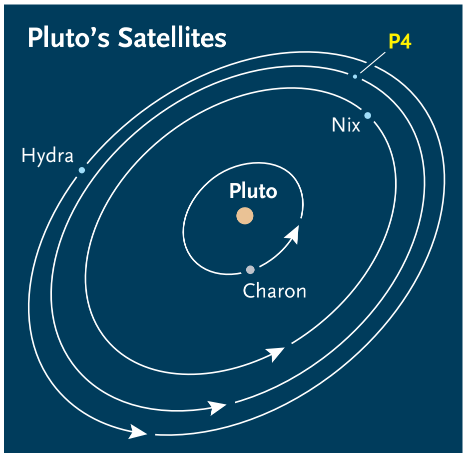
Although astronomers are looking forward to the rich discoveries that the Webb telescope would surely make, they're also aware that its price tag, now estimated at more than $6.8 billion, will continue to suck up federal dollars that NASA could use to fund an entire slate of other promising astronomical spacecraft.

Several committee leaders are looking for ways to keep the project going. Moreover, NASA has a powerful ally in Maryland Senator Barbara Mikulski; she has steadfastly supported her state's Goddard Space Flight Center, which plays a major role in JWST. Many see the committee's recommendation to kill JWST as a shot across NASA's bow rather than a determined effort to scuttle the mission, but no one knows what may happen to U.S. space-science projects in these austere times. Clearly JWST will be a lightning rod for discussing what's going right and wrong at NASA in the months ahead.

Hubble Spots New Pluto Moon

Astronomers using the Hubble Space Telescope have discovered a tiny fourth moon orbiting Pluto. Designated S/2011 (134340 Pluto) but nicknamed P4, the newcomer orbits Pluto every 32 days at a distance of about 37,000 miles (59,000 km). This puts it between the orbits of Nix and Hydra, the two small satellites found circling Pluto in 2005.

A team led by Mark Showalter (SETI Institute) and Douglas Hamilton (University of Maryland) recorded P4 in images taken by Hubble's Wide Field Camera 3 on June 28th, July 3rd, and July 18th. P4 is only 26th magnitude, about a tenth as bright as Nix. If P4's albedo (reflectivity) is 35%, like Pluto's largest moon, Charon, then P4 would measure only 9 miles (14 km) across.



S&T: LEAH TISCIONE

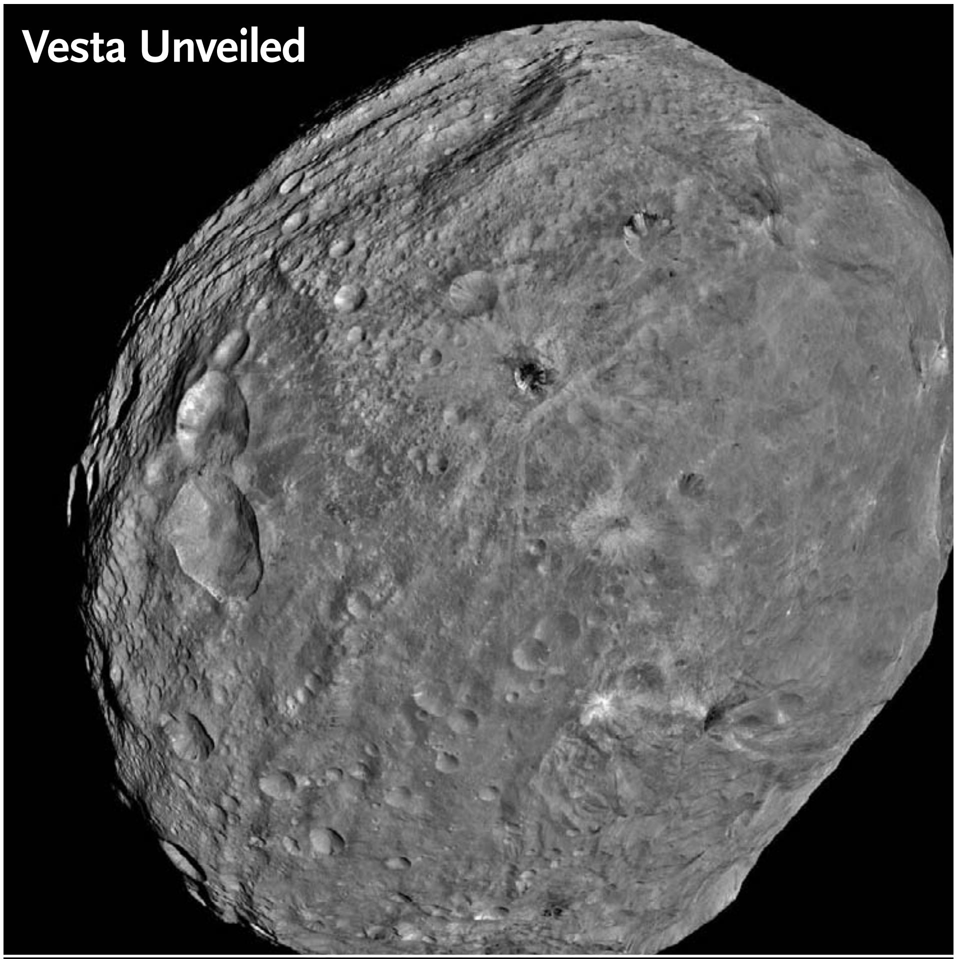
Pluto's newest moon is small enough to orbit between little Nix and Hydra without, apparently, disturbing them gravitationally.

Pluto is 1,440 miles in diameter, Charon is about half as wide at 750 miles, and Nix and Hydra are probably about 50 to 70 miles across. All the satellites probably accreted from debris cast out when a massive object collided and merged with Pluto, much the way Earth's Moon formed and unlike the "mini-solar systems" of satellites orbiting Jupiter, Saturn, and Uranus.

The discovery means that NASA's New Horizons spacecraft will have more to do when it speeds through the Pluto system in July 2015. "It's going to make the encounter even more exciting, and even busier than the pace we planned with just three moons to observe," says New Horizons principal investigator Alan Stern (Southwest Research Institute).

And what about a name for the new find? "Mark and I like the name Cerberus, the three-headed dog that guards Pluto's realm," Hamilton says. "But the name is unofficial for now."

Vesta Unveiled



NASA / JPL-CALTECH / UCLA / MPS / DLR / IDA

NASA's Dawn spacecraft took up orbit around 4 Vesta in July and began returning spectacular high-resolution images of the asteroid, the second largest with a diameter of 330 miles (530 km). Dawn will spiral down to a much lower imaging orbit by early 2012. More in next month's issue.

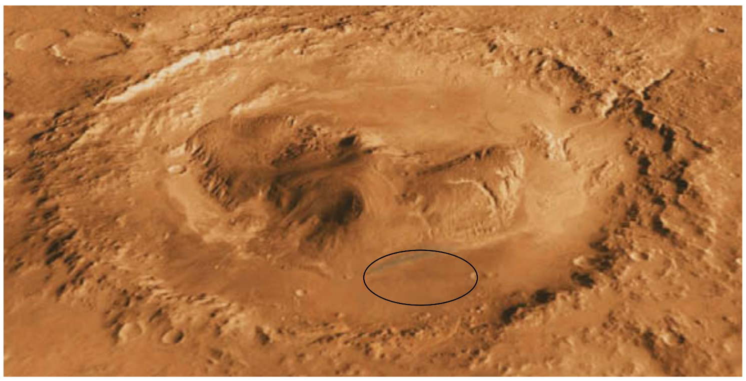
Next Mars Landing Site: Gale Crater

NASA's Mars Science Laboratory, a.k.a. "Curiosity," is due to depart Earth on or around November 25th. Mission planners have decided it will set down on the broad floor of Gale Crater in Gomer Sinus, where the heavily cratered ancient terrain of Mare Cimmerium runs down to vast, flat plains to the north.

Gale (named for Australian banker-turned-astronomer Walter Frederick Gale, 1865–1945) is 96 miles (154 km) across and is likely at least 3½ billion years old. It's distinguished by a massive layered mound at its center that rises 3 miles above the crater floor. To astrobiologist Nathalie Cabrol (SETI Institute), the geology inside Gale suggests a water-rich environment that changed "from warm and wet to cold with ice-covered water, which could have provided suitable oases for various communities of microorganisms."

Gale's big draw was the massive central mound. Orbital scrutiny shows that the towering stack has layers of clay minerals near its base, sulfates above those, and an enigmatic cap of younger fractured sediment. The site offers a chance to understand water's role in a sequence of ancient environments — "an opportunity," observes John Grant (Smithsonian Institution), "to read chapters in a book of the history of past deposition on Mars."

After arriving in August 2012, the rover — five times as heavy as Spirit and Opportunity — is expected to drive at least 12 miles during its two-year basic mission. Its complement of instruments (including 17 cameras) is oriented toward analyzing rock and soil chemistry in what was once a water-rich environment. Among other things, Curiosity can measure carbon isotopes that could have been sorted out by living organisms. ✦



This computer-generated view, based on many images from orbit, shows Gale crater as if seen from the northwest. The black ellipse shows the area within which Curiosity will land.

NASA / JPL-CALTECH / ASU / UA

Planetary Changes of the Fourth Kind

Studying the terraforming of other planets can help us survive on Earth.

OUR PLANET IS not what it used to be. *S&T* readers know that the night sky has become muted with widely scattered light. Looking down at Earth from orbit, we've seen and measured numerous far-reaching changes, from illumination to land usage to atmospheric composition. Whatever you think about the threat of anthropogenic global warming (AGW), you cannot deny that our species has radically altered our planet. Recently, geologists have been discussing the possibility that we have entered a new geological age — the Anthropocene — defined by humans as agents of global change.

But is this truly unprecedented? After all, our planet, like any other complex system of interacting feedbacks, has a history of unrelenting change. Any planet with robust life will be a dynamic and shifting system. Other species have caused previous planetary transformations, including some that were traumatic for the biosphere. The first photosynthetic microbes 2.4 billion years ago introduced poisonous oxygen gas that had massive "unintended" consequences. Besides causing extinctions, these irresponsible photosynthesizers may have plunged our planet into a frightening "snowball Earth" phase.

We can't return Earth to "normal" because there never was an ideal and steady climate. Earth history is a sequence of radical changes that, in the absence of intervention, will continue. We might group these, broadly, into four categories, distinguished by the differing roles of life:

1. **Natural disasters:** life plays no role (asteroid impact).
2. **Biologically induced:** simple life causes radical changes (oxygen catastrophe).
3. **Inadvertent:** proto-intelligent life causes accidental changes (ozone destruction, uncontrolled AGW).
4. **Purposeful:** intelligent life acts to change the environment for its own benefit (repairing the ozone layer, active regulation of climate, the Anthropocene).

Viewed this way, the Anthropocene is something to welcome, to strive for. The natural capriciousness of planetary systems means that long-term survival will require that we learn to enact planetary changes of the fourth kind: purposeful change. To avoid disaster over a billion years as our star and planet evolve, we will need to intervene in planetary climate. What's new here is foresight — the ability to model future trends, see the consequences of our actions, and contemplate course corrections. We're only partway there, so in my view we have achieved only proto-intelligence. Viewed large, our current survival challenge is to attain this capability and thus become fully intelligent.

Perhaps we should call our current phase of accidental tinkering the proto-Anthropocene. How do we progress to the point where we are thoughtfully altering our planet's environment? Sci-fi writers and planetary scientists have studied the problem for a long time — they call it "terraforming" — the alteration of other planets to make them Earthlike by, for example, enhancing the greenhouse on Mars or damping it down on Venus, so that their surfaces can support liquid water and plant life.

Many environmentalists have written about the Anthropocene as a topic of fear or shame, but I see it as a hopeful step, albeit one we are still trying to achieve. Regardless of the imminence of the climate change threat, it's encouraging that there is now more broad discussion of our role on the planet. This is a teachable moment for humanity. As the writer H. G. Wells foretold, "There is no way back into the past. The choice is the Universe — or nothing." ✦

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

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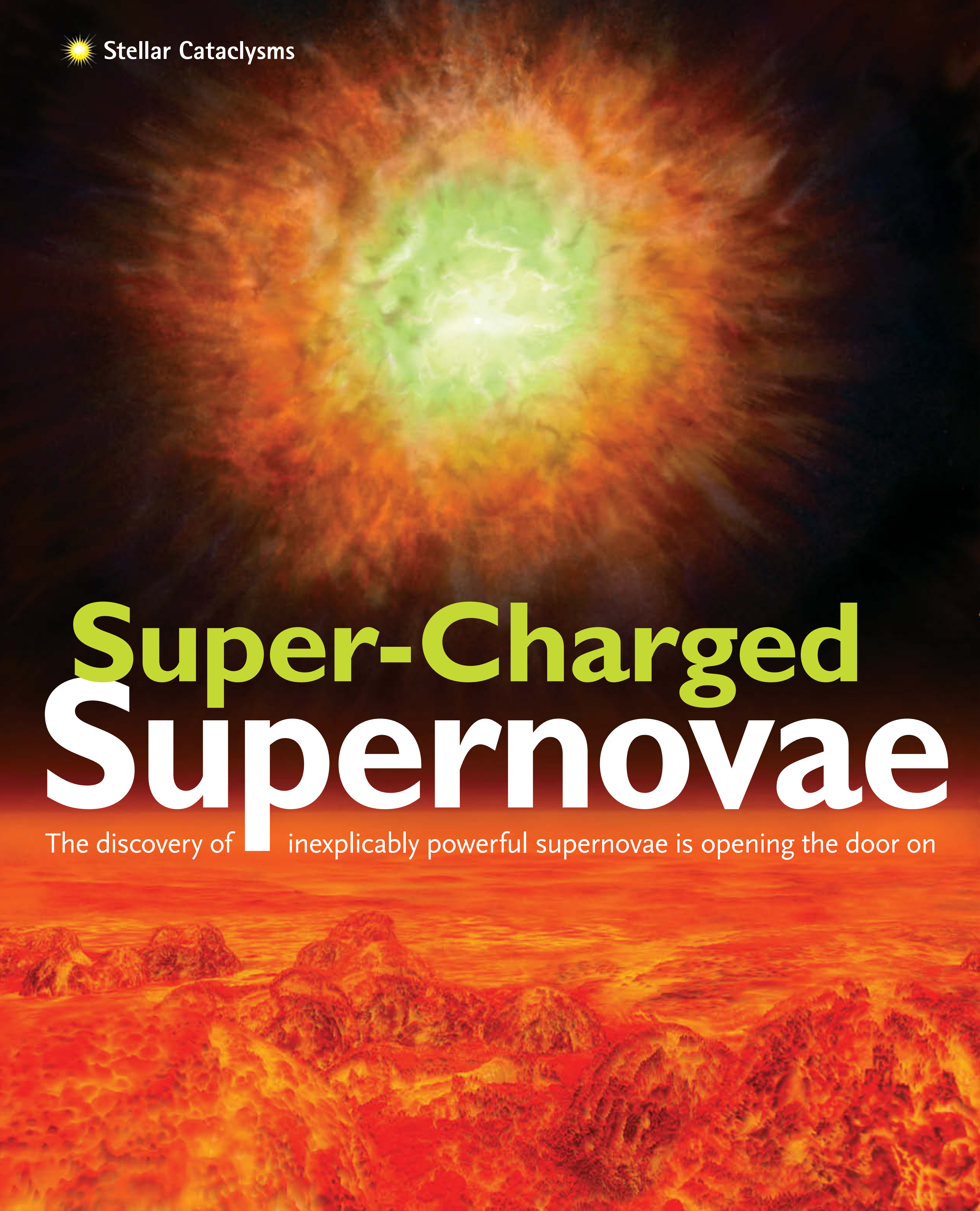


Super-Charged Supernovae

The discovery of inexplicably powerful supernovae is opening the door on

DAVID SINCLAIR STEVENSON

INSPIRED BY THE DESIRE to probe the universe's expansion history, several robotic supernova searches over the past 20 years have greatly increased the discovery rate of exploding stars. With advances in CCD technology, high-speed computing, and fully automated telescopes, these surveys are churning out supernovae on a nearly daily basis. The Palomar Transient Factory (PTF), for example, has identified more than 900 explosions in its first two years alone. And amateurs continue to chime in with occasional discoveries. Among all of these findings is a smattering of unusual beasts.

Exploding massive stars are among nature's most extraordinary spectacles, often outshining their host galaxies for days or weeks. But buried in this haystack of data are gargantuan blasts that exceed even the lofty standards of typical supernovae, and that elude standard explanations. Astronomers are now scrambling to classify and understand the most energetic explosions.

According to textbooks, a typical core-collapse supernova goes something like this: Massive stars swell into red supergiants, then, with increasing desperation, they fuse successively heavier elements — helium, carbon, oxygen, neon, silicon — in an attempt to stave off gravity's fatal embrace. But once iron is forged from silicon, the core can no longer produce energy from fusion; it gravitationally collapses, forming a neutron star or black hole. In the ensuing maelstrom, a shock wave blows the rest of the star apart.

The shock wave, and huge quantities of radioactive nickel and cobalt, heat the exploded star's expanding debris, producing the extreme luminosity of core-collapse supernovae. The debris cools over the ensuing days, but its increasing surface area keeps the luminosity roughly constant. The supernova peaks in luminosity a few days or weeks after the explosion, followed by a decline over the next 100 days or so. Once the debris has thinned and cooled, the final phase of the decline is powered by the radioactive decay of nickel-56 synthesized in the explosion.

But the recent discoveries of supernovae that are 10 to 100 times more luminous than typical core-collapse explosions have taken astronomers by surprise. Even more mysterious, some displayed narrow emission lines in their spectra that indicated a light source not powered by radioactive decay or expansion, but by violent collision. What's going on with these super-charged supernovae?

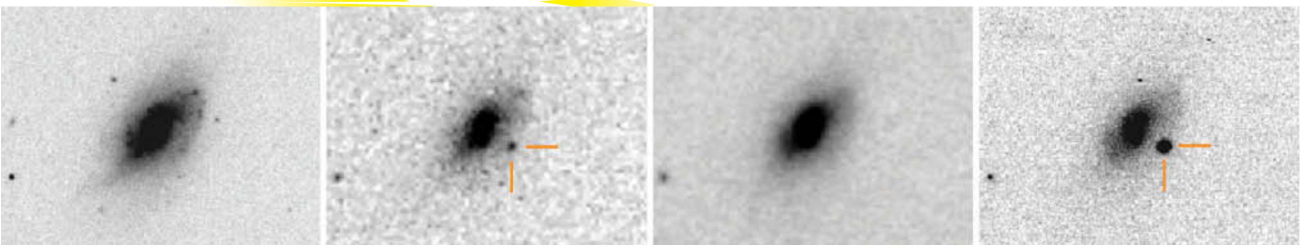
Left: Artist Don Dixon portrays a star going supernova near a hypothetical (and unfortunate) planet. For decades, most observed supernovae seemed to fit into one of several well-defined classes. But with the recent increase in the supernova discovery rate, astronomers are finding occasional oddballs, including some that are significantly more luminous than typical supernovae.

The Impostor

SN 2006jc was one of the first of these atypical supernovae. Discovered by Japanese amateur Koichi Itagaki on October 9, 2006, and independently by Tim Puckett and Roberto Gorelli, it peaked at an absolute magnitude of –18.3, more luminous than many core-collapse supernovae, which have absolute magnitudes of about –16.5. Despite clearly belonging to the Type Ic class, SN 2006jc's spectrum exhibited abundant helium, suggesting that this rather peculiar explosion occurred within a dense shell of helium-rich gas. But where did all this helium come from?

The clue came from an observation made two years earlier by Itagaki himself. He observed an eruption at the

extremely violent events that occur before and after stars explode.



SDSS / *NATURE* | KOICHI ITAGAKI / *NATURE* | KOICHI ITAGAKI / *NATURE* | ASIAGO OBS. / *NATURE*

SUPERNOVA IMPOSTOR These images show galaxy UGC 4904, 78 million light-years away in Lynx. *Far left:* This December 2001 Sloan Digital Sky Survey image shows UGC 4904 without anything unusual going on. *Left center:* In October 2004, Japanese amateur Koichi Itagaki captured what he thought was a supernova in the galaxy's outskirts, but it was actually a supernova impostor. *Right center:* By September 2006, the bright spot had faded from view. *Far right:* In October 2006, the 1.82-meter Asiago Telescope in Italy imaged a much brighter explosion at exactly the same spot as the 2004 transient. This was the actual supernova, named SN 2006jc.

same location in galaxy UGC 4904, which he and others initially assumed to be a supernova. But it was not. In 2004 the progenitor star explosively ejected its helium-rich outer envelope, an event bright enough to be mistaken for a supernova, but which left the remainder of the star intact. Astronomers have been fooled before by these powerful eruptions, which have come to be known as *supernova impostors*. Two years later, the progenitor's core imploded, triggering a supernova that blew the star apart. The expanding debris slammed into the previously ejected slow-moving helium shell. As Nathan Smith (University of Arizona) points out, "SN 2006jc really opened our eyes to the possibility that some unexpected and violent events can occur shortly before core collapse."

Although SN 2006jc's progenitor was not observed directly, it behaved like a Luminous Blue Variable. LBVs are extremely hot and massive stars that occasionally eject their outer layers in violent outbursts. In the 1840s, the Milky Way LBV Eta Carinae suddenly brightened as it threw off more than 10 solar masses in a "great eruption" (*S&T:* October 2004, page 42). Had alien astronomers viewed that outburst from a distant galaxy, they almost certainly would have initially classified it as a supernova.

The fact that SN 2006jc's progenitor apparently ejected its outer envelope two years prior to exploding creates significant problems for prevailing stellar-evolution models. LBVs generate such colossal energy that they desperately shed matter to regain stability. The LBV phase is thought to occur just after a star leaves the main sequence, and it's expected to last tens of thousand of years. After ejecting tens of solar masses, the star evolves into a slimmed-down Wolf-Rayet star. The Wolf-Rayet phase is expected to last at least 100,000 years before the star goes supernova. The idea that LBVs could self-destruct as supernovae was heretical. If SN 2006jc's progenitor star was indeed an LBV, its terminal explosion was a sacrilegious event.

An Even Bigger Bang

As if to underscore the growing uncertainty in the models, SN 2006gy shattered assumptions regarding luminous core-collapse supernovae. Discovered on September 18, 2006, the explosion peaked at a staggering absolute magnitude of –22, roughly a hundred times more luminous than a typical core-collapse supernova (*S&T:* April 2007, page 14). Astronomers were unable to detect the radioactive nickel thought necessary to provide such high luminosity. From 2005 to 2008, surveys revealed several similarly brilliant explosions also with minimal amounts of nickel: their brilliance was born of violent collisions.

Three models have been proposed for SN 2006gy's high luminosity. The first is a scaled-up version of the LBV-ejection mechanism proposed for SN 2006jc. When the supernova's blast wave collided with surrounding matter, the wave's substantial kinetic energy was converted into radiant energy. The second possibility invokes pulsational pair-instability models. The third involves a magnetar rather than an energetic collision.

In the magnetar model, the star has already gone supernova when the real fireworks begin. A small fraction of supernovae leave behind highly magnetized neutron stars called magnetars. Initially these energetic objects spin hundreds of times per second, but their ultra-intense magnetic fields rapidly decelerate the magnetar's rotation. The rotational energy is transferred to the supernova ejecta, causing it to emit a prolonged additional pulse of light. This interaction could provide the extra oomph in the display of some of these super-charged supernovae.

In the most complex model, pulsational pair-instability (PPI), the star's late evolution radically departs from the textbook scenario. In some cases, stars with more than 95 solar masses may hit a nasty snag as they approach oxygen fusion. The core's extremely high temperature sets off an instability. Radiation (mostly in the form of gamma rays) props stars up against gravity. But in very massive stars, fusion reactions eventually produce gamma rays that are so energetic that they turn copiously into matter-antimatter pairs (electrons and positrons) via Einstein's famous equation $E=mc^2$. The withdrawal of photon pressure emanating from the core triggers a catastrophe.

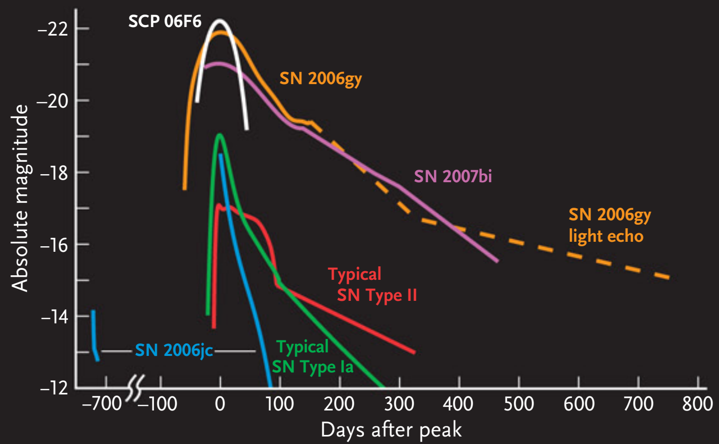
Following initial work by Gideon Rakavy, Zalman Barkat, and Giora Shaviv (Caltech) in 1967, Gary Fraley (also at Caltech) modelled various scenarios following the onset of this instability. Formation of electron-positron pairs knocks the crutches from under the struggling star by suddenly withdrawing the gamma rays. The inner core gravitationally contracts, triggering a cascade of explosive nuclear reactions. Modelling by Stan Woosley (University of California, Santa Cruz) and others show that in some instances the ensuing firestorm is insufficient to completely destroy the star; instead much of the star's hydrogen envelope is ejected, which can be observed as a supernova impostor, but the stellar core remains intact.

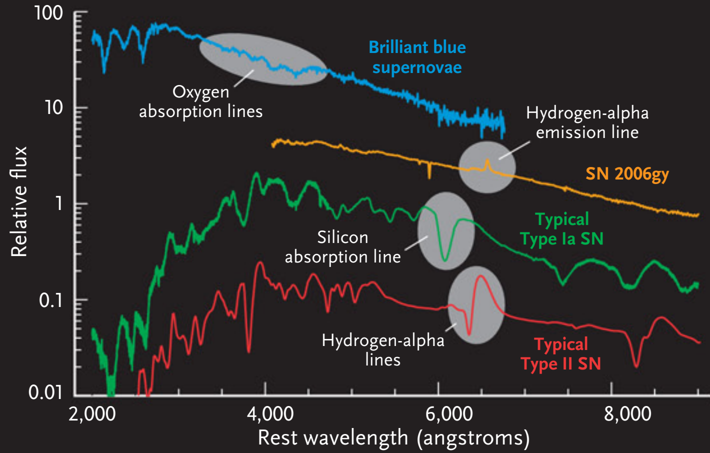
The PPI model suggests that after a brief hiatus the helium core contracts again, renewing heating and triggering the same instability. This drives a second, more violent explosion that blows off part of the helium-rich envelope at great speed. This shell slams into the previously ejected hydrogen-rich layer, generating a brilliant eruption. The remaining core completes its evolution, generating a conventional core-collapse supernova a few

CLASSIFYING SUPERNOVAE

Most core-collapse supernovae — those classified as Type II — display hydrogen in their spectra. Some massive stars shed their hydrogen envelopes, and sometimes their helium layers, before they explode, appearing as Type Ib or Type Ic events, respectively. Supernovae resulting from exploding white dwarfs are known as Type Ia.

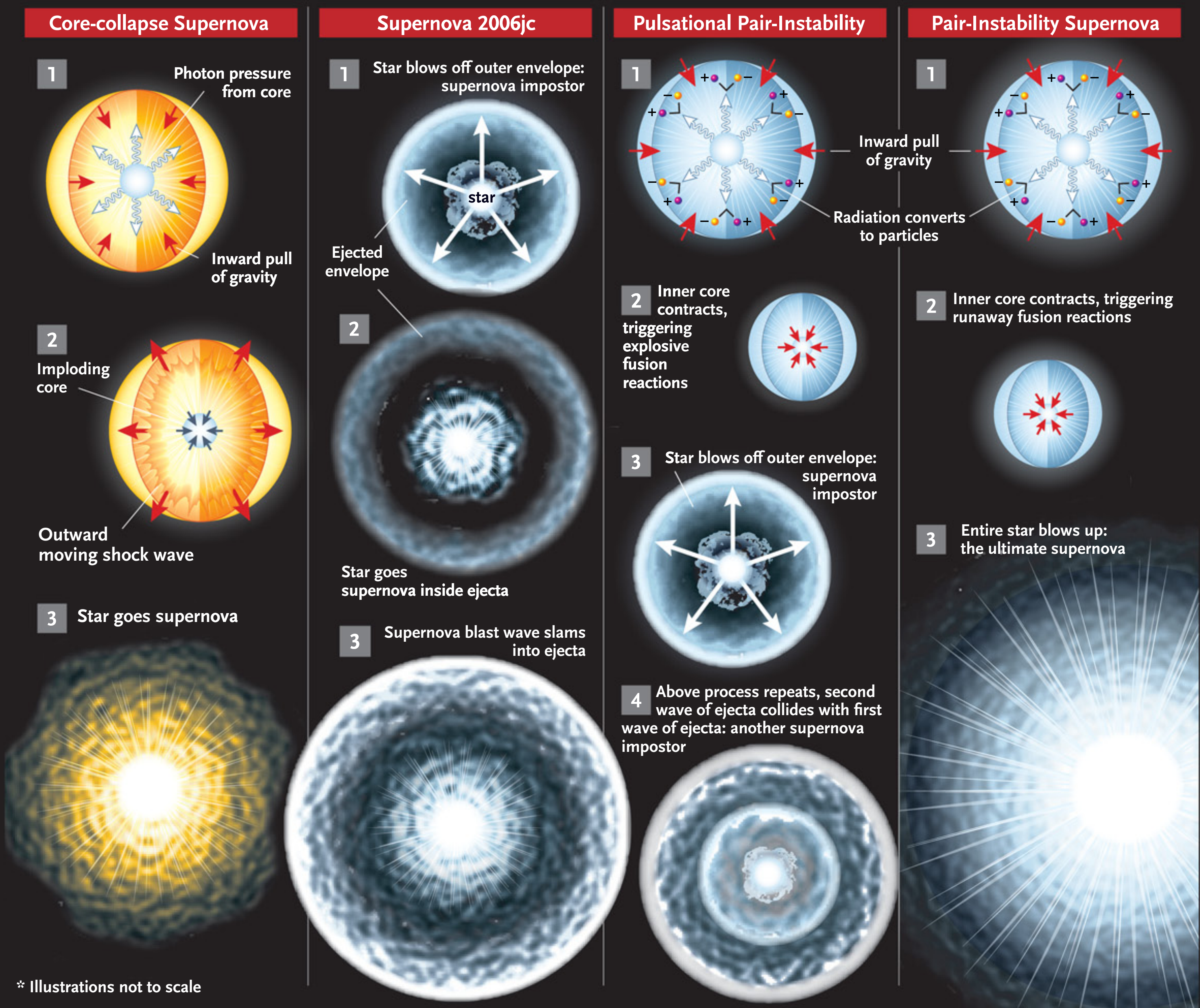
Comparing Supernovae





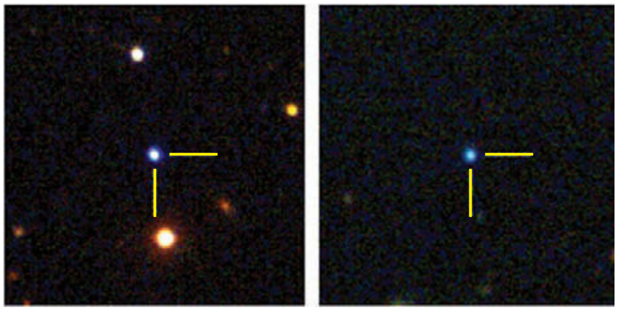
S&T: GREGG DINDERMAN / SOURCE: ROBERT QUIMBY (2)

Left: These light curves show how several recently observed supernovae shine much brighter and for longer periods of time than typical Type Ia and Type II supernovae. *Right:* Astronomers classify supernovae according to their spectra, because different types of explosions produce different chemical signatures.



S&T: LEAH TISCIONE

These illustrations show different pathways in which massive stars can either explode as supernovae or appear as supernova impostors. Astronomers can disentangle the different mechanisms by taking light curves and spectra.



CALTECH / ROBERT QUIMBY / *NATURE* (2)

BLUE EXPLOSIONS In the past few years, the Palomar Transient Factory project has picked up several unusually luminous blue explosions that probably herald the discovery of a new class of supernova as yet unexplained. Here we see two of these supernovae, both occurring at immense distances from Earth.

HYPERNOVAE A small subset of supernovae have been dubbed *hypernovae* due to their high luminosities and fast expansion speeds. But this is a fast-and-loose term, and astronomers have not yet agreed upon a formal definition. Some stellar explosions that have been labeled as hypernovae have been associated with gamma-ray bursts, which are powered by relativistic jets. All of the supernovae described in this article were not associated with GRBs, but it's possible that one or more of them had jets that were not pointed toward Earth.

years later. In this PPI scenario, SN 2006gy could have been an extremely luminous supernova impostor, and we have yet to see the progenitor explode. "In this model, there can be multiple outbursts (supernova impostors) prior to the star's final demise," says Robert Quimby (Caltech).

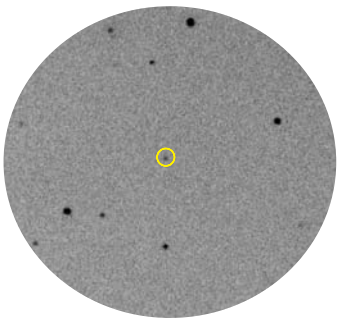
The PPI model makes a testable prediction: since the stellar core remains intact, there should be little or no nickel-56 in the supernova's spectrum because this radioactive isotope still hasn't been synthesized. SN 2006gy appears to fit the bill. Various observations place an upper limit of nickel-56 of 3 solar masses. Later spectra revealed the clear presence of dense circumstellar material ejected prior to the explosion in accordance with the PPI model.

Bolstering this interpretation, astronomers later discovered two similar ultraluminous supernovae: SN 2006tf and SN 2008am. Both exhibited the hallmarks of strong circumstellar interaction with a supernova blast wave. There is clear kinship between these events, and there's growing suspicion that many ultraluminous supernovae are actually driven by stellar pulsations rather than terminal explosions. Astronomers will clinch the deal if they observe an actual supernova at SN 2006gy's location in the near future. If they do, the first mighty brightening merely served as a prelude to the final cataclysm.

Brilliant Blue Blasts

But nature can up the ante even further. In its first two years the Palomar Transient Factory detected four brilliant, blue explosions. Subsequent analysis by Quimby and others showed that these events are related to an intense, blue explosion known as SCP 06F6. Discovered by the Supernova Cosmology Project on February 21, 2006, it attained higher luminosity than SN 2006gy's peak absolute magnitude of –22. For a few years these peculiar explosions remained enigmatic, bearing little resemblance to other supernovae. But Quimby realized that by tweaking their spectra to take into account differences in redshift, the PTF events could be aligned with SCP 06F6 and another weird superluminous explosion, SN 2005ap. "Boom — it was a perfect match," recalls Quimby.

The close synergy of these events extended to a number of features. Quite aside from the extreme luminosities, the spectra revealed an absence of hydrogen, unusually high expansion velocities (14,000 km per second), strong interactions between the blast wave and fast-moving, hydrogen-free material, and particularly hot ejecta (10,000 to 20,000 Kelvins). These explosions also share a prolonged rise time of 30 to 50 days — in excess of most Type II explosions, but their rate of decline was too fast to be powered by radioactive decay. Quimby tentatively assigned the cause to either PPI events or post-core-collapse injections of energy from nascent magnetars. But the enigmatic nature of these events certainly demands further scrutiny.



PAIR-INSTABILITY SUPERNOVA SN 2007bi offers the first compelling candidate of a rare type of extremely energetic explosion known as a pair-instability supernova. The progenitor probably started off with about 200 solar masses. Such massive stars are exceedingly rare in the modern universe, but they may have been more common in earlier epochs.

NEARBY SUPERNOVA FACTORY / AVISHAY GAL-YAM (WEIZMANN INST.)

The Ultimate Supernovae

What happens if a star's mass exceeds those giving rise to PPI events? A possible answer came in early 2007 when the Nearby Supernova Factory group discovered SN 2007bi in the outskirts of a nondescript dwarf galaxy. The spectrum revealed broad lines indicating high expansion speeds, and its brilliance was observed for more than 600 days. This suggested that the supernova synthesized between 3 and 10 solar masses of nickel-56. Such a large quantity left few reasonable mechanisms for its production. The front runner was a pair-instability explosion theorized by Gary Fraley and others — the death of a star with between 130 and 260 solar masses. In this explosion, the instability decimates the star with one killer blow and can generate a huge supply of radioactive nickel.

"Supernova 2007bi is a pretty convincing case of a pair-instability supernova," says Alex Filippenko (University of California, Berkeley). "Based on the light curve and late-time spectra, we find that the progenitor star had a helium core of about 100 solar masses. The resulting explosion is very difficult to explain in any way other than a pair-instability supernova."

The nature of these progenitors is contentious, because it's difficult to explain how stars can attain such large masses. A key issue is mass loss, particularly as stars age. Most massive stars shed considerable mass, particularly after they leave the main sequence. Elements heavier than helium (metals) exacerbate stellar mass loss. Most astro-

STAR ON THE BRINK
The Luminous Blue Variable Eta Carinae is an extremely massive, energetic, and unstable star that is destined to go supernova. This Hubble image reveals two expanding lobes of gas and dust, which were produced by an eruption that caused the star to brighten noticeably in the 1840s. This event would have been a supernova impostor to astronomers in distant galaxies. If the star explodes in the near future, the blast wave will slam into this ejecta, causing a brightening that could make the supernova appear unusually luminous.

NATHAN SMITH / JON A. MORSE / NASA

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ROBERT QUIMBY

To listen to an audio interview with supernova researcher Robert Quimby, visit SkyandTelescope.com/supernova.

physical models, even those that adopt very low metal content, end up with stars that are insufficiently massive to undergo pair-instability explosions. Another controversial area is the formation of ultramassive stars. Dense molecular clouds with high metal content tend to cool and fragment prematurely into smaller clumps, preventing them from forming extremely massive stars.

A possible solution to these conundrums is the merger of massive stars in dense clusters. There is agreement that if all else fails, stellar collisions could give rise to the sort of monster we saw dying in SN 2007bi. Simon Portegies Zwart and Edward van den Heuvel (University of Amsterdam) proposed this mechanism for SN 2006gy, with the formation of an intermediate-mass black hole accompanying the explosion.

As is apparent from observations of various supernovae, some stars can retain sufficient mass to die through novel, violent mechanisms. Will similar events be observed? Yes, thanks to automation. Theorists think that pair-instability events may occur at a rate of 1 in 1,000 to 10,000 supernovae; this is well within the detection limits of current supernova searches.

Done and Dusted?

The deaths of the most massive stars undoubtedly hold many surprises. Stars between the regimes of core-collapse and pair instability could form a range of objects visible to astronomers. As we ascend the mass ladder, the burps and wheezes of LBVs might give way to isolated PPI-driven eruptions. With increasing mass, PPI events could increase in frequency until instability results in the total annihilation of the star. Further observations are clearly warranted.

"Stellar evolution models are based on a lot of assumptions about how stars lose mass during their lives," says Smith. "We have learned recently that some of the key assumptions are wrong at a basic level and need to be reconsidered." Where better to conclude a narrative and begin an adventure? ✦

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Rocks

Canadian scientists get a close look at

from

a meteor as it breaks up

Heaven

over southern Ontario.

PHILIP DOWNEY

Most modern meteorite tales begin with a long voyage to an exotic locale, such as the deserts of Antarctica, Sudan, or Oman. But one group of Canadian scientists was lucky to have a much shorter trip when a meteorite fell nearly in its backyard, right over the camera network it had built to record these kinds of falls. The fine details observed by the scientists have resulted in the most instrumentally recorded fireball to date, 13 recovered fragments, and detailed knowledge of the parent body's orbit.

Lighting Up the Sky

September 25, 2009, was a cool, clear evening across nearly all of southern Ontario. At 9:03 p.m. from a star party I was attending, a bright light suddenly appeared high in the west and traveled down toward the western horizon, lighting up the field with three brilliant whitish-green flashes that cast sharp shadows on the ground. After we got over our surprise, we all agreed it was the brightest meteor we had seen in a long time.

University of Western Ontario (UWO) meteoriticist Phil McCausland also saw the fireball from London, Ontario. He didn't view it directly, but it was so bright that the reflected light was visible in the edges of his bedroom window. He immediately thought that the event would be worth checking the next day.

McCausland, Peter G. Brown, and other UWO scientists operate the multi-instrumental Southern Ontario Meteor Network. It includes seven sensitive video cameras that have been making fisheye-lens recordings of the entire sky since 2006. The cameras are spread over 300 kilometers (190 miles), generally about 50 to 70 km apart. Each one is under a heated, clear plastic dome to keep dew, ice, and snow from accumulating. The network also consists of an infrasound detector array 30 km north of London, which records atmospheric shock waves, and a radar array 100 km northeast, which bounces radio waves off the ionized trail left by an ablating meteoroid's speedy passage. The three types of observations provide independent measurements

FIREBALL PHOTO Local resident Miranda Nenadovich happened to be taking photos of the Cleveland, Ohio, skyline "when out of nowhere was a flash of green light. I had no idea what it was until I researched it online the next day," she recalls. Her Canon XTi DSLR camera caught the brilliant fireball speeding toward Grimsby, Ontario. She was 250 kilometers (155 miles) from the fireball, which is why the streak appears near the horizon. The apparent gaps in the streak are due to clouds.

of a meteor's trajectory, speed, and energy.

When a camera records a bright event, it sends the information to a central computer server noting the time, brightness, and direction. If multiple cameras simultaneously record a bright event, the computer flags it for the scientists' attention the following morning in an e-mail summarizing the night's events. "All of the cameras detected the September 25th meteorite, but I should emphasize none of them automatically detected it. It was actually *too bright* for our automated detection software," says Brown.

Brown's initial rough trajectory showed that any meteorites must have fallen into Lake Ontario near the town of Grimsby. But over the next few days, a closer examination of the radar and infrasound data, along with the higher-precision camera data, revealed that meteorites may have landed a bit farther south, perhaps in Grimsby itself.

The team's excitement grew and McCausland was handed responsibility for the ground search. He and a large group of UWO students, along with faculty members Roberta (Robbie) Flemming, Howard Plotkin, and Gordon Osinski, made daily trips to Grimsby to examine the local terrain, interview residents, and do some scouting to determine the likelihood of finding fragments.

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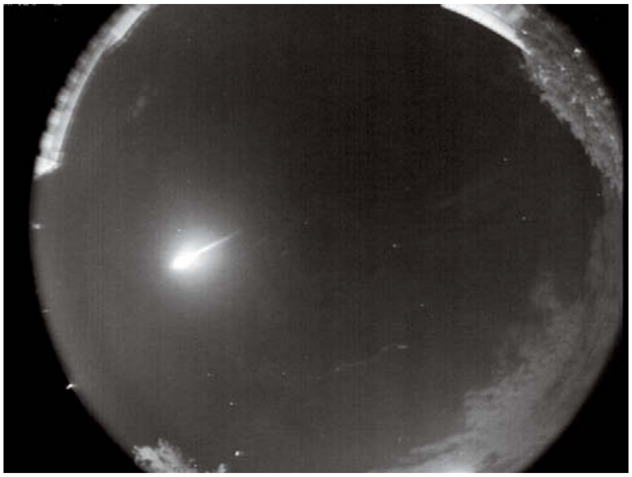


GRIMSBY METEOR The Southern Ontario Meteor Network's all-sky camera 3 at McMaster University in Hamilton had the best view of the fireball, which passed nearly overhead. This image is a composite stack of 12 video frames selected from the final second of the fireball as it streaked toward the southeastern horizon.

They went door-to-door asking residents if they had seen or heard the fireball. Many had seen it, but they were really hoping to find people who had heard it — not the fireball's sonic boom but the whistle of a small fragment overhead, or even better, the thud or bang of a fragment hitting a tree, a building, or the ground. "Broken windows or a dent in a car are the best signs, but very rare," says Martin Beech (University of Regina). After hearing a few reports of sounds, they took a quick look through some grassy fields and farms but turned up no fragments.

McCausland alerted the local media that the fireball may have produced fragments that landed in Grimsby and gave a brief description of what to look for. The next few days resulted in a flurry of television and newspaper reports, followed by a deluge of e-mails and phone calls. McCausland skimmed his overflowing inbox as quickly as possible for mentions of rocks or stones. None panned out. On a closer examination of less-promising e-mails, he found one tantalizing candidate from Grimsby resident Yvonne Garchinski.

Broken Windshield

The morning after the fireball, Yvonne's 30-year-old son Tony found that the front windshield of the family's SUV had been smashed (but not penetrated) by a stone, which he promptly found in five pieces on the driveway. He reconstructed the five pieces' trajectory and found that the stone traveled nearly straight down then crashed into and bounced off the windshield. After that it split into pieces that left scratches on the front hood and twin dents in the garage door. He assumed that it was the mischief of vandals, but was puzzled: Why they would have thrown the stone straight down? Luckily, he kept the pieces, and Yvonne began the process of filing an insurance claim and replacing the windshield.

A week and a half after the fireball, Yvonne saw a television report about possible fragments on the ground. She checked her calendar to see what night her windshield had been broken, realized it was the right one, and that Tony's stones matched McCausland's description of probable meteorites. As McCausland had suggested to the public, she bagged them and sent him an e-mail. Unfortunately, it had the vague subject "meteor sighting" and nothing about

GRIMSBY RESIDENTS *Above:* Tony and Yvonne Garchinski examine the meteorite that cracked their SUV's windshield. *Right:* Tony Garchinski found these five meteorite fragments in their driveway on the morning after it fell.

STONES FROM SPACE ***Left:*** **Phil McCausland holds a 46-gram piece recovered from the Garchinski's driveway.** ***Middle*****: This fragment was recovered in a field near Grimsby.** ***Right:*** **Local volunteer Rob Williamson and University of Calgary grad student Ellen Milley search for meteorites.**

stones or rocks. He read her message a day and a half later. "Immediately upon reading her message, I just knew it was the real McCoy," he recalls. "I stopped right there. I sent her a message, I picked up the phone, I called Howard, called Peter, called Robbie, and said, 'Yes, I think we've got it.'"

After talking with Yvonne on the phone, he and Plotkin arranged a visit the next morning. As soon as she appeared with her bagged stones, McCausland only had to glance at them before saying, "Congratulations, you've got a meteorite." (In Canada, meteorites are legally owned by the people whose property they land on.) This was the first confirmed find of the Grimsby meteorite fall. They had an impromptu celebration on the driveway where it had been found.

McCausland could now tell the media that meteorites had been found. His team, as well as professional meteorite hunters, spread over the Grimsby area in an attempt to find more. In the next six weeks, 12 more meteorites were found in the surrounding area, bringing the total to 13 pieces with a combined mass of 215 grams (0.47 pound).

McCausland suspended the search during winter and resumed it in the spring of 2010, before many farmers had planted their fields. Despite numerous tries with search teams ranging in size from three to 20, they failed to uncover any of the rarer but expected larger meteorites. In November, using the most refined trajectories yet, a search of more soybean fields and vineyards yielded no success.

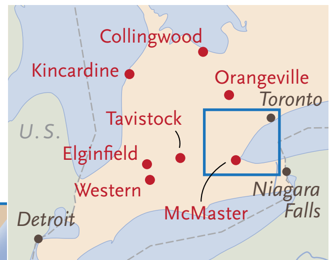
Careful Calculations

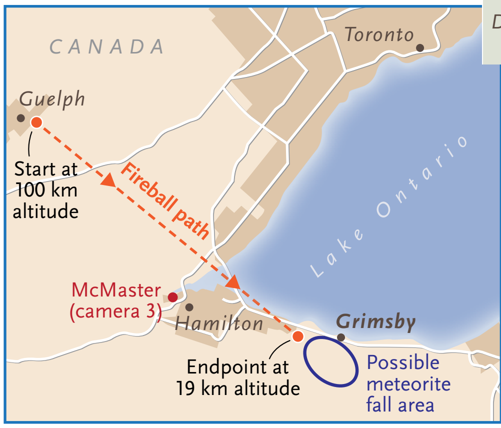
Calculating where a meteorite will land is no simple matter; each event's unique characteristics make it difficult to develop a general model that accepts a short set of numbers as input and gives a location as output. Astronomers need detailed observations of a fall to calculate what happens during the bright period when the meteor burns and breaks up in the atmosphere and then calculate what happens in the "dark flight" period, when fragments stop glowing and are subjected to air drag, wind, and gravity until they hit the ground.

After examining the video recorded by the network, Brown found that there was enough resolution to watch the meteorite disintegrate into pieces. "The extraordinary part about this is that camera 3 at McMaster University was only 30 kilometers from the end point of the fireball, so it was extremely close, and that's what allowed us to get what would otherwise be almost unobtainable resolution of the end of the fireball," he says. "Here we were close enough that we could distinguish very small fragments."

The cameras caught explosions at the three bright burst points, which occurred between 30 and 40 km over the city of Hamilton. Going frame by frame and measuring the fragments' positions, Brown could calculate each one's deceleration in the atmosphere and thereby estimate its mass. This revealed how the debris spread out and fell to the ground, depending on each fragment's altitude, size, mass, and velocity when it broke off the meteorite's main body.

FIREBALL TRAJECTORY These maps show the trajectory of the Grimsby fireball and the location of the 7 camera stations in the Southern Ontario Meteor Network. A radar station is also located at Tavistock and an infrasound station is also at Elginfield.





LUCK ON THEIR SIDE

The parent body of the Grimsby meteor hit the atmosphere at a speed of 21 km per second (47,000 mph). The Canadian scientists were lucky it wasn't going much faster, since few objects survive if they enter Earth's atmosphere at more than 25 km per second.

"When you do that modeling for the major burst points, they all stack on top of one another and dump a lot of small material, things that are anything from sand grains to multi-gram fragments," says McCausland. Minutes after the fireball, the Doppler weather radar station in Buffalo, New York, picked up this cloud of dropping debris, initially as larger chunks but mainly later as sub-gram pieces.

The group's most refined calculations show that the fireball lit up when it entered Earth's atmosphere at a 55° angle over the city of Guelph, traveled southeast, reached its maximum brightness over Hamilton, and continued on to Grimsby before fading out and landing. "We think the object itself was 30 to 50 kilograms in total. We know that it was coming in at 21 kilometers per second when it hit the atmosphere; we know that the last fragment became subluminous at about 19 kilometers altitude, right over the extreme western end of Grimsby," says Brown.

Reconstructing the History

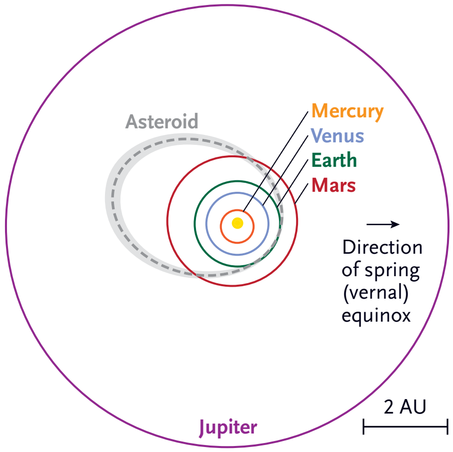
The meteorite is a stony ordinary chondrite, which is the most common class of meteorite. It's classified as a mixed type H4 to H6, which means that it is composed of pieces of an H (high iron content) chondrite that have experienced varied levels of heating and recrystallization in the parent asteroid. Working backward from the fireball path, the group found that the far part of its orbit (aphelion) is in the main asteroid belt between Mars and Jupiter.

McCausland and Brown are analyzing the meteorite's isotopic composition with collaborators in Canada, the U.S., and Germany to determine how long ago the meteorite broke off from its parent meteoroid and how large it was. High-energy cosmic rays bombard asteroids in space, creating short- and long-lived rare isotopes both on the meteorite's surface and deeper inside it. Isotopes are different forms of the same element, with a different number of neutrons in their nucleus, and therefore a different atomic weight. Sensitive assays and measurement of the telltale gamma-ray emission during radioactive decay can reveal the quantities and ratios of isotopes of aluminum, cobalt, and other elements, which the scientists can use to calculate the meteorite's age, shape, and history in space. They have also extracted samples of radiogenically produced noble gases such as neon, xenon, and helium from the meteorite, which can provide similar information.

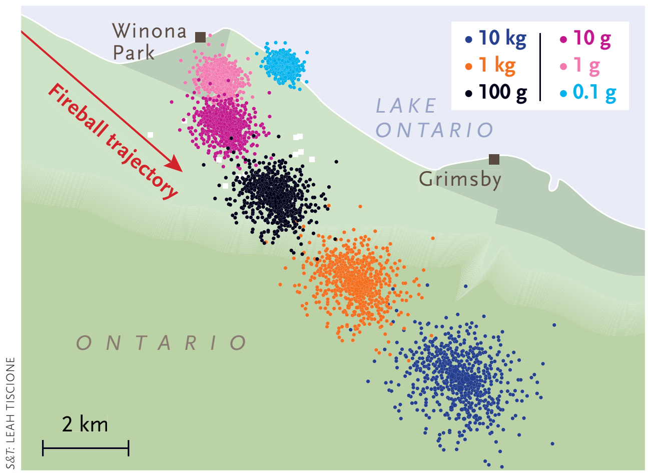
Coupled with information from the fireball, they can calculate the meteoroid's strength. "We learn things about the objects: how weak they are, how they break up, how big they were prior to atmospheric breakup, and test all of our different techniques for measuring these things," says Brown. "One of these meteorite falls provides an excellent way of ground-truthing all that, because we can compare the rocks and their makeup against what we see in the astronomical side of fireballs. It's a great end-to-end check."

When scientists add it all up, the Grimsby meteorite has provided a wealth of information, beginning with its orbit, through images of the fireball, and ending with the meteorite itself. "That's never really been done before with any meteorite on the ground," says Beech. "There are only a handful of meteorites with accurate orbits. This will be another important one to add to that list." ✦

To watch videos of the Grimsby meteor, visit SkyandTelescope.com/Grimsby.



ASTEROID ORBIT By working backward from the Grimsby fireball's initial entry speed and trajectory, the Canadian astronomers could calculate the parent body's approximate orbit. The uncertainty is shown in gray. They estimate that the parent body was about 30 cm (1 foot) across when it entered Earth's atmosphere.



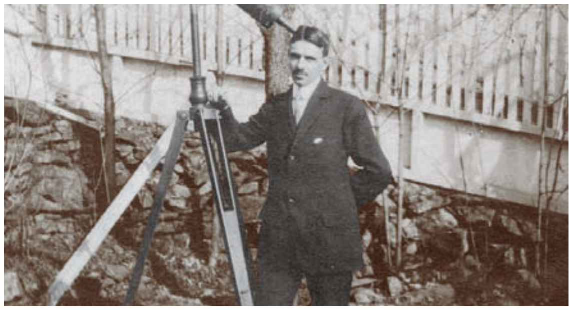
FLIGHT MODEL The UWO team produced this model showing how imaginary fragments of different masses would spread out in flight and fall to possible ground locations after the meteor broke up between about 39 and 22 km altitude.

Philip Downey is a freelance science writer and amateur astronomer. The Grimsby meteorite landed 25 kilometers from his home in St. Catharines, Ontario.

A Century of AAVSO PROGRESS


THOMAS R. WILLIAMS
AND MICHAEL SALADYGA

This internationally renowned organization has grown from a handful of amateurs making observations for professional astronomers.



VARIABLE STARS provide exciting insights about many stages of stellar evolution. Although variables have interested astronomers for more than a century and a half, only recently has the theory of stellar evolution and refined observational technology made clear exactly how important variables are. The centennial of the world's largest association of variable-star observers is therefore a reason for celebration.

During 2011 the American Association of Variable Star Observers (AAVSO) is marking the centennial of its birth. Filled with exciting discoveries and significant astronomical progress, that century witnessed the AAVSO's growth from a handful of amateurs making observations for professional astronomers to a robust organization with the world's largest archive of variable-star observations and historical light curves. But this achievement only

Lawyer by day and amateur astronomer by night, William Tyler Olcott (*above* with a 3-inch refractor at his Norwich, Connecticut, home) established the AAVSO in 1911 as a small group of amateurs making observations for astronomers at Harvard College Observatory (*left*). All photos are from the AAVSO archive.

The AAVSO's membership reads like a virtual who's who of early 20th-century American amateurs. From left, a young Walter Scott Houston, Joseph Meek, and Leslie Peltier gather for the AAVSO's annual spring meeting in 1932.

happened because of the tireless efforts of the people who made it possible, the variable-star observers and the AAVSO's staff and elected leaders.

One of the AAVSO's early guiding lights was Leon Campbell, who began as a night assistant at Harvard College Observatory at the turn of the century. He joined the AAVSO in 1915.

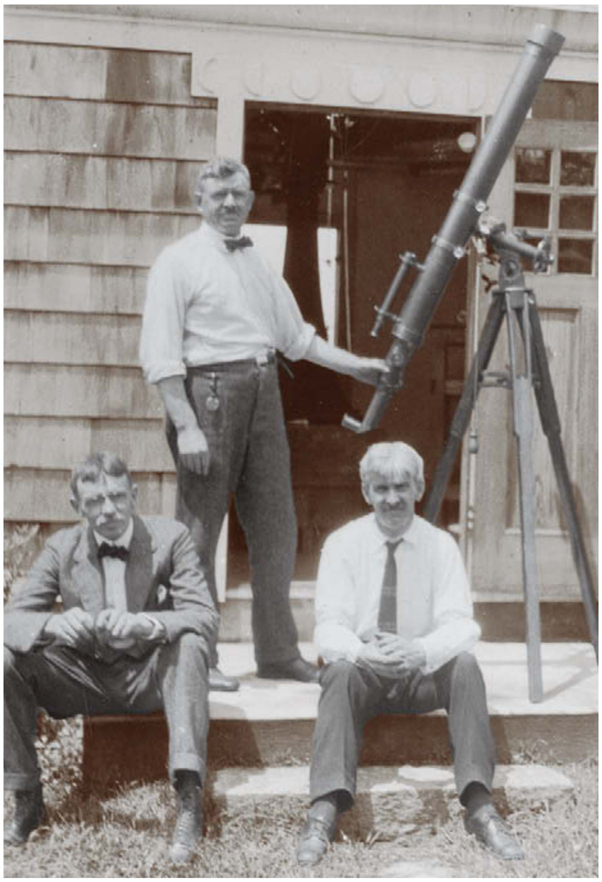
A Century Begins

Connecticut lawyer William Tyler Olcott (1873–1936) announced the founding of the AAVSO and reported the association's first variable-star observations in the December 1911 issue of *Popular Astronomy*. Olcott made it clear that he formed the association to gather variable-star observations for astronomers at Harvard College Observatory (HCO) in Cambridge, Massachusetts. He recruited observers intensively, attracting an early membership that included many professional women astronomers from New England colleges as well as other American and international observers.

After six years of effort, Olcott achieved his goal. The members formalized an association, elected officers, and incorporated. Exhausted by the process, Olcott handed over the leadership reins to others with pleasure and satisfaction. He remained as actively involved as his failing health would allow, but many others took up various tasks that he had handled by himself in the early years.

One of those who helped pick up the slack for Olcott was Leon Campbell (1880–1951). A native of Cambridge, Campbell joined the HCO staff as a night assistant in 1899 after graduating from Cambridge High School. His early success earned him a promotion to full observer, roughly akin to a professional astronomer in those days. From 1911 to 1915, Campbell served as supervisor of HCO's Boyden Station in Arequipa, Peru.

Upon his return to Cambridge in late 1915, Campbell immediately joined the AAVSO and began participating in its affairs. He helped Olcott organize observations for publication and advised members on technical aspects of observing variables. Campbell quickly became well known and liked by the members of the AAVSO, and he served as a council member after the group incorporated. Since this work wasn't part of his regular HCO duties,



Olcott, William Henry (standing), and Campbell were among those attending the AAVSO's 1923 spring meeting at Charles Elmer's observatory (of Perkin-Elmer fame) at Southold, Long Island.

Below: **Edward C. Pickering, director of Harvard College Observatory from 1877 until his death in 1919, had a longstanding interest in variable stars.**

Above left: **Harlow Shapley (standing at left with Olcott) succeeded Pickering and continued his interest in variables.** ***Center:*** **AAVSO chart maker Dalmiro Brocchi is often remembered today for the Coathanger asterism in Vulpecula that bears his name.** ***Right:*** **Campbell sits in his office at Harvard College Observatory.**

Campbell carried out his AAVSO activities at home.

In 1925 the AAVSO council recognized Campbell's many years of loyal and dedicated service by formally establishing a new position, AAVSO Recorder, and it elected Campbell to serve. Olcott remained as the corresponding secretary.

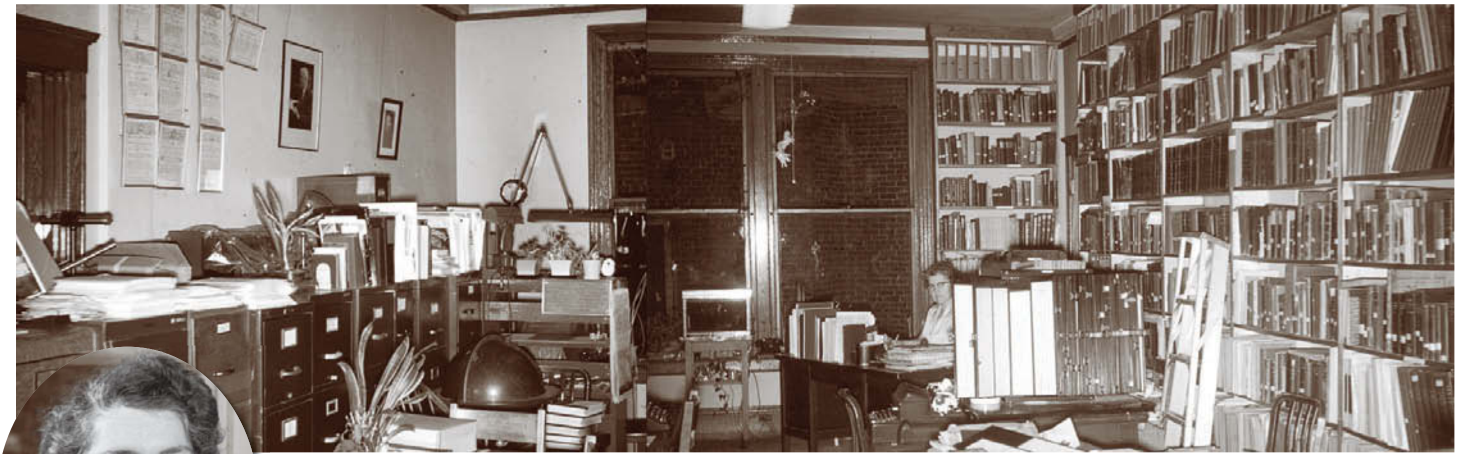
Edward Charles Pickering, the director of HCO during the AAVSO's early history, died in 1919. After a three-year search, Harvard University replaced him with a rising young star, Harlow Shapley of Mount Wilson Observatory. Shapley staffed the observatory with younger, highly qualified professional astronomers and rebuilt HCO's aging physical assets.

The AAVSO's membership was not confined to North America. Radha Gobinda Chandra of India made more than 49,000 observations from 1919 to 1954 with telescopes on loan from the AAVSO.

As part of a Rockefeller Foundation grant to fund Shapley's modernization program, Harvard received $100,000 to endow a Pickering Memorial Astronomer. When Harvard awarded the endowed chair to Campbell as its first incumbent, Shapley defined Campbell's role as full-time support to the AAVSO. In return, the AAVSO identified the Pickering Memorial Astronomer as synonymous with the AAVSO Recorder. Thus the tie between the AAVSO and HCO was formalized for the first time in 1931.

The 1930s and '40s were exciting times for astronomy despite the economic depression and World War II. Variable-star astronomy at HCO expanded significantly as Cecilia Payne-Gaposchkin and others studied variability in pulsating stars and eclipsing binaries while Campbell and the AAVSO concentrated on the long-period variables. These decades also witnessed astronomers making progress in understanding the mechanisms behind stellar variation.

When Campbell retired in late 1949, Shapley nominated Margaret Walton Mayall (1902–95) as the next Pickering Memorial Astronomer and AAVSO Recorder. Mayall had worked at HCO since the mid-1920s as Annie Jump Cannon's assistant, classifying stellar spectra for the *Henry Draper Catalogue*. With a degree in astronomy from Radcliffe College, Mayall immediately started broadening the AAVSO's effort, adding entire classes of variable stars to its observing programs. Eclipsing binaries were the first addition at the suggestion of Joseph Ashbrook of Yale University. Mayall's success initiating this program depended not only on observers in the United States, but also several in Sweden and Greece.



Margaret Mayall headed the AAVSO after Campbell and guided the organization through difficult years after its eviction from Harvard in 1954 and the move to cramped quarters (*above*).

A Change of Plans

Unfortunately, Mayall's freedom to reinvent the AAVSO's observing program ended suddenly. Harvard University had other plans for the observatory that were at cross-purposes with those of Mayall and the AAVSO. Progress at the observatory during Shapley's tenure peaked before World War II, but during and after the war the program deteriorated. When Shapley stepped down as HCO director in September 1952, Harvard appointed solar astronomer Donald H. Menzel as chairman of the Observatory Council, and the interim director of HCO.

Menzel was tasked with reducing expenses and reinvigorating the HCO program. His lengthy list of cost reduction and efficiency improvements included severing HCO's long-standing relationship with the AAVSO. In October 1952, he advised Mayall that the association was likely to lose its financial support and that she should begin planning to vacate the office space at the observatory.

At first Mayall resisted the eviction, but eventually she had to look for alternate arrangements with the help of AAVSO Secretary Clinton B. Ford and the council. In January 1954 the association moved to a tiny office on Brattle Street near Harvard Square in Cambridge. Tirelessly working extraordinarily long hours (even without a salary for at least the first year), Mayall saved the AAVSO from extinction. In 1956 the council changed Mayall's title to AAVSO Director in recognition of her dedication. Aided by financial support and advice from Ford and other members of the council, Mayall kept observers motivated, and the total observations recorded each year after the eviction continued to rise.

When survival was assured as the association found its financial footing, Mayall moved in July 1965 to larger office space on Concord Avenue only a short distance from HCO. Once settled, Mayall began recording observations on IBM punch cards. The observing program was also expanded, adding Cepheid variables, RV Tauri stars, and various eruptive and cataclysmic variables.

By the mid-1960s the AAVSO's future had become relatively secure, and it relocated to more spacious offices on Concord Avenue (*top*) in Cambridge. Helen Stephansky (pictured with Mayall) served as the director's assistant for many years.

Perhaps the most exciting new study in this era was initiated by AAVSO members Thomas Cragg and Larry Bornhurst at Ford Observatory in California. After astronomers accumulated evidence that the typical cataclysmic

During the AAVSO's 1973 spring meeting in Stamford, Connecticut, Mayall, *S&T* editor Joseph Ashbrook (behind her), Charles Scovil (seated), and Dorrit Hoffleit displayed some of the AAVSO's historic light curves.

variable was part of a binary system, Cragg and Bornhurst followed U Geminorum intensively at minimum light, looking for eclipses during the star's quiescent periods. They found changes that likely reflected events of astrophysical significance (see "50 & 25 Years Ago," page 10).

Other AAVSO members with large telescopes began undertaking similar studies, cooperating with professional astronomers who eagerly sought their help. Leslie Peltier, at Delphos, Ohio, and a few other AAVSO observers, joined this effort, which helped support profound changes in the theoretical models for cataclysmic variables. The program expanded as fast as Clinton Ford and Charles Scovil at the AAVSO could make new charts for additional stars.

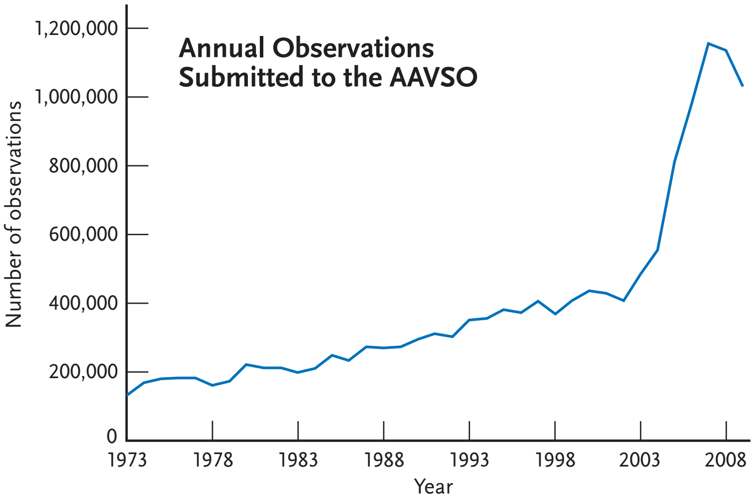
In 1971 Mayall announced her desire to retire, presenting the council with the unfamiliar problem of selecting a new director, since Mayall had started out as Shapley's choice as HCO's Pickering Memorial Astronomer. Furthermore, while Mayall had guided the AAVSO through difficult years, by the time she retired the association was a thriving independent entity.

After considering many candidates, the council hired Janet Akyüz Mattei (1943–2004), who held a degree in physics from Ege University in Turkey, and another in astronomy from the University of Virginia. She had also gained much variable-star experience during a six-month stint at Maria Mitchell Observatory on Nantucket Island working with the observatory's director, Dorrit Hoffleit.

Mattei took the helm following the AAVSO's annual meeting in 1973 and immediately began dealing with issues involving the observing program and data processing. With the help of Owen Gingerich, Barbara Welther, and others at the Harvard-Smithsonian Center for Astrophysics, Mattei began converting observations on punch cards into light curves. The council also authorized hiring data-entry operators who were devoted full time to transferring observations dating back to 1902 to punch cards.

The publication of Scovil's *The AAVSO Variable Star Atlas* in 1980 generated considerable interest and drew in new members. The same was true for new observing programs that emphasized monitoring eruptive and cataclysmic variables. The AAVSO program that began with the Cragg and Bornhurst observations of these stars, and

Under Mayall's leadership, the AAVSO began the computerization of historic data. The work-study students pictured here are keypunching IBM cards in the late 1970s at the Concord Avenue office.



The number of observations submitted to the AAVSO each year has steadily risen. The huge upsurge that began in 2003 reflects observers' increasing transition to electronic detectors.

e AAVSO's historical light curves for a number of them, tracted the attention of professional astronomers. This d to requests for more monitoring of cataclysmic stars, well as other variables, in support of orbiting observatoes then being launched. The AAVSO was soon providg formal alerts to professional astronomers and those in arge of NASA's satellite observatories.

One early breakthrough involved the organization's mmitment for intensive visual monitoring of U Gemirum and SS Cygni during the late 1970s flight of the -ray satellite HEAO-1. Astrophysicists were astonished at e correlations between the visual light curves of these ars and the unexpected onset of emissions of both hard d soft X-rays. The results led to significant changes in the theoretical models for this class of variable.

As the AAVSO staff expanded and the Concord Avenue headquarters filled up with punch cards, relocation became necessary. With generous support from Ford, the AAVSO acquired is own building at 25 Birch Street in Cambridge, next door to *S&T*'s offices. The new headquarters were dedicated during the celebration of the association's 75th anniversary in August 1986. Distinguished X-ray astronomer Riccardo Giacconi graced the occasion with an address that pointed to new directions for the AAVSO while celebrating its past accomplishments.

A New Era

The association continued to grow in membership, active observers, and especially the number of observations submitted each year. In the three decades after being evicted from HCO, annual observing totals doubled twice, rising from about 55,000 to more than 200,000 observations per year. In recent years, these annual totals have grown at an even faster rate as more members began observing with photoelectric photometers, and later with CCDs.

The association's educational program was broadened with the introduction of the Hands-On-Astrophysics curriculum codirected by Mattei and Canadian astronomer John R. Percy. It helped interest teachers from around the nation in variable-star astronomy. The association's international participation also grew, especially with the help of meetings held in Brussels, Belgium, in 1990 and Sion, Switzerland, in 1996.

Collaboration with professional astronomers continued to rise. NASA astronomers encouraged AAVSO observers by sponsoring several joint High Energy Astrophysics Workshops with the association, and joint meetings with the American Astronomical Society also emphasized professional astronomers' growing appreciation of the AAVSO. The High Energy Astrophysics Workshops led

Visit SkyandTelescope.com/AAVSO to watch a video interview with AAVSO Director Arne Henden.

In 1973 Janet Mattei succeeded Mayall as AAVSO Director after serving as Mayall's scientific assistant. At *right* Mattei confers with council members Clinton Ford (seated) and Ted Wales, while *below* she poses with mentors Mayall and Hoffleit.

With generous support from Clinton Ford (second from right in the photo *above*), the AAVSO purchased its own headquarters building on Birch Street in Cambridge in late 1985 and celebrated the organization's 75th anniversary with a meeting there the following year. *Below:* By 1996 the headquarter's staff had grown to a dozen full- and part-time employees, including coauthor Michael Saladyga (second from left).

The AAVSO's latest move to a new Cambridge headquarters was also the shortest. In 2007 the organization acquired one of *S&T*'s former offices (two-tone building at center right) on Bay State Road, less than 100 yards from the Birch Street office (left foreground).

to a very successful cooperative program to search for the afterglows of gamma-ray bursts.

One of the crowning achievements of the Mattei era came in early 2004 when she announced that the entire database of observations, from 1911 to the current period, was fully digitized. Light curves could now be generated that revealed the scientific treasure these historical observing records had always represented.

Tragically, Mattei was diagnosed with acute myelogenous leukemia shortly after the AAVSO's third International Meeting and High Energy Workshop in 2003, and she died the following year. Elizabeth O. Waagen, the senior member of the staff, served as the AAVSO's interim director while the council searched for a replacement.

In 2005 the council chose Arne Henden, a professional astronomer at the U. S. Naval Observatory in Flagstaff, Arizona, as Mattei's successor. An expert photometrist, Henden brought a new level of sophistication to the

Many individuals have helped make the AAVSO what it is today. Mattei's 20-year directorship ended with her death from leukemia in 2004. Ford (pictured with council member Howard Landis) provided enormous financial support for more than half a century.

AAVSO's observing programs, encouraging rapid growth in the number and quality of observations added annually to the AAVSO's database.

Members of the association volunteered to work with the staff to upgrade the AAVSO's computer software. They created a sophisticated system of programs that receive, validate, and store observations submitted via the internet. There are also new programs for creating and printing variable-star charts on demand, and generating customized light curves. More than 20 million observations are presently stored in the database. It has every known or suspected variable star, including thousands of new variables discovered during ESA's Hipparcos spacecraft mission and other all-sky surveys. Arguably, the AAVSO International Database (AID) is the most comprehensive catalog of variable stars now in existence.

Effort is underway to add observations of important 19th- and early 20th-century observers to the AID. For example, South African Alexander William Roberts recorded most of his variable-star observations before the founding of the AAVSO. Volunteers in South Africa have recently reduced more than 70,000 of Roberts's observations, and they are now included in the AID.

Henden's energetic style created the opportunity for a move to much more spacious quarters literally next door to the Birch Street office. Under his leadership, the association purchased one of the office buildings on Bay State Road that had served as *S&T*'s some for half a century. Henden, his wife Linda, and the AAVSO staff worked tirelessly to refurbish the new headquarters. Thus, as it did with the 75th anniversary, the AAVSO will celebrate its centennial anniversary in a new location.

Astronomer Arne Henden has been AAVSO Director since 2005. His strong background in photometry and instrumentation is helping guide the organization as observations are increasingly made with CCDs and other electronic detectors.

As a new century of variable-star observing begins, William Tyler Olcott's dream of a small band of observers in service to Harvard College Observatory has succeeded beyond his wildest dreams. AAVSO now encompasses a large international group of sophisticated observers in service to astrophysics. And as Henden explains on page 86, the next century will certainly be an exciting one. ✦

***Thomas R. Williams** has served as AAVSO President and is currently its historian. **Michael Saladyga** is the organization's Technical Assistant and Archivist. Cambridge University Press has just published their centennial history of the AAVSO titled,* Advancing Variable Star Astronomy.

The AAVSO is dedicating its new headquarters as the Clinton B. Ford Astronomical Data and Research Center during it's centennial celebration this October.

Great Autumn

Here's a sample of the season's best stellar pairings.

James Mullaney

Double Stars of Autumn

Name		Mag.	Sep.	PA	RA	Dec.
γ Del		4.4, 5.0	9.0″	266°	$20^h\,46.7^m$	+16° 07′
Σ2725		7.5, 8.2	6.1″	10°	$20^h\,46.2^m$	+15° 54′
61 Cyg		5.2, 6.0	31″	152°	$21^h\,06.9^m$	+38° 45′
ζ Aqr		4.3, 4.5	2.2″	168°	$22^h\,28.8^m$	–0° 01′
Σ3053		6.0, 7.2	15″	71°	$0^h\,02.6^m$	+66° 06′
η Cas		3.5, 7.4	13″	322°	$0^h\,49.1^m$	+57° 49′
γ Ari		4.5, 4.6	7.3″	1°	$01^h\,53.5^m$	+19° 18′
γ And	AB	2.3, 5.0	9.5″	63°	$02^h\,03.9^m$	+42° 20′
	BC	5.0, 6.3	0.2″	97°		

This is the third installment of my four-part roundup of attractive double and multiple stars (the previous ones were in the February and July issues, and the next will be in spring 2012). My selection barely hints at the multitude of these jewels that lie within reach of even the smallest telescopes at this time of year.

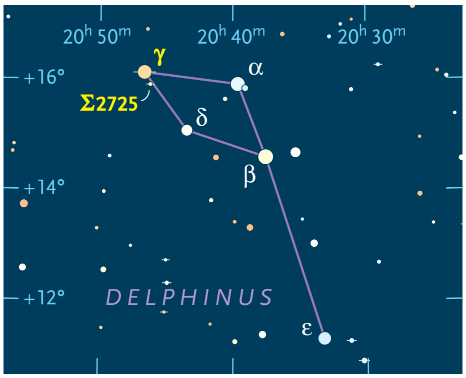
Gamma (γ) Delphini is a beautifully tinted combination of a deep yellow primary and pale green companion that's neatly split in a 3-inch refractor at 45×. My favorite description of this pair's hues comes from the well-known double-star enthusiast Sissy Haas, who sees them as "muted lemon and lime green." Adding to the delight of viewing Gamma is **Struve 2725 (Σ2725)** lying in the same eyepiece field 15′ to the southwest. I've dubbed Struve 2725 the Ghost Double, since it seems like a faint specter of Gamma itself. Can you scare it up?

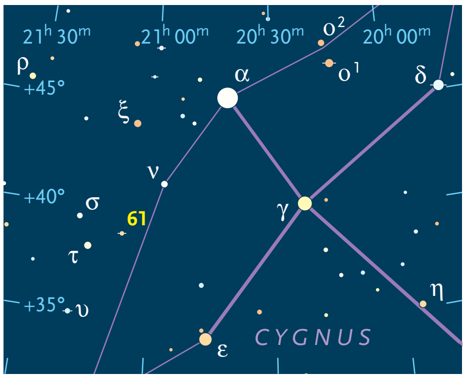
The two pairs are at slightly different distances — 125 light-years for Struve 2725 compared to 100 light-years for Gamma — and they're moving though space in nearly opposite directions. So they must be physically unrelated despite their proximity in the sky.

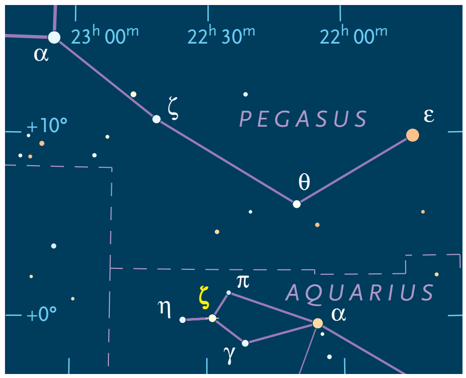
61 Cygni is a lovely sight in all telescopes. It consists of roughly matched, vivid orange suns floating serenely in front of the rich Cygnus Milky Way. It's the 5th-closest naked-eye star, just 11.4 light-years from us, and it has an extremely high proper motion across the sky of 5″ per year. So the pair moves the apparent distance between the stars in just six years! 61 Cygni is a true binary; its components orbit each other every 650 years.

Zeta (ζ) Aquarii is a close double sitting in the midst of Aquarius' well-known Water Jar asterism, making it a snap to find. A binary with an orbital period around 500 years, it's currently quite snug at 2.2″ separation. Both components of this neatly matched pair appear off-white to most observers, with a slight greenish hue often reported. Unlike our previous offerings, this double needs aperture, magnification, and a steady night to appreciate. I can split it with a 3-inch scope at 90×, but at least a 6-inch at 150× is required to see Zeta in its full glory.

Struve 3053 (Σ3053) in Cassiopeia is rarely observed except by true double-star aficionados. What a pity, for







Double Stars

61 Cygni

Struve 3053

Gamma Arietis

Gamma Andromedae

All sketches here were prepared by Arizona stargazer and graphic artist Jeremy Perez. They represent his views through a 6-inch Newtonian reflector at 240×.

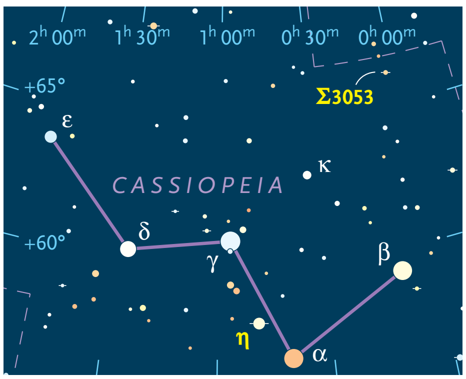
here we find a beautiful miniature of famed Albireo itself! Its components are fainter and closer to each other than Albireo's, but its color contrast is immediately obvious in a small scope. Indeed, many observers who are unaware of its existence are stunned when they encounter it while sweeping the sky between Cassiopeia and neighboring Cepheus in search of other deep-sky targets.

Eta (η) Cassiopeiae is a double that definitely *is* well known thanks to its striking tints. And here we find not only a lovely contrast in color but one in brightness, with the stars four magnitudes apart. I see the primary as rich yellow and the companion as ruddy purple — a combination that has prompted me to call this pair the Easter Egg Double. Various observers report other tints for the fainter star, including lilac, lavender, garnet, orange, and red. Its unique hues show up nicely in a 4-inch reflector at 60×, but as aperture increases the effect becomes ever more wondrous. I consider Eta to be one of the most striking double stars in the entire sky when viewed through a 13-inch refractor at 150×. This 480-year-period binary lies close by, at a distance of just 19 light-years.

Gamma Arietis (also called Mesartim) is a stunning, perfectly matched double with both components shining a silvery blue. (This pair and the next can be found above the eastern horizon using the all-sky chart on page 44.) Gamma Arietis is lovely in all apertures, with a 2-inch scope neatly showing the stars in contact at 25×. Sissy Haas calls this object "hauntingly beautiful" and sees these suns as "snowy white equals that look like eyes." Leland Copeland, writer of the *Deep-Sky Wonders* column during the early years of *Sky & Telescope*, said that it "suggests two little girls in blue." This was one of the very first doubles to be discovered — by Robert Hooke in 1664. The two suns are gliding through space together as a common-proper-motion (CPM) pair.

Gamma Andromedae (or Almach) ranks as one of the brightest and finest double stars in the entire heavens. Actually, it's a triple; the fainter star is itself a challenging visual binary, with a 64-year orbital period. However, the B and C components are currently just 0.2″ apart, too close to split with any normal telescope.

The magnificent topaz and greenish blue hues of the two main stars are intense and unmistakable, even in a 2.4-inch refractor at 60×. And here's one pair that remains striking in large backyard and observatory telescopes, which unduly separate the components of many doubles, muting their color contrast. I find the tints perhaps most striking in 5- to 8-inch apertures (not too little nor too much light) at around 100×. Among other hues reported here are orange and emerald, deep yellow and sea green, and burnished gold and cerulean blue. If you're not already a double-star observing addict like myself, this beauty will make you one — guaranteed! ✦



The chart of Delphinus shows stars to magnitude 7.5, the chart of Cassiopeia shows stars down to magnitude 6.5, and the other two charts go down to magnitude 5.5.

James Mullaney, coauthor with Wil Tirion of The Cambridge Double Star Atlas, *has been seeing double for more than 50 years*

S&T: SEAN WALKER

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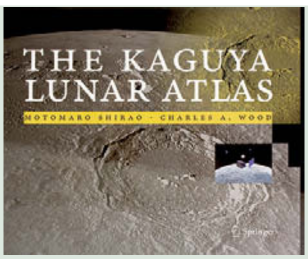

S&T: SEAN WALKER

◄ MOON ATLAS Motomaro Shirao and Charles A. Wood (author of *S&T*'s Explore the Moon column) take readers on a unique tour of the Moon in *The Kaguya Lunar Atlas* ($39.95). The book begins with a brief overview of the Japanese Kaguya/Selene mission to help determine the origin and evolution of the Moon, with a heavy emphasis on the spacecraft's first-of-a-kind HDTV system developed by the Japan Broadcasting Corporation. The authors provide details of the workings of the HDTV system and methods used to combine the camera's images (including a technique developed by Shirao), and early mission results close out the first third of the book. The remaining pages feature 100 beautifully reproduced black-and-white plates assembled from the wide-angle HDTV images, providing readers a view of select lunar vistas from an oblique angle. Each plate includes a position chart as well as commentary on particular details appearing within the image.

Available from Springer
233 Spring St., New York, NY 10013
212-460-1500; www.springer.com
173 pages, ISBN 978-1-4419-7284-2

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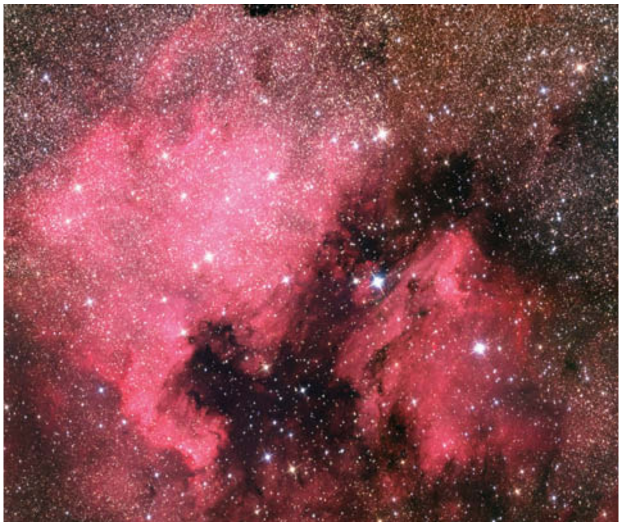
Around the Northern Cross

Deep-sky wonders are scattered all over Cygnus the Swan.

THE ROMANS USED to say that all roads lead to Rome. We can't make that claim about any one point in the October evening sky, for it holds several marvelous regions that compete for our attention.

What we can say is that an amazing number of roads in Cygnus lead *away* from the constellation's central asterism, the Northern Cross. These roads aren't always easy to follow, but they're well worth pursuing because they lead to a remarkable variety of deep-sky objects.



ADAM BLOCK / NOAO / AURA / NSF

The North America Nebula is on the left in this photo and the Pelican Nebula lies in the right-center. The area around the "Gulf of Mexico" is the most prominent part of the North America Nebula when seen through a telescope's eyepiece.

Wonders east of Deneb. Last month we looked at marvels which were essentially right on the Northern Cross itself. But most of Cygnus's celestial wonders lie off the Cross — some near, others far.

Let's start at Deneb, the top of the Northern Cross. Just a few degrees east of this 1st-magnitude star is the North America Nebula (NGC 7000), a patch of cloudy light about 120′ × 100′. It's visible to the unaided eye in dark skies, but you will probably need optical aid to detect the resemblance to its namesake continent. A wide-field telescope at low magnification works best. A nebula filter is a huge help in seeing this and the other nebulae discussed in this article.

Much farther from Deneb — about 9° east-northeast — is the large, bright, open star cluster M39, which is plotted near the zenith on the all-sky chart on pages 44–45. At magnitude 4.6, M39 is so bright that Aristotle recorded it in ancient times. To the unaided eye in a moderately dark sky, M39 looks like a hazy spot of light just east of an impressively deep cut of darkness in the Milky Way band. The ½°-wide cluster is easy to resolve in binoculars. It contains about a dozen stars of similar brightness plus a dozen fainter stars.

The Veil and the Blinking Planetary. Two very different remnants of star death shine north and south of the ends of the Northern Cross's transverse bar. Alternatively, you can picture these nebulae as being near the wingtips of Cygnus the Swan.

The first, which is usually called the Veil Nebula, is a collection of wisps covering about 3° of sky mostly south of Epsilon (ε) Cygni, the east end of the Northern Cross's transverse bar. The entire complex is often called the Cygnus Loop. It's a supernova remnant — the leftovers from a star that exploded thousands of years ago.

The easiest wisp to find in telescopes is the one that cuts right through the 4.2-magnitude star 52 Cygni (due south of Epsilon). But there's a brighter wisp centered 2½° east-northeast of 52 Cygni. Both wisps can be spotted in small, wide-field telescopes — and even glimpsed in 7×50 binoculars in really dark skies. But larger apertures bring out ever more wisps, many with intricate, fantastic detail, as described on page 60 of last month's issue.

Parts of the Cygnus Loop have been called the Network Nebula, Filamentary Nebula, Lacework Nebula, Cirrus Nebula, and Bridal Veil Nebula. These beautiful glowing shreds lie an estimated 1,500 light-years from Earth.

A *planetary nebula* is the less violent outpuffing from a dying star of more modest mass. The marvelous Blinking Planetary, NGC 6826, shines about 12° north of Delta (δ) Cygni, the west end of the Northern Cross's transverse bar. In medium-size telescopes, look straight at the 10.4-magnitude central star, and you don't see the nebula. Then use averted vision, and the nebula pops into view, overwhelming the central star with its light. ✦

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

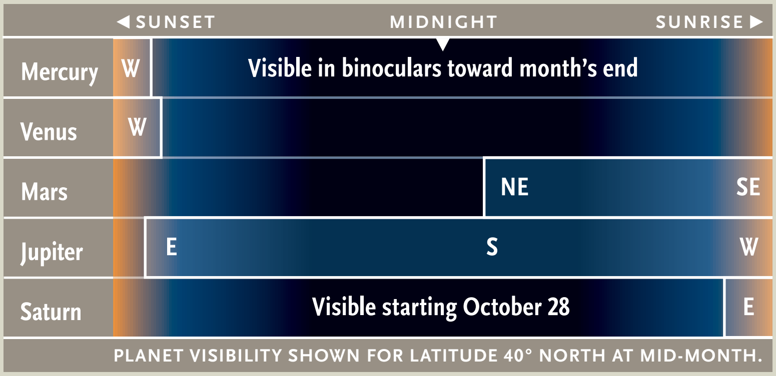
Sky at a Glance

SKY & TELESCOPE

MOON PHASES

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

PLANET VISIBILITY



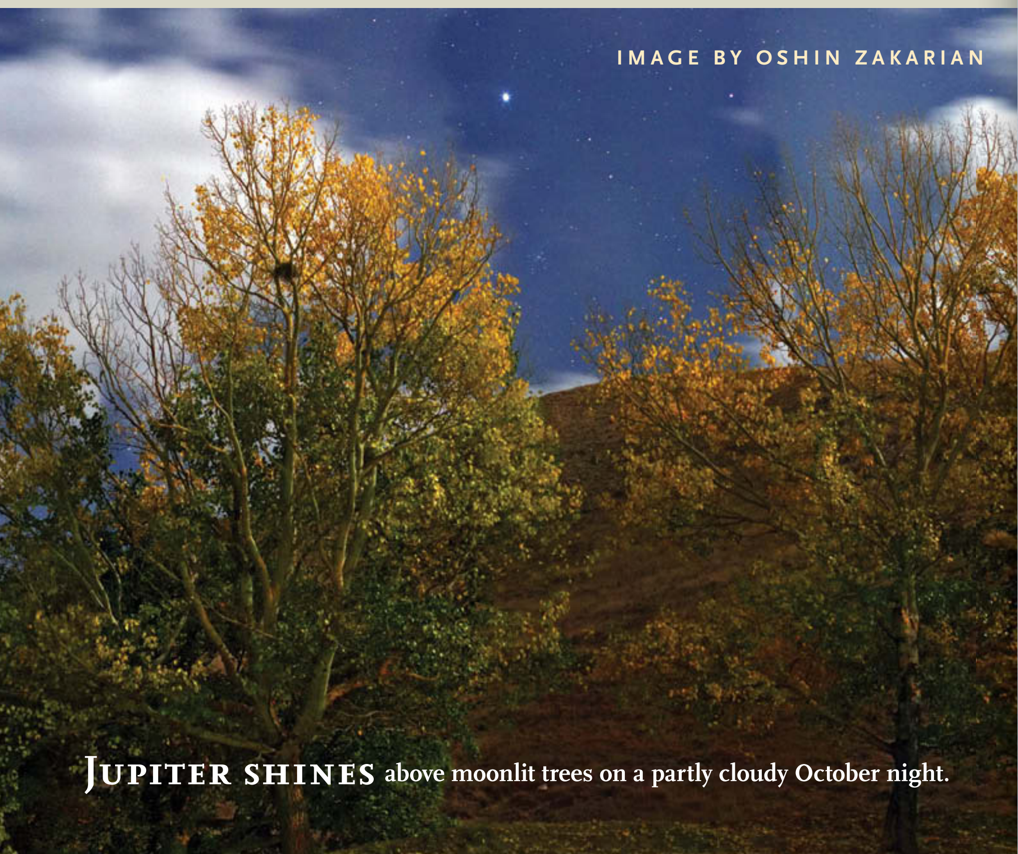


IMAGE BY OSHIN ZAKARIAN

JUPITER SHINES above moonlit trees on a partly cloudy October night.

October 2011

Sept. 25 – Oct. 10 **PREDAWN:** The zodiacal light, or "false dawn," is visible in the east about 120 to 80 minutes before sunrise from dark locations at mid-northern latitudes.

1 **PREDAWN:** Binoculars and telescopes show Mars passing through the Beehive Cluster, Messier 44.

DUSK: Look for Antares a few degrees below the waxing crescent Moon, low in the southwest as twilight fades.

3 **FIRST-QUARTER MOON** (11:15 p.m. EDT).

8 **EVENING:** The Draconid meteor shower may put on an intense burst of activity in Europe or perhaps elsewhere; however, the nearly full Moon will hide all but the brightest meteors. See page 53.

11 **FULL MOON** (10:06 p.m. EDT).

12–14 **TWO NIGHTS:** Jupiter is near the just-past-full Moon from dusk on October 12th to dawn on the 14th.

14, 15 **EVENING:** Binoculars show the Pleiades left of the Moon on the 14th and above it on the 15th.

19 **LAST-QUARTER MOON** (11:30 p.m. EDT).

21–22 **LATE NIGHT:** The modest Orionid meteor shower peaks late tonight. Best in the early hours of the 22nd.

25 **DAWN:** A very thin crescent Moon should be visible low in the east-southeast a half hour before sunrise. Binoculars may show Saturn about 10° to the Moon's lower left.

26 **NEW MOON** (3:56 p.m. EDT).

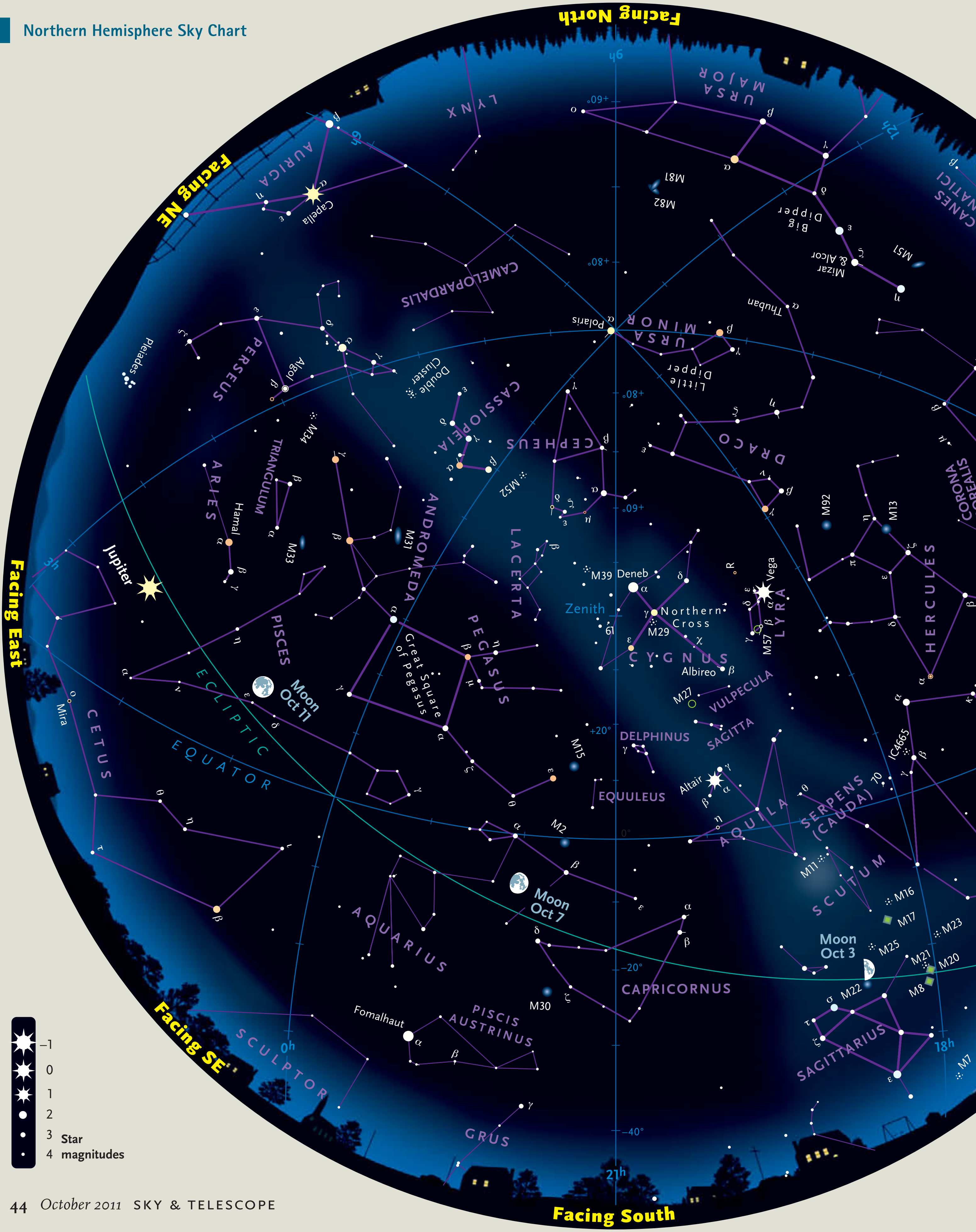
27 **DUSK:** Telescopes and binoculars should show Mercury 2° below Venus very low in the southwest 15 minutes after sunset in North America. If conditions are perfect, they might also show the superthin Moon about 1.5° to 2.5° below or lower right of Mercury (in North America).

Oct. 28 – Nov. 16 **DUSK:** Binoculars continue to show Mercury 2° below Venus very low in the southwest a half hour after sunset.

28 **DUSK:** The thin crescent Moon is about 10° upper left of Venus and Mercury.

28–29 **ALL NIGHT:** Jupiter is at opposition and almost at its brightest; see page 54.

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


Facing North
Facing NE
Facing East
Facing SE
Facing South
URSA MAJOR
Big Dipper
Mizar & Alcor
M51
M81
M82
LYNX
AURIGA
Capella
CANES VENATICI
CAMELOPARDALIS
Polaris
URSA MINOR
Little Dipper
Thuban
DRACO
PERSEUS
Algol
Pleiades
Double Cluster
CASSIOPEIA
CEPHEUS
M52
M34
TRIANGULUM
ARIES
Hamal
M33
M31
ANDROMEDA
LACERTA
M39
Deneb
Zenith
61
Northern Cross
M29
CYGNUS
Albireo
Vega
LYRA
M57
M92
M13
HERCULES
CORONA BOREALIS
Jupiter
PISCES
Moon Oct 11
ECLIPTIC
EQUATOR
Mira
CETUS
PEGASUS
Great Square of Pegasus
M27
VULPECULA
SAGITTA
DELPHINUS
M15
EQUULEUS
Altair
AQUILA
IC4665
SERPENS (CAUDA)
M11
SCUTUM
M16
M17
M23
M25
M21
M20
M8
Moon Oct 3
M22
M2
Moon Oct 7
AQUARIUS
CAPRICORNUS
M30
Fomalhaut
PISCIS AUSTRINUS
SCULPTOR
GRUS
SAGITTARIUS
M7
0h
3h
6h
9h
12h
18h
21h
+80°
+60°
+20°
0°
–20°
–40°
–1
0
1
2
3
4
Star magnitudes

Using the Map

WHEN

Late August	Midnight*
Early September	11 p.m.*
Late September	10 p.m.*
Early October	9 p.m.*
Late October	8 p.m.*

*Daylight-saving time

HOW

Go outside within an hour or so of a time listed above. Hold the map out in front of you and turn it around so the yellow label for the direction you're facing (such as west or 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. Three-quarters of the way from there to the map's center is the brilliant star Vega. Go out, face west, and look three-quarters of the way up the sky. There's Vega!

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

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: Little Globular M75

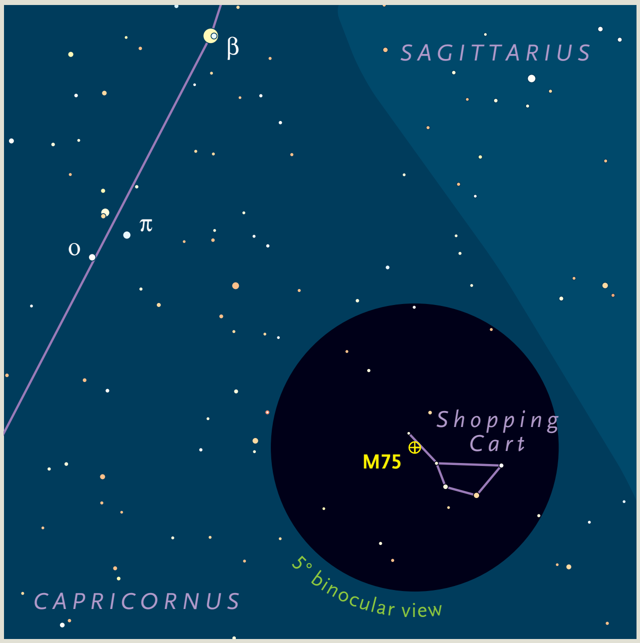
Lying some 68,000 light-years away in Sagittarius, **M75** is the second most distant globular cluster in the Messier catalog. It's also the second dimmest on the list, though at magnitude 8.2, it's still bright enough to be visible in binoculars under reasonably dark skies.

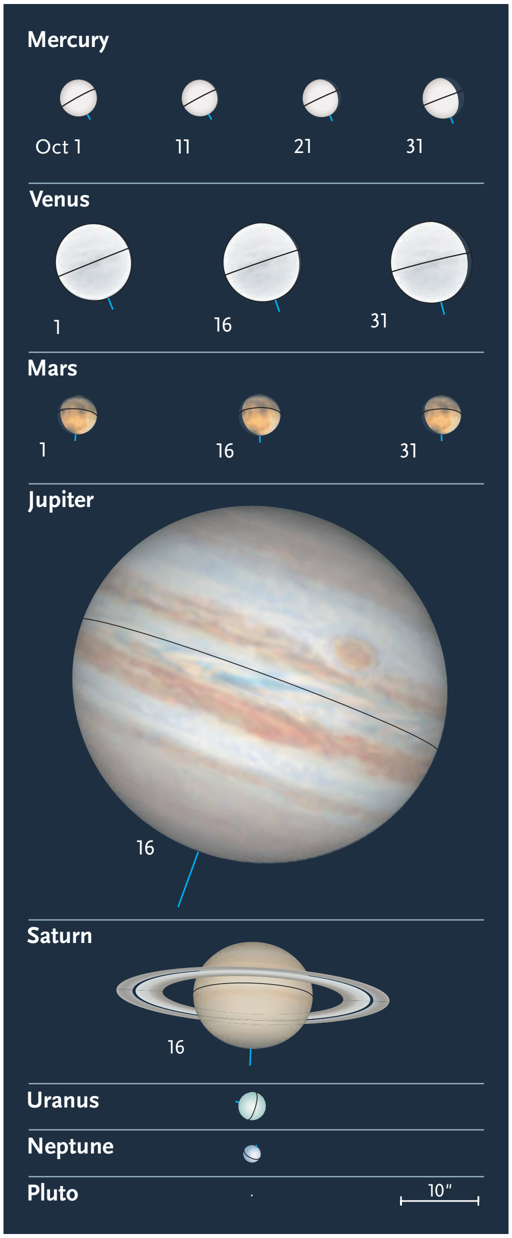
The real difficulty with M75 is that it spans only 6.8′, making it the smallest Messier globular. That means it's easy to mistake for a field star at typical binocular magnifications. To claim M75, you'll have to use your star-hopping skills and pinpoint its exact position. Begin your hunt in Capricornus, at a nifty isosceles triangle anchored by 5th-magnitude Pi (π) Capricornus. From there proceed a little more than one binocular field southwest to an asterism of 6th- and 7th-magnitude stars that outlines the shape of a small shopping cart. The cluster is situated just below the cart's handle.

Although I can see M75 in my 10×30 image-stabilized binoculars, the magnification boost provided by 15×45s really helps with identification. The globular is a tiny, round ball and barely larger than the surrounding stars. In 10×50s, M75 exhibits a curious "blinking" effect — when I look directly at the cluster it appears stellar, but when I look slightly to one side, it seems to grow a small, hazy halo. Do you see this?

If you're up for another challenge and have 15× binoculars, jump back to the Pi triangle and take a careful look at **Omicron (ο) Capricorni**. Omicron is a very tight double star consisting of 5.9- and 6.7-magnitude components separated by a scant 22″. I can split the pair cleanly with my 15×45s, but it isn't easy. ✦

— *Gary Seronik*



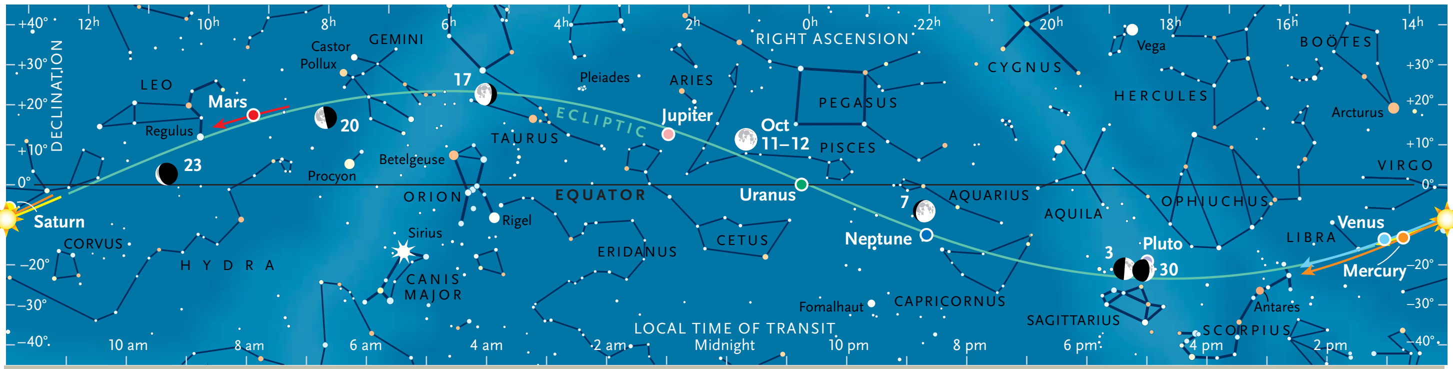


Sun and Planets, October 2011

	October	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$12^h\ 26.9^m$	–2° 54′	—	–26.8	31′ 57″	—	1.001
	31	$14^h\ 18.8^m$	–13° 52′	—	–26.8	32′ 13″	—	0.993
Mercury	1	$12^h\ 35.0^m$	–2° 30′	2° Ev	–1.6	4.8″	100%	1.406
	11	$13^h\ 36.2^m$	–9° 54′	9° Ev	–0.8	4.8″	97%	1.410
	21	$14^h\ 35.1^m$	–16° 17′	14° Ev	–0.4	4.9″	92%	1.358
	31	$15^h\ 33.1^m$	–21° 16′	19° Ev	–0.3	5.3″	85%	1.257
Venus	1	$13^h\ 13.8^m$	–6° 47′	12° Ev	–3.9	10.0″	98%	1.669
	11	$14^h\ 00.2^m$	–11° 36′	15° Ev	–3.9	10.2″	97%	1.642
	21	$14^h\ 48.2^m$	–15° 58′	17° Ev	–3.8	10.3″	96%	1.612
	31	$15^h\ 38.2^m$	–19° 40′	20° Ev	–3.8	10.6″	94%	1.578
Mars	1	$8^h\ 38.9^m$	+19° 36′	60° Mo	+1.3	5.2″	92%	1.814
	16	$9^h\ 14.5^m$	+17° 24′	66° Mo	+1.2	5.5″	91%	1.707
	31	$9^h\ 47.5^m$	+15° 01′	73° Mo	+1.1	5.9″	90%	1.591
Jupiter	1	$2^h\ 26.7^m$	+12° 58′	149° Mo	–2.8	48.4″	100%	4.077
	31	$2^h\ 12.3^m$	+11° 45′	177° Ev	–2.9	49.6″	100%	3.971
Saturn	1	$13^h\ 11.5^m$	–5° 09′	11° Ev	+0.8	15.6″	100%	10.646
	31	$13^h\ 25.1^m$	–6° 30′	15° Mo	+0.7	15.6″	100%	10.630
Uranus	16	$0^h\ 07.2^m$	–0° 04′	159° Ev	+5.7	3.7″	100%	19.143
Neptune	16	$22^h\ 02.0^m$	–12° 39′	126° Ev	+7.9	2.3″	100%	29.408
Pluto	16	$18^h\ 20.9^m$	–19° 13′	73° Ev	+14.1	0.1″	100%	32.391

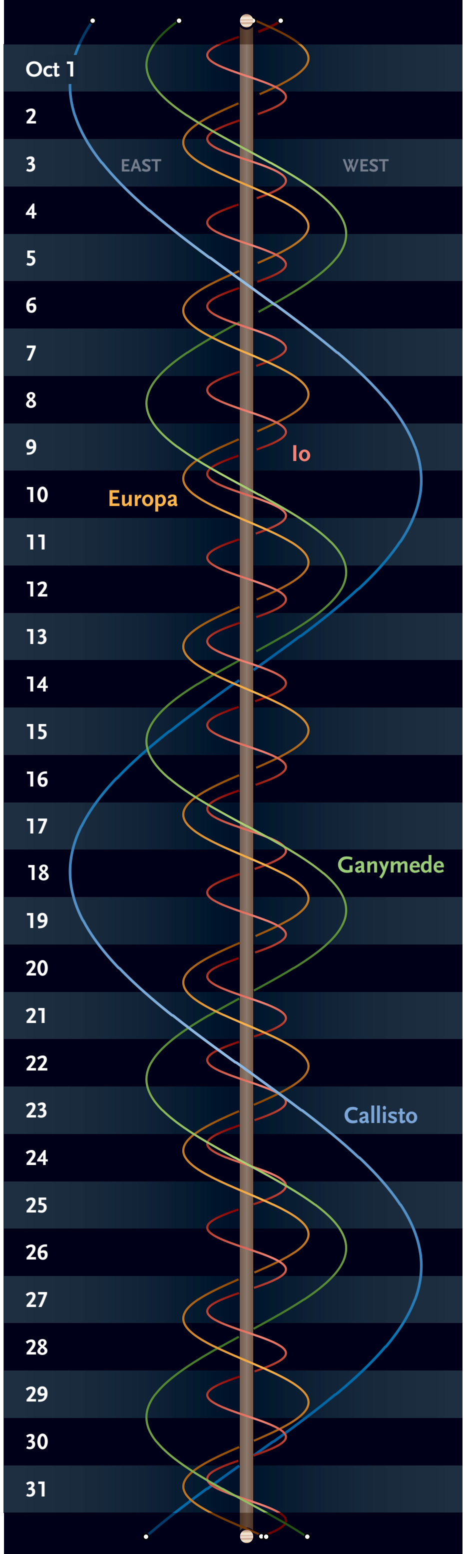
The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial 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-October; 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). All Moon dates are in October. "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.

Jupiter Reaches Opposition

The king of planets shines at its brightest and biggest.

THE MOST DRAMATIC solar-system sight of October for observers in the right part of the world could be a strong display of the Draconid meteor shower (page 53). But all of us everywhere can count on Jupiter blazing almost all night long as it nears and reaches opposition.

Evening twilight features Venus sinking in the west as Jupiter rises in the east. Mercury sneaks up under Venus late in October. Mars, finally brightening a bit, clears the eastern horizon around 1 or 2 a.m. (daylight-saving time). And Saturn pops up in the east at dawn near month's end.

DUSK

Venus is visible very low in the west shortly after sunset, shining at magnitude –3.9. It starts October setting just a half hour after the Sun for viewers at mid-northern latitudes, but it remains up about an hour after sunset by month's end. Venus is slowly climbing toward a grand, high apparition as the blazing "Evening Star" this winter and spring.

Mercury appears 2° below Venus in the last week of October. It shines at magnitude –0.3, but it's so low in bright twilight that you'll need binoculars to spot it.

EVENING

Jupiter rises more than an hour after sunset on October 1st, but it comes up earlier each evening as the month advances. Jupiter reaches opposition to the Sun on the night of October 28–29, when it rises at sunset and sets at sunrise.

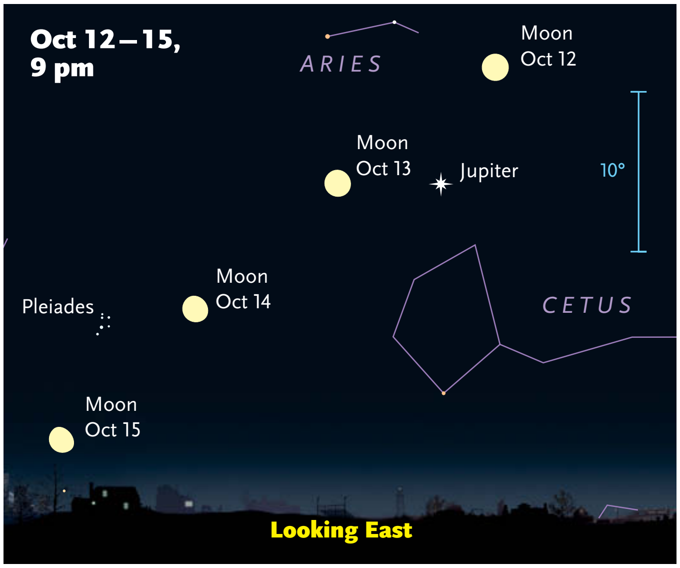
Last year Jupiter came closer to Earth than it had since 1963. At this year's closest approach, on October 27th, it's only 0.4% farther, at 369 million miles (594 million km). Jupiter blazes at magnitude –2.9 from early October to mid-November, and its mammoth globe grows to a maximum of 49.6″ wide in late October.

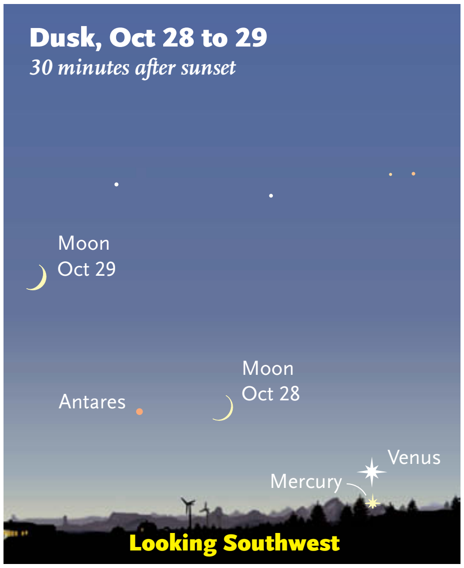
Mighty Jupiter now creeps with retrograde motion (west relative to the stars) in southwest Aries near that constellation's meeting place with Cetus and Pisces, close to Cetus's head. By the middle of the night the behemoth world shines more than 60° high in the south for viewers at latitude 40° north, and on nights of good seeing, a 6-inch or larger telescope should show a feast of intricate detail in its colorful clouds.

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

Jupiter's Galilean moons are also at their biggest, making this a good time to try to view their tiny disks and study their different appearances. When one of the moons crosses Jupiter's face (see page 54), it's normally hard to see because it blends into the brightness. But near opposition, the moons are relatively easy to locate because they appear close to their much more prominent tiny black shadows.

Uranus, in Pisces, and **Neptune**, in Aquarius, are best viewed in late and mid-

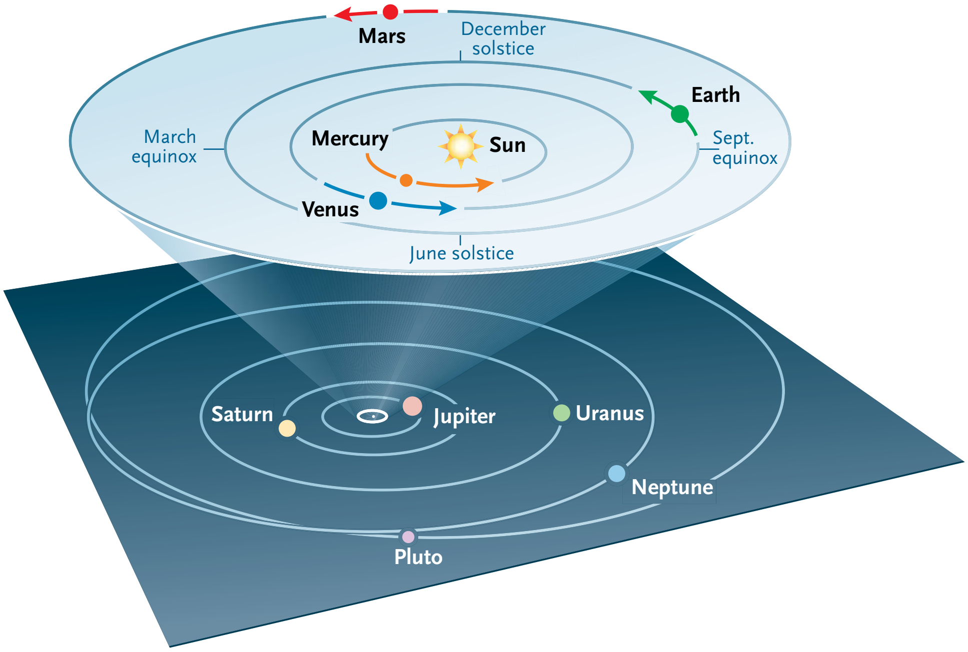




These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. The blue 10° scale bar is about the width of your fist at arm's length. For clarity, the Moon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

ORBITS OF THE PLANETS

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



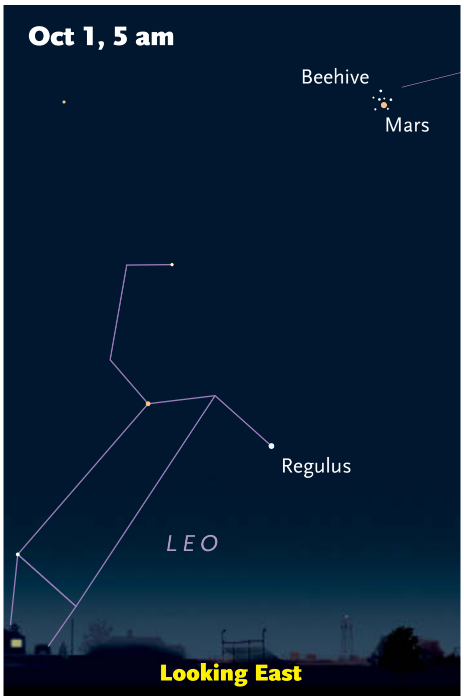
evening, respectively. Use the charts at SkyandTelescope.com/uranusneptune or page 53 of last month's issue.

Pluto, in Sagittarius, is low and getting lower when the sky becomes fully dark, but it can still be located with the chart on page 64 of the July issue.

PREDAWN

Mars rises around 1 or 2 a.m. (daylight-saving time) and is high in the southeast by dawn. On the very first morning of October, Mars is in the middle of M44, the Beehive Cluster in Cancer — a fine view in binoculars and telescopes, and a great photo opportunity.

Mars spends the rest of the month moving toward Regulus, crossing the border into Leo on the 19th. The Red Planet brightens from magnitude +1.3 to +1.1 in October and thus slightly outshines Regulus by the time it pulls within 6° of the star at month's end.

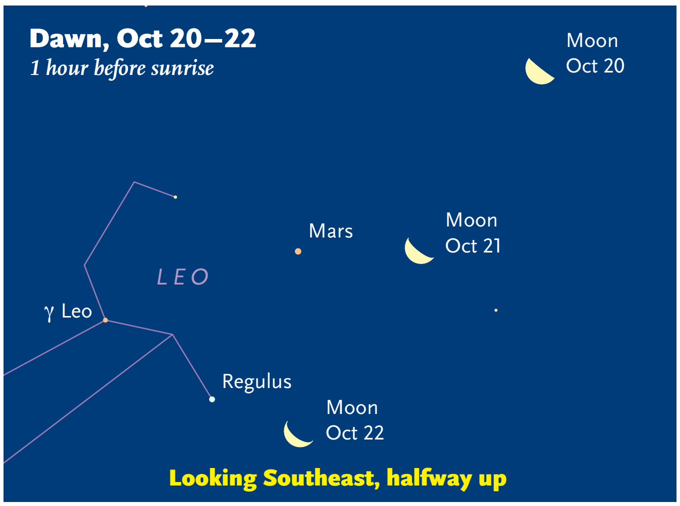


In a telescope, though, Mars is disappointing. It enlarges from a mere 5.2″ to 5.9″ in October, not yet big enough to reveal surface features through most amateur telescopes.

DAWN

Saturn passes through conjunction with the Sun on October 13th. But the planet climbs rapidly into dawn visibility in the latter half of the month, rising about 1½ hours before the Sun at month's end. On October 31st, about 30 minutes before sunrise, Saturn stands almost 10° high in the east-southeast with Spica less than 5° to its lower right.

Saturn brightens to magnitude +0.7 in October, slightly brighter than Spica. The angle of Saturn's ring-tilt opens from 11° to 12½° this month, but Saturn's rings and globe won't appear sharp through a telescope so low in the sky.



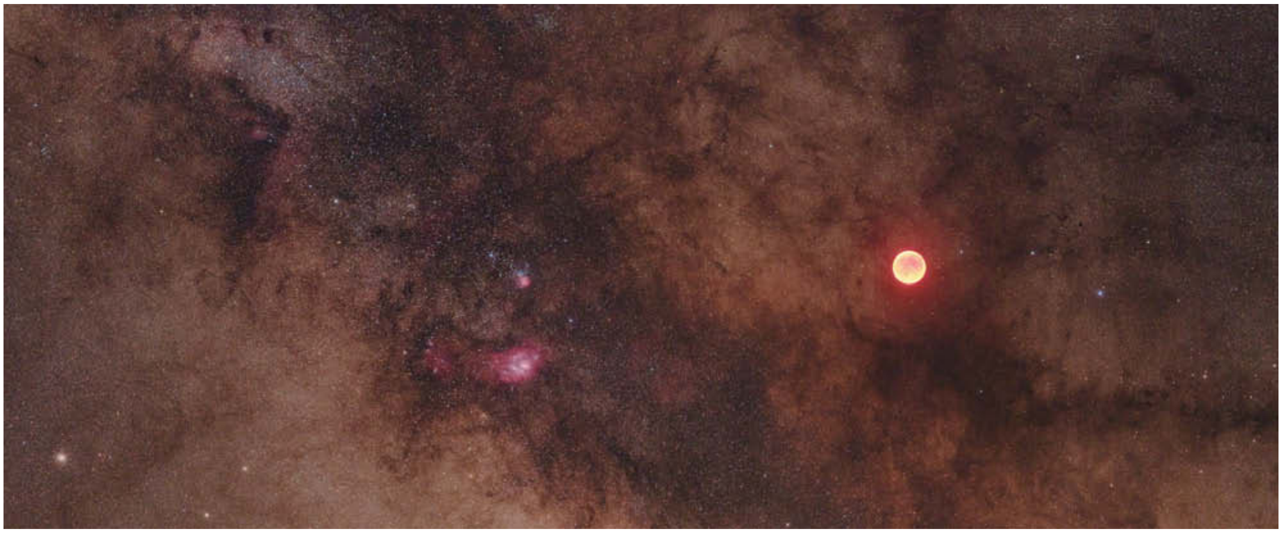
MOON PASSAGES

The **Moon** is a waxing crescent on October 1st, when it sits a few degrees above Antares low in the southwest around the middle of evening twilight. The waxing gibbous Moon brightens the sky on October 8th for most of the night for would-be viewers of any Draconid meteor outburst. A just-past-full Moon makes an impressive pair with Jupiter on the night of October 12–13. A thick waning lunar crescent lies not far to the right of Mars at dawn on October 21st. The next morning, the Moon is closer to the lower right of Regulus.

On October 28th at dusk, a slender lunar crescent lies far left of and a little higher then Venus, and right of Antares, as shown on the facing page. ✦

Lunar Dominance

No other object in the night sky offers so much to observe.

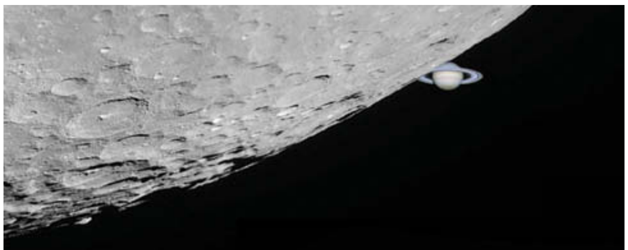


BABAK TAFRESHI

Above: **The June 15th total lunar eclipse gave observers a very rare opportunity to directly compare the Moon's large apparent diameter to nebulae M8 and M20 in Sagittarius. Few objects in the night sky are larger than the Moon, yet none offer as much detail through even small telescopes.**

THE MOON IS THE BRIGHTEST and most fascinating object in the night sky. This may seem an outrageous statement, but it is undeniably the brightest one. Is it also the most fascinating? By "fascinating," I mean an object that presents considerable visible detail (encouraging prolonged observing) and changes enough to add uncertainty to any observation.

Consider the Moon's competition. Within the solar system, Mars, Jupiter, and Saturn are favorite targets for planetary observers. But the apparent sizes of these planets are tiny compared to the Moon; Jupiter and Saturn (including its resplendent ring system), are each about the same angular diameter as the 93-kilometer-wide (58-mile) crater Copernicus. Though you can argue that Jupiter has as many splendid subtle details to observe as Copernicus, this magnificent crater is but one of *thousands* of features visible on the Moon.



PETE LAWRENCE

Glorious Saturn with its showcase ring system is dwarfed by our neighboring satellite in this remarkable composite image taken during the March 2, 2007 lunar occultation.

Mars at its best is smaller in apparent size than the gas giants, roughly comparable to the 48-km crater Playfair. You probably haven't heard of Playfair because it's a relatively small lunar crater; so what does that say about Mars? Spacecraft images reveal the beauty and complexity of the Martian surface, but even in the best amateur telescopes Mars appears as a small disk with vague albedo features.

The clouds of both Mars and Jupiter undergo fascinating changes, and recently Saturn has birthed a remarkable atmospheric storm. But all of these details are relatively small and often difficult to see. While the Moon has very few, if any, physical changes that are observable, every time you point your telescope at the Moon it looks different. Lunar features change appearance as the Sun slowly

S&T: SEAN WALKER

NASA / GSFC / ARIZONA STATE UNIV.

While it takes CCDs many minutes to accumulate enough light to reveal color and subtle structure within the Ring Nebula, the lunar region shown to the same scale at right offers hundreds of interesting details that you can see immediately.

rises and sets over them, and the Moon's librations shift them around. For example, gentle-sloped volcanic domes pop into view with grazing illumination, and dark halo craters become visible under a high Sun.

Comparisons between the Moon and deep-sky objects provide more evidence of our satellite's richness as an observational target. Backyard telescopes reveal thousands of stars that differ only in brightness and color. But look at the intricate detail of the Humorum impact basin, with its ridges, faults, rilles, and craters, and realize that its 425-km diameter is only slightly wider than the 208 arcseconds separating the main components of the famous Double Double in Lyra.

Another favorite in Lyra is M57, the Ring Nebula. This bright planetary nebula presents wonderful colors in astrophotos, but at the eyepiece it's a tiny gray donut. The Ring's angular diameter of 1.2 arcminutes makes it similar in size to the lava-flooded crater that hosts Rupes Recta, the Straight Wall.

The night sky contains dozens of individual objects that are roughly the Moon's angular size or larger. Observers may rightly point out that the nearby galaxy M31 is eight times larger than the Moon, but they also admit that far fewer details can be seen visually in M31 than on the Moon. The biggest observable object at night — the Milky Way — circles the entire sky and contains many thousands of telescopic targets, but disappears nearly every time the Moon is up.

While I enjoy being a tourist of the cosmos when the Moon is down, there's more to see in its little half-degree of sky than in all the rest combined! Only on the Moon can we all intimately explore the nooks and crannies of another world. So rather than packing away your scope to await the next new Moon, use it to explore our nearest neighbor. There's a good chance you'll see something new every time. ✦

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

The Moon • October 2011

Phases

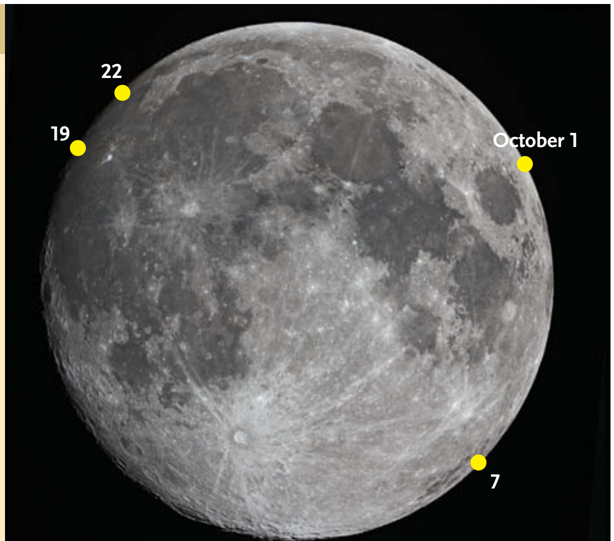
First quarter	October 4, 3:15 UT
Full Moon	October 12, 2:06 UT
Last quarter	October 20, 3:30 UT
New Moon	October 26, 19:56 UT

Distances

Apogee	October 12, 12^h UT
252,863 miles	diam. 29′ 22″
Perigee	October 26, 12^h UT
221,298 miles	diam. 33′ 33″

Librations

Mare Marginis	October 1
Lyot (crater)	October 7
Einstein (crater)	October 19
Lavoisier (crater)	October 22



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

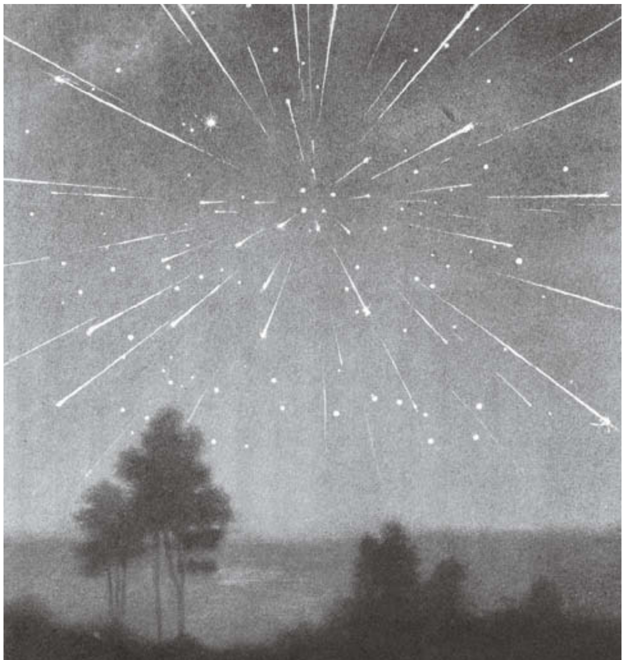
S&T: DENNIS DI CICCO

Draconid Meteor Outburst?

On the evening of October 8th, some places may get quite a show.

Circle Saturday evening, October 8th, on your calendar, particularly if you're in Europe or the Middle East. That evening, astronomers predict that Earth will pass through a rich part of the irregular and surprise-filled Draconid meteor stream. If you're in North America, the predicted peak will occur in the afternoon, so you'll be looking for the tail-off of the expected outburst — or perhaps you'll benefit from an error of just a few hours in when we're supposed to meet the bulk of the Draconids.

Around October 8th every year, Earth passes through a tenuous band of crumbly bits spread along the orbit of the periodic comet 21P/Giacobini-Zinner. Usually the Draconid shower (formerly called the Giacobinids) puts on only a weak show of about 10 or 20 meteors visible per hour at most, even as seen by an observer under a black sky with the shower's radiant point in Draco directly overhead (the shower's *zenithal hourly rate,* or ZHR). However, the Draconids have a Jekyll-and-Hyde personality. In 1933 and 1946 they dazzled skywatchers with astounding meteor "storms" that briefly topped 10,000 per hour.


The Draconid meteor storm of October 9, 1933, was witnessed all across Europe. Formerly called the Giacobinids, the shower appears to radiate from a point near in the head of Draco. Painting by Lucien Rudaux from the *Larousse Encyclopedia of Astronomy* (1959).

In those years Earth crossed through a particularly dense ribbon of debris that the comet shed during its pass by the Sun in 1900. The shower hasn't put on that kind of performance since, though rates reached into hundreds per hour in 1952, 1985, and 1998.

If meteor forecasters are right, this year the Draconids' peak ZHR could top 600 per hour — a shooting star every several seconds. That's because we'll likely clip the same stream of particles ejected in 1900. Odds are that it's still largely intact, even though the comet's 6.6-year orbit periodically carries everything that's strung out along it into Jupiter's disruptive vicinity.

At a meeting of planetary scientists last year, meteor dynamicist Jérémie Vaubaillon (IMCEE, France) presented predictions that he calculated with Mikiya Sato and Junichi Watanabe (NAOJ, Japan). If they're right, this October 8th Earth will also cross relatively dense debris streams that Comet G-Z shed between 1873 and 1894. The group predicts a surge to about 60 meteors per hour centered at 17:09 Universal Time due to these streams, followed by the much stronger, 600-per-hour pulse from the 1900 stream around 19:57 UT. But those rates are very uncertain, Vaubaillon admits, because there's no way to know whether the streams are still densely packed or have spread thin.

Other meteor specialists have also struggled to come up with firm rates and times. In 2008 Sato and Watanabe independently estimated a maximum of 500 per hour centered on 20:36 UT. NASA researchers Danielle Moser and William Cooke offer a more optimistic 800 per hour at 19:11 UT. Moser predicts a peak ZHR of about 750 per hour lasting for about two hours centered on 19:52 UT.

Now the Bad News

But don't get your hopes too high. All those times favor observers in Europe, not North America — and, sadly, the moonlight will be seriously bright. The waxing gibbous Moon is just two days from full and won't set until the beginning of dawn. This is especially problematic because many Draconids tend to be faint.

The shower's radiant is near the head of Draco (at declination +54°), so the best observing locations would likewise be at high northern latitudes. But there's a reason why few people book vacations to Scandinavia in October. "Weather in Northern Europe is not very pretty," says Canadian meteorologist Jay Anderson. "October can be very nice, but usually it is the time when the winter cloudiness begins to encroach."

The head of Draco is highest after sunset. So unlike most showers, this one is best seen in early evening rather than before dawn. Draconid meteors are also unusual for being very slow moving as meteors go. They're catching up to Earth from behind as the planet moves along its orbit, not hitting Earth on its front side, the morning side.

But if you never pushed your luck in astronomy you wouldn't see much of anything. And good meteor counts are always needed away from a shower's peak

Orionid Meteors

The Draconids come and go, but October's Orionid shower is reliable, producing roughly 20 meteors visible per hour before dawn under dark-sky conditions. The shower is strongest for several mornings around October 21st each year, and this year the Moon is a mere waning crescent.

The Orionids, fragments of the periodic comet 1P/Halley, are unusually swift. Their radiant is in the top of Orion's upraised club, near the border with Gemini.

Jupiter's Moons and Great Red Spot

The king planet spends most of October approaching its opposition on the 28th, which means it's about as big and close as we see it this year. It's up and blazing in good view in the east before 10 p.m., and it's highest in the south and sharpest in a telescope between about midnight and 3 a.m. (daylight-saving time).

Even the smallest scope shows Jupiter's four big Galilean moons, and binoculars usually show at least two or three. Identify them with the diagram on page 47. Listed below are all their interactions with Jupiter's disk and shadow during October.

On Jupiter itself, the North Equatorial Belt remained dark red-brown as of early July, while the South Equatorial Belt (SEB) was paler but broader. The Great Red Spot, sitting in the south edge of the SEB, had lost the white Red Spot Hollow that usually separates it from contact with the belt.

Here are the dates and times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. Eastern Daylight Time is UT minus 4 hours. The Red Spot appears closer to the

Phenomena of Jupiter's Moons, October 2011

Oct. 1	14:10	I.Sh.I
	14:52	I.Tr.I
	16:20	I.Sh.E
	17:00	I.Tr.E
Oct. 2	1:27	II.Ec.D
	5:15	II.Oc.R
	11:30	I.Ec.D
	14:20	I.Oc.R
Oct. 3	1:40	III.Sh.I
	3:41	III.Sh.E
	4:45	III.Tr.I
	5:55	III.Tr.E
	8:38	I.Sh.I
	9:18	I.Tr.I
	10:48	I.Sh.E
	11:26	I.Tr.E
	20:38	II.Sh.I
	21:59	II.Tr.I
	23:07	II.Sh.E
Oct. 4	0:19	II.Tr.E
	5:59	I.Ec.D
	8:46	I.Oc.R
Oct. 5	3:07	I.Sh.I
	3:44	I.Tr.I
	5:17	I.Sh.E
	5:52	I.Tr.E
	14:46	II.Ec.D
	18:24	II.Oc.R
Oct. 6	0:27	I.Ec.D
	3:12	I.Oc.R
	15:33	III.Ec.D
	17:34	III.Ec.R
	18:17	III.Oc.D
	19:30	III.Oc.R
	21:35	I.Sh.I
	22:11	I.Tr.I
	23:46	I.Sh.E
Oct. 7	0:18	I.Tr.E
	9:56	II.Sh.I
	11:07	II.Tr.I
	12:25	II.Sh.E
	13:27	II.Tr.E
	18:56	I.Ec.D
	21:38	I.Oc.R
Oct. 8	16:04	I.Sh.I
	16:37	I.Tr.I
	18:14	I.Sh.E
	18:45	I.Tr.E
Oct. 9	4:04	II.Ec.D
	7:31	II.Oc.R
	13:24	I.Ec.D
	16:04	I.Oc.R
Oct. 10	5:42	III.Sh.I
	7:41	III.Sh.E
	8:04	III.Tr.I
	9:16	III.Tr.E
	10:33	I.Sh.I
	11:03	I.Tr.I
	12:43	I.Sh.E
	13:11	I.Tr.E
	23:14	II.Sh.I
Oct. 11	0:14	II.Tr.I
	1:42	II.Sh.E
	2:34	II.Tr.E
	7:53	I.Ec.D
	10:30	I.Oc.R
Oct. 12	5:01	I.Sh.I
	5:29	I.Tr.I
	7:11	I.Sh.E
	7:37	I.Tr.E
	17:23	II.Ec.D
	20:40	II.Oc.R
Oct. 13	2:22	I.Ec.D
	4:56	I.Oc.R
	19:34	III.Ec.D
	22:49	III.Oc.R
	23:30	I.Sh.I
	23:55	I.Tr.I
Oct. 14	1:40	I.Sh.E
	2:03	I.Tr.E
	12:32	II.Sh.I
	13:22	II.Tr.I
	15:00	II.Sh.E
	15:42	II.Tr.E
	20:50	I.Ec.D
	23:22	I.Oc.R
Oct. 15	17:59	I.Sh.I
	18:21	I.Tr.I
	20:09	I.Sh.E
	20:29	I.Tr.E
Oct. 16	6:41	II.Ec.D
	9:47	II.Oc.R
	15:19	I.Ec.D
	17:48	I.Oc.R
Oct. 17	9:44	III.Sh.I
	11:21	III.Tr.I
	11:43	III.Sh.E
	12:27	I.Sh.I
	12:35	III.Tr.E
	12:46	I.Tr.I
	14:37	I.Sh.E
	14:55	I.Tr.E
Oct. 18	1:50	II.Sh.I
	2:28	II.Tr.I
	4:18	II.Sh.E
	4:49	II.Tr.E
	9:48	I.Ec.D
	12:14	I.Oc.R
Oct. 19	6:56	I.Sh.I
	7:12	I.Tr.I
	9:06	I.Sh.E
	9:21	I.Tr.E
	20:00	II.Ec.D
	22:55	II.Oc.R
Oct. 20	4:16	I.Ec.D
	6:39	I.Oc.R
	23:35	III.Ec.D
Oct. 21	1:25	I.Sh.I
	1:38	I.Tr.I
	2:06	III.Oc.R
	3:35	I.Sh.E
	3:46	I.Tr.E
	15:08	II.Sh.I
	15:35	II.Tr.I
	17:36	II.Sh.E
	17:56	II.Tr.E
	22:45	I.Ec.D
Oct. 22	1:05	I.Oc.R
	19:53	I.Sh.I
	20:04	I.Tr.I
	22:04	I.Sh.E
	22:12	I.Tr.E
Oct. 23	9:18	II.Ec.D
	12:02	II.Oc.R
	17:13	I.Ec.D
	19:31	I.Oc.R
Oct. 24	13:46	III.Sh.I
	14:22	I.Sh.I
	14:30	I.Tr.I
	14:34	III.Tr.I
	15:43	III.Sh.E
	15:52	III.Tr.E
	16:32	I.Sh.E
	16:38	I.Tr.E
Oct. 25	4:26	II.Sh.I
	4:42	II.Tr.I
	6:54	II.Sh.E
	7:03	II.Tr.E
	11:42	I.Ec.D
	13:57	I.Oc.R
Oct. 26	8:51	I.Sh.I
	8:56	I.Tr.I
	11:01	I.Sh.E
	11:04	I.Tr.E
	22:37	II.Ec.D
Oct. 27	1:09	II.Oc.R
	6:11	I.Ec.D
	8:23	I.Oc.R
Oct. 28	3:19	I.Sh.I
	3:22	I.Tr.I
	3:37	III.Ec.D
	5:30	I.Sh.E
	5:30	I.Tr.E
	5:35	III.Ec.R
	17:44	II.Sh.I
	17:48	II.Tr.I
	20:09	II.Tr.E
	20:12	II.Sh.E
Oct. 29	0:39	I.Ec.D
	2:49	I.Ec.R
	21:48	I.Tr.I
	21:48	I.Sh.I
	23:56	I.Tr.E
	23:58	I.Sh.E
Oct. 30	11:54	II.Oc.D
	14:24	II.Ec.R
	19:06	I.Oc.D
	21:18	I.Ec.R
Oct. 31	16:13	I.Tr.I
	16:17	I.Sh.I
	17:46	III.Tr.I
	17:47	III.Sh.I
	18:22	I.Tr.E
	18:27	I.Sh.E
	19:09	III.Tr.E
	19:44	III.Sh.E

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.

to keep track of what's really going on. So if the sky is clear, go out regardless.

You want more incentive? Meteor researcher Peter Jenniskens (SETI Institute) says that this is the last big meteor outburst predicted until 2030.

Jenniskens himself is planning an airborne observing run over Finland, Sweden, and Norway above any clouds. See his website at **airborne.seti.org/draconids** for updates and results afterward. ✦

planet's central meridian than to the limb (edge) for 50 minutes before and after:

September 1, 6:17, 16:13; **2**, 2:08, 12:04, 21:59; **3**, 7:55, 17:51; **4**, 3:46, 13:42, 23:38; **5**, 9:33, 19:29; **6**, 5:24, 15:20; **7**, 1:16, 11:11, 21:07; **8**, 7:03, 16:58; **9**, 2:54, 12:49, 22:45; **10**, 8:41, 18:36; **11**, 4:32, 14:27; **12**, 0:23, 10:19, 20:14; **13**, 6:10, 16:05; **14**, 2:01, 11:57, 21:52; **15**, 7:48, 17:43; **16**, 3:39, 13:35, 23:30; **17**, 9:26, 19:21; **18**, 5:17, 15:13; **19**, 1:08, 11:04, 20:59; **20**, 6:55, 16:51; **21**, 2:46, 12:42, 22:37; **22**, 8:33, 18:29; **23**, 4:24, 14:20; **24**, 0:15, 10:11, 20:07; **25**, 6:02, 15:58; **26**, 1:53, 11:49, 21:44; **27**, 7:40, 17:36; **28**, 3:31, 13:27, 23:22; **29**, 9:18, 19:14; **30**, 5:09, 15:05.

October 1, 1:00, 10:56, 20:51; **2**, 6:47, 16:43; **3**, 2:38, 12:34, 22:29; **4**, 8:25, 18:21; **5**, 4:16, 14:12; **6**, 0:07, 10:03, 19:58; **7**, 5:54, 15:50; **8**, 1:45, 11:41, 21:36; **9**, 7:32, 17:28; **10**, 3:23, 13:19, 23:14; **11**, 9:10, 19:05; **12**, 5:01, 14:57; **13**, 0:52, 10:48, 20:43; **14**, 6:39, 16:34; **15**, 2:30, 12:26, 22:21; **16**, 8:17, 18:12; **17**, 4:08, 14:03, 23:59; **18**, 9:55, 19:50; **19**, 5:46, 15:41; **20**, 1:37, 11:33, 21:28; **21**, 7:24, 17:19; **22**, 3:15, 13:10, 23:06; **23**, 9:02, 18:57; **24**, 4:53, 14:48; **25**, 0:44, 10:40, 20:35; **26**, 6:31, 16:26; **27**, 2:22, 12:17, 22:13; **28**, 8:09, 18:04; **29**, 4:00, 13:55, 23:51; **30**, 9:47, 19:42; **31**, 5:38, 15:33.

These times assume that the spot is centered at System II longitude 173°. If it's elsewhere, it will transit 1⅔ minutes late for every 1° of longitude greater than 173°, or 1⅔ minutes early for every 1° less.

The Great Red Spot was on Jupiter's central meridian when Christopher Go took this stacked-video image on June 8th. South is up.

The Fleet-Winged Bird

There's more to Cygnus than well-known showpieces.

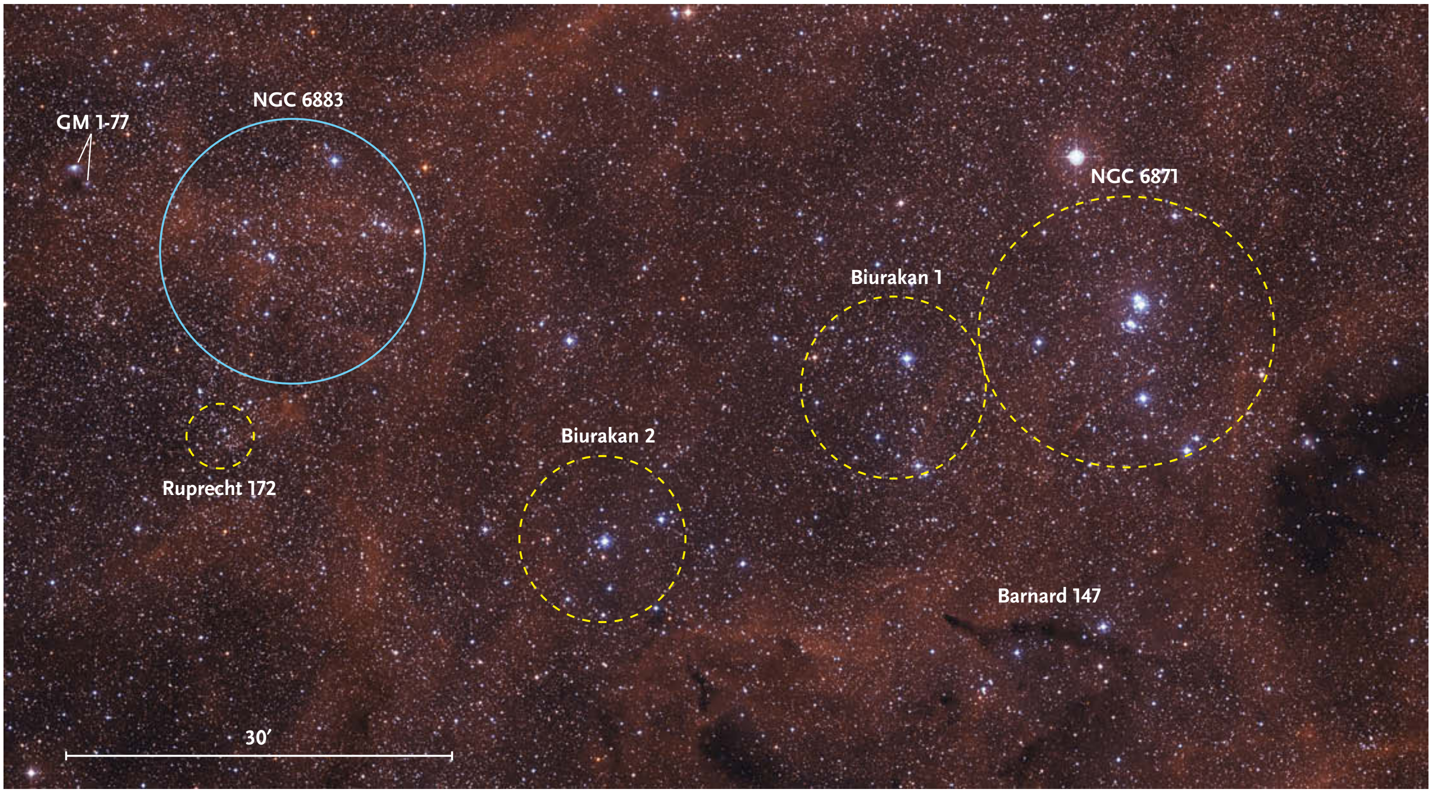
For heaven's floor has a fleet-winged Bird,
Airy his body, his wings roughened
With stars not largest-sized and yet not dim.
Exulting in the blue deeps of the sky . . .
— Aratus, *Phaenomena*

NINE CELESTIAL BIRDS grace the starry sky as constellations, but none so resembles its namesake as Cygnus, the Swan. Bright Deneb ornaments his stubby tail, his elegant neck extends southwest with his beak nipping Albireo, and the stars Zeta (ζ) and Iota (ι) glitter at the tips of his outspread wings.

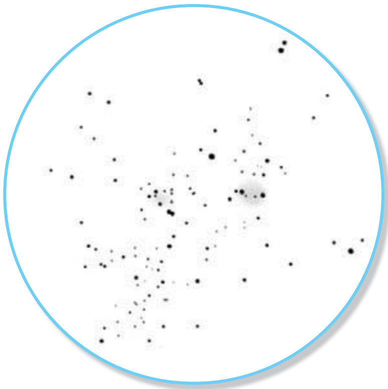
Cygnus is adorned with myriad deep-sky wonders, many of which we routinely pass by on the way to the constellation's best-known treasures. Let's visit a few of the unsung yet noteworthy sights that decorate our fleet-winged bird.

A remarkable quintet of open clusters lies along the Swan's neck, about 2½° east-northeast of golden, 4th-magnitude Eta (η) Cygni. The entire group just fits in my 10-inch reflector through an eyepiece that gives me a magnification of 43× and a field of 1½°. The area is rich in Milky Way stars, and although the clusters all have indefinite boundaries, their combined effect is quite pretty.

NGC 6871 is large and loose, with two prominent star pairs at the center of a splashy, cluster-spanning arc of stars. The northern pair is SHJ 314, whose 6.8-magnitude primary has a 7.3-magnitude attendant 36″ north-northeast. A closer and dimmer companion sits west-northwest of the primary. The southern pair, SHJ 315, consists of 7.9- and 8.7-magnitude stars separated by 20″. It's ghosted on either side by fainter pairs having nearly the same component separation as SHJ 315, but a somewhat different orientation. NGC 6871 spans about 23′ × 17′ and



POSS-II / CALTECH / PALOMAR OBSERVATORY



Finnish stargazer Jaakko Saloranta sketched NGC 6883 (the big cluster in the center) as seen through an 8-inch scope at 60×.

is guarded north-northeast by the 5th-magnitude golden star 27 Cygni.

Biurakan 1 abuts the east-southeastern side of NGC 6871. It's dominated by a 7th-magnitude star and filled out to roughly 15′ by 40 stars of magnitude 9 and fainter. About 25′ east-southeast, **Biurakan 2** is a little smaller and holds the bright double star Σ2639 at its heart. The 7.8-magnitude primary hugs an 8.7-magnitude companion 5.9″ west-northwest. This duo sits amid 30 fainter suns forming a 12′ cluster. The Biurakan clusters derive their name from Armenia's Byurakan Astrophysical Observatory, where they were discovered.

NGC 6883 lies 33′ northeast of Biurakan 2 and struts a rich collection of stars strewn across an irregular misty backdrop. Five of the brightest stars form a distinctive Y just east of center, while others embellish the northwestern border of this 20′ group. Near the south-southeastern edge of NGC 6883, **Ruprecht 172** is an unremarkable bit of fluff, perhaps 5′ in diameter, pocked by two moderately faint stars and rimmed by several more.

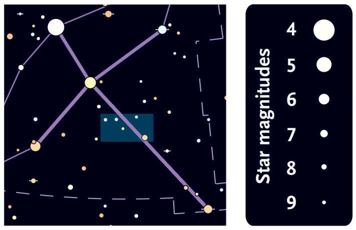
With the exception of Ruprecht 172, the clusters above are also fair game for a small telescope. My 105-mm (4.1-inch) refractor at 28× shows 10 moderately bright and 20 faint stars in NGC 6871. Biurakan 1 is a triangular group of several stars, while Biurakan 2 is a 15-star oblong running west-northwest to east-southeast. NGC 6883 looks like a particularly bright patch of Milky Way dotted with at least 25 stars.

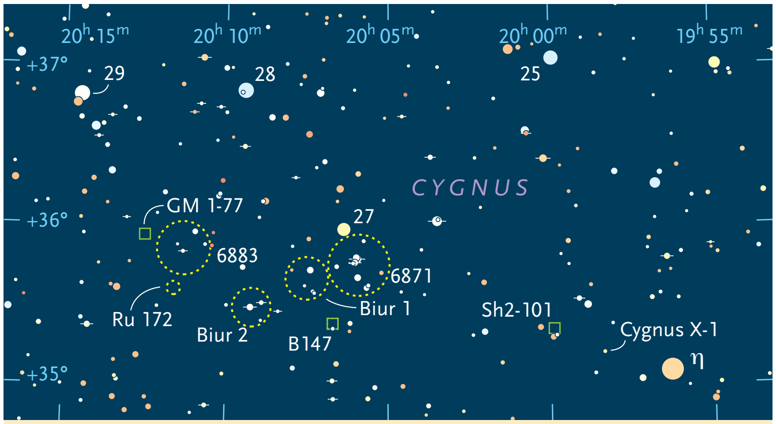
The cluster-quintet region is lavishly laced with meandering bright and dark nebulae. Just east of NGC 6883, a more discrete pair of compact nebulae designated **GM 1-77** is among the "new cometary nebulae" announced in a 1977 paper by Armenian astronomers Armen Liparit Gyulbudaghian and Tigran Yuri Magakian. The authors comment: "Two nebulae of neutral color. One is divided into two parts, with a star perceptible in one part. Size of nebulae on red print: 0′.9 × 0′.8 and 0′.7 × 0′.6."

Through my 10-inch reflector at 68×, the northeastern nebula is readily visible as a glow surrounding a faint star, and it's quite obvious at 115×. Comparing the nebula to the distance between nearby field stars at 213×, I estimate its apparent size as 40″ × 50″, elongated east-west. Nebula filters don't improve the view, which isn't surprising. These nebulae appear brightest on images taken at blue wavelengths, indicating that much of their glow is reflected starlight. Nebula filters only pass wavelengths of light that are actually emitted by nebulae, mainly green.

I can see the star that lurks in the southwestern component of GM 1-77, but the nebula itself eludes me. Perhaps someone with a larger telescope or darker skies can nail it down. I'd be very interested to hear about the observation if you do.

The dark nebula **Barnard 147** sits about 20′ south of a spot midway between NGC 6871 and Biurakan 1. On a typical night from my semirural home, it doesn't stand out from the other sooty strands that thread much of the area. But on one night of good transparency, my 10-inch scope at 43× surprised me with something that looked like a blocky numeral 3 of darkness. The northern bar of the 3 passes through a 6¼′ isosceles triangle of three stars that points

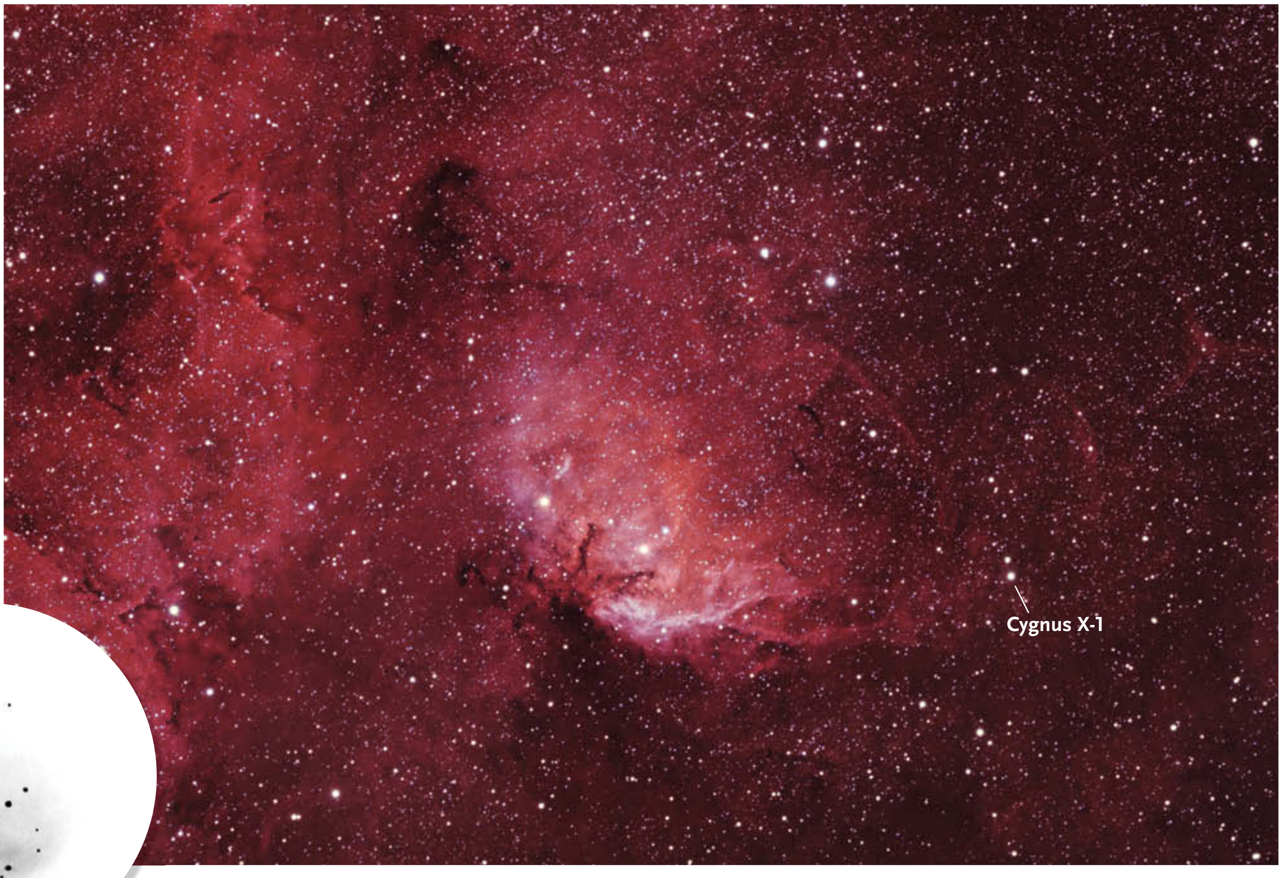




Unsung Treasures in Cygnus

Object	Type	Mag(v)	Size	RA	Dec.
NGC 6871	Open cluster	5.2	20′	$20^h\ 05.9^m$	+35° 46′
Biurakan 1	Open cluster	—	14′	$20^h\ 07.5^m$	+35° 41′
Biurakan 2	Open cluster	6.3	12′	$20^h\ 09.2^m$	+35° 29′
NGC 6883	Open cluster	8.0	20′	$20^h\ 11.3^m$	+35° 51′
Ruprecht 172	Open cluster	—	5.0′	$20^h\ 11.6^m$	+35° 36′
GM 1-77	Bright nebula	—	2.5′	$20^h\ 12.5^m$	+35° 56′
Barnard 147	Dark nebula	—	11′ × 1′	$20^h\ 06.7^m$	+35° 23′
Sh 2-101	Bright nebula	—	21′ × 12′	$19^h\ 59.9^m$	+35° 21′
Cygnus X-1	Star/Black hole	8.9	—	$19^h\ 58.4^m$	+35° 12′

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.



NEIL FLEMING

Sharpless 2-101, the Tulip Nebula, is a bright concentration within the nebulosity of central Cygnus. The X-ray source Cygnus X-1 is actually the unseen companion of the 9th-magnitude star labeled here. *Sketch at left*: Here's Saloranta's impression of Sharpless 2-101 through his 8-inch scope at 38× with a UHC filter.

east, and the entire 3 is 19′ tall. Only the northern bar makes up Barnard 147. The whole figure is designated H445 in the *Atlas and Catalog of Dark Clouds* (Dobashi et al., 2005).

Near our quintet, and only 47′ east-northeast of Eta Cygni, the emission nebula **Sharpless 2-101** is visible through my 130-mm refractor at 37×. It contains three bright stars in a skinny, 6½′-long triangle pointed east-northeast, with a faint star in the middle of the triangle. The two brightest stars glow orange and are clearly involved in the nebula's bright southeastern flank. A UHC filter enhances the nebulosity, which runs approximately 15′ northeast-southwest, and an O-III filter also works fairly well. A filterless view at 63× brings out irregularities in the nebula's light, including a dimmer region denting into the bright flank. Several very faint stars are involved.

In many astrophotos, the dark dent in Sh 2-101 appears forked, like the sepals of a flower having three pink or reddish petals. This pretty display of nebular light has thus become known as the Tulip Nebula.

While in the realm of Sh 2-101, you might wish to gaze at ordinary-looking, 9th-magnitude HDE 226868, located ¼° west of the nebula's southwestern tip. It's easy to spot as the brightest star in the area, and it's accompanied by a 10th-magnitude star just 55″ north. Both appear yellow.

HDE 226868 is an *O*9.7 blue supergiant somewhere between 17 to 21 times as massive as our Sun. It's the visible component of the famed X-ray binary **Cygnus X-1**. The unseen companion, most probably a black hole, weighs in around 15 solar masses and completes an orbit every 5.6 days. The X-rays are emitted by material stripped from HDE 226868 and superheated as it spirals down into the black hole, which is only half as far from its companion star as Mercury is from the Sun.

Why does such a blue star appear yellow through a telescope? Its light is highly reddened due to selective scattering of blue light by copious amounts of interstellar dust. In a similar fashion, our atmosphere scatters blue light from the Sun. When the Sun is low in the sky, we view it through a longer column of air, and so much of the blue and green light is scattered away that the Sun is left with a red-orange hue. ✦

***Sue French** welcomes comments at scfrench@nycap.rr.com. Her latest book,* Deep-Sky Wonders*, goes on sale this fall.*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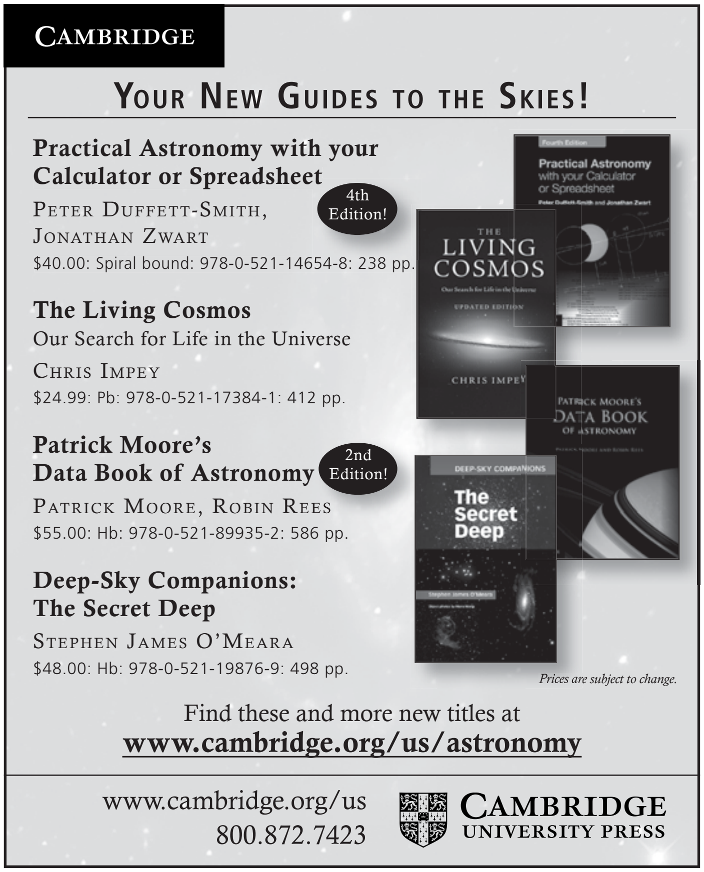
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Dennis di Cicco

The Telescope Drive Master

There's a new wrinkle in the centuries-old quest for the perfect telescope drive.

ALL PHOTOGRAPHS BY THE AUTHOR

No guiding necessary. The author acquired this image of the Whirlpool Galaxy, M51, last July 1st when the recently discovered supernova (arrowed) was still shining at about 13th magnitude. The image was assembled from multiple 5-minute exposures made through red, green, blue, and clear filters with an SBIG ST-8300 CCD camera. His Meade 16-inch f/10 LX200 Schmidt-Cassegrain telescope was controlled only by the Telescope Drive Master (*left*) during the exposures.

Telescope Drive Master

U.S. price: $1,799.95 (encoder and electronics only; mounting hardware for various telescopes is sold separately)
Available from Explore Scientific, 621 Madison St. Springdale, AR 72762
explorescientific.com
888-599-7597

If the definitive history of telescopes ever gets written, you can rest assured that there will be many chapters devoted to telescope drives. While the concept of a clockwork drive dates back to experiments performed by Italian-born astronomer Jean Dominique Cassini in the 1680s, it wasn't until Bavarian instrument maker Joseph von Fraunhofer introduced what we now call the German equatorial mount in the early 19th century that drive systems became a major concern. Over the years the pursuit for the perfect telescope drive has drawn on the talents of professional and amateur astronomers, skilled craftsmen, basement tinkers, a few dreamers, and, of late, electrical engineers.

Until the turn of the 20th century, drive improvements were achieved mechanically with increasingly better-made drive components and clockwork regulators. After the introduction of motors, electronics entered the picture, first as speed controllers for the motors and more recently as digital memory, issuing pre-recorded speed adjustments to compensate for small, periodic irregularities of the drive mechanism. The latter is popularly known as periodic-error correction, or PEC for short, and it's a standard feature on today's high-quality drive systems.

A New Twist

Now there's another wrinkle in the quest for the perfect drive, and it's based on a new breed of shaft encoder that can count tens of millions of "clicks" for a single rotation — technology that was almost unimaginable a few years ago. Attached directly to a telescope's polar shaft, the encoder samples the drive's speed many times per second, feeding the information to electronics that control the speed of the drive motor. Since the encoder can respond to any type of mechanical irregularity in the drive train (not just the periodic ones), it can maintain an essentially perfect drive speed indefinitely.

This is the principle behind the Telescope Drive Master (TDM), available in North America from Explore Scientific. The brainchild of Hungarian astronomers Istvan Papp and Attila Madai, the TDM consists of a small electronic module and a shaft encoder. Encoders and mounting hardware are currently available for a variety of popular telescope mounts, and I suspect more will be added as interest in the TDM grows.

The model I borrowed for this review is designed for Meade's current 16-inch LX200 fork mount, but with very slight modification it attached to my 1995-vintage 16-inch LX200. The TDM comes with very detailed, heavily illustrated instructions for installing the hardware.

Described in the accompanying text, these TDM "first-light" snapshots offer dramatic evidence of the telescope's improved tracking when the TDM is running (*top*) compared to when it's not (*bottom*). Each shot is a single 10-minute exposure with a Nikon D700 DSLR and the 16-inch f/10 telescope. Sean Walker processed all the astronomical images appearing in this review.

What we liked:

Exceptionally accurate drive rate
Very easy to use

What we didn't like:

Can interfere with manual fine-motion control of some drive electronics (especially those of older telescopes)

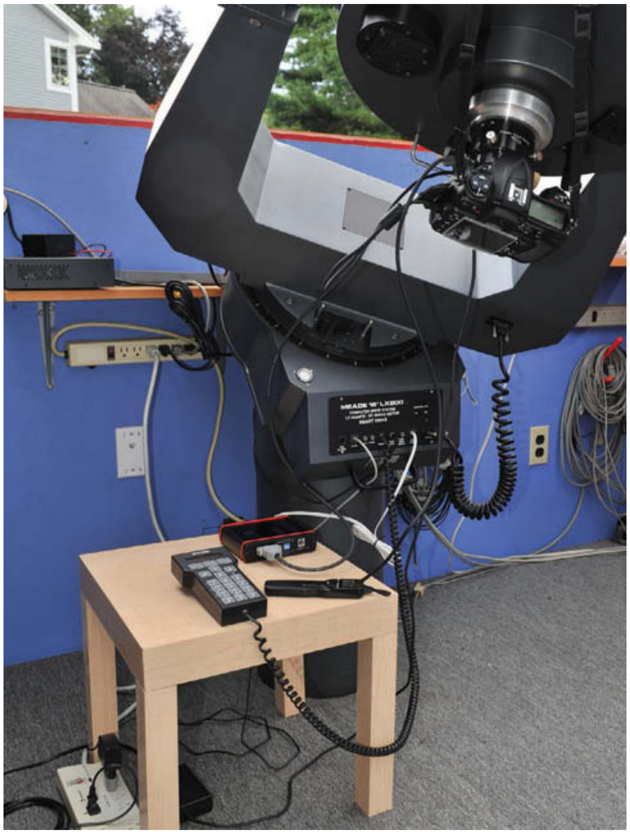
The encoder connects to the TDM with a single cable, and the TDM controls the mount via a single wire that plugs into the scope's ST-4-compatible autoguider port. If you also want to use an autoguider, you simply connect it to the ST-4 port on the TDM. In short, making the TDM's electrical hookups couldn't be simpler.

And if I thought that setting up the TDM was easy, using it was even easier. I would power up the scope in normal fashion without power supplied to the TDM (there is no on/off switch; the TDM simply begins working when you connect it to a 12-volt DC source — it comes with a small wall transformer). When the TDM is powered up, it performs a self calibration that takes a couple of seconds and then just starts working.

The TDM uses a high-resolution shaft encoder made by the German firm Heidenhain. Capable of resolving tens of millions of "clicks" per turn, the encoder provides the TDM with constant feedback about the rotational speed of the telescope's polar axis, allowing tracking with sub-arcsecond precision.

First Light

In all my years of testing astronomical equipment, I can't recall having a more dramatic "first-light" result than I had with the TDM. Since I was interested in how the TDM performed and not in taking pretty pictures, I just attached a DSLR camera to the scope, slewed to the moderately bright spiral galaxy M66 in Leo, and opened the shutter for 10 minutes without the TDM running. As expected, stars showed significant east-west elongation because of periodic error in the drive. With the 16-inch scope's 4-meter focal length, it takes only a tiny bit of tracking error to distort star images.



Although the mechanical complexity of installing the TDM's encoder can vary depending on the telescope model (the author's scope has the encoder mounted inside the base of the fork), the electrical connections are extremely simple and only involve plugging a few wires into existing ports on the TDM and telescope.

I then powered up the TDM, waited a few seconds for the self calibration to finish, and opened the camera's shutter for another 10-minute exposure. The pictures on page 61 pretty much tell the story — when the TDM is running, the scope's drive turns the polar axis with sub-arcsecond precision. In the weeks that followed, I made dozens of additional exposures, all with similar results.

This performance was a bit surprising, since my 16-inch scope is not an ideal candidate for the TDM. Here's why. The encoder samples a scope's drive rate many times each second and the TDM can issue commands to adjust the speed as often as five times each second. As such, it works best when the scope's guide rate is set very low; ideally between 0.1× and 1× the sidereal rate. Most modern drives have guide rates within this range, but the slowest guide rate available on my 17-year-old Meade is 2× sidereal. Because of this, I expected the scope to "ping-pong" around the correct drive rate as it overreacted to commands issued by the TDM. Occasionally it did, but overall the TDM maintained the tracking rate to tolerances that were better than my seeing conditions, so star images almost always appeared uniformly round in my photos.

While I was setting up and testing the TDM, I was corresponding with noted astrophotographer and asteroid observer Jerry Hubbell, who was doing the same thing at his home in Locust Grove, Virginia, only he was using a Synta EQ6 Pro mount (which does have the desired range of guiding rates). Jerry was also doing extensive analysis of his mount's performance using a data-logging feature of the TDM and supplied software. His bottom line very much parallels mine, and his TDM “operated as expected and provided excellent drive-rate control to within ±1 arcsecond tracking.”

In addition to my scope’s out-of-spec guide rate, I encountered another issue with the TDM. From my telescope’s point of view, the TDM looks like an autoguider, albeit one sending very rapid updates. When an autoguider is active, my scope’s slow-motion controls are disabled (I’ve also experienced this with other telescopes, but I certainly haven’t tested everything that’s out there). Thus, when the TDM is running I can’t move the scope by pushing the direction buttons on the hand control.

The scope will accept commands to slew to a new object or location when the TDM is running, but if I needed to tweak the scope’s position, I had to first cut the power to the TDM. I could also have reactivated the scope’s slow-motion controls by unplugging the TDM from the autoguider port, but this isn’t practical because it messes with the TDM’s brain.

An End to Guiding?

With the astrophotographer’s long-sought Holy Grail of an essentially perfect telescope drive rate now within reach of the TDM, it’s reasonable to ask if we can do astrophotography without guiding. The short answer is a flat-out “no.” But the longer answer is, well, “maybe.”

Even with an absolutely flawless drive rate, a telescope can’t keep stars fixed on a camera’s detector indefinitely. The biggest problem is atmospheric refraction, which increasingly slows the apparent diurnal motion of stars as they appear farther from the zenith. And, with almost all telescopes, there are also the problems of optical and mechanical flexure. Of course, the focal length of the optical system is an important factor in this equation. A short focal length, such as a 100-mm camera lens, coupled with a TDM-equipped solid mounting, could conceivably run unguided for many hours.

A typical amateur telescope, however, is likely to be limited to exposures of 5 or 10 minutes even with the TDM. But that’s where the “maybe” comes from. Many astrophotographers today assemble their images from stacks of short exposures. And people using imaging for various sky patrols or searches often make short exposures that are well within the capability of the TDM. So depending on your application, the TDM can indeed eliminate the need for guiding.

Even those of us who must autoguide can benefit from the TDM. A mount that tracks accurately for minutes will make finding a suitable guide star a snap. There’s no need to hunt for a star bright enough to make the fast autoguiding corrections that most mounts require. Indeed, long exposures for the guide camera are actually desirable because autoguider corrections that are

The TDM has only four adjustments, which are made with small DIP switches. From left to right they let you select the telescope’s tracking rate (sidereal or average King rate); the resolution of the instantaneous tracking error displayed on the ladder-like LED array at right; the frequency that speed corrections are sent to the scope’s autoguider port; and the tracking tolerance that the TDM attempts to maintain. The switch settings can be changed on the fly, making it easy to fine-tune the TDM’s performance.

passed through the TDM to the mount must be spaced a minimum of two seconds apart for technical reasons. This would be a boon to anyone using one of SBIG’s self-guiding cameras and shooting through filters that reduce the apparent brightness of a guide star.

And then there’s the issue of intermittent clouds. Because the TDM works without any feedback from the sky, it will keep a telescope tracking properly even if a guide star is temporarily dimmed by a passing cloud. I’m certainly not the only astrophotographer to have had half-hour exposures ruined because a guide star slipped behind a cloud for a minute or two.

Throughout the history of telescope making, very talented people have spent untold hours trying to build ever-more accurate drive systems. To think that I could spend a half hour installing the TDM and achieve results they only dreamed about, gives me an appreciation for the wonders of modern technology — not to mention the vision of Istvan Papp and Attila Madai. ✦

Sky & Telescope *senior editor* ***Dennis di Cicco*** *has been pursuing the perfect telescope drive since he was a teenager in the 1960s.*

A Collapsable-Tube Dob

This all-aluminum Dobsonian features portability and aperture.

Telescope makers today often strive to combine large aperture with portability. The result is generally a Dobsonian with some kind of truss-tube assembly. I have previously covered instruments with folding trusses, telescoping trusses, 3-pole configurations, and even a couple of single-strut designs. What keeps the game interesting is that builders continue to find new approaches and fascinating ways to utilize everyday parts. David Shouldice's 12½-inch f/4.8 reflector is a good example.

The optics for David's telescope were originally housed in a 14-inch-diameter fiberglass tube that rode on a beefy German equatorial mount. The scope tipped the scales at 135 pounds (61 kg) — a weight that eventually became a disincentive for bringing the scope out for a night under the stars. "When the sky is gorgeous," David explains, "I just want to take it all in without bench-pressing 100 pounds of telescope in and out of my car."

His reconfigured scope is a thoroughly modern Dobsonian with many nifty features that help satisfy his desire for transportability and quick setup. Most obvious is his choice of aluminum instead of plywood as the scope's main building material. While some telescope makers might hesitate to use metal if they don't have a well-equipped machine shop, it didn't stop David. "The scope's side bearings," he reports, "were made from a piece of 1-inch-square aluminum tubing rolled to a 12-inch radius by a local sheet-metal company."

DAVID SHOULDICE

Colorado telescope maker David Shouldice transformed his 12½-inch telescope from a heavy equatorially mounted instrument into a lightweight, all-aluminum truss design. His main design goals were easy portability and quick setup.

This is a good tip. Often telescope makers will avoid designs that involve components they personally lack the equipment or skills to make. I've always found this curious considering that so many ATMs are perfectly happy to purchase a scope's primary mirror, yet remain strangely reluctant to seek assistance for other parts. David's "outsourcing" strategy made the all-aluminum aspect of his scope's construction viable. In addition to the side bearings, he had the same company bend the aluminum strips used for the front ring of the secondary cage.

Another method of getting what you want is to repurpose store-bought items as telescope components. In the past I've seen everything from tent poles to camera monopods used in truss assemblies. Look closely at the truss poles in David's scope and you'll see another variation on this theme. "I bought a surveyor's tripod at my local Home Depot," he explains. "Its fully extended legs were just long enough for my scope's focal length, and they give the tube the collapsible trusses I wanted." At the mirror end of the scope the tripod legs bolt to a frame that holds the mirror cell, while at the front end they attach to the metal ring of the secondary cage.

So did David's conversion from an equatorial heavyweight into a 50-pound wonderscope deliver quick and easy field assembly? "That is what I am most proud of," he says. "I roll the scope out of the back of my minivan, extend the trusses, remove the mirror covers, and I'm up and running — usually before anyone else in my group."

Readers wanting to know more can contact David at davids.scope@yahoo.com. ✦

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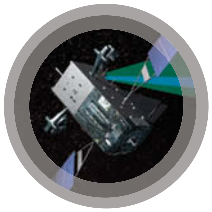
*Contributing editor **Gary Seronik** has built numerous truss-tube telescopes, some of which are featured at his website, www.garyseronik.com*



Observing Geosynchronous Satellites

You don't need a telescope drive to "track" these Earth-orbiting satellites.

Randy Rhea

One chilly October evening in northern New Mexico, I was observing the Wild Duck Cluster (M11) with a 24-inch Ritchey-Chrétien telescope when I noticed a 10th-magnitude satellite moving by the edge of the field. Satellites are a common sight in the early evening in a large scope, but this satellite seemed to be moving slower than most.

On a whim, I decided to try tracking it. I grabbed the telescope's control paddle, centered the satellite in the eyepiece field, and started following it among the stars. Tracking was easier than expected, and after awhile I noticed I was pushing only the scope's east button. That seemed strange. Why only east and why was this satellite moving so slowly? Then it struck me; to follow the satellite the only thing my button pushing was doing was stopping the westward movement of the scope's drive. As proof, I turned the drive off, and sure enough, the satellite remained fixed in the eyepiece. I was "tracking" a geosynchronous satellite.

That evening, as stars drifted slowly by the satellite, I became fascinated with observing these high-altitude objects. It's relatively easy and relaxing to do with almost any scope, and it's an enjoyable alternative when conditions are less than ideal for deep-sky observing.

The Back Story

A satellite in low-Earth orbit takes approximately 88 minutes to circle our planet. Its motion against the stellar background is swift, and most of the orbit on the night side of our planet keeps the satellite within Earth's shadow and thus hidden from view. As such, we only see satellites that are in low-Earth orbits for brief periods before dawn and after dusk. As a satellite's orbital altitude increases, its period also increases. At an altitude of 35,786 kilometers (22,236 miles) above mean sea level, the orbital period of a satellite equals that of Earth's rotation, and the object can theoretically remain above a fixed point on the globe.

A geosynchronous orbit can, however, be elongated and inclined with respect to the Earth's equator and still have a period equal to a sidereal day, making the satellite appear to wander around a fixed point on the sky. Satellites are also perturbed by the solar wind, solar radiation, and the gravity of the Sun and Moon, so geosynchronous satellites have thrusters that are used periodically to maintain their positions sufficiently to satisfy their mission requirements.

In a letter to the editor published in the February 1945 issue of the British magazine *Wireless World,* the late renowned science-fiction author Arthur C. Clarke


The U.S. military's Sbris GEO-1 launched last May is one of the newest members of the geosychronous-satellite family. It's infrared detectors are designed to provide early detection and classification of rocket launches.

LOCKHEED MARTIN (2)

proposed the possibility of worldwide television broadcasts using a system of three "repeater stations" spaced 120° apart in geosynchronous orbits. He followed up with a more complete article in the October issue. Today this ring of satellites is often referred to as the Clarke Belt in his honor. But Clarke wasn't the first to recognize geosynchronous orbits. That honor goes to the Austro-Hungarian engineer Herman Potočnik, who proposed the concept in his relatively obscure 1928 book *Das Problem der Befahrung des Weltraums* (*The Problem of Space Travel*). Both Clarke and Potočnik envisioned these satellites as manned space stations and neither used the terms geosynchronous or geostationary. At the time, Clarke imagined his concept wouldn't happen until the "remote future — perhaps half a century ahead." But progress was more rapid than that.

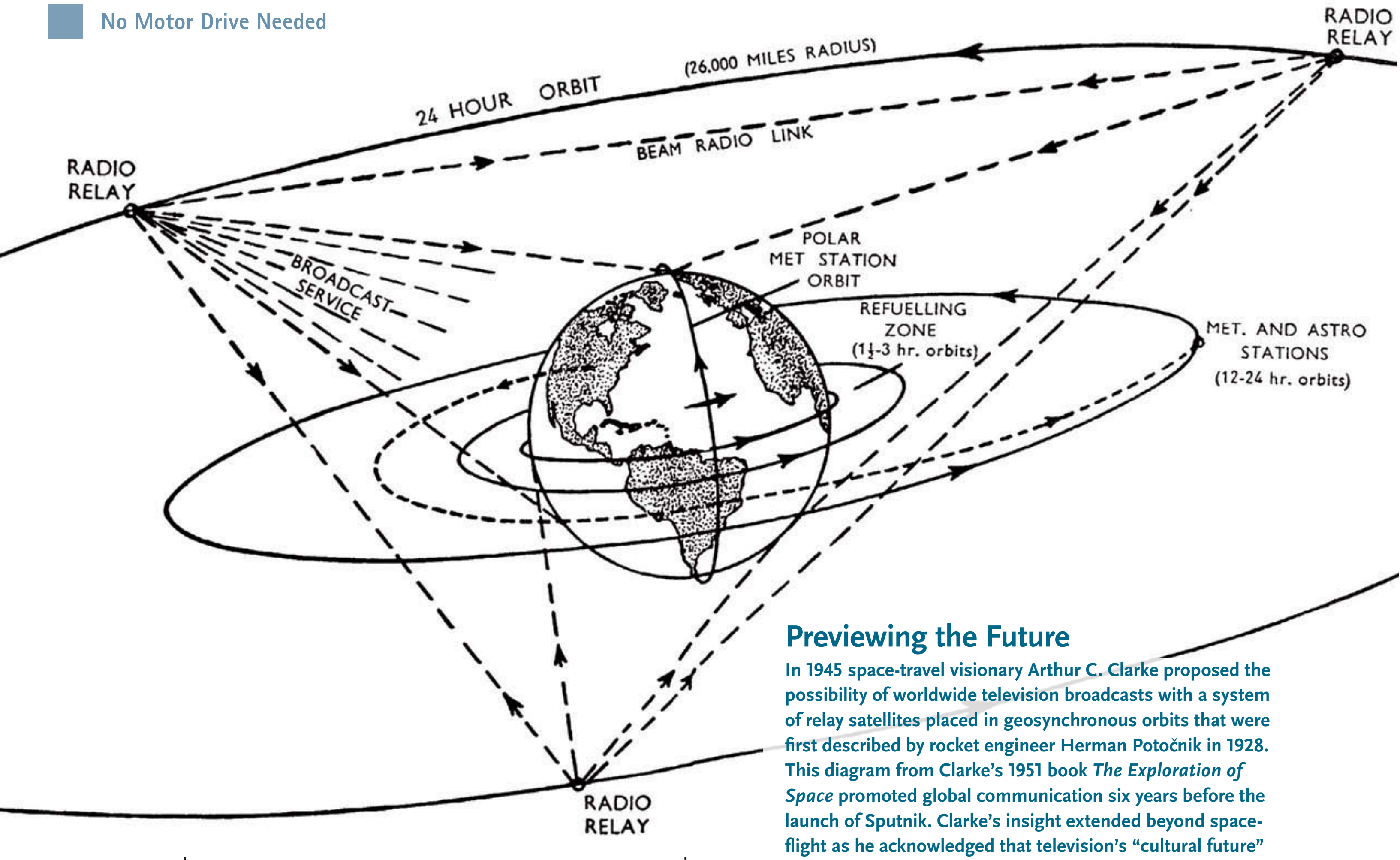
The first operational geosynchronous communication satellite was Syncom 2, launched by the U.S. in July 1963. Its orbit, however, was sufficiently inclined to Earth's equator that movable ground-station antennas were required. Syncom 3 was launched in August 1964 with a relatively stationary orbit that used fixed ground-station antennas. Since then, more that 400 geosynchronous satellites have been launched. Many of them have significant orbital inclinations and are not geostationary. It's very common for satellites in the Clarke Belt to appear within a degree of one another, especially in the sky over the Americas and Europe. The spacing between satellites is wider over portions of Asia and the Pacific Ocean.

Locating Geosynchronous Satellites

The orbital altitude of a geosynchronous satellite is much greater than that of the International Space Station, the Hubble Space Telescope, the Space Shuttle, and other low-Earth-orbit satellites, making most of them too faint to be seen with the unaided eye (they typically range between magnitude 9 and 15). Near the time of the spring and autumn equinoxes, the orientation of geosynchronous satellites is often more favorable for reflecting sunlight and the magnitude may brighten to 5 or 6. Rarely, one may glint to conspicuous naked-eye visibility.

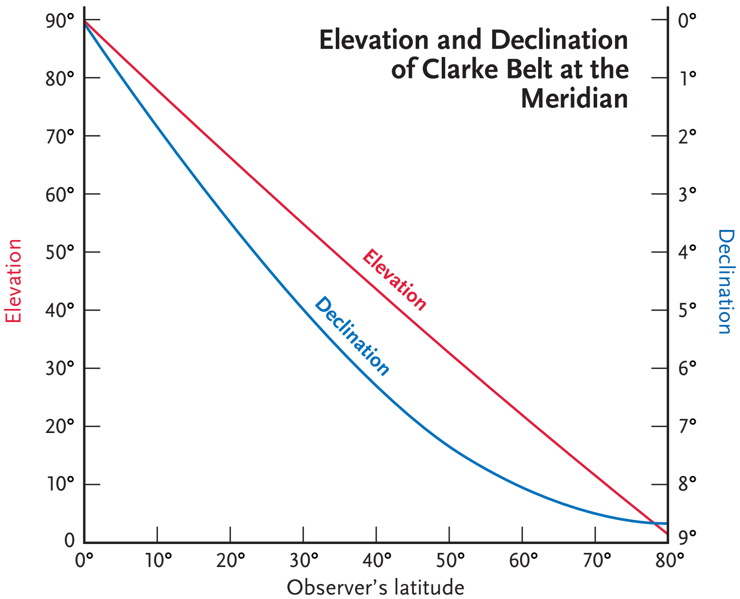
Many of these satellites are within reach of an 8-inch (20-cm) telescope at any time of the year. Their brilliance is stunning in larger scopes, but their apparent size is so small that they always remain stellar in appearance.

If geosynchronous satellites were at infinite altitude above Earth, their location within the Clarke Belt would make them appear on the celestial equator. But because the altitude is less than six Earth radii, Northern Hemisphere observers see the Clarke Belt south of the celestial



Previewing the Future

In 1945 space-travel visionary Arthur C. Clarke proposed the possibility of worldwide television broadcasts with a system of relay satellites placed in geosynchronous orbits that were first described by rocket engineer Herman Potočnik in 1928. This diagram from Clarke's 1951 book *The Exploration of Space* promoted global communication six years before the launch of Sputnik. Clarke's insight extended beyond space-flight as he acknowledged that television's "cultural future" and the thought of global broadcasting could be used by some as the best "argument against space-travel."



S&T DIAGRAM: LEAH TISCIONE
SOURCE: RANDY RHEA

Geosynchronous satellites orbit Earth in a band known as the Clarke Belt. Its position on the sky depends mainly on the observer's latitude. This graph shows the belt's location at the meridian in terms of elevation and apparent declination. As seen from northern latitudes the elevation is above the southern horizon and the declination is south of the celestial equator (minus values). From southern latitudes it's the northern horizon and north declinations.

equator, whereas Southern Hemisphere observers see it to the north of the equator.

The chart at left shows elevations above the horizon and the celestial declinations where the Clarke Belt appears when on the meridian for an observer's given latitude. These values change slightly as we look east or west of the meridian. The Clarke Belt does not appear above the horizon for observers more than 80° from the equator.

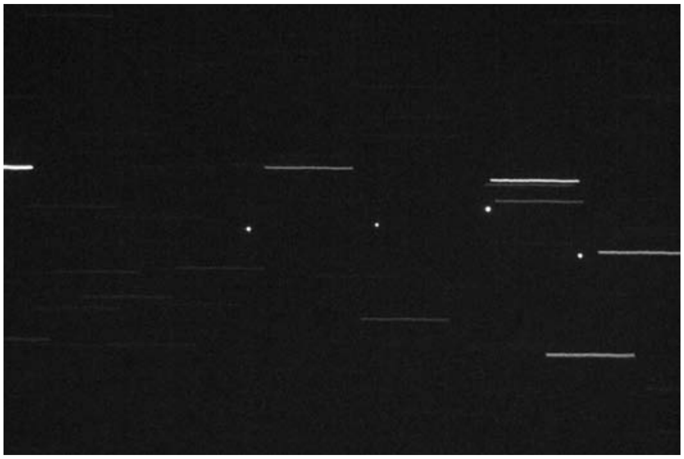
Sometimes you can see multiple satellites in one telescopic field of view. But not all of them will appear to move the same way. This is because of slight orbital eccentricities and inclinations relative to Earth's equator. A satellite's north-south excursion from a fixed point of the sky is caused by orbital inclination, whereas an east-west excursion is caused by eccentricity. These patterns vary among the satellites.

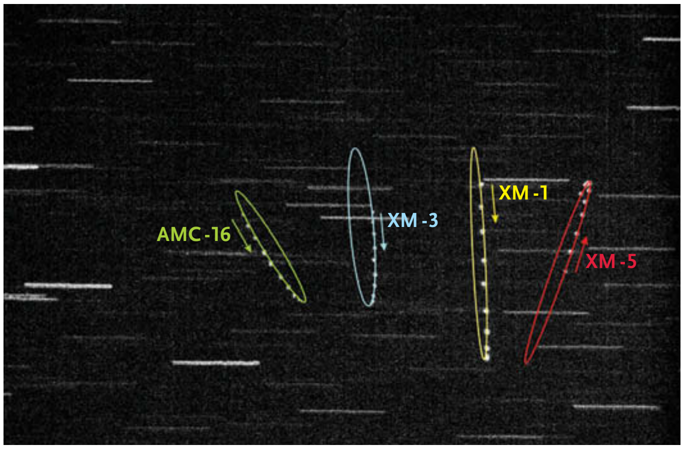
Tips on Observing

A large field of view requires less-accurate telescope pointing to locate the Clarke Belt, but the easiest way to detect a geosynchronous satellite is by its apparent motion relative to the stars. This slow movement is more difficult to spot when the field of view is greater than about 2°. I prefer to sweep for them with a field 0.5° to 1° across. Once I find one, or a group of them, increasing the magnification results in more dramatic viewing.

You can use either equatorial or alt-azimuth mounts for observing. These satellites make great targets for Dobsonian telescopes that don't have drives. You can use a pencil or piece of tape to mark the telescope's altitude for the position of the Clarke Belt on the meridian. This elevation decreases when you are looking east or west of the meridian, and you can make additional elevation marks when you locate geosynchronous satellites at other azimuth locations.

For equatorial mounts, you can set the scope at the declination indicated in the chart and then sweep along the Clarke Belt by moving the scope in right ascension. It's much easier to scan the Clarke Belt this way than to use an alt-azimuth mount. While the declination of the Clarke Belt changes slightly when you are looking away from the meridian, the error is small. You can also find these satellites by star hopping, but to do this you'll need to prepare a





RANDY RHEA (2)

The author recorded four geosynchronous communication satellites in a 0.6°-wide field captured with an SBIG ST-8 CCD camera and stationary Meade 8-inch f/6.3 Schmidt-Cassegrain telescope. The top view shows stars appearing to drift by the satellites in a single 20-second exposure, while the view below it is a composite of 10 exposures made at 1-hour intervals showing the slowly changing positions of the satellites due to their slight orbital inclinations and eccentricities.

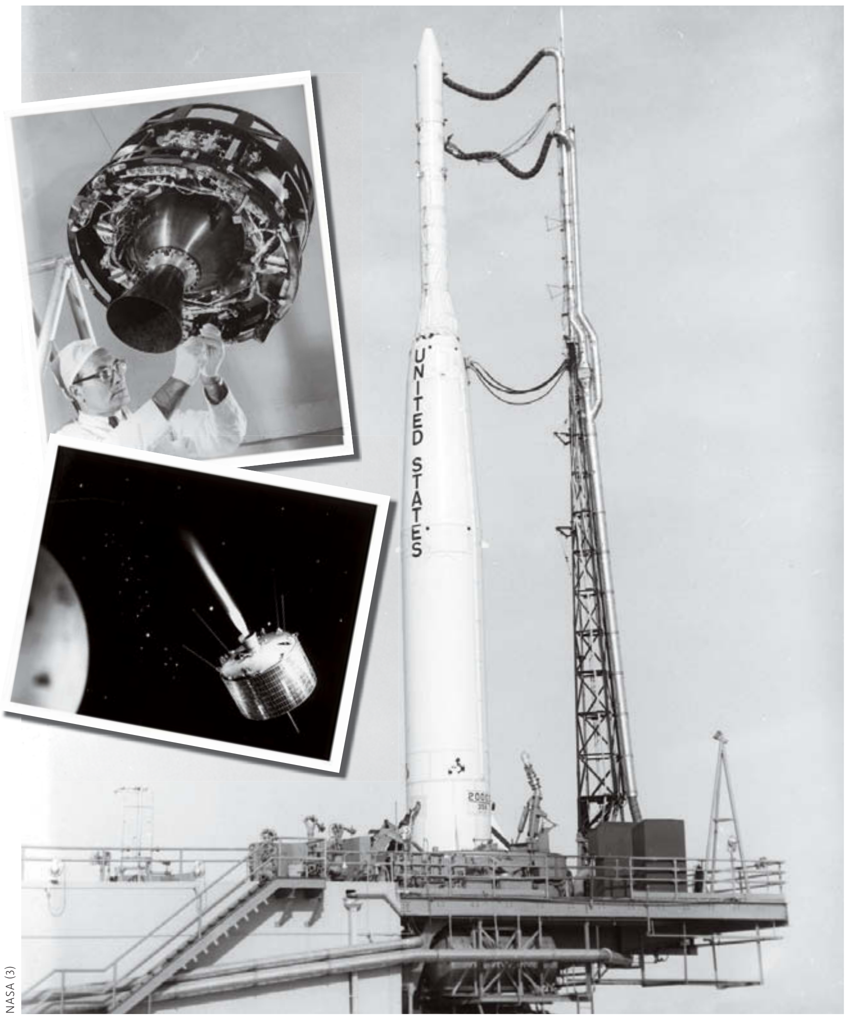
Deep-Sky Objects Near the Clarke Belt

Observer's Latitude	Declination	Objects*
75° to 55° N	–8.6° to –7.7°	N157, N1042, N1052, M50, N3115, N4487, N4699, N4958, N4995, N6664, N7606
55° to 45° N	–7.7° to –6.8°	I430, N584, N596, N1084, N1276, N1909, N2215, N2302, N2309, N3115, N4504, N6539
45° to 40° N	–6.8° to –6.3°	I430, N584, N596, N1022, N1909, M48, N4731, N4775, N4981, N6683
40° to 35° N	–6.3° to –5.7°	N779, M42, M48, N4697, N4731, N4941, N5427, N5634, N6683, M11
35° to 30° N	–5.7° to –5.0°	N1600, N1700, M42, M43, N2232, N2250, N4593, N4697, M48, N4941, N6366, N6704
30° to 25° N	–5.0° to –4.3°	N1600, N1700, N1981, N2232, N2250, N2311, N6366, N7585
25° to 20° N	–4.3° to –3.4°	N1453, N2652, N4546, M10
20° to 15° N	–3.4° to –2.6°	N1253, N1637, N2286, N4684, N4691, M14
20° to 25° S	+3.4° to +4.3°	N520, N3166, N3169, N4457, N4496, N5300, N5566, N5775, N6755
25° to 30° S	+4.3° to +5.0°	N2180, N2238, N2244, N2269, M61, N5317, N5668, N5921, N6755, N6756
30° to 35° S	+5.0° to +5.7°	N488, N2186, N2238, N2244, N2252, N3423, N4261, I4665, I4756, N5317, N5363, N5701, N5921
35° to 40° S	+5.7° to +6.3°	N676, N741, N864, N3423, N4261, N4339, N4532, I4665, I4756

*Objects from the *New General Catalogue of Nebulae and Clusters of Stars* (NGC) are identified with a preceding N; those from the Messier list, M; and those from the *Index Catalogue*, I.

Planetary Crossings of the Clarke Belt for Latitudes 20° to 50° North

Year	Venus	Mars	Jupiter	Saturn
2011	20° to 50° N: Apr	None	None until 2017	20° to 25° N: Aug-Sep
				25° to 20° N: Dec
2012	20° to 50° N: Jan-Feb	20° to 40° N: Jul		60° to 40° N: Mar-Jun
		50° N: Aug		20° to 50° N: Jun-Sep
2013	20° to 50° N: Aug	None		None
2014	20° to 50° N: Apr	20° to 40° N: Jan		None
		50° N: Feb		
		40° N: Mar		
		30° to 20°N: Apr		
		15° N: May		
		20° to 50° N: Jun		
2015	None	50° N: Jan		None
		40° to 20° N: Feb		
		20° to 40° N: Dec		



NASA (3)

star chart for the specific observing date and time.

During favorable conditions, such as near the equinoxes, you can see some geosynchronous satellites in small telescopes or even binoculars, but the wide field of binoculars makes it very difficult to notice their relative motion against the starry background.

Around the time of the equinoxes, Earth casts a shadow on the Clarke Belt up to 10° east and west of the Sun's opposition point. At sunset, geosynchronous satellites located in the eastern sky are in shadow, while at sunrise the shadow has swept across the sky to obscure those in the west. Earth does not cast a shadow on the Clarke Belt for any dates more than 80 days removed from the equinoxes. Geosynchronous satellites can be observed entering and exiting Earth's shadow, with these eclipses lasting about 70 minutes during the equinoxes.

Nearby Passes

Besides observing eclipses of these satellites near the equinoxes, other special events include direct or near passes of deep-sky and solar-system objects. You can predict passes near deep-sky objects by noting the apparent declination of the Clarke Belt for your latitude and searching catalogs for deep-sky objects with the same declination. There's a listing on page 69 of brighter deep-sky objects that, for a given latitude, pass within 1° of the Clarke Belt.

For solar-system objects, predicting the passage through the Clarke Belt is more complex, and these passes are best determined using planetarium software. I have prepared the table on this page showing Clarke Belt passes for Venus, Mars, and Saturn for the years 2011 through 2015. Clarke Belt passes for the more-distant planets are quite rare.

All of us have watched satellites sail overhead among the stars. When you track down geosynchronous satellites you get to enjoy the view as stars appear to sail past the satellites. ✦

Randy Rhea *is a retired electrical engineer who began observing with an Edmund Scientific 3-inch Space Conqueror reflector purchased for $29.95 in 1961. He may be reached at 24scope@gmail.com.*

Visit SkyandTelescope.com/geosynchronous for links to a variety of web resources for observing and identifying geosynchronous satellites.

Launched on a three-stage Delta rocket in July 1963, Syncom 2 (insets) became the first successful geosynchronous communications satellite. Five months earlier, Syncom 1's electronics had failed before it reached orbit.

Chilean Imaging Odyssey

Klaus Brasch

Expand your views with a trip to the southern skies of Chile.

IMAGINE SPENDING 12 DAYS AND NIGHTS observing under pristine skies, surrounded by stunning scenery, unique artistic, gastronomic, and cultural delights, and extremely friendly people. Would you feel like you've died and gone to heaven? Well maybe not, but at an elevation near 8,000 feet (2,440 meters) above sea level on the Atacama Plateau in northern Chile, you're definitely a step closer.

I recently had the good fortune of joining a dozen dedicated Canadian amateur astronomers on a journey to the Atacama Lodge **(www.spaceobs.com/en/lodge.php)** near the delightful town of San Pedro de Atacama. Operated by astronomer Alain Maury and partners, the lodge is part of San Pedro de Atacama Celestial Explorations (SPACE), a tour company that specifically caters to amateur astronomers from all over the world. SPACE provides accommodations, star tours, rental telescopes, and sightseeing excursions to nearby natural wonders.

The physical setting of the region is simply stunning. Surrounded by some of the highest snow-capped volcanoes in the world, the Atacama Plateau lies against the Andean Cordillera, extending from about 8,000 feet to more than 16,000 feet in elevation.

There are many reasons why several major observa– tories are located in the Atacama Desert. It is among the driest localities on Earth, with virtually no measurable

Below: **Author Klaus Brasch shares his experiences visiting the Atacama Lodge, pictured here in the foreground of the Licancabur volcano in the Chilean Andes. Only from the Southern Hemisphere does the heart of the Milky Way cross the sky directly overhead, and few places south of the equator offer a view as vivid as that from the Atacama Plateau in Chile.**

Above: **This 22-inch Dobsonian telescope provided stunning views of southern deep-sky targets.**

precipitation and almost year-round clear skies. Combine that with exceptional transparency, no appreciable light pollution, very good seeing conditions, and the incomparable southern skies and you are in indeed in astronomical heaven.

Although extremely dry, the Atacama region contains a number of fresh-water lagoons replenished by snowmelt from the nearby Andes. Spectacular Laguna Chaxa, part of Chile's Reserva Nacional los Flamencos, is home to hundreds of species of birds, reptiles, and crustaceans. Even more impressive is nearby Valle de la Luna (Valley of the Moon). This aptly named geologic wonderland has vistas reminiscent of the Moon and Mars and was used to test NASA's Mars rover prototypes. If you enjoy astronomy, culture, hiking, mountaineering, wildlife, geology, or archaeology, this place has it all.

Under Southern Skies

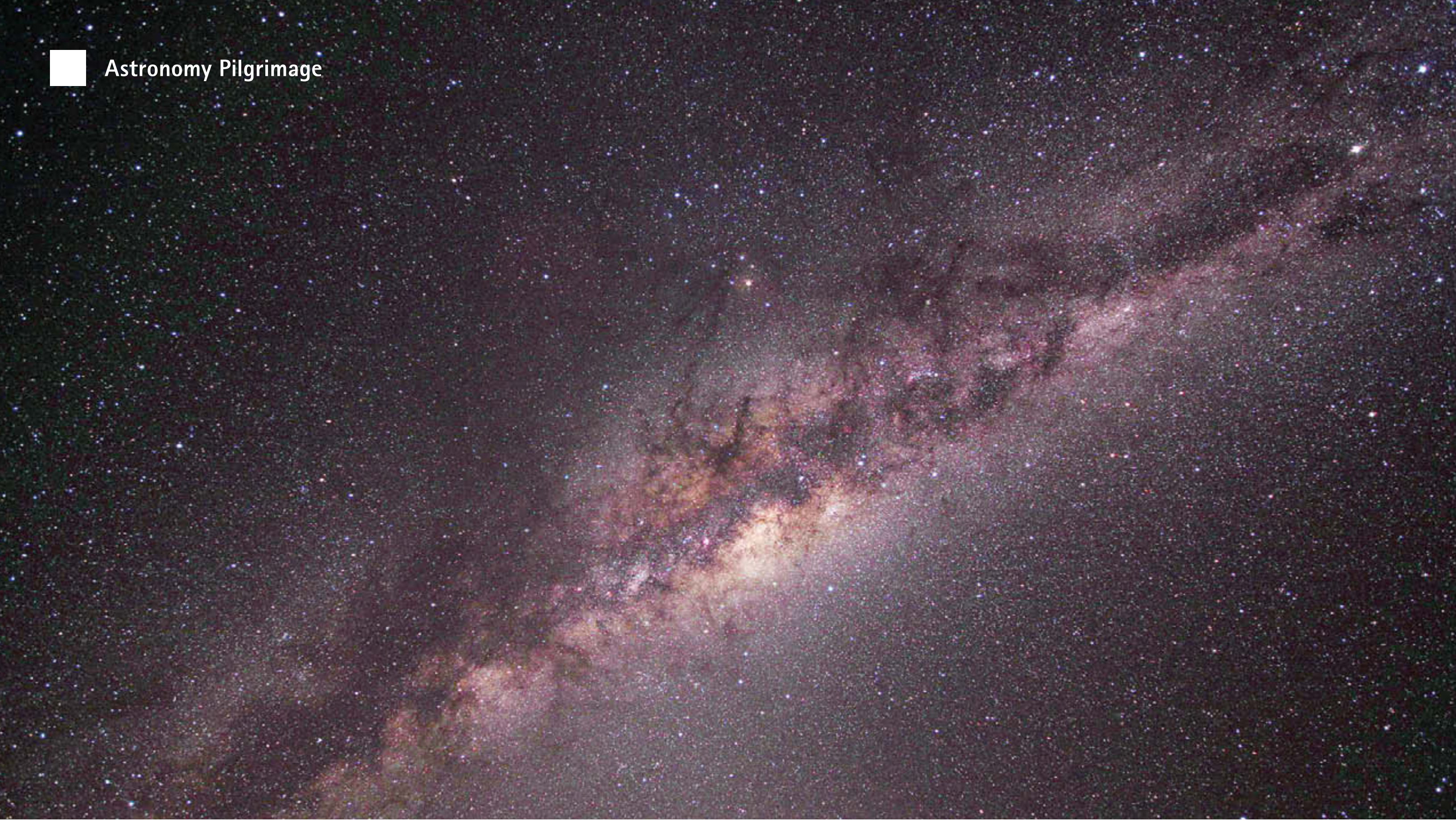
Ultimately, the unparalleled beauty of the southern Milky Way drew us to the region. Incredible showpieces such as the Eta Carina Nebula, Omega Centauri, the Coal Sack, 47 Tucanae, and countless other objects that are hidden below the horizon back home, are in full view from Chile. Under the jet-black Chilean skies, we were overwhelmed by the Milky Way bridging the firmament, and it even cast shadows when near the zenith! Likewise, viewing and imaging the Magellanic Clouds gave us the feeling that we were traveling in space.

The Eta Carina Nebula is the biggest and brightest nebulous complex in the sky. Although barely visible from the most southern locations in the United States, it reveals its true extent under the dark Chilean skies. The author recorded this four-panel mosaic with a Takahashi FS-102 and a modified Canon EOS 50D DSLR camera.

Although some of our fellow travelers brought complete CCD imaging gear including their own telescopes, my friend Terry Dickinson and I opted to keep things light. Between the two of us we had several modified Canon DSLRs, a wide assortment of lenses, and a small equatorial mount suitable for piggyback astrophotography. In addition, we rented time on a permanently mounted Takahashi FS-102 apochromatic refractor and a Celestron C14 with HyperStar. These setups proved so successful that we secured some 300 individual astrophotos for later processing. Our exposures were typically a few minutes long, and we recorded multiple images for later stacking and processing.

So what sorts of equipment should you bring to capture some of the southern sky's splendors? Given concerns with air-travel security and carry-on luggage limits, it's best to keep things as simple and light as possible.

Clearly, a high-end DSLR camera is the most versatile



Above: **Relatively short exposures reveal the Milky Way in all its colorful glory. This image is a stack of two 3-minute exposures recorded with a modified Canon 20D DSLR and 10-mm f/4 lens at ISO 1600.**

Below: **While the Northern Hemisphere was experiencing late spring, the chilly autumn Atacama nights required the author to bundle up while shooting the sky using a rented Takahashi FS-102 refractor. Rental equipment allows visitors to leave their bulky gear back home.**

TERENCE DICKINSON

camera for travel. Most DSLRs available today fit the bill nicely as long as they have a "bulb" setting for long exposures. Be sure to bring a remote-release cable for your particular camera, to avoid vibrations during exposures. Although these cameras are great for all-around photography on a trip, many astrophotographers opt for modified cameras that have increased response to the reddish-pink light of emission nebulae permeating our galaxy. Under the dark Atacama skies, unmodified DSLRs work just fine but will not record fainter emission nebulae.

A key factor with astrophotography is focusing. You want pinpoint stars, not fuzzy little donuts. Most late-model DSLRs have a "live view" feature that makes focusing an easy task. The best way to insure tack-sharp focus, however, especially with camera lenses that often do not have a focus stop at the infinity setting, is to take test exposures and adjust the lens accordingly.

If you're new to astrophotography, just bring a solid tripod and a good wide-angle lens and set the ISO to 1600 or higher. You can take pleasing images of the Milky Way without objectionable star trailing with unguided exposures up to 40 seconds long. Many of my fellow travelers got superb results with an AstroTrac **(www.astrotrac.com)**. This beautifully engineered, battery-driven drive is lightweight and designed for traveling. Coupled with a solid camera tripod and ball head, the AstroTrac can be polar aligned and used for exposures as long as 10 minutes with telephoto lenses up to 400-mm focal length. A word of advice to first time Southern Hemisphere visitors though:

there is no Polaris down under to aid in alignment, so it can be a challenge initially.

In addition to astrophotography, we also spent many nights observing deep-sky objects with telescopes available at the lodge. The Eta Carina Nebula (NGC 3372) is brighter than M42 and roughly four times its angular size — so bright that it actually appears distinctly pink through a 22-inch Dobsonian! Globular clusters Omega Centauri and 47 Tucanae were dazzling, and the Tarantula Nebula (NGC 2070) in the Large Magellanic Cloud (LMC) showed extensive structure and detail. One of our fellow travelers identified some 20 planetary nebulae in the LMC alone. Other favorite objects, including the Sagittarius array of M8, M16, M17, M20, and M22, appeared far brighter and more imposing because they were straight overhead rather than low on the horizon as they are at our northern latitudes back home.

Every amateur from the Northern Hemisphere should make a pilgrimage to the south to see the sky they are missing out on. Some feel the best sights within our galaxy are only visible south of the equator. Whether you're a seasoned observer or astronomical novice, the Atacama Lodge offers a full complement of telescopes for visual and imaging enthusiasts, as well as a full range of non-astronomy activities for the entire family. ✦

__Klaus Brasch__ is a docent and lecturer in the public program at Lowell Observatory in Flagstaff, Arizona, and a life-long amateur astronomer.

Top: **While in Chile, amateurs should arrange a visit to the European Southern Observatory at Cerro Paranal, home of the four 8.2-meter telescopes together known as the Very Large Telescope.**

Above left: **Among the interesting sights near San Pedro de Atacama is Valle de la Luna, a wind-sculpted nature sanctuary bearing resemblance to the surfaces of both the Moon and Mars.**

Above right: **Another jewel of the south, Omega Centauri (NGC 5139), is the largest globular cluster as seen from Earth.**

Below: **The historic church and main plaza of San Pedro de Atacama.**

To see more of Klaus Brasch's photography, visit SkyandTelescope.com/Chile.

Sean Walker
Gallery

Gallery showcases the finest astronomical images submitted to us by our readers. Send your very best shots to gallery@SkyandTelescope.com. We pay $50 for each published photo. See SkyandTelescope.com/aboutsky/guidelines.

◄◄ **THE SPLINTER GALAXY**

Bob Fera

Located in the southern area of Draco, NGC 5907 is a warped spiral galaxy known to be surrounded by faint tidal streams of stars.

Details: *Officina Stellare RC-360AST 14-inch Ritchey-Chrétien astrograph with an Apogee Alta U16M CCD camera. Total exposure was 5⅓ hours through Astrodon color filters.*

▲ **BRILLIANT NORTHERN SPIRAL**

Warren Keller

Among the largest galaxies in Canes Venatici is M106, a Seyfert galaxy that displays a bright core and an extended halo of young bluish stars.

Details: *10-inch RCOS Ritchey-Chrétien astrograph with an ATIK 11000C CCD camera. Total exposure was 13⅓ hours.*

◄ **GALACTIC GHOSTS**

Lynn Hilborn

Located along the plane of the Milky Way, Cepheus is home to a large number of nebulae, including van den Bergh 141, a thick knot of dust known to contain a cluster of embryonic stars.

Details: *Telescope Engineering Company APO140ED refractor with an FLI ML8300 CCD camera. Total exposure was 13⅓ hours.*

► **ECLIPSE OF THE MIDNIGHT SUN**

Arne Danielsen

The June 1st partial solar eclipse is seen gracing the skies near local midnight over the strait of Tromsøysundet at Tromsø, Norway.

Details: *Canon EOS 5D Mark II DSLR with 70-200mm lens at 70-mm. HDR composite of 11 images ranging from 1⁄2000 to ½ second.*

▲ **SCORPION DUST**

by Alistair Simon

Often passed over by astrophotographers for the famous Rho Ophiuchi region 3° to its southwest, vdB 102 is a delicate reflection nebula within a large dust cloud permeating most of northern Scorpius.

Details: *Takahashi TOA-130 refractor with an SBIG STL-11000M CCD camera. Total exposure was about 9½ hours through color filters.*

► **NORTHERN DISPLAY**

Andrew Keen

Mid-autumn auroras such as this brilliant display are frequent occurrences above the Arctic Circle. ✦

Details: *Canon EOS 5D Mark II DSLR camera with 24-mm lens. Exposure time was 4 seconds at ISO 100.*

Visit SkyandTelescope.com/gallery for more gallery online.

Transit of Venus 2012

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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.

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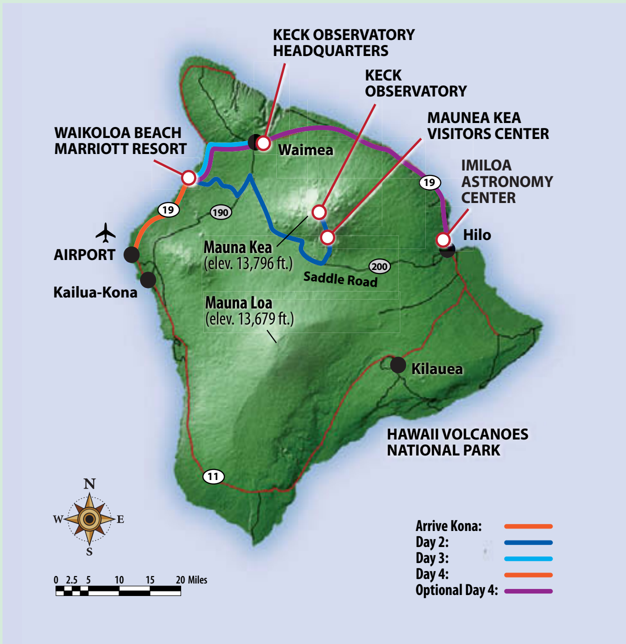

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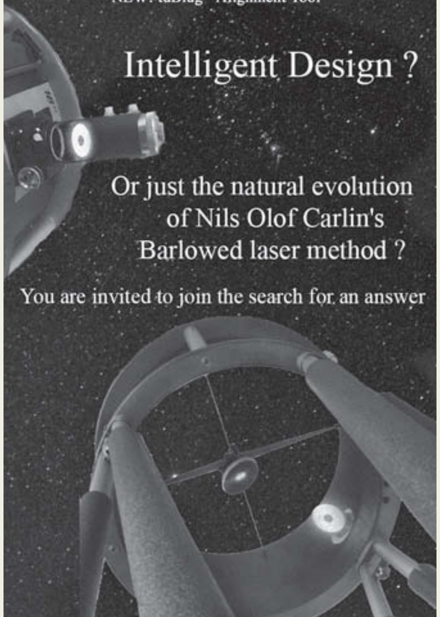

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IN THE NEXT ISSUE

Galaxy Zoo

By turning to legions of citizen scientists, astronomers have gained new insight into the evolution of galaxies.

Growing Up with *S&T*

Two insiders look back and explain why the origin of *Sky & Telescope* magazine was truly a family affair.

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The AAVSO's Future Plans

The organization's director anticipates an exciting century ahead.

The article on page 30 provides an excellent synopsis of the past 100 years of the American Association of Variable Star Observers (AAVSO). What should be the organization's future strategic directions?

Interestingly, the AAVSO was born during a great era of all-sky surveys, made possible with photographic plates taken by the Harvard College Observatory. We're entering a new era of all-sky surveys, led by the amazing Large Synoptic Survey Telescope. LSST will issue thousands of transient alerts every night, most of them so faint that follow-up will require the world's largest telescopes. But professionals expect dozens to be so bright that their detectors will saturate, so they will have no idea how bright the objects really are. Current surveys are also turning up interesting objects, most of which are not being followed up.

Amateurs will again be called upon to study these objects, since they have enough telescope time to monitor them. LSST will also rely on "crowd-sourcing," where humans will be needed to classify the transients or eliminate instrumental artifacts — much like Galaxy Zoo did with galaxies imaged by the Sloan Digital Sky Survey. Anyone with a computer, an internet connection, and some database expertise can data mine these surveys.

Amateurs are also starting to use commercial spectrographs, providing a new window for long-term monitoring of variable objects. Another innovative development is the use of DSLR cameras. These affordable devices can provide a permanent digital record of the heavens, useful for monitoring the entire sky every night (April issue, page 64).

Visual observers will still be needed, but for the highest scientific value they will need to perform specific observations — watching for an outburst of a rare class of star, making time-critical observations when robotic facilities might be clouded out, measuring the brightness of close optical doubles, and so on. Just as professional surveys have nearly eliminated amateur asteroid discoveries, and digital techniques have supplanted visual discoveries of novae and supernovae, amateurs need to be flexible and understand that as some doors close, others open up. Demand for visual observations will transition in new directions.

TOM PHILBROOK

The AAVSO's role will remain much as it has for the past century. We will educate amateurs (and professionals!) in proper methods to obtain the most scientific value from their equipment and observations. We will bring astronomy to the public, and show that science can be exciting. We will utilize the modern media to attract talented young people into the variable-star field.

Astronomy is filled with innovators who utilize smart phones for scientific observations, who write control software for robotic telescopes, who find applications for low-cost cameras, and who make use of technology developed for the gaming community to create high-powered computers for theoretical modeling. I don't see any of this activity changing in the near future, and I'm making sure that the AAVSO invests considerable effort in keeping abreast of the changing world and continues to provide a useful service to the astronomical community. Besides, this is fun stuff, and I want everyone to hear about it! ✦

Arne Henden *is the Director of the AAVSO. Visit SkyandTelescope.com/AAVSO to watch an interview with Dr. Henden.*