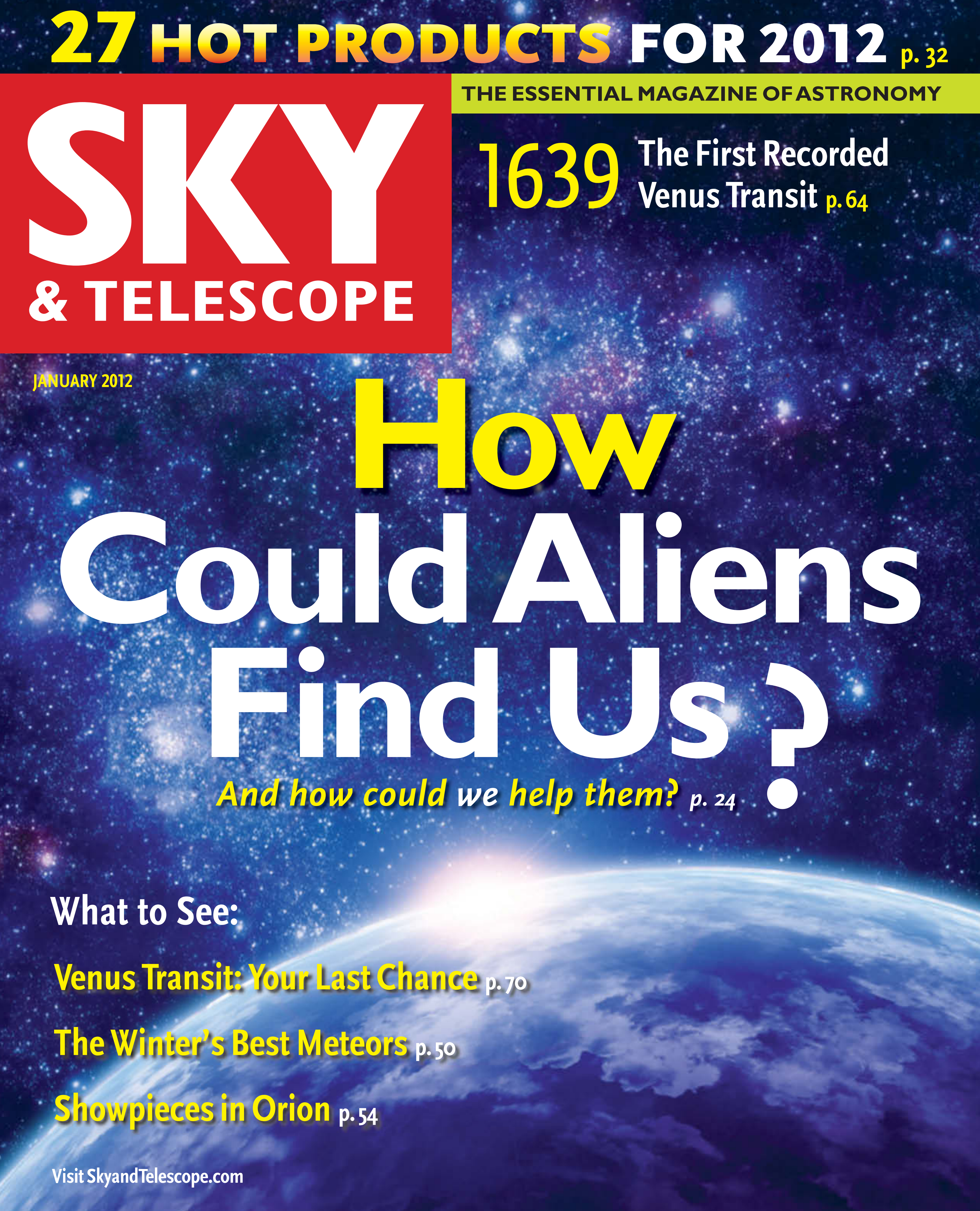

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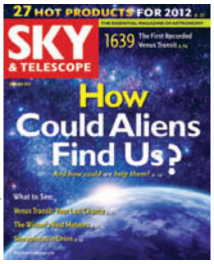
# January 2012

VOL. 123, NO. 1

SKY & TELESCOPE




BIGSTOCK / SARAH HARLAND

**On the cover:** Considering just how hard to spot our own planet might be puts a new spin on finding exo-Earths like the one illustrated here.

## FEATURES



## THIS MONTH'S SKY



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# Superfast Neutrinos?

ON A LATE September evening I was in my hotel room in Santiago, Chile, having arrived earlier that day after an overnight flight from Miami. I was accompanying an *S&T* tour group to visit great astronomical facilities in Chile. I felt weary eyed, but while surfing the web I came across a provocative news story on the BBC home page about a European experiment (called OPERA) that measured muon neutrinos traveling faster than the speed of light. I was intrigued, but I assumed the result would soon go away as other groups poked holes in the methodology or interpretation.

As I joined my fellow tourists for breakfast the next morning, I realized that this story had gone viral, and despite it being our first full day together in a foreign land, it was a big topic of conversation. When asked about it, I repeated my thoughts from the previous night, emphasizing the need for other scientists to check the result, but also not dismissing the possibility outright. After breakfast, I read several other news stories and physics blogs, along with the OPERA paper. All of this info reinforced my initial reaction.

Over the next week, our tour group had a wonderful time visiting major professional observatories: Cerro Tololo, La Silla, and Paranal (home of the Very Large Telescope). We enjoyed spectacular telescopic views of Southern Hemisphere deep-sky objects from three amateur observatories: Collowara, del Pangue, and Mamalluca. But every now and then, the supposed superluminal neutrinos popped up in conversation. It was the story that would not go away.

As of late October, the result is still waiting to be confirmed or refuted. Although my head is pretty much convinced it will be overturned, deep down in my heart, I hope it stands. No offense to Professor Einstein, but science makes its most rapid progress whenever a major result runs counter to expectation. If muon neutrinos do, in fact, travel faster through rock than light travels in a vacuum, it would undoubtedly open the door to new physics and a deeper understanding of our universe. After all, less than two weeks after the OPERA team announced its results, Saul Perlmutter, Adam Riess, and Brian Schmidt deservedly won the 2011 Nobel Prize in Physics for discovering the accelerating universe, another result running contrary to the accepted wisdom of its time.

Before closing, I welcome Camille Carlisle to our editorial staff. Camille had a very successful *S&T* internship in 2008 and a 15-month stint at *Science News*. She studied astronomy and English at Villanova University, and earned a graduate degree in science writing at MIT. She will work for the magazine and website, and you'll undoubtedly come across her byline in the months ahead.

Robert Naeye
*Editor in Chief*



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## Wandering Geosynch Satellites

In "Observing Geosynchronous Satellites" (October issue, page 66), Randy Rhea states, "A satellite's north-south excursion from a fixed point on the sky is caused by orbital inclination, whereas an east-west excursion is caused by eccentricity."

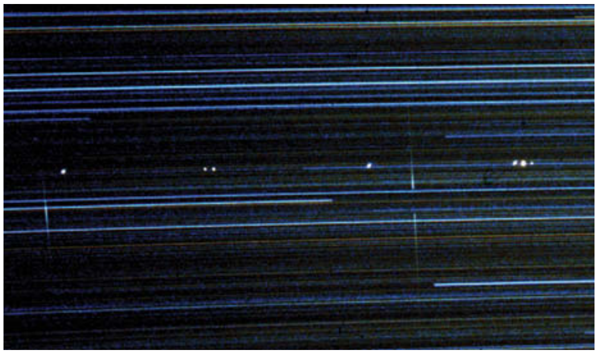
The first statement is true; the second is mostly not. Even if a satellite in an inclined orbit has zero eccentricity (a circular orbit), it still appears to move in a figure-8 that includes some east-west motion. This happens for the same reason Earth's own axial inclination causes the Sun to go through east-west excursions to form the familiar figure-8 of the analemma. (The analemma is the Sun's position on the sky as seen at the same time of day through the year). In both cases, the reason has to do with the fact that at high or low latitudes (or declinations), lines of longitude (or right ascension) are spaced more closely together.

If the orbit is circular, the figure-8 will be symmetric, with its lines crossing in the middle at the equator. Non-zero eccentricity makes the figure-8 asymmetric. For instance, the small top and big bottom of the Sun's analemma shows that Earth's orbit is not a perfect circle.

In the case of a geosynch satellite, each time the satellite crosses the equator its longitude must be within an assigned "longitude box" 0.1° to 0.2° wide. To ensure this, the satellite must do station-keeping maneuvers to maintain an eccentricity of zero to within several ten-thousandths.

So, the east-west excursions that we see geosynchronous satellites performing are dominated by the effect of orbital inclination, not eccentricity (unless the inclination is so small that the orbit is better described as geostationary).

***Robert D. Furber***
*Manhattan Beach, California*



Aim a fixed camera at the "Clark Belt" as seen from your latitude, let the stars trail for a very long exposure, and you may pick up the row of geostationary satellites (the points here). You may also pick up nonstationary but geosynchronous satellites moving not quite north-south, like the nearly vertical streaks here. William Livingston took this exposure on March 1, 2009.

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 300 words.

## Rates of Climate Change

I believe David Grinspoon's heart is in the right place with his column "Planetary Changes of the Fourth Kind" (October issue, page 16). We need to learn how to manage global environmental changes and maintain a biosphere that will support our species. However, in referring to the fact that Earth has already gone through many major environmental changes, I wish authors would remind readers that these have typically happened very slowly, taking thousands or millions of years. The rate of change in the last 100 years is much faster. I'd hate to see someone read this article and respond: "See, we've been through this before, there's nothing to worry about."

***Cliff Paino***
*Lincoln Park, New Jersey*

## Spade a Spade

Thank you for a fair and honest review of an excellent but not-quite-perfect scope (the Lunt 80-mm H-alpha Solar Scope, November issue, page 38). In my experience, magazines rarely bring up any problems with advertisers' products. But Sean Walker mentioned and discussed every issue I've had or noticed with this scope. Not only is this a useful service to potential purchasers, it tells me that my scope isn't unique.

And I agree with Sean's conclusion that even with its shortcomings, it's a great solar scope.

***Woody Schlom***
*Spring Valley, California*

## Behind These Walls

I can't see much of the night sky here, due to the paradoxically bright lights in this otherwise gloomy place, but you have brightened my time with *Sky & Telescope*. I look forward to studying our universe a lot more once I can find my ideal dark-sky location, with a small cabin and an old dog. Thank you!

***Thomas Darby***
*Corcoran State Prison, California*

## Solar Filter Accidents

With an annular solar eclipse and a transit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of Venus coming up in May and June, respectively, I am researching accidents with solar filters and would be very interested in hearing from readers.

I hope everyone knows that it's highly dangerous to let unfiltered or improperly filtered sunlight from a telescope into the eye. But how often do eye injuries actually occur, given the number of observers worldwide? How often does the wind blow Mylar filters off telescopes? This happened to me while I was looking through a 1-inch finderscope, and again just partially with a 2-inch finderscope. Neither accident harmed my eye.

Searching the web I found only a few stories, all by non-astronomers — including one by a guy who looked into the Griffith Observatory public telescope while it was pointed at the Sun because his "silly girlfriend" told him it would be cool to do. This resulted in at least temporary eye problems.

Please tell me your experiences. Also, I can't find any scientific studies about eye damage from Sun exposure through telescopes. Can you refer me to any?

***Martin Stangl***
*stanglulbs@gmail.com*
*Graz, Austria*

## 75, 50 & 25 Years Ago

*Roger W. Sinnott*

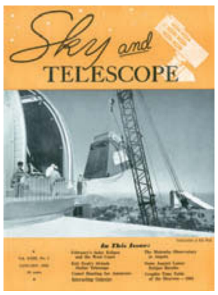
### January 1937

**Red Nebulae** "The discovery and exploration by Dr. Otto Struve and his colleagues at the Yerkes Observatory of a "red" nebulosity around the bright star Antares was announced at Harvard's Tercentenary Conferences. Nebulae which reflect light of blue stars, such as the Pleiades, have long been known. But this is an important advance in indicating the power of nebulosity to reflect light from red stars. A small Schmidt camera was useful in this research. . . ."


*Harlow Shapley was noting some astronomical advances of 1936, when red-sensitive photographic emulsions and Schmidt optics were exciting novelties.*

### January 1962

**When Galaxies Collide** "In 1959, the Soviet astronomer B. A. Vorontsov-Velyaminov, of Sternberg Astronomical Institute in Moscow, published an atlas and catalogue of 355 cases of interacting galaxies. . . . Of special interest are [those] with luminous filaments that extend from one to the other, as in M51. . . .




"Is Vorontsov-Velyaminov correct in discarding gravitation as the main force producing connecting filaments and tails? Recent theoretical studies by the Swedish astronomers Bertil Lindblad and his son P. O. Lindblad suggest that gravitation can account for certain of the observed structural features. . . . The younger Lindblad has used an electronic computer to calculate step by step the evolutionary development. . . ."

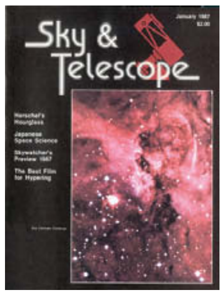
*Computer simulation of galaxy dynamics was in its infancy when Otto Struve wrote this article. Today's supercomputers have firmly established that gravity and tidal effects, rather than an unknown repulsive force, explain the bizarre rings and tails of stars found in interacting pairs.*

### January 1987

**Quantized Redshifts** "A growing body of observations suggests that one of the most fundamental assumptions of cosmology is wrong. . . .

"By far the most intriguing result of these initial studies was the suggestion that galaxy redshifts take on preferred or 'quantized' values. First revealed in the Coma cluster redshift-versus-brightness diagram, it appeared as if redshifts were in some way analogous to the energy levels within atoms."

*William G. Tifft and W. John Cocke wrote about their finding, soon to be supported by several other researchers. But most if not all astronomers today regard it as a statistical effect that melts away as redshifts are measured for more and more galaxies.*



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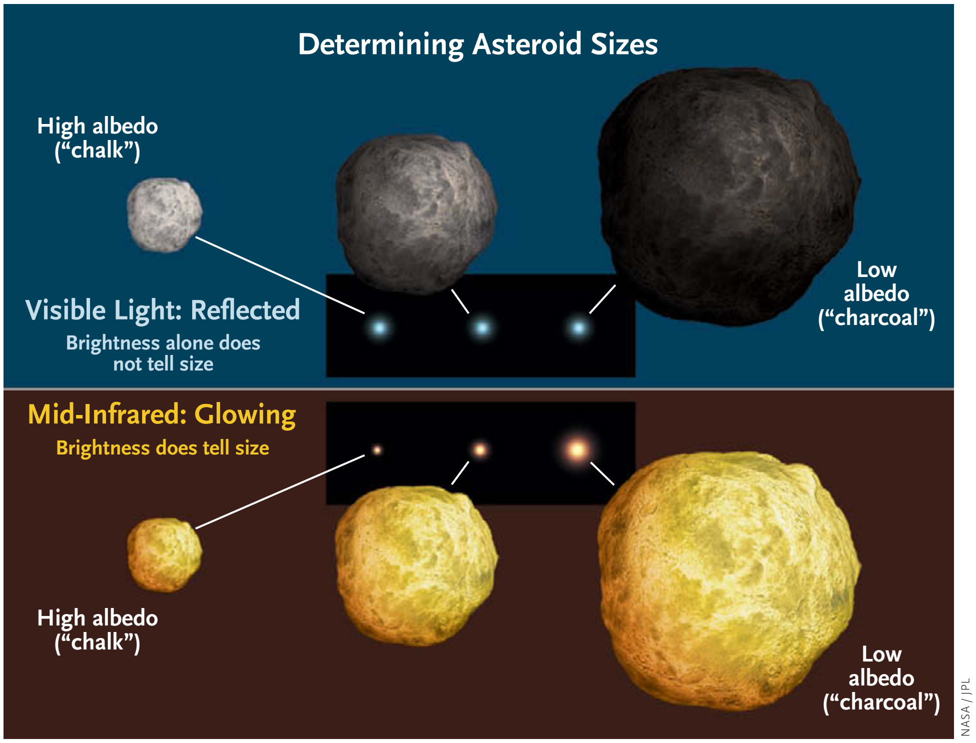
# Near-Earth Asteroids: Fewer than Expected

Humanity has more immediate threats to consider, but if you worry about a giant asteroid hitting Earth, the already slim chance of that happening in a given millennium just dropped by nearly half — thanks to the much-awaited asteroid survey carried out by NASA's Wide-field Infrared Survey Explorer (WISE) space telescope (*S&T:* December 2009, page 26). The WISE team finds that there are less than 60% as many near-Earth asteroids, or NEAs, as earlier estimated.

"Near-Earth" asteroids are defined as those whose orbits bring them within 0.3 a.u. (28 million miles; 45 million km) of Earth's orbit. Astronomers realize that for every big one they find, there must be many smaller ones. Moreover, judging the size and mass of a given space rock isn't easy. It depends on a guesstimate of the albedo (reflectivity) of the object's surface. A small white body and a big dark one can appear as equally bright points of light, as illustrated at top right. Past tallies have assumed a dark-gray albedo averaging 14%, representative of asteroids in general.




**Visible-light images aren't enough to determine an asteroid's diameter. A small, chalk-white body can appear the same brightness as a large, charcoal-dark one. But views in the mid-infrared tell the true story. At these wavelengths, we're seeing the asteroids glowing due to their own temperatures. Once the temperature is known, the amount of glow tells the object's size.**

WISE can do better. Its primary mission was to map mid-infrared sources in the deep universe. But it's also very good at detecting the feeble heat glow from asteroidal surfaces — and this is about the same per square foot regardless of whether the surface is chalk-white or charcoal-black at visible wavelengths. Thus was born NEOWISE, a mission add-on coordinated by Amy Mainzer (Jet Propulsion Laboratory). "WISE had four infrared channels ranging from 3 to 22 microns, and we detected most of the NEAs in the two longest channels, 12 and 22," she explains. "We didn't find every single asteroid out there, but we did find a good, representative sample."

The NEOWISE team concludes that there are a total of about 19,500 "midsize" NEAs, those with diameters between 100 meters and 1 km, far fewer than the pre-WISE estimate of 35,000.

For astronomers trying to keep tabs on them, this is a really big deal. "NEOWISE is the most important project of my career," exults Timothy Spahr, who directs the IAU Minor Planet Center — not only because WISE spotted so many objects (585 NEAs and some 150,000 main-belt asteroids) but also because it got enough looks at them over time so astronomers could compute their orbits.

Nothing seen so far is on a collision course with Earth, and especially nothing more than 0.6 mile (1 km) across. Such a large NEA would wreak global havoc. "The good news here is that, with NEOWISE, the worldwide community of astronomers — both amateur and professional — has now found more than 90% of all these really big asteroids," says Mainzer. She and her team now estimate there are 981 ± 19 such biggies in all, of which 911 have been found. So, astronomers have achieved the Project Spaceguard milestone established by NASA and Congress in 1998: finding 90% of the NEAs larger than 1 km.

Still in the works is WISE's estimate of how many *comets* pass through our part of space. These are less predictable.

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

## The Secret of Blue Stragglers: They Steal

Most stars that get a second lease on life do so by thievery — or so say two astronomers who think they've settled a question that's been around for more than a half century.

"Blue stragglers" have been a mystery since Allan Sandage discovered them in 1953. These are stars that appear deceptively young: they're hot, bright, and blue compared to the other members of an aged stellar population of which they're a member. Long after all the other hot, massive stars in a cluster have aged away to red-gianthood, blue stragglers continue to burn with the heat and brilliance of an extended youth.

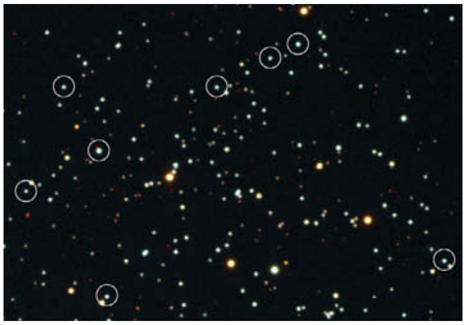
Astronomers have long proposed three scenarios for why they exist. All involve a radical addition of mass, resetting a star's evolutionary clock back as if to a new birth. Two stars could collide and become one. A binary pair could somehow lose orbital energy, spiral together, and merge. Or one member of a close binary could siphon off most of its companion star.

Aaron Geller (Northwestern University) and Robert Mathieu (University of Wisconsin–Madison) now say that siphoning is usually to blame, at least in star clusters.

Blue stragglers can exist singly, but like other stars they may have companions. When they do, the companion's mass can mark the system's evolutionary trail, because each origin scenario predicts a different range for companions' masses.

Geller and Mathieu studied 16 blue-straggler binaries in NGC 188, an open cluster 7 billion years old (judging by the pattern the rest of its stars make when plotted on a color-magnitude diagram). Although the companions were unresolved in visible light, they showed up by inducing Doppler shifts in the spectra of the blue stragglers they orbit. The solution that fit the data best put each of the unseen partners at just over 0.5 solar mass, suggesting that these are white dwarfs — the cinders of dead stars that evolved to the end of their fuel-burning lives.

If the blue stragglers had been born via collisions with other stars, any companions they have would mostly be ordinary stars averaging about 1 solar mass. The same would be pretty much true of companions



K. GARMANY & F. HAASE / NOAO / AURA

**Deceptively youthful "blue stragglers" are circled in this image of the center of NGC 188, a loose open cluster near the north celestial pole that's about 7 billion years old.**

that witnessed a late spiral-together of two stars perturbed into a very close orbit.

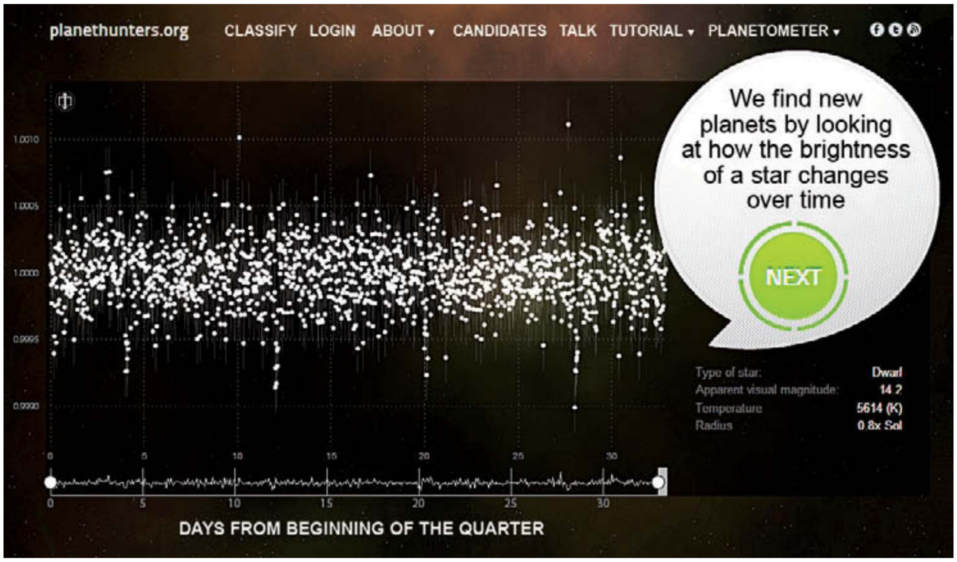
That's not the case with binary mass-theft. "Basically, in a mass-transfer scenario, the reason one star ends up as a blue straggler is that its companion dumps mass on it," says Christian Knigge (Southampton University, England). In any binary pair, the more massive star burns faster, ages faster, and swells toward red-gianthood first. But if the pair orbit each other closely, the swelling star overspills its Roche lobe, the region where it can gravitationally hold onto its outer layers. Rather than enlarging to become a red giant, it dumps most of its mass onto the other star, leaving only its tiny, very dense core. "The end result of the process," says Knigge, "is a blue straggler with a white-dwarf companion." Just as observed.

## Random Volunteers Find Two Possible New Planets

Many astronomers were skeptical when the Kepler exoplanet-search team rolled out Planet Hunters — a citizen-science project that asks people to examine noisy light curves of stars and spot any slight dips in brightness that may have slipped past the statistical prowess of computer analysis. A big problem is that the human eye and brain notoriously overinterpret noisy data and see patterns that don't exist — in all aspects of life, not just in swarms of dots on a screen. We're hard-wired that way, for good evolutionary reasons.

The public was certainly willing to try. Planet Hunters is one of the Zooniverse projects (zooniverse.org), as told in our November cover story. By November 2nd, volunteers for Planet Hunters had examined 5 million light curves and were reporting lots of false patterns as expected. But when the same uncataloged pattern is flagged by five or more people independently, Kepler astronomers take a closer look. In October, exoplanet specialist Debra Fischer announced that the volunteers may have found two transiting planets that computer analyses had indeed overlooked.

The potential discoveries circle two stars in Cygnus about 500 and 3,000 light-years away. One object seems to be a mini-Neptune with 2½ times Earth's diameter; the other is roughly Saturn-sized with 8

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Earth diameters. Astronomers are planning follow-up observations to look for telltale radial-velocity wobbles that could prove the planets real.

"I was skeptical whether the project would work, since computers are very efficient," says Fischer, a Planet Hunters founder. "But the users are actually amazing. It's astonishing how sophisticated they are."

"Human eyes will remain our best tools for spotting unusual or rare events," adds exoplanet specialist Daniel Apai. "Some of these will undoubtedly lead to the most exciting discoveries." That's good news for the rapidly growing world of citizen data-mining.

## Taking Mars's Ancient Temperature

Mention the meteorite ALH 84001 in a room full of planetary scientists, and they'll know exactly what you're talking about. And their blood pressure may rise. This fragment of ancient Martian bedrock, found in the icy wastes of Antarctica in 1984, exploded into world news in 1996 when a team of NASA researchers announced that they'd found evidence for fossilized microbes inside it.

The hoopla died down after most of the purported biogenic evidence was negated. Yet ALH 84001 remains unique among the several dozen known Martian meteorites because it's the only one that's truly ancient — 4.1 billion years old — and because it's riddled with tiny, round nodules of carbonate mineral with a striking layered composition.

Over the years, researchers have offered competing theories for how the carbonate beads formed. Some scenarios require a hot environment (an impact or volcanos), while others would have taken place in cooler standing water or perhaps below freezing. Consensus proved elusive, partly because no one really knew how hot or cold Mars was a few eons ago.

Now we know — at least for whatever spot on Mars ALH 84001 called home. John Eiler (Caltech) and colleagues used a new technique to measure precisely the isotopes of carbon and oxygen in the carbonate beads. The relative abundances of oxygen-18

**Weighing 4¼ pounds (1.9 kg), the meteorite Allan Hills 84001 is a piece of Martian bedrock that solidified 4.1 billion years ago.**

and carbon-13 are very sensitive to formation temperature. They imply that the rock was a pleasant 64°F (18°C) when the carbonates precipitated out of Martian water.

The researchers aren't saying that ancient Mars basked in a warm, wet climate on any large scale. The carbonates in ALH 84001 could have formed over just a few hours, perhaps following a regional impact or a burst of warmth from a hydrothermal vent.

## Planet in the Making

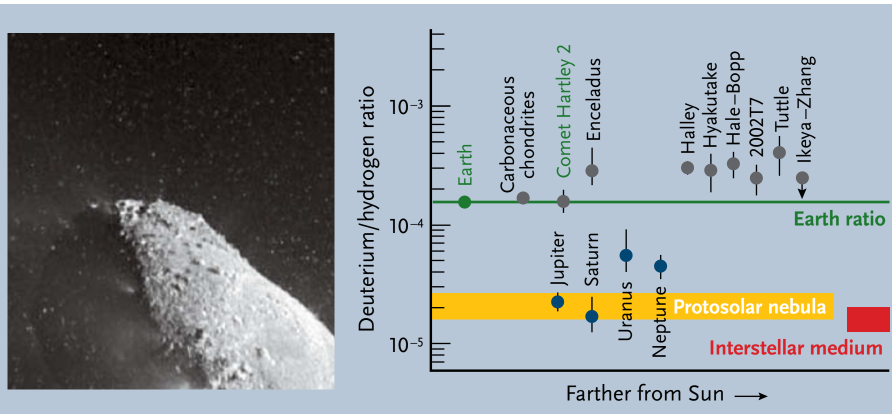
There's plenty of evidence for young planets circling young stars, but now two astronomers have recorded one actually assembling itself. Adam Kraus (University of Hawaii at Manoa) and Michael Ireland (Macquarie University) examined the infant star LkCa 15 using the Keck II telescope in November 2009, August 2010, and November 2010. Located about 450 light-years away in the dusty Taurus-Auriga star-forming region, LkCa 15 was already known to be encircled by a massive dust disk with a big empty gap.

Kraus and Ireland used Keck II's adaptive-optics system and an interferometric trick to obtain the sharpest possible infrared images of LkCa 15's dusty disk as close to the star as possible. What they found was a changing blob of glow — a planet drawing streams of material from its surroundings — orbiting within the disk's clearing. "LkCa 15b is the youngest planet ever found, about five times younger than the previous record holder," says Kraus.

The discovery turned up in a survey that is examining 150 young dusty stars with Keck's powerful optics.

## Comet Water for a Parched Earth

Earth ought to be dry. When Earth formed, the newborn Sun was still so hot that it should have driven all water out of the material that collected to make the inner solar system. Today's consensus is that the water in our oceans (and in the atmosphere of Venus) arrived later, perhaps as much as 800 million years after




***Left:*** **When NASA's EPOXI spacecraft flew by the nucleus of Comet Hartley 2 on November 4, 2010, the rubbly lump was spraying gas and shedding clumps of water ice, visible in this highly contrast-enhanced image. The frame is about 2 miles (3.2 km) wide.** ***Right:*** **Water in different parts of the solar system has very different ratios of deuterium to hydrogen (D/H ratio). Earth has much more deuterium than the protosolar nebula did or the giant planets do today. But Earth's water didn't match the water in comets either — until Comet Hartley 2 came along.**

PHOTOS: JSC / NASA (2X); DIAGRAM DATA: P. HARTOCH / NATURE

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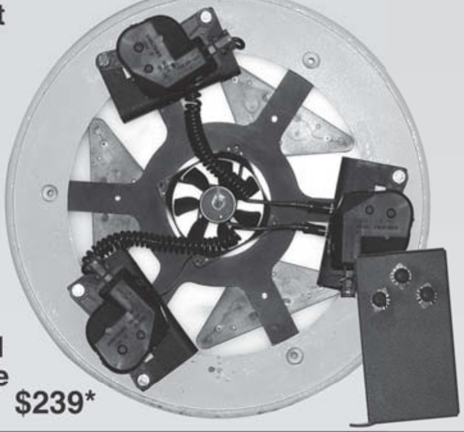

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JMI Telescopes - Jim's Mobile, Inc. - 8550 W 14th Ave - Lakewood, CO 80215 - U.S.A. - Info 303-233-5353 - Fax 303-233-5359 - Orders 800-247-0304 - info@jmitelescopes.com the rest of Earth had collected itself. The water could have come from comets falling in from the solar system's far fringes, or from water-rich asteroids originating closer by. But which?

Different solar-system bodies have different varieties of water, as defined by the water's ratio of ordinary hydrogen to the heavier isotope hydrogen-2 (deuterium). In Earth's oceans, the "D/H ratio" is 0.00016. But when the spectra of comets could be studied well enough, their water vapor turned out to have twice as much deuterium (0.0003) — a poor match. On the other hand, traces of water in primitive meteorites (carbonaceous chondrites), likely derived from asteroids, show almost the same isotopic ratio as Earth's water. (See the January 2011 cover story, "Where Did Earth's Water Come From?")

A new observation now updates the tale.

When Comet 103P/Hartley 2 passed Earth in November 2010, an international team led by Paul Hartogh studied it with the spectrograph on the infrared Herschel Space Observatory. In October they published their results: Hartley 2's water is an exact match for Earth's.

This suggests that Hartley 2 originated not in the very distant Oort Cloud, the source of most comets, but in the Kuiper Belt not far beyond the orbit of Neptune. Models suggest that Kuiper Belt bodies should have less deuterium than objects originating farther away. So comets are back in the running — with a warning that our understanding of the early solar system's dynamics is still incomplete.

## The Ghost of Comet Elenin

Comet C/2010 X1 (Elenin) was supposed to become a nice 6th-magnitude comet for binocular observers in early fall, but it was better known for a worldwide conspiracy hysteria that it would smash Earth and end civilization. Either way, many people were disappointed when it crumbled to nothing as it approached its September 8th perihelion. But traces remain. After perihelion, several imagers recorded an extremely diffuse debris cloud following the comet's predicted path. Rolando Ligustri in Italy took this contrast-boosted image on October 22nd, remotely operating a 4-inch imaging telescope in New Mexico. The field is nearly 2° wide.

## More on a *Y* Dwarf

The coldest discrete object measured outside our solar system is WD 0806-661 B, a dim, mid-infrared fellow-traveler of a white dwarf star 63 light-years away in Volans. This object is a very wide 130 arcseconds from the white dwarf, or at least 2,500 astronomical units, but they share the same motion through space. (*S&T:* June 2011, page 12).

Kevin Luhman (Penn State University) and two colleagues, who have studied the object with the infrared Spitzer Space Telescope, have refined their estimates to give it a temperature between 80° and 160° Fahrenheit (30° and 70° Celsius) and a mass of 6 to 9 Jupiters. Although its spectrum has not been obtained, such a low temperature should put it squarely in the realm of the new spectral class *Y* — a class that's been proposed to extend the cool end of the spectral sequence beyond types *G, K, M, L,* and *T.*

## Past Meets Future at AAVSO's Centennial

With speeches, cake, memories of decades long gone, and excitement about the very different data-rich decades to come, more than 100 people celebrated the 100th birthday of the American Association of Variable Star Observers (AAVSO) on October 6th. But hanging over the room was the knowledge that the old days and old ways are fast disappearing.

Eyeball estimates of variable stars' brightnesses, which most people at the gathering had done for much of their lives, are on their way to becoming as obsolete as vacuum-tube radios and rotary-dial telephones. Serious variable-star observers now use CCD cameras or photometers to make measurements that are much more precise. But automated sky surveys promise even bigger changes. The day is in sight when, for instance, the planned 8.4-meter Large Synoptic Survey Telescope (LSST) should gather more star-brightness data each night than all the AAVSO's eyeball estimators have done in a century. The LSST is supposed to start work late this decade, but its construction is not yet fully funded.

Addressing this impending sea


S&T: ROBERT NAEYE

**The AAVSO's old wall sign, newly installed on its current headquarters, was unveiled by director Arne Henden (right) and former president David B. Williams before a crowd at the AAVSO's 100th anniversary celebration.**

change was Charles Alcock, director of the Harvard-Smithsonian Center for Astrophysics a mile up the street. Alcock told the crowd that floods of sky-survey data already outstrip astronomers' ability to look for what they contain beyond the needs of a specific project. These data sets are full of objects that deserve the kind of individual follow-ups that well-equipped amateurs can study — if interesting objects can be recognized via the types of global data management that the AAVSO sees as a big part of its future. Many small-telescope users equipped with photometric CCD cameras and spectrographs will be needed to perform quick follow-ups and long-term studies on fast-paced or mysterious objects. "The amateurs of the world," Alcock said, "will have a great opportunity."

Rick Fienberg, *Sky & Telescope*'s former editor in chief and now the press officer for the American Astronomical Society (AAS) in Washington, D.C., informed the crowd that the AAS recently closed down its committee on amateur-professional collaborations. This, he explained, is good news. Amateur-professional collaborations on things such as variable stars have become so routine that there's no longer a need for a committee. "It astonishes me how many professional papers now routinely have amateur contributors as coauthors," Fienberg said. He closed by pointedly congratulating the AAVSO for "the bright future you have as you move wholeheartedly into the digital age." ✦


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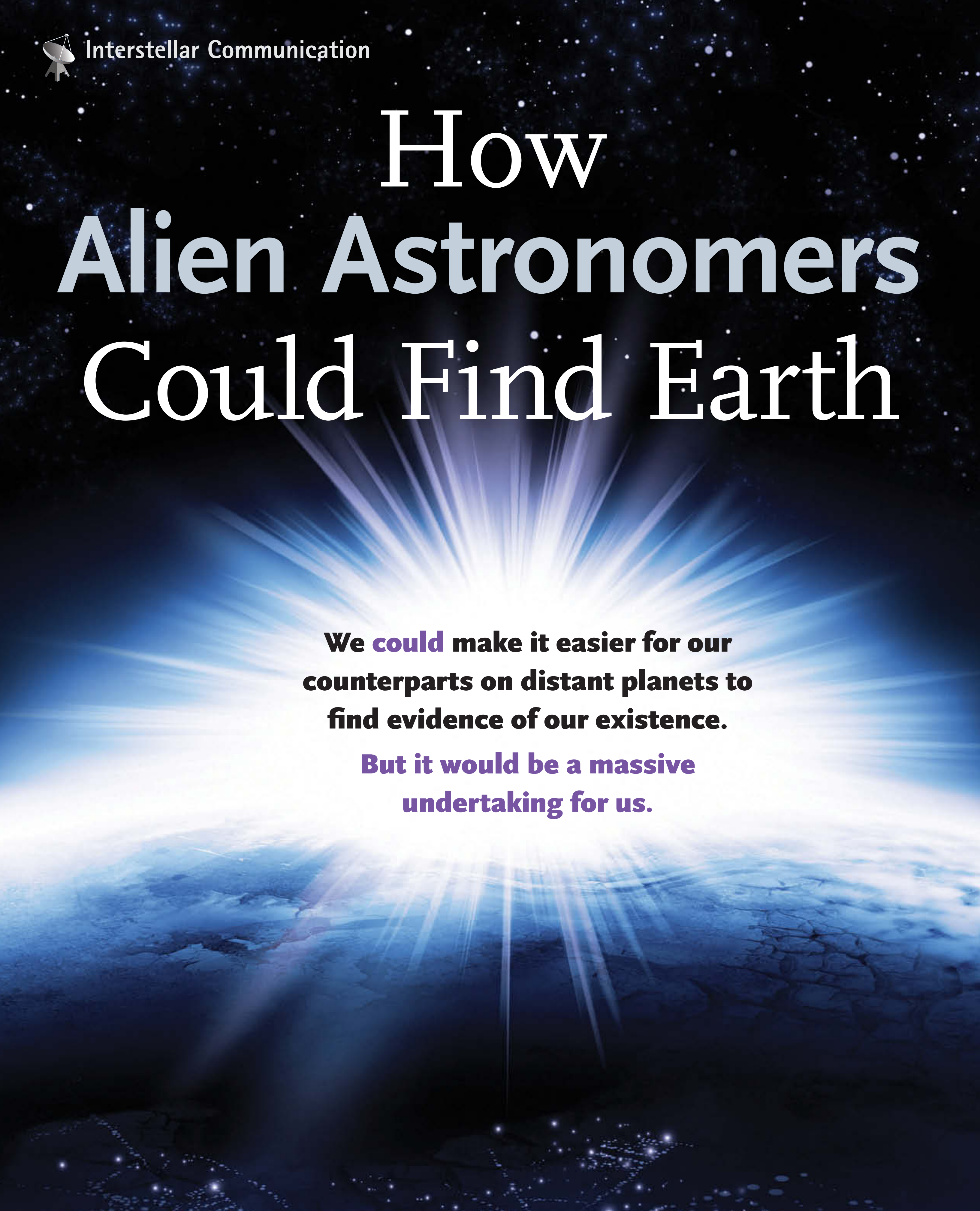
# How Alien Astronomers Could Find Earth



**We could make it easier for our counterparts on distant planets to find evidence of our existence.**

**But it would be a massive undertaking for us.**

JOSEPH LAZIO

*On Valentine's Day in 1990*, before closing its robotic eyes forever, Voyager 1 turned them back to its planet of origin. Though we have seen pictures of Earth from space before, most notably from the Apollo missions, Voyager 1's portrait provided the first glimpse of how a distant observer might see Earth — as a pale blue dot nearly lost in the inky darkness of the cosmic ocean.

Voyager 1 knew where to look. Could another civilization, perhaps also attempting to find the first signs of life elsewhere in the universe, find Earth? If so, would they just detect the planet, or might they infer humanity's existence?

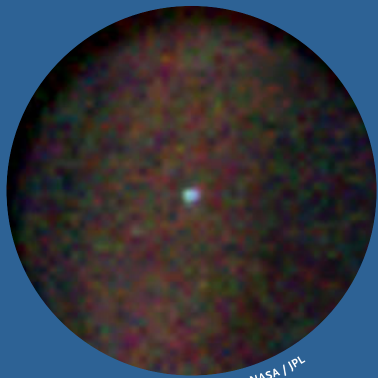
We can divide these questions into two parts. The first is how much Earth emits naturally, which would allow another civilization to detect the planet itself. The second part is how much radiation our civilization produces or could produce, which would allow them to infer our existence.

## Natural Emissions

The Sun and Earth emit the bulk of their natural radiation at visible and infrared wavelengths. The Sun's light output peaks in the green-yellow part of the spectrum. Earth reflects a portion of this visible radiation, as anybody who has seen earthshine on the Moon can attest. Even today, astronomers observe earthshine in an effort to understand how we might someday study the reflected light of extrasolar planets.

The amount of light that Earth reflects varies dramatically, depending upon a variety of factors. These include whether one is viewing primarily the Northern or Southern Hemisphere (the Northern Hemisphere has more land; the Southern Hemisphere has more water), the amount of cloud cover, and the amount of snow on the ground.

Nonetheless, a remote observer attempting to find Earth has an incredibly difficult job. Consider an astronomer only 10 light-years away, essentially on our cosmic doorstep. At this distance, the Sun and Earth are separated by no more than 0.1 arcsecond (about 30 millionths of a degree). Even though Earth is a fairly good reflector, reflecting about one-third of the Sun's incident light, the Sun is extremely bright. At visible wavelengths, the Sun is about 10 billion times (about 25 magnitudes) brighter than Earth.



NASA / JPL

The situation improves somewhat if we switch to infrared wavelengths. With a temperature of about 15°C (290 K), Earth's light output peaks in the infrared, while the Sun is not as bright as it is in the visible. The result is that Earth is "only" 10 million times (about 18 magnitudes) fainter than the Sun.

Astronomers are currently studying advanced space telescope concepts that would block or cancel out a star's light, which would allow us to detect any orbiting Earth-like planets. If civilizations only slightly more advanced than ours exist

**EARTH FROM AFAR** *Above:* Astronomers on planets orbiting other stars could detect Earth with advanced telescopes, but they might see it little better than how it was seen here by Voyager 1: as a pale blue dot floating in the vast darkness of interstellar space.

ILLUSTRATION: BIGSTOCK.COM / SOLARSEVEN

around nearby stars, they may have already identified at least some of the Sun's planets, including Earth.

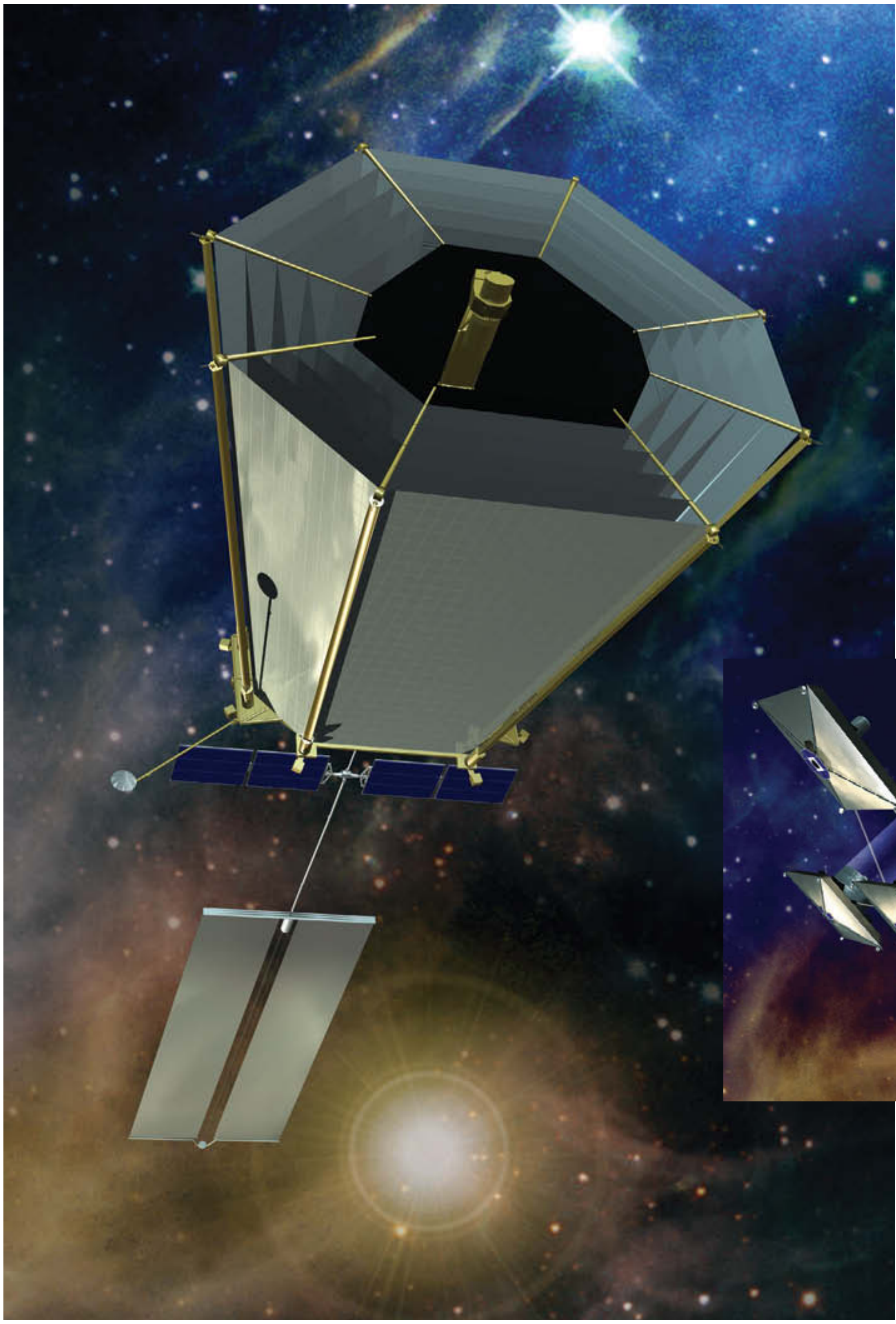
Even if a nearby civilization has detected Earth, that doesn't necessarily mean they know *we* exist. For example, Venus, with its thick clouds, is an extremely efficient reflector of sunlight, so another civilization might find it. But Venus's surface is inhospitable to life as we know it. Today's most ambitious telescope concepts aim not only to detect Earth-like planets around nearby stars, but to determine their atmospheric gases. Because of life's effects on Earth, the atmosphere has far more oxygen and far less carbon dioxide than either Venus or Mars. Indeed, oxygen is such a chemically reactive element that if all life on Earth were suddenly to disappear, most of the atmospheric oxygen would be removed by various processes within about 300 years. Thus, a nearby Earth-like planet with atmospheric oxygen would be a telltale indicator of a life-bearing world.

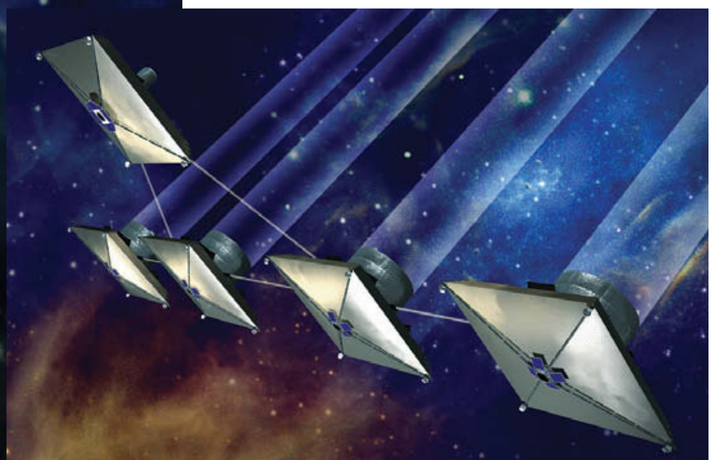
Measuring the chemical composition of an exoplanet's atmosphere is not as far-fetched as it might seem. Even with today's telescopes, astronomers are beginning to probe the atmospheres of some giant planets that transit in front of their host star. The advanced telescope designs being studied today could do the same for nearby Earth-size planets in habitable zones, even if they don't transit their stars.

## Optical Transmissions

If another civilization has measured Earth's atmospheric composition, it still couldn't determine if the life was in the form of plants, dinosaurs, the Roman Empire, or today's jet-setting crowd. How could another civilization detect us?

Anyone who has ever seen a picture of Earth at night might wonder if they could detect our light pollution. Our stray light is obnoxious to amateur astronomers and wildlife, but it pales in comparison to the amount of light that Earth reflects from the Sun. Simply put, our host star is so bright that in order to be detectable, our





NASA / JKL (2)

**TERRESTRIAL PLANET FINDER** Under the auspices of NASA's Terrestrial Planet Finder concept, astronomers are developing the technology to detect Earth-sized exoplanets using either an interferometric array of space telescopes *(above)* or a telescope with an advanced coronagraph *(left)* to block out the blazing light of the host star.

civilization has to compete with the Sun. A civilization with an extremely large and advanced optical telescope might be able to detect our city lights, but if our streetlights aren't up to snuff, there's a way we could compete with the Sun and do so in a way to make it completely obvious that an intelligent civilization is signaling.

If we observe a relatively nearby Sun-like star through a modest amateur telescope, we receive about 1 billion photons every 10 seconds. Observed for a much shorter interval, say, 1 billionth of a second, we probably would not receive a single photon from the star. If we could produce, on average, more photons in a short interval than the Sun does, it would signal a distant civilization that we're here.

We have built lasers, such as the National Ignition Facility's Petawatt Laser (located at the Lawrence Livermore National Laboratory in California) and the University of Texas at Austin's Texas Petawatt Laser, that for brief instants produce extremely energetic pulses of light. If we used one of the 10-meter Keck telescopes in Hawaii not to receive starlight but to transmit the light from a petawatt laser, over interstellar distances the flash would greatly outshine the Sun for a brief interval of time.

None of these petawatt lasers is currently hooked up to a large telescope. But knowing that we could construct such a system, professional and amateur astronomers have conducted modest searches for analogous signals from other civilizations. Known as optical SETI, these systems typically use relatively small telescopes equipped with ultra-fast detectors (*S&T:* November 2010, page 22).

## High-Energy Transmissions

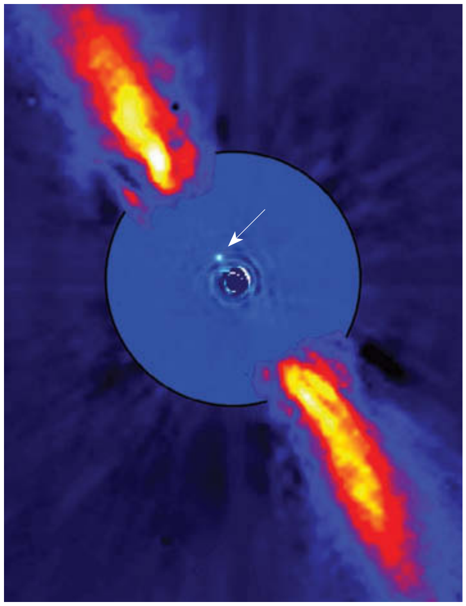
The Sun dims rapidly at wavelengths increasingly shorter than visible light. It produces enough ultraviolet (UV) light to cause a nasty sunburn, and its magnetic fields interact to produce X-rays and gamma rays, but the bulk of the Sun's energy output is at visible wavelengths. Is Earth brighter than the Sun at high energies, or could we make it so?

Thunderstorms can generate small amounts of X-rays and gamma rays, but not in sufficient quantities to detect over interstellar distances. Fortunately, our civilization doesn't generate much X- or gamma-ray emission either, because these energetic photons damage our cells. Moreover, Earth's atmosphere is opaque to X- and gamma rays, meaning that any attempt to send or receive signals must be done in space. Interestingly, gamma rays share an important attribute with radio waves: These are the only two kinds of electromagnetic radiation to which our galaxy is essentially transparent. Other wavelengths of light suffer varying amounts of absorption from the giant clouds of gas and dust in the Milky Way's disk.

A straightforward means of generating an X- and gamma-ray signal is to detonate a nuclear device in space. Most of a nuclear explosion's energy is initially emitted as X- and gamma rays; it is only upon interaction with Earth's atmosphere and surface that a nuclear explosion assumes the standard mushroom-cloud shape.

Our civilization no longer produces such signals because the 1967 Outer Space Treaty prohibits the detonation of nuclear devices in space. Nonetheless, suppose we decided to try to broadcast our existence via X- and gamma rays, perhaps by detonating nuclear devices on the far side of the Moon. NASA's Fermi Gamma-ray Space Telescope is currently detecting gamma-ray bursts (GRBs), brief flashes of gamma rays that originate in the destruction of distant stars. U.S. Department of Defense Vela satellites discovered GRBs in the 1960s while monitoring Earth and the immediate space environment for clandestine Soviet nuclear tests. Could we use nuclear explosions to signal a nearby civilization that has a Fermi-like telescope?

An obvious tactic would be to produce an explosion similar to but clearly different from GRBs. We could explode more than one device from the same location (a nuclear Morse code), which would clearly not be expected from natural GRBs. But the X- and gamma-ray signals from individual nuclear explosions are so weak at the distance of the nearest stars that the number of nuclear devices we would need to explode vastly exceeds the largest stockpiles maintained during the Cold War.



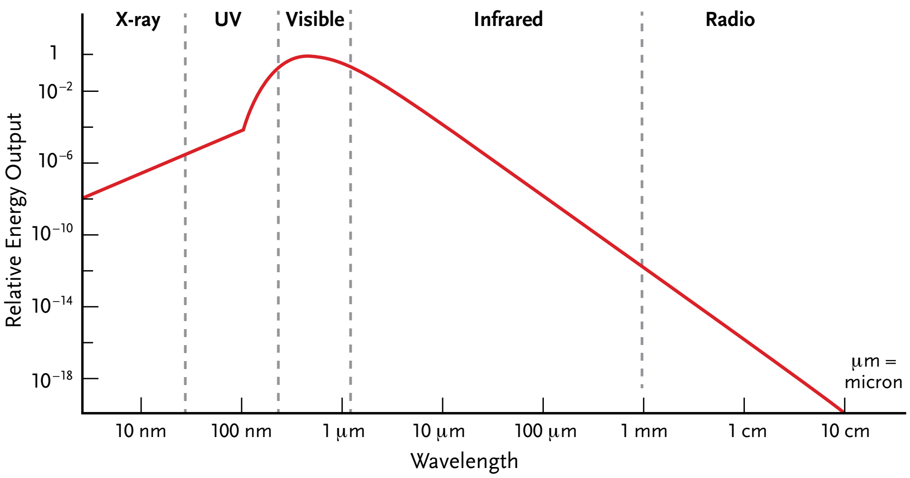
ESO / ANN-MARIE LAGRANGE, ET AL

**EXOPLANET IMAGE** Astronomers have already imaged planets around other stars, including this picture of a planet orbiting Beta Pictoris taken by the European Southern Observatory's Very Large Telescope. The Beta Pic planet is much easier to image from afar than Earth would be, because it's larger, hotter, and much farther from its host star.

## Non-Photonic Communication

What about other means of interstellar signaling and communication? All light is transmitted via photons, the carriers of the electromagnetic force — one of the four fundamental forces. Alternative communication methods must rely on non-photonic (non-electromagnetic) means.

We can dismiss one of the other four forces quickly. The gravitational force is transmitted via gravitational waves, and since gravity is the weakest force, these waves are extremely difficult to detect. Astronomers can indirectly detect gravitational waves from binary systems consisting of two neutron stars (*S&T:* August 2010, page 28). Ongoing upgrades to the Laser Interferometer Gravitational-Wave Observatory (LIGO) may advance to the point that we will directly detect gravitational waves from the collisions of neutron stars and black holes, thereby opening up an entirely new way of viewing the uni-




S&T: LEAH TISCIONE; SOURCE: COMET / HAO / NCAR

**SOLAR SPECTRUM** The Sun gives us life, but its extreme brightness at certain wavelengths makes it very difficult for other civilizations to detect our planet and civilization, since we essentially have to compete with the Sun's intense glare. This graph shows the Sun's luminosity across most of the electromagnetic spectrum. Because the Sun shines brightest at near-ultraviolet, visible, and near-infrared wavelengths, our best chance to make our presence known to extraterrestrials is to make plenty of "noise" in other parts of the spectrum.

verse. Although the laws of physics do not prevent a sufficiently advanced civilization from using gravitational waves for communication, it will be decades before we could hope to listen in on such communications, to say nothing of taking part.

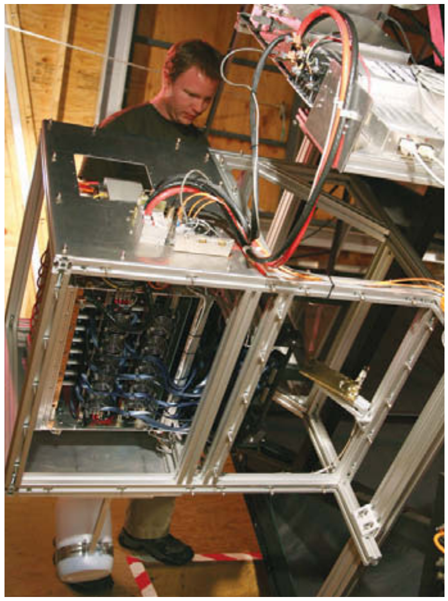
The other possibilities involve the strong and the weak nuclear forces. The strong force binds an atomic nucleus together. One could imagine sending atoms as a means of communication. In a sense, we have already done this, as NASA's Voyager 1 and 2 and Pioneer 10 and 11 spacecraft head out of the solar system. But traveling at only about 0.005% of the speed of light, it will take millennia for these spacecraft to cover the distance to even the nearest star.

Alternatively, we could shoot particle beams toward stars at nearly the speed of light, such as those being created at the Large Hadron Collider (LHC) in Europe. We have instruments looking for naturally occurring high-energy particles from space (cosmic rays). A charged particle beam pulsed in some non-random fashion would be a clear signal of our existence.

A significant problem in using beams of protons or electrons for communication is that these charged particles are deflected by magnetic fields. The amount by which a proton is bent from a straight-line path by a magnetic field depends

ANDREW COOPER / W. M. KECK OBSERVATORY

**LASER COMMUNICATION** Three large telescopes atop the summit of Mauna Kea in Hawaii shoot laser beams into space (left to right): Subaru, Keck II, and Keck I. These lasers do a great job helping adaptive optics correct for atmospheric turbulence, but they are far too weak to be detectable across interstellar distances. In principle, we could use a large telescope such as Keck I or II to boost the signal of a petawatt laser and beam detectable messages to the stars.



PAUL HOROWITZ / HARVARD UNIVERSITY

**OSETI SCOPE** Physicist Jason Gallicchio inspects the detector array of Harvard University's 72-inch telescope near Boston. The telescope is looking for nanosecond flashes of light from other civilizations.

MAXIMILIEN BRICE / CERN

BAHTIYAR RUZYBAYEV / NSF

**PARTICLE BEAM** ***Right:*** **This blue tube is just a tiny portion of the Large Hadron Collider, a 27-km-circumference particle accelerator in Switzerland. If scientists could somehow launch or construct such a massive facility in space, they could beam streams of particles to other stars that would be unmistakable signals from our technological civilization. The LHC primarily collides protons, but a particle accelerator in space would presumably beam neutrons, whose trajectories would be unaffected by interstellar magnetic fields.**

**NEUTRINO DETECTOR** ***Below right:*** **The workers in this picture are drilling a deep hole into Antarctic ice, part of a giant neutrino "telescope" called IceCube. IceCube was built to detect neutrinos from natural astronomical sources, but it could, in theory, detect a neutrino beam from another civilization.**

upon both the strength of the magnetic field and its orientation. Unfortunately, we know too little about the interstellar magnetic fields near the Sun to accurately "aim" a proton or electron beam toward any nearby star. If we built a space-based LHC (where Earth's atmosphere wouldn't interfere), we wouldn't know which (if any) stars would be in the beam's path. And even if we decided that we don't need to know where recipients might be, a space-based LHC lies *many* years in the future.

We could also transmit a beam of neutral particles. Such a beam could be aimed at a star, and it would travel undeflected by magnetic fields. One candidate would be the neutron. Curiously, the neutron is an unstable particle in isolation. The half-life of a bare neutron is only 11 minutes. Eleven minutes after launch, half the neutrons in the beam would have decayed to other particles, 22 minutes later, only ¼ of the original number of neutrons would remain, 33 minutes later, only ⅛, and so forth. Recalling Einstein's special theory of relativity, however, 11 minutes to an observer riding with the neutron beam need not be 11 minutes to those of us back on Earth. We would want the beam to travel relativistically anyway.

Could we produce a neutron beam so that 11 minutes in the neutron beam's frame of reference would be 4 years in our frame of reference, thereby allowing about

# Could Aliens Listen to Our Radio or Watch Our TV?

**HOW BRIGHT** is our civilization at radio wavelengths? Consider the Arecibo planetary radar system. It has led to a number of discoveries, such as water ice on the poles of the Moon and Mercury and improvements in our understanding of the properties of potentially hazardous asteroids. In addition to using the world's largest radio telescope (305 meters in diameter), the Arecibo planetary radar system will soon be using a transmitter with a power of 1,000 kilowatts (1 MW), operating at a frequency of 2380 MHz. For comparison, a typical TV or FM radio transmitter, operating around 100 MHz, might broadcast with a power of 50 kW, some 20 times less powerful.

The Arecibo planetary radar transmitter would have a radio brightness of about 50 Janskys to a civilization some 25 light-years distant. For comparison, typical celestial radio objects have brightnesses of about 1 Jy, while a cell phone at a distance of about 1 km would have a radio brightness of millions of Janskys. A radio brightness of 50 Jy is easy to detect with instruments such as the Expanded Very Large Array (EVLA) in New Mexico, and even on galactic scales, two Arecibo-like systems could engage in a conversation, albeit one with a very long time lag.

There are complications to any civilization detecting transmissions from the Arecibo planetary radar system. The first is that the system doesn't operate all of the time. The Arecibo telescope is used for other astronomical and atmospheric research. Clearly, no matter how sensitive another civilization's telescopes are, if we are not transmitting, they cannot detect us.

The second complication is that the Arecibo telescope is attached to the rotating Earth when transmitting. Because of the telescope's large diameter, its radar transmissions are strongly beamed, not unlike a lighthouse beacon. Only if the other civilization is looking at exactly the correct moment as the Arecibo radar beam sweeps across their planet will they be able to detect it. Even worse, if another civilization is monitoring our planet continuously, but the orientation between their radio telescope and the Arecibo telescope is incorrect, they will never detect Arecibo. (No matter how often an astronomer watches the sky in Minnesota, she will never see Alpha Centauri.)

A final complication is that the planetary radar system hasn't been operating in its current form over Arecibo's entire life span; previous systems were lower power, which means they could not have been detected as far away. The extraterrestrial civilization must also be watching the sky at the correct frequency.

One possibility to improve the odds of detection would be to produce a signal that is "on" continuously. Perhaps the next most powerful radio signal on the planet, and one that is transmitted continuously, is the Air Force Space Surveillance System (AFSSS). This radar system tracks satellites and has been operating for almost 40 years. This system is always operational, but, like Arecibo, the AFSSS is also attached to a rotating planet, so a distant civilization would still have to be observing at the correct time and have the appropriate orientation between the AFSSS and their telescope.

However, AFSSS's power is slightly less than that of Arecibo and its transmitting beam is not as focused. The less-focused beam is directly related to its mission to establish a "space fence" that orbiting satellites must cross as they orbit Earth. The combination of less power and wider beam means that it would be perhaps 10,000 times weaker, but likely still detectable at about 25 light-years by a radio telescope comparable to the EVLA or the Giant Metrewave Radio Telescope (GMRT) in India.

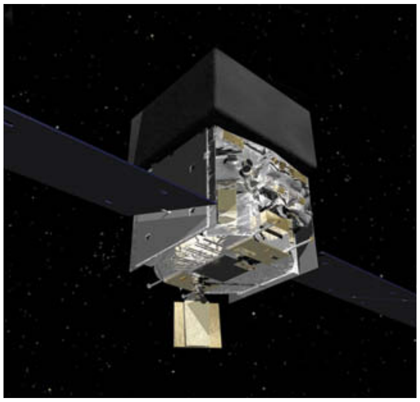
A common worry about Earth's transmissions is that other civilizations will intercept TV transmissions such as *Gilligan's Island* and conclude that no intelligent life exists on Earth. But receiving TV transmissions over interstellar distances is even more difficult. TV and FM radio transmissions are not only typically much lower in power, they tend to be far less strongly beamed (so that many people here on Earth can receive them). The combination of low power and wide beams means that any nearby civilization must have telescopes at least 100 times more sensitive than our current radio telescopes to have any hope of detecting our TV signals.

Taking all of these considerations into account, it's easy to appreciate why SETI programs are still in their beginning stages. Only with much larger telescopes, operating with "piggyback" SETI programs all the time (such as the SETI@home program at Arecibo), are we likely to have a reasonable chance of detecting our cosmic neighbors.

NAIC / ARECIBO OBSERVATORY / NSF

**RADIO DISH** Despite many different strategies proposed for interstellar communication, radio signals are still the most practical because of their ease of transmission and detection, and the fact that they travel at the speed of light. This image shows the Arecibo Observatory in Puerto Rico, which could detect signals broadcast by its counterpart even if it's on the other side of our galaxy.

WIKIMEDIA COMMONS



NASA

**NUKE BLAST** ***Above left:*** **Before a 1967 treaty banned nuclear explosions above Earth's atmosphere, the U.S. and Soviet Union conducted nuclear tests in space. This image shows an "aurora" as seen from Honolulu after the American Starfish Prime test. The two superpowers built enough nukes to wipe out human civilization, but not enough to signal other civilizations.** ***Above right*****: NASA launched the Fermi Gamma-ray Space Telescope to study high-energy radiation from natural sources such as exploding stars, black holes, and neutron stars. But other civilizations would need vastly more powerful versions of Fermi to detect human nuclear blasts in space.**

### SHOULD WE TRY TO SIGNAL OTHER CIVILIZATIONS?

Stephen Hawking recently remarked, "If aliens visit us, the outcome would be much as when Columbus landed in America, which didn't turn out well for the native Americans." True, but if extraterrestrials have the incredibly advanced technology to traverse interstellar distances, they surely have space telescopes that would have identified Earth as a life-bearing world long before the dawn of human civilization. If extraterrestrials suddenly appear on our doorsteps, it will almost certainly be because they wanted to explore a life-bearing world up close, not because they heard from us.

half of the neutrons to make it to the nearest star? Unfortunately, no. Scientists would have to accelerate neutrons to energies comparable to particles accelerated near the surfaces of neutron stars, which is at least 1,000 times beyond the LHC's capabilities.

The final force is the weak interaction, which governs radioactive decay. We have already detected weakly interacting particles from the cosmos in the form of neutrinos from the Sun and Supernova 1987A. Large neutrino detectors have been built and others are under construction for conducting neutrino astrophysics, and our particle accelerators can produce neutrino beams. Thus, another civilization at a comparable level of development might also have neutrino detectors.

Neutrino communication has peculiar advantages and disadvantages. Because the weak force is indeed weak, neutrinos barely interact with other forms of matter. A neutrino beam can travel through Earth with almost no neutrinos being absorbed or deflected. But the fact that these ethereal particles can pass through an entire planet with incredible ease also makes reception extremely difficult. Our largest neutrino detectors are immense, approaching 1 cubic kilometer in volume.

A European team recently reported that some neutrinos might travel faster than light. Even in the unlikely event that this result is confirmed, it's not obvious it helps us signal other civilizations because the difference between the apparent neutrino speed and the speed of light from the experiment was only about 0.0025%.

Unfortunately, producing a sufficiently luminous neutrino beam lies well beyond our current capability. Fewer than two-dozen neutrinos were detected from Supernova 1987A in the Large Magellanic Cloud. Suppose that we wanted to communicate with a civilization much closer, say, 160 light-years instead of the 160,000 light-years to the LMC. Moving SN 1987A this much closer would result in it being 1 million times more neutrino luminous, but a supernova also involves the conversion of about 10% of a star's mass to energy. Producing enough neutrinos so that a civilization about 160 light-years distant would still detect about two-dozen neutrinos would require liberating the energy stored in a body about the size of Mars. Clearly, effective neutrino transmission will remain beyond our capabilities for a bit longer.

## Limited Capabilities

Could "They" see us now? Certainly we are developing the technology to see other planets around nearby stars. If technological civilizations exist around nearby stars, they may have already observed (and named) Earth. Depending upon their level of technology, they may have even determined the approximate composition of Earth's atmosphere and deduced that some kind of life is present.

As we have seen, detecting our civilization is difficult, or, equivalently, our capability to signal other civilizations remains fairly limited. In the few cases for which we have the technology, we have not chosen to deploy it in a way to signal or communicate with others. For now, any nearby civilizations might also be trying to figure out if they are alone in the universe. ✦

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***Joseph Lazio*** *is a radio astronomer at the Jet Propulsion Laboratory. He observes frequently with many of the world's premier radio telescopes, including the Very Large Array and the Green Bank Telescope, and leads searches to find natural radio emissions from known extrasolar planets.*

**BONUS AUDIO INTERVIEW**

**To listen to a wide-ranging audio interview with author Joseph Lazio about interstellar communication, visit SkyandTelescope.com/DetectingEarth.**

By the Editors of SKY & TELESCOPE

# Hot NEW Products for 2012

*Our 14th annual roundup of Hot Products highlights the most intriguing new astronomy gear in the worldwide market.*

If there's a lesson we've learned from preparing our annual survey of new products entering the astronomical market, it's to expect the unexpected. There are always cycles and trends, but some take us by surprise. We didn't need a crystal ball at the turn of the century to see that digital photography was rapidly replacing film. But the flood of premium short-focus apo refractors that arrived with the new millennium was a bit of an eye-opener.

We had a robust "short list" of candidates for this year's Hot Products, and we were particularly impressed with the innovative items. From Howie Glatter's Parallizer (opposite) to the Telescope Drive Master (page 34) and Meade's LX800 mount with StarLock (pictured here), there are numerous products that address long-standing needs of amateur astronomers in novel ways.

Just because something is new doesn't mean we consider it "hot." For that we need to see an item offering a new technology, providing a simple solution to an old problem, or delivering a remarkable price-to-performance ratio. Whether or not you agree with our picks, we hope you'll enjoy reading about the products that intrigued us the most for 2012.

## ROBOTIC GUIDING ▸

There are lots of ways to guide a telescope for astrophotography, but nothing before like Meade's LX800 German equatorial mount with StarLock. Each time you slew to a new target, the mount uses built-in optical systems and digital detectors to automatically center the object and begin precision guiding without the need for an external computer or human intervention. The potential for changing the way that astrophotographers work is enormous. The mount and its heavy-duty tripod sell for $5,999, and there are package deals available for Meade's new 10-, 12- and 14-inch f/8 ACF catadioptric tube assemblies and its 130-mm f/7 apo refractor.


**Meade LX800 mount**
U.S. price: $5,999
**Meade Instruments**
www.meade.com

MEADE

## PRECISION FOCUSING ▸

We got our first peak at Optec's FastFOCUS system for Celestron Edge HD Schmidt-Cassegrain telescopes at the Northeast Astronomy Forum last April. Because the new telescopes are designed with a fixed optical back focus that leaves little room for a traditional precision focuser at the back of the telescope, Optec developed the FastFOCUS, which moves the secondary mirror by computer control using the company's FocusLynx controller.

S&T: SEAN WALKER

**FastFOCUS and FocusLynx**
U.S. introductory price: $1,495
**Optec**
**www.optecinc.com**

SOUTHERN STARS

***SkySafari 3***
U.S. price: from $2.99 to $59.99
**Southern Stars**
**www.southernstars.com**

## ◂ STARRY APP

Here's an all-in-one astronomy app for your iPhone, iPad, and iPod Touch. Available in three versions with databases of differing sizes, *SkySafari 3* is a powerful planetarium program that literally puts the heavens at your fingertips. And with the exception of the most basic version, you can add an optional cable or wireless module and use it to control your Go To telescopes. As the review on page 54 of last month's issue points out, *SkySafari 3* is so complete it may be the only astronomy app many amateurs will need.

SANTA BARBARA INSTRUMENT GROUP

## PINTSIZED PLANET SHOOTER

Smaller than many eyepieces and designed to fit directly into 1¼-inch focusers, the ST-i Planet Camera and Autoguider from SBIG features 16-bit, low-noise performance optimized for video-rate imaging of the Sun, Moon, and planets. Powered by its USB 2.0 computer connection, the ST-i can do double duty as a low-noise autoguider with a built-in mechanical shutter for making automatic dark frames. We wouldn't expect less from the folks who wrote the book on autoguiding amateur telescopes.

**ST-i Planet Camera and Autoguider**
U.S. price: $595
**Santa Barbara Instrument Group**
**www.sbig.com**

S&T: DENNIS DI CICCO

**Glatter Parallizer**
U.S. price: $45
**Howie Glatter**
**www.collimator.com**

## ◂ KEEP IT SQUARE

Eyepieces and imaging systems work best when everything is perfectly square to a telescope's optical axis. But conventional 2-to-1¼-inch adapters often tip slightly when tightened into a focuser, and they can also tip whatever is tightened into them. Enter Howie Glatter's Parallizer with a patented design that provides three points of contact on the inner and outer surfaces, keeping everything perfectly square to the telescope's focuser. It's simple, it's clever, and it works. It's a Hot Product!


S&T: SEAN WALKER

## ◄ MORE THAN JUST DEAD WEIGHT

This is one of those products that simply makes us want to say "Duh!" The PowerWeight from iOptron does double duty as a 7-pound (3.2-kg) counterweight and a rechargeable lead-acid battery pack rated for 12 volts and 8 amp hours. Made for the company's iEQ45 German equatorial mount (reviewed last July, page 60), the PowerWeight can be easily adapted to work with other portable telescope mounts.

**PowerWeight**
U.S. price: $119
**iOptron**
www.ioptron.com


S&T: SEAN WALKER

**CenterLine Filter Wheel**
U.S. price: $2,495
**Finger Lakes Instrumentation**
www.flicamera.com

## ▲ FILTERS GALORE

Many of today's advanced astrophotographers are adding images made at three narrowband wavelengths to their traditional red-, green-, blue-, and clear-filtered exposures to produce dramatic color images of nebulae. The resulting demand for a system that can accommodate at least seven large-format filters, led Finger Lakes Instrumentation to create the CenterLine CL1-10 Filter Wheel with an overlapping pair of motorized 5-position filter carousels. Its symmetric design helps keep imaging setups evenly balanced.

## RECORD BREAKER

Everyone marveled when the apparent field of an astronomical eyepiece broke the 80° barrier in 1980. The 100° hurdle was reached in 2008, and in 2010 it was 110°. Now we've hit the 120° mark with a new model from Explore Scientific. Made for 2-inch focusers, the multi-coated 9-mm eyepiece has 13 mm of eye relief and is completely waterproof. Tipping the scales at 3 pounds (1.4 kg), the 120° eyepiece is 40% heavier than the Explore Scientific 20-mm 100° model, which was the previous heavyweight contender in the company's expanding line of eyepieces.


EXPLORE SCIENTIFIC

**120° eyepiece**
U.S. introductory price: $999.95
**Explore Scientific**
www.explorescientific.com

## DRIVEN TO PERFECTION ►

Observers and especially astrophotographers have traveled a long, sometimes tortuous, and often costly road in their quest for telescope drives that track the sky's motion with unerring precision. Now there's a shortcut. The Telescope Drive Master (see our full review in last October's issue, page 62) uses an ultra-high-precision shaft encoder and a compact electronic module to adjust a telescope's drive rate up to five times per second. For many digital-imaging applications, the Telescope Drive Master can eliminate the need for guiding.

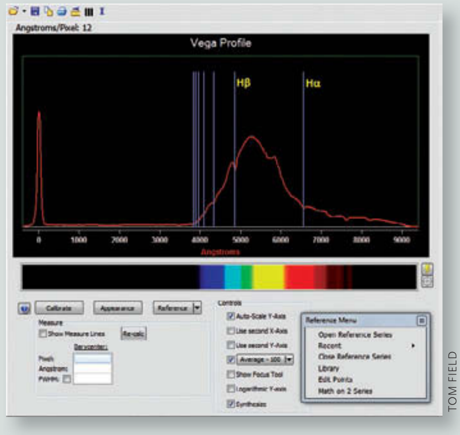
**Telescope Drive Master**
U.S. price: $1,799.95
**Explore Scientific**
www.explorescientific.com


S&T: DENNIS DI CICCO

CELESTRON

## SPECTRUM ANALYSIS

Digital cameras and low-cost diffraction gratings are opening the fascinating world of astronomical spectroscopy to a growing corps of amateur astronomers (*S&T:* August 2011, page 68). *RSpec* software makes it easy to analyze spectra recorded with a variety of cameras, including video images captured in real time. Amateurs are now using modest backyard telescopes and spectroscopy to "see" everything from the methane signature in the atmosphere of Uranus to the redshift of quasars billions of light-years away. *RSpec* makes it easy to join in on the fun.




TOM FIELD

***Rspec* software**
U.S. price: $99
**Field Tested Software**
**www.rspec-astro.com**

**SkyProdigy Telescopes**
U.S. price: from $699
**Celestron**
**www.celestron.com**

## ▲ SELF-ALIGNING SCOPE

Telescopes with Go To pointing take the hassle out of observing faint star clusters, nebulae, and galaxies, especially for beginning observers. But beginners often struggle with identifying the stars needed to initialize the Go To systems. That's not a problem for Celestron's award-winning SkyProdigy telescopes, which use onboard electronics to automatically locate and align on the proper reference stars. Just flip on the power and in a few minutes you'll be exploring the heavens with push-button ease. Current SkyProdigy models include a 70-mm refractor, 90-mm Maksutov, and 130-mm Newtonian reflector (pictured).

## POWER TO GO ▶

Telescopes, laptop computers, CCD cameras, and dew-heaters are just a sampling of the power-hungry devices that amateur astronomers are routinely carting to remote locations for their observing sessions. To meet the demand, Kendrick Astro Instruments has developed the Titan Power Tower. Based on a 12-volt, 55-amp-hour rechargeable battery, and housed in a heavy-duty travel case, the Titan Power Tower has multiple outlets for 12-volt and USB-powered equipment, as well as a special 18-volt outlet for Meade and Losmandy telescopes that require this higher voltage.

**Titan Power Tower**
U.S. price: $980
**Kendrick Astro Instruments**
**www.kendrickastro.com**

KENDRICK ASTRO INSTRUMENTS

S&T: DENNIS DI CICCO

**ONAG (On-axis guider)**
U.S. price: $989
**Innovations Foresight**
**www.innovationsforesight.com**

## ◀ ON-AXIS GUIDING

This product intrigued us the moment we saw it. With its "hot mirror" reflecting all of a telescope's visible light to an imaging camera (or spectrograph), while letting near-infrared light pass straight through to the guiding camera, the ONAG lets you guide on objects in the same field that you are imaging, including the target of interest. A precision X-Y stage for the guiding camera lets you move around the field to select a suitable guide star. Watch for our review of the ONAG later this year.

## ▼ PANNING CAMERA MOUNT

While it looks and acts like a conventional tracking mount when polar aligned, the StarLapse from Losmandy has a novel drive system that can turn at non-astronomical rates from 7½° to 240° per hour. This gives time-lapse photographers (both terrestrial and celestial) the opportunity to make dramatic panning movies. Losmandy offers numerous accessories to mount single and multiple cameras to the StarLapse.


LOSMANDY

**StarLapse**
U.S. price: $649
**Losmandy**
www.losmandy.com

STARIZONA

**SCT Corrector**
U.S. price: $349
**Starizona**
www.starizona.com

## SCHMIDT-CASSEGRAIN CORRECTOR ▲

For more than a quarter century, f/10 Schmidt-Cassegrain telescopes by Celestron and Meade reigned as astrophotography's workhorse instruments until they were recently superseded by coma-free models from both companies. But don't give up on those older scopes just yet. Starizona's new SCT corrector will turn them into f/7.5 systems with tight, coma-free star images to the corners of digital cameras with APS-size detectors. In addition to the SCT corrector, you'll need an adapter ($50 to $60) made for your camera model.

ORION TELESCOPES & BINOCULARS

## WIDE-FIELD SHOOTING

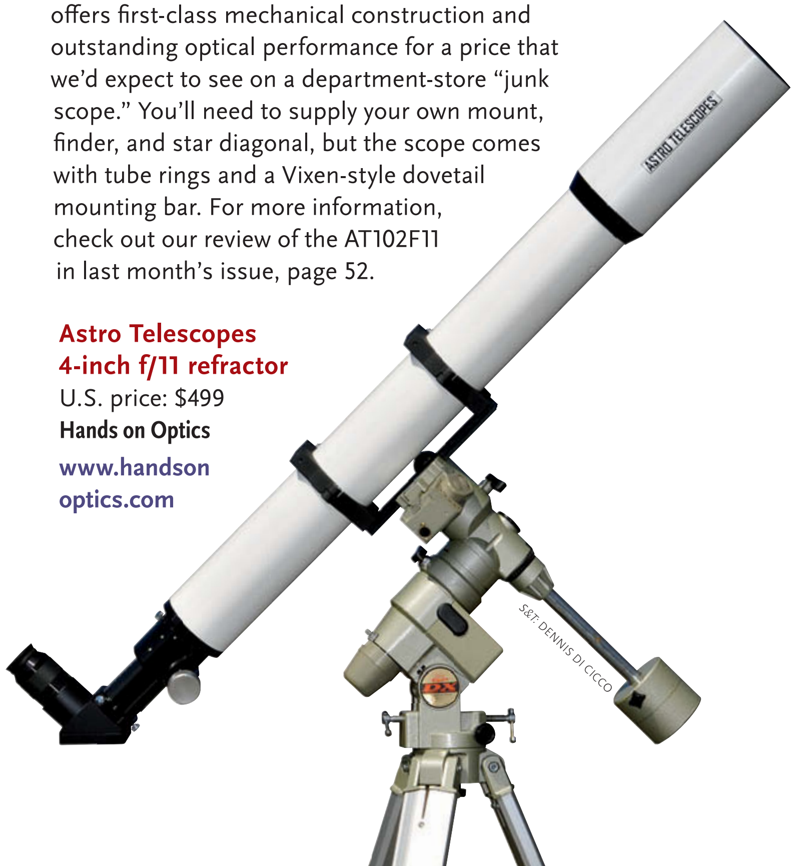
Readers are constantly asking us how they can attach camera lenses to their astronomical CCD cameras so they can do wide-field imaging. Orion Telescopes & Binoculars offers a simple solution for anyone with a CCD camera that has a T-thread mount. Called the Orion Parsec and Universal CCD Camera to Nikon Lens Adapter, we think the name alone pretty much describes the product. Depending on what type of camera and which Nikon lenses you have, you may need additional T-thread spacers which are widely available. Orion also has an adapter made specifically for its StarShoot Pro camera, which has a built-in spacer.

**Orion Nikon Lens Adapter**
U.S. price: from $109.99
**Orion Telescopes & Binoculars**
www.oriontelescopes.com

## ▼ BARGAIN-PRICED REFRACTOR

This 4-inch f/11 refractor from Astro Telescopes offers first-class mechanical construction and outstanding optical performance for a price that we'd expect to see on a department-store "junk scope." You'll need to supply your own mount, finder, and star diagonal, but the scope comes with tube rings and a Vixen-style dovetail mounting bar. For more information, check out our review of the AT102F11 in last month's issue, page 52.

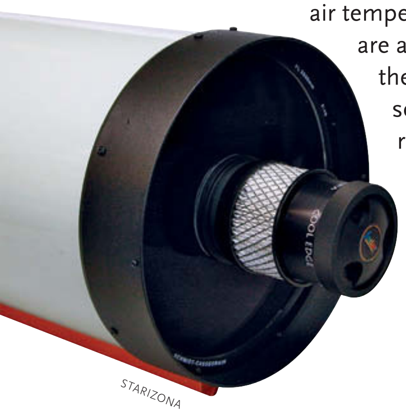
**Astro Telescopes 4-inch f/11 refractor**
U.S. price: $499
**Hands on Optics**
www.handsonoptics.com



S&T: DENNIS DI CICCO

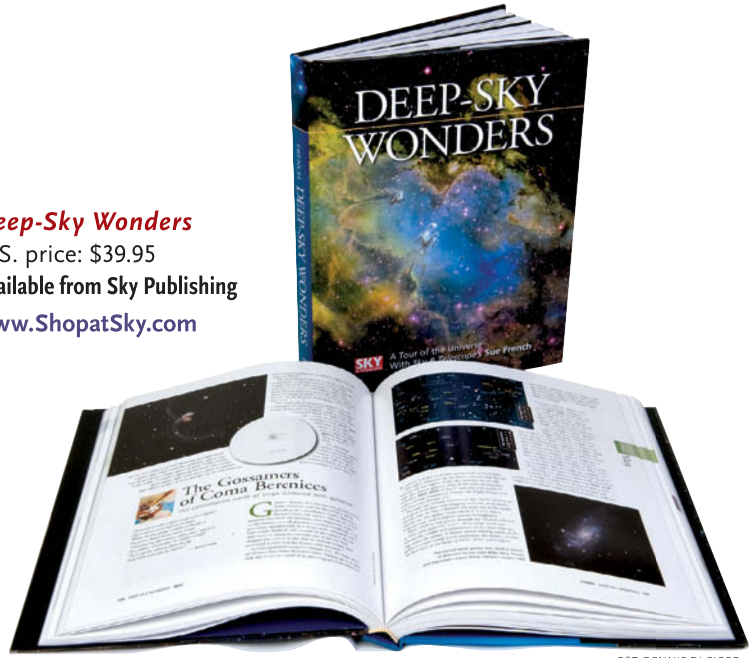
## ▼ EDGE HD COOLER

Here's a fast way to bring your Celestron 8-, 11-, or 14-inch Edge HD telescope to ambient air temperature in preparation for a night of observing and astrophotography. Simply insert Starizona's Cool Edge module between the scope's removable secondary mirror and the mirror's mounting base, and fan-forced filtered air will quickly bring the scope's optics to ambient air temperature. When the optics are acclimated, you remove the Cool Edge, replace the secondary mirror, and you're ready to go.



STARIZONA

**Cool Edge**
U.S. price: $149
**Starizona**
www.starizona.com



S&T: DENNIS DI CICCO

***Deep-Sky Wonders***
U.S. price: $39.95
**Available from Sky Publishing**
www.ShopatSky.com

## ▲ DEEP-SKY COMPILATION

No need for a vote recount on this Hot Product candidate; the decision was unanimous. Published by Firefly Books, *Deep-Sky Wonders* is a compilation of Sue French's extremely popular monthly columns in this magazine. Chronologically organized by months, French's engaging text is lavishly illustrated with color photographs, charts, and tables. The hardbound book is equally at home on a coffee table as it is under a dark sky next to your telescope.

ORION TELESCOPES & BINOCULARS

**Orion StarShoot G3 CCD camera**
U.S. price: $499.99
**Orion Telescopes & Binoculars**
www.oriontelescopes.com

## ▲ BARGAIN-PRICED CCD CAMERA

About a decade ago you might have paid $3,000 or more to get roughly the same imaging performance available from the new Orion StarShoot G3 Deep Space Color Imaging Camera (a monochrome version will follow shortly). Regulated thermoelectric cooling, 16-bit images, and a ½-inch-format CCD detector are just a few of the noteworthy features available in this compact camera that can also double as an autoguider. Imaging and autoguiding functions are powered by the camera's USB 2.0 computer connection; only the thermoelectric cooling requires a separate 12-volt source.

## VERSATILE MOUNT

Meade's LX80 mount is billed as three mounts in one. For quick setup with motorized tracking and Go To pointing, it can be used in altazimuth mode and configured to carry one or two telescopes with a combined weight of up to 75 pounds (34 kg). If your interests are long-exposure imaging, you can tip the LX80's head and polar align it as a traditional German equatorial mount. The LX80 comes with a stainless-steel tripod and the AudioStar hand controller that features audio descriptions of hundreds of celestial objects.


MEADE

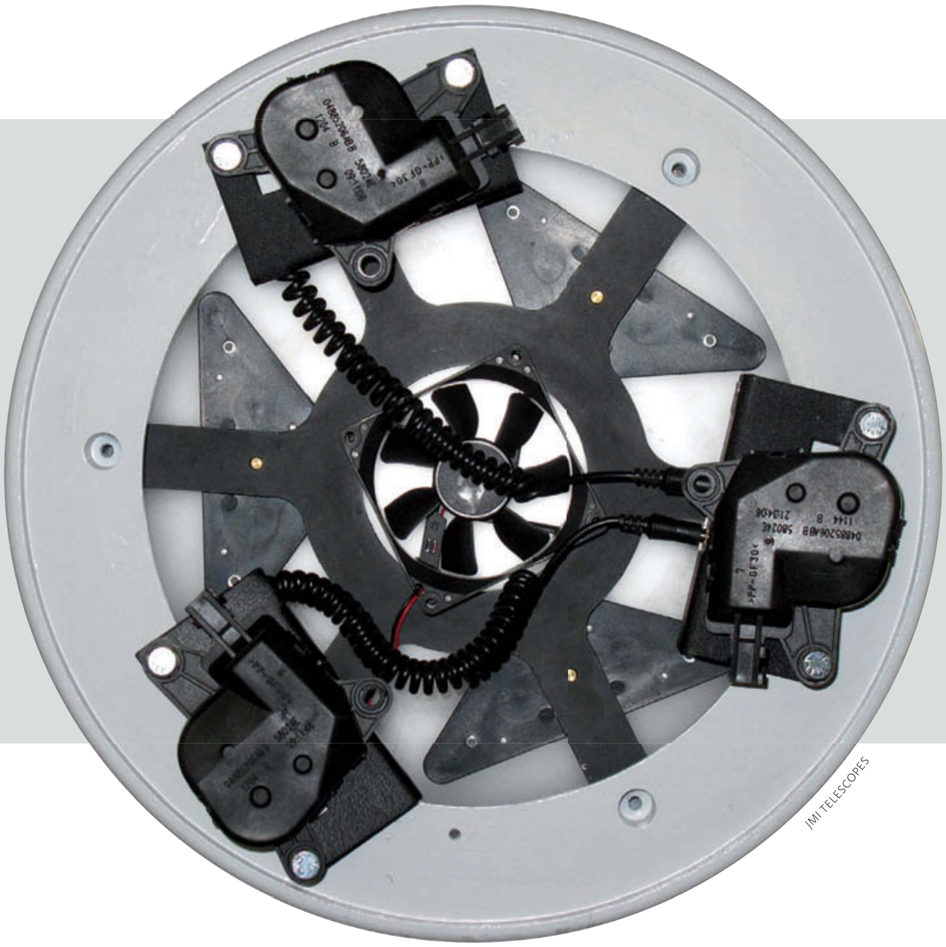
**Meade LX80 mount**
U.S. price: from $799
**Meade Instruments**
www.meade.com

## ALL-SKY VIEWING ►

Ever wonder what's happening overhead when you're not watching the sky? Fret no more. With the Orion StarShoot AllSky CCD camera you can monitor a 180° fisheye view of the sky day and night on your TV or computer. The weatherproof housing is designed for permanent outdoor installation. A video-capture device and computer software (both included) allow you to automatically detect meteors and make time-lapse movies, as well as broadcast the camera's output on the Internet.

**Orion AllSky Camera**
U.S. price: $899.95
**Orion Telescopes & Binoculars**
www.oriontelescopes.com

ORION TELESCOPES & BINOCULARS


JMI TELESCOPES

## ELECTRIC COLLIMATION

You won't have to run back and forth between the eyepiece and mirror cell of your Meade 10-, 12-, or 16-inch LightBridge Dobsonian reflector to achieve perfect collimation if you have the new ColliMotor system from JMI Telescopes. This easy-to-install retrofit kit lets you make precise adjustments to the primary mirror using a push-button hand box.

**ColliMotor**
U.S. price: $239
**JMI Telescopes**
www.jimsmobile.com

S&T: SEAN WALKER

**Vixen Polarie**
U.S. estimated street price: $399
**Vixen Optics**
www.vixenoptics.com

## POCKET-SIZE TRACKER ►

Looking a bit like a hefty point-and-shoot camera, the Vixen Polarie is a completely self-contained, battery-powered tracking mount. Just attach it to your camera tripod, eyeball polar alignment (or use the optional polar-alignment scope for more precise aiming), and you're ready to start shooting sky photos. One special feature is the half-sidereal tracking rate, which is popular with skyscape photographers who capture wide-field images of the heavens above earthly visas without excessive blurring. Watch for our review in the coming months.

## MEGAPIXELS FROM CELESTRON ▼

Nightscape is the most advanced CCD camera to date from Celestron. The 10.7-megapixel, one-shot color camera has regulated thermoelectric cooling and a mechanical shutter that makes it easy to take dark calibration frames without having to cover the telescope's aperture. It comes with easy-to-use *AstroFX* software for making exposures and processing astronomical images. The software is specially designed with novice imagers in mind. Watch for our review of the Nightscape camera in the coming months, but we can already tell you that the camera and its images are impressive.

CELESTRON

**Nightscape CCD camera**
U.S. price: $1,499
**Celestron**
**www.celestron.com**


TELESKOP-SERVICE

**Modified astrographs**
Price: from 2,099 Euros (about $2,900)
**Teleskop-Service**
**www.teleskop-express.de**

## ▲ FAST ASTROGRAPHS

Germany's Teleskop-Service has made several user-requested modifications to the Boren-Simon 8-inch f/3.6 and f/2.8 PowerNewt Astrographs (*S&T:* December 2010, page 59). Models are now available with carbon-fiber tubes, low-profile Baader Steeltrack focusers, and secondary mirrors with enhanced coatings. The company can also customize the position of the astrograph's primary mirror to meet the back-focus needs of special cameras and filter wheels.

## MORE THAN EXPECTED

Given the company's reputation for excellence, no one was surprised that Tele Vue's new Delos eyepieces (6- and 10-mm models are currently available with more planned) deliver pinpoint stars across their 72° apparent fields of view. And while the 20 mm of eye relief make them attractive for those who observe wearing eyeglasses, it was the "distinctly pleasurable" observing experience that most impressed our reviewer (see last June's issue, page 58). When it comes to eyepiece design, the Delos seems to have hit all the sweet spots.



**Delos eyepieces**
U.S. street price: $325
**Tele Vue Optics**
**www.televue.com**

*S&T:* DENNIS DI CICCO

# Brilliance by the Numbers

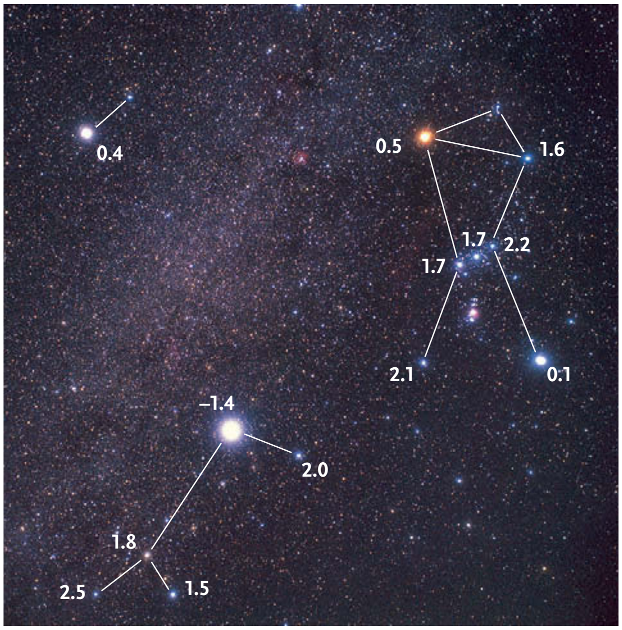
*Statistics reveal how extraordinary the winter sky is.*

GO OUT ON A CLEAR January evening at mid-northern latitudes and you're likely to have to brave the coldest weather of the year. You'd best be sure your body is insulated from the chill — especially your head, hands, and feet. But there's also a way to warm your imagination and ignite a fire in your sense of wonder. Just face the southeast and east sky. For that's where you'll find a veritable blaze of stellar fire, the concentrated group of brilliant constellations that's centered on Orion the Hunter.

**Why do winter's stars appear bright?** Even people who don't normally look much at the night sky often notice that the stars look brighter in winter. They usually assume that's due to clearer skies.

In reality, September and October are when most of North America has the fewest clouds — and many of the most transparent nights, too.

The main reason the stars seem brighter in winter is that they *are* brighter. The sky's greatest concentration of brilliant stars is centered around Orion, the preeminent constellation of winter. You can see this conflagration in the southeast and east on our January all-sky chart — and in the January evening sky.




The brightest stars of Orion and his Dogs are labeled with their magnitudes.

**How bright are the winter stars?** Orion is the brightest of all constellations, his three-star Belt the most striking compact asterism. Sirius, in nearby Canis Major, is by far the brightest nighttime star, equal to the combined light of the four next brightest stars visible from northern latitudes (Arcturus, Vega, Capella, and Rigel). But the supporting cast is what makes this show a full spectacle.

Sirius's companions in the Big Dog include Epsilon (1.5-magnitude Adhara), Delta (1.8-magnitude Wezen), and Beta Canis Majoris (2.0-magnitude Mirzam).

In Orion, Rigel and Betelgeuse are usually the 5th and 7th brightest stars visible from latitude 40° north (Betelgeuse varies somewhat). The other stars outlining Orion's body are Gamma (1.6-magnitude Bellatrix) as the west shoulder and Kappa Orionis (2.1-magnitude Saiph) as the east knee. The Belt, east to west, consists of 1.7-magnitude Zeta and Epsilon Orionis (Alnitak and Alnilam) together with 2.2-magnitude Delta Orionis (Mintaka).

Zero-magnitude Capella and Procyon and 1st-magnitude Aldebaran and Pollux lead the list of stars in the surrounding constellations. They're closely followed by 1.6-magnitude Castor and Elnath (Beta Tauri), plus 1.9-magnitude Beta Aurigae (Menaklinan) and Gamma Geminorum (Alhena).

Of the 20 brightest stars ever visible from latitude 40° north, 11 are concentrated in the east and southeast quadrant of January's evening sky.

**Orion Association or close stars?** Astronomy writers sometimes point out that the winter sky's brilliance is largely due to the Orion Association of young, hot, ultraluminous stars. More of these stars are being born — even as you read this — in M42, the Great Orion Nebula in Orion's Sword. The Orion Association lies about 1,500 light-years away. But many of winter's very brightest stars are much too close to be members of this association.

Six of the Northern Hemisphere's 10 brightest winter stars are located within 65 light-years of Earth; it's pure coincidence that they appear near Orion's distant stars from our perspective. The distances of these stars in light-years are 8.6 (Sirius), 11.4 (Procyon), 34 (Pollux), 42 (Capella), 52 (Castor), and 65 (Aldebaran). ✦

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

# Sky at a Glance

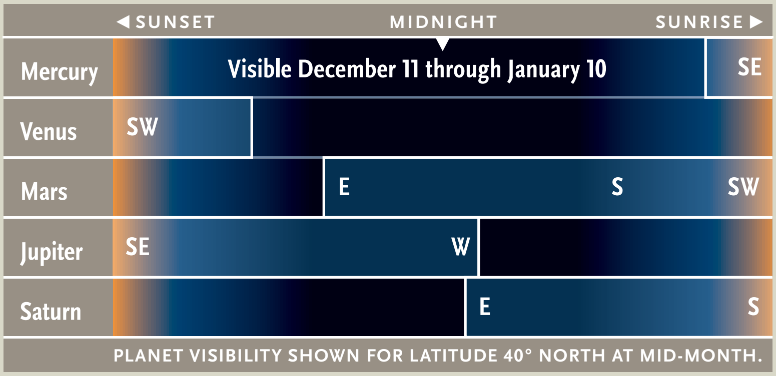
SKY & TELESCOPE

## January 2012

**MOON PHASES**

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

**PLANET VISIBILITY**




1 **FIRST-QUARTER MOON** (1:15 a.m. EST).

2 **EVENING:** Jupiter shines about 5° below or lower left of the Moon, as shown on page 48. And Algol is at minimum brightness for about 2 hours centered on 7:19 p.m. EST.

3 **NIGHT:** Europa and Ganymede cast their shadows on Jupiter simultaneously tonight from 10:27 to 11:57 p.m. PST (11:27 p.m. to 12:57 a.m. MST). See page 52 for other phenomena involving Jupiter's moons and their shadows.

4 **PREDAWN:** The brief but intense Quadrantid meteor shower should be strong between moonset and the first glimmering of dawn in North America; see page 50.

**EARTH** passes through *perihelion*, its closest point to the Sun for the year. But we're just 1 part in 30 closer to the Sun at perihelion than at aphelion in July.

4, 5 **EVENING:** The waxing gibbous Moon is near the Pleiades on the 4th and between the Pleiades and the Hyades on the 5th.

9 **FULL MOON** (2:30 a.m. EST).

16 **LAST-QUARTER MOON** (4:08 a.m. EST).

19 **DAWN:** Look for Antares 3° or 4° lower right of the crescent Moon.

19 **EVENING OR NIGHT:** Algol is at minimum brightness for roughly 2 hours centered on 9:15 p.m. PST (12:15 a.m. on the 20th EST).

22 **NEW MOON** (2:39 a.m. EST).

**EVENING:** Algol is at minimum brightness for roughly 2 hours centered on 9:05 p.m. EST (6:05 p.m. PST).

25, 26 **DUSK:** Venus blazes about 8° from the thin crescent Moon both these evenings (seen from the Americas), as shown on page 49.

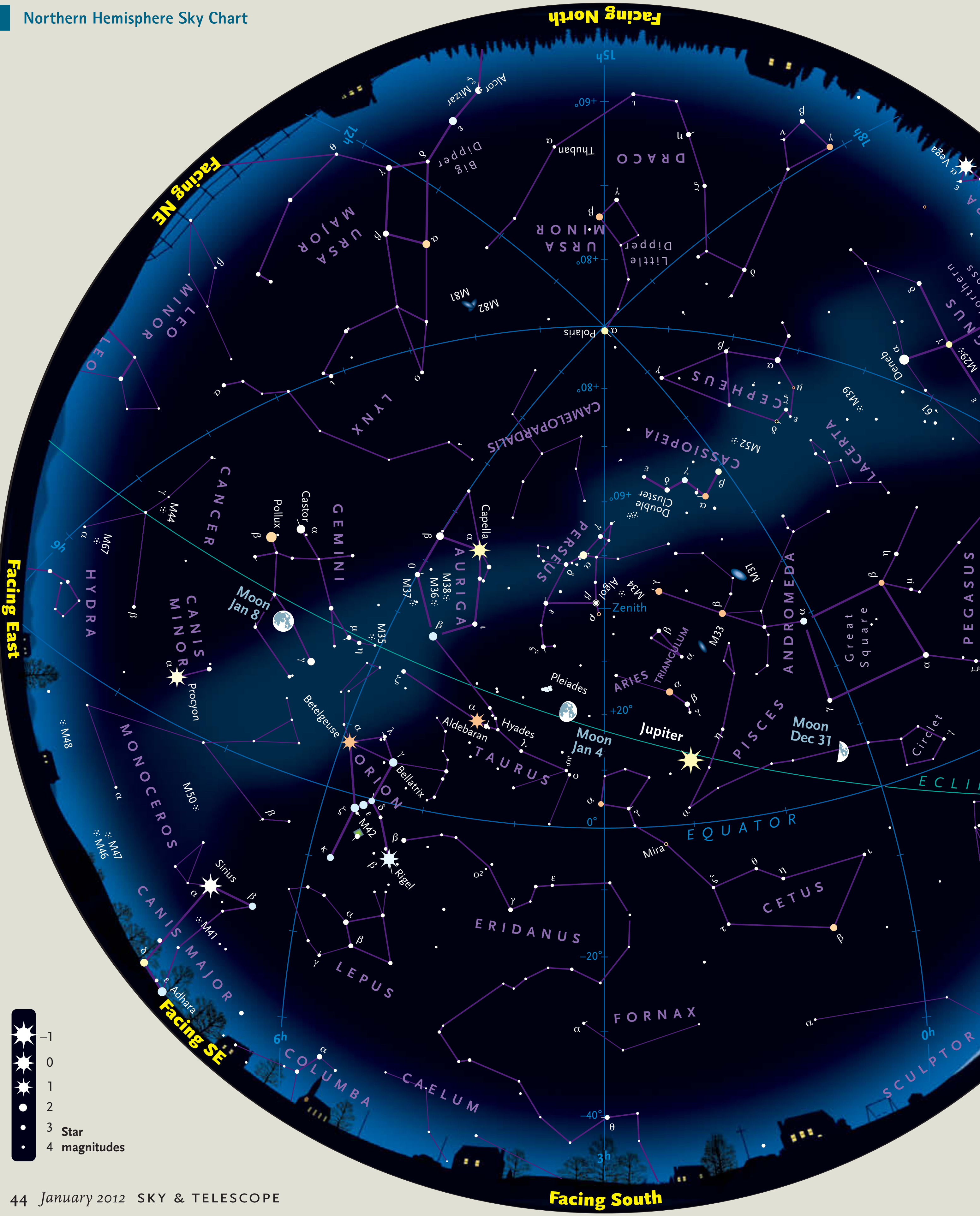
29, 30 **EVENING:** The Moon shines about 8° right or upper right of Jupiter on the 29th and a similar distance upper left of Jupiter on the 30th.

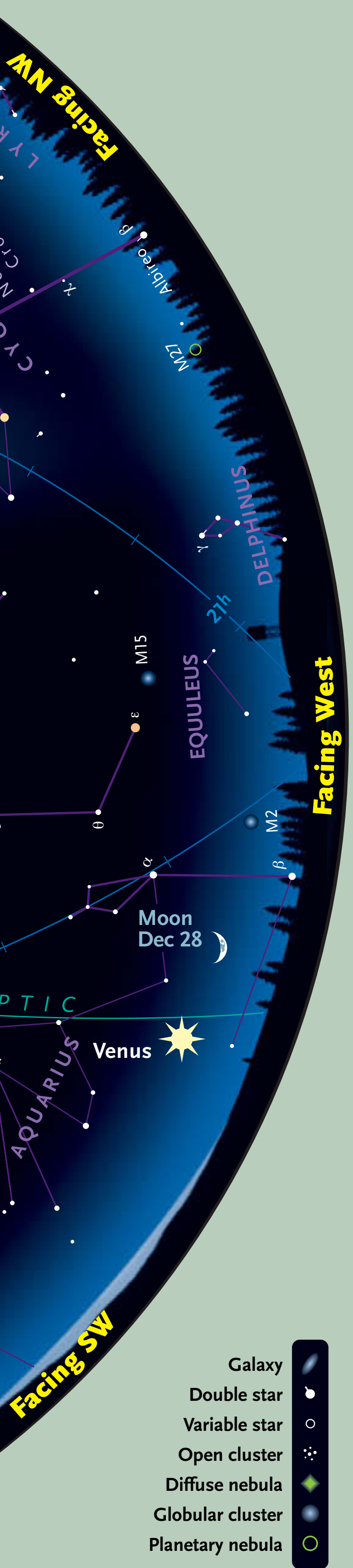
30 **FIRST-QUARTER MOON** (11:10 p.m. EST).

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

**THE HUBBLE** Space Telescope snapped Io and its shadow transiting Jupiter in unearthly detail.

JOHN SPENCER (LOWELL OBSERVATORY) / NASA


Facing North
Facing NE
Facing East
Facing SE
Facing South
15h
12h
18h
9h
6h
3h
0h
+60°
+80°
+40°
+20°
0°
–20°
–40°
Alcor
Mizar
Big Dipper
Thuban
DRACO
URSA MAJOR
URSA MINOR
Little Dipper
M81
M82
Polaris
LEO MINOR
LEO
LYNX
CAMELOPARDALIS
CEPHEUS
Deneb
CYGNUS
Northern Cross
Vega
LYRA
M29
M39
M52
LACERTA
CASSIOPEIA
Double Cluster
PERSEUS
Algol
M34
Zenith
M31
ANDROMEDA
Great Square
PEGASUS
TRIANGULUM
M33
ARIES
PISCES
Circlet
Moon Dec 31
Jupiter
Pleiades
Moon Jan 4
Hyades
Aldebaran
TAURUS
ECLIPTIC
EQUATOR
Mira
CETUS
ERIDANUS
FORNAX
SCULPTOR
CAELUM
COLUMBA
LEPUS
Rigel
M42
ORION
Bellatrix
Betelgeuse
Capella
AURIGA
M36
M37
M38
M35
GEMINI
Castor
Pollux
Moon Jan 8
CANCER
M44
M67
HYDRA
CANIS MINOR
Procyon
MONOCEROS
M50
M48
M46
M47
Sirius
M41
CANIS MAJOR
Adhara
–1
0
1
2
3
4
Star magnitudes




## Using the Map

**WHEN**

| | |
|---|---|
| Late November | 11 p.m. |
| Early December | 10 p.m. |
| Late December | 9 p.m. |
| Early January | 8 p.m. |
| Late January | 7 p.m. |

These are standard times.

**HOW**

Go outside within an hour or so of a time listed above. Hold the map out in front of you and turn it around so the yellow label for the direction you're facing (such as west or southeast) is at the bottom, right-side up. The curved edge is the horizon, and the stars above it on the map now match the stars in front of you in the sky. The map's center is the zenith, the point overhead.

**Example:** Rotate the map a little so that "Facing SE" is right-side up. Nearly halfway from there to the map's center is the constellation Orion. Go out, face southeast, and look halfway up the sky. There's Orion!

**Note:** The map is plotted for 40° north latitude (for example, Denver, New York, 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 and Venus are positioned for mid-January.

**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.

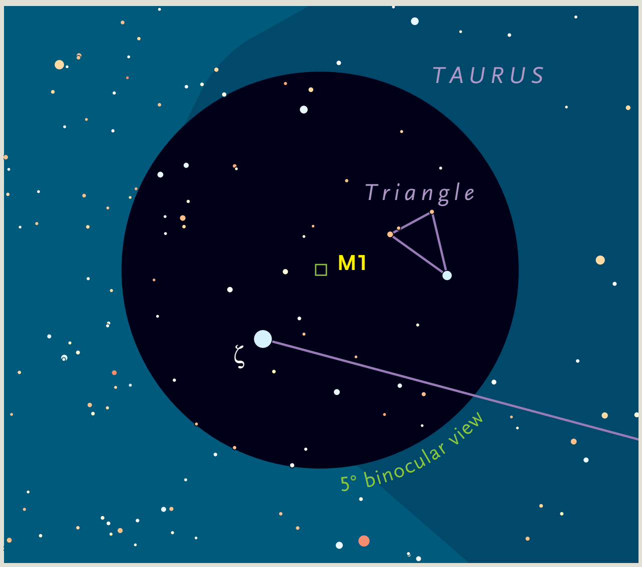
# Binocular Highlight: Messier's Number One

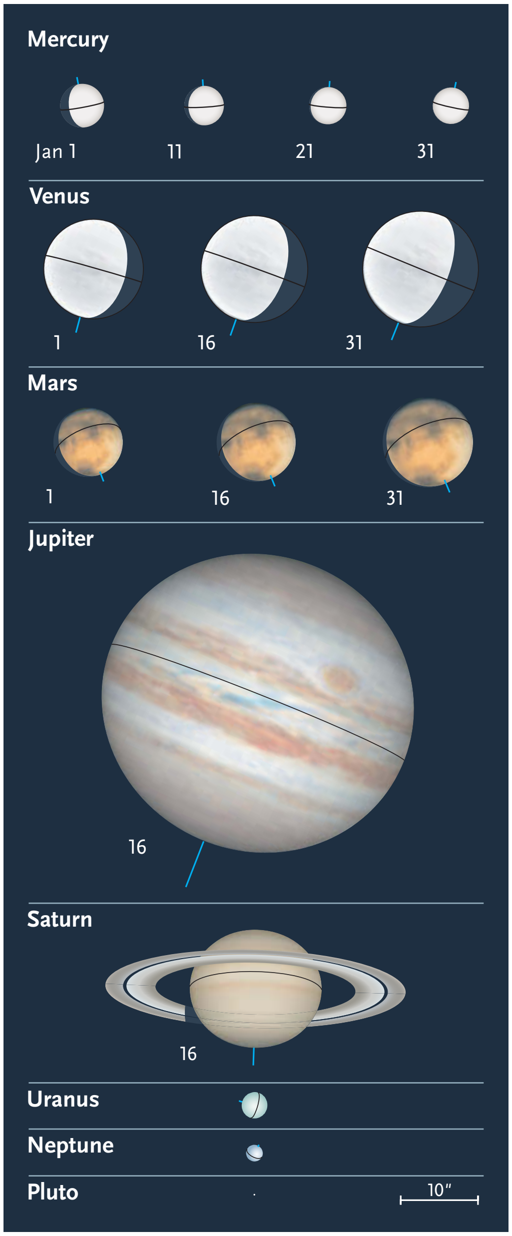
French astronomer Charles Messier's 18th-century list of comets-that-weren't started off with a bang — literally. **M1**, in Taurus, is the catalog's one and only supernova remnant. And while it's true that in space no one can hear you explode (or scream), the blast from the massive star certainly made its presence felt when its light reached Earth in 1054 AD. At its brightest, the supernova shone as brilliantly as Venus and could be seen in broad daylight. When Messier observed the dying remnant of that cataclysmic event in September 1758, it inspired him to begin compiling a list of nebulae that could be mistaken for comets.

Also known as the Crab Nebula, M1 is easy to locate a mere 1° northwest of 3rd-magnitude Zeta (ζ) Tauri, and midway between Zeta and a small isosceles triangle of stars. The nebula glows at magnitude 8.4, and it's a little difficult to sight in binoculars — mainly because it's fairly small. Most catalogs list M1 around 6′ × 4′, roughly equal to the much brighter Dumbbell Nebula (M27) in Vulpecula. But novice observers often make the mistake of assuming that well-known objects such as the Crab are big and bright. And unrealistic expectations make any object more difficult to locate.

With expectations properly calibrated, I don't have much trouble seeing M1 as a little, round glow in my 10×50s. When I switch to my 15×45 image-stabilized binoculars, the nebula takes on a definite oval shape. I can even see the object intermittently in my 10×30s, though it's difficult. Still, given its historical significance, even a fleeting glimpse of M1 is a thrill. ✦

— *Gary Seronik*



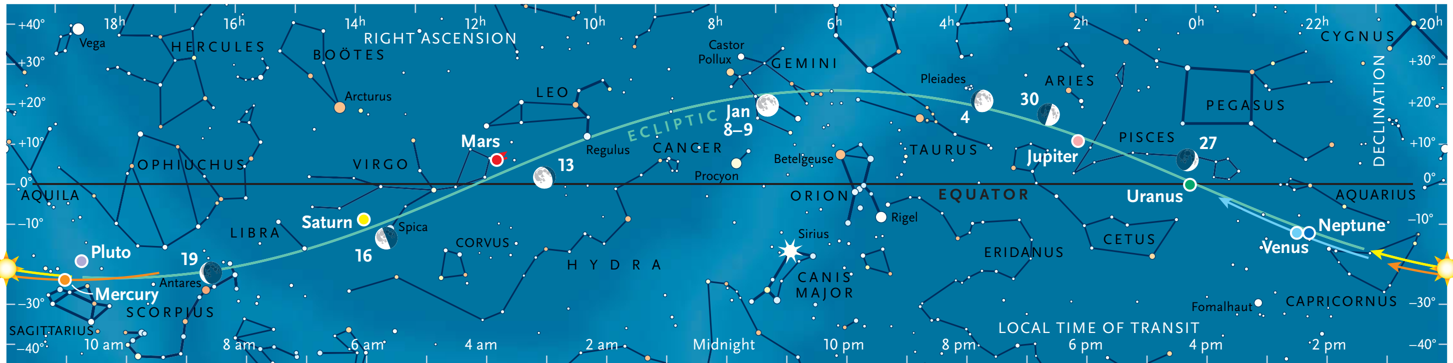



## Sun and Planets, January 2012

| | January | Right Ascension | Declination | Elongation | Magnitude | Diameter | Illumination | Distance |
|---|---|---|---|---|---|---|---|---|
| Sun | 1 | $18^h\ 42.6^m$ | –23° 05′ | — | –26.8 | 32′ 32″ | — | 0.983 |
| | 31 | $20^h\ 51.1^m$ | –17° 39′ | — | –26.8 | 32′ 28″ | — | 0.985 |
| Mercury | 1 | $17^h\ 15.3^m$ | –22° 07′ | 20° Mo | –0.4 | 5.7″ | 80% | 1.183 |
| | 11 | $18^h\ 16.7^m$ | –23° 46′ | 16° Mo | –0.4 | 5.1″ | 90% | 1.313 |
| | 21 | $19^h\ 23.2^m$ | –23° 29′ | 11° Mo | –0.6 | 4.8″ | 96% | 1.390 |
| | 31 | $20^h\ 32.2^m$ | –20° 55′ | 6° Mo | –1.1 | 4.8″ | 99% | 1.415 |
| Venus | 1 | $21^h\ 06.7^m$ | –18° 29′ | 34° Ev | –4.0 | 12.9″ | 83% | 1.292 |
| | 11 | $21^h\ 54.9^m$ | –14° 29′ | 36° Ev | –4.0 | 13.5″ | 80% | 1.235 |
| | 21 | $22^h\ 40.8^m$ | –9° 52′ | 38° Ev | –4.0 | 14.2″ | 78% | 1.175 |
| | 31 | $23^h\ 24.9^m$ | –4° 50′ | 40° Ev | –4.1 | 15.0″ | 75% | 1.112 |
| Mars | 1 | $11^h\ 27.7^m$ | +6° 41′ | 110° Mo | +0.2 | 9.0″ | 91% | 1.040 |
| | 16 | $11^h\ 37.9^m$ | +6° 04′ | 122° Mo | –0.1 | 10.3″ | 93% | 0.911 |
| | 31 | $11^h\ 38.9^m$ | +6° 26′ | 138° Mo | –0.5 | 11.7″ | 96% | 0.799 |
| Jupiter | 1 | $1^h\ 54.4^m$ | +10° 25′ | 110° Ev | –2.6 | 43.4″ | 99% | 4.543 |
| | 31 | $2^h\ 02.2^m$ | +11° 16′ | 82° Ev | –2.4 | 39.3″ | 99% | 5.018 |
| Saturn | 1 | $13^h\ 48.0^m$ | –8° 33′ | 72° Mo | +0.7 | 16.7″ | 100% | 9.956 |
| | 31 | $13^h\ 52.6^m$ | –8° 50′ | 101° Mo | +0.6 | 17.6″ | 100% | 9.464 |
| Uranus | 16 | $0^h\ 05.0^m$ | –0° 14′ | 66° Ev | +5.9 | 3.4″ | 100% | 20.456 |
| Neptune | 16 | $22^h\ 06.0^m$ | –12° 16′ | 34° Ev | +8.0 | 2.2″ | 100% | 30.811 |
| Pluto | 16 | $18^h\ 32.5^m$ | –19° 19′ | 18° Mo | +14.1 | 0.1″ | 100% | 33.098 |

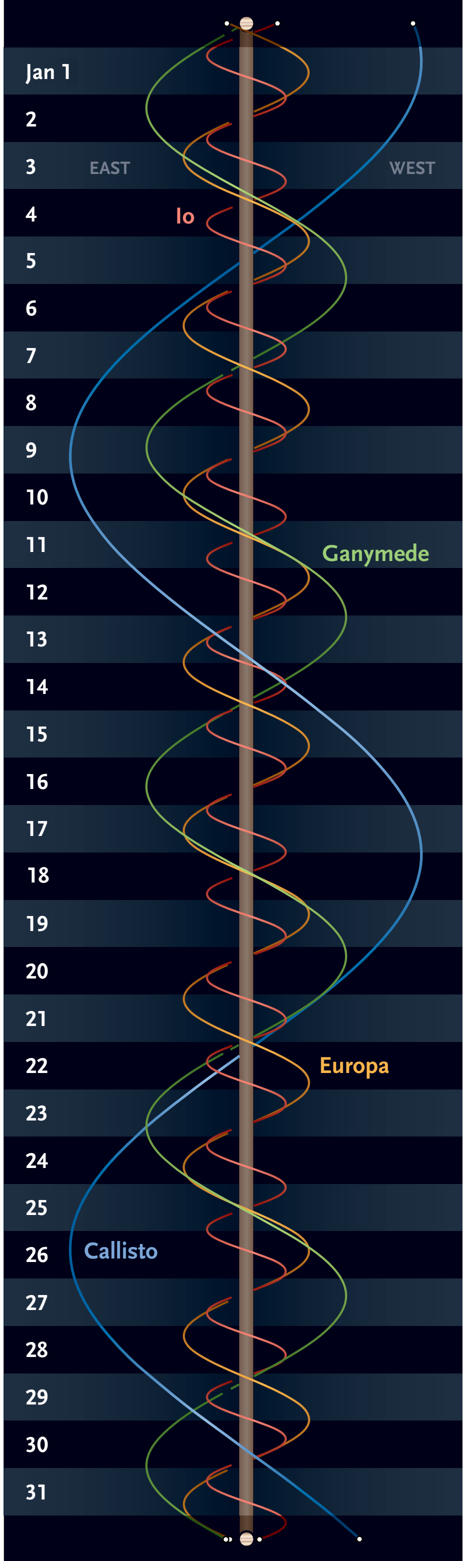
**The table above** gives each object's right ascension and declination (equinox 2000.0) at $0^h$ Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial 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. Ticks indicate the pole currently tilted toward Earth.




**The Sun and planets** are positioned for mid-January; 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 January. "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 January 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.

# Two Brilliant Planets at Dusk

*Venus and Jupiter shine high as night arrives.*

BRILLIANT VENUS shines in the southwest at dusk in January, appearing higher at each successive nightfall. Meanwhile, Jupiter is high and conspicuous in the southeast or south.

Mars rises in late evening at the start of the year but comes up in mid-evening by January's end. Saturn rises in the middle of the night, just before Jupiter sets. And for the first week or two of January, Mercury still peeks up very low in the southeast during dawn.

## DUSK AND EVENING

**Venus** on New Year's Day shines impressively about 18° high in the southwest as the sky darkens 45 minutes after sunset (for skywatchers at latitude 40° north). By month's end, Venus is almost 10° higher at the same stage of twilight. During January it also brightens a trace, from magnitude –4.0 to –4.1. In a telescope Venus is a dazzling but small gibbous dusk, enlarging from 13″ to 15″ across while waning from 83% to 75% lit.

**Neptune** glows at magnitude 8.0 in Aquarius, appearing lower each evening. It starts the year to Venus's upper left, though even then it's disappointingly low for telescopic observing. Venus overtakes Neptune on January 12th and 13th, shining about 1.2° north of (and 60,000 times brighter than) the faint speck.

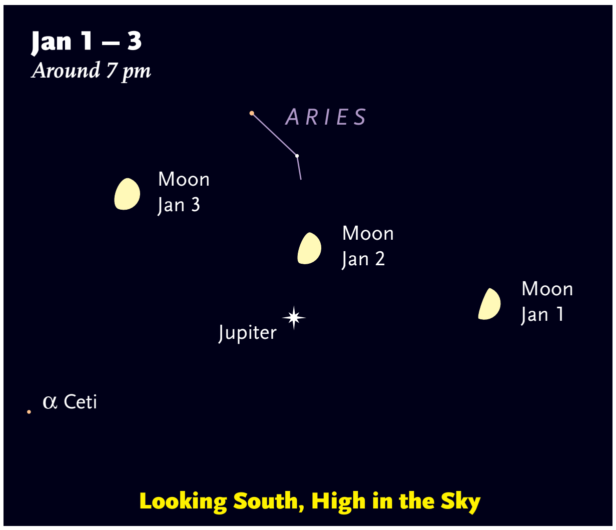
**Uranus**, in Pisces, is higher and, at magnitude 5.9, brighter than Neptune. You can locate it by using the chart at **SkyandTelescope.com/uranusneptune** (extrapolate past the plotted position for January 1st). On January 28th Uranus crosses into the north celestial hemisphere for a 42-year stay.

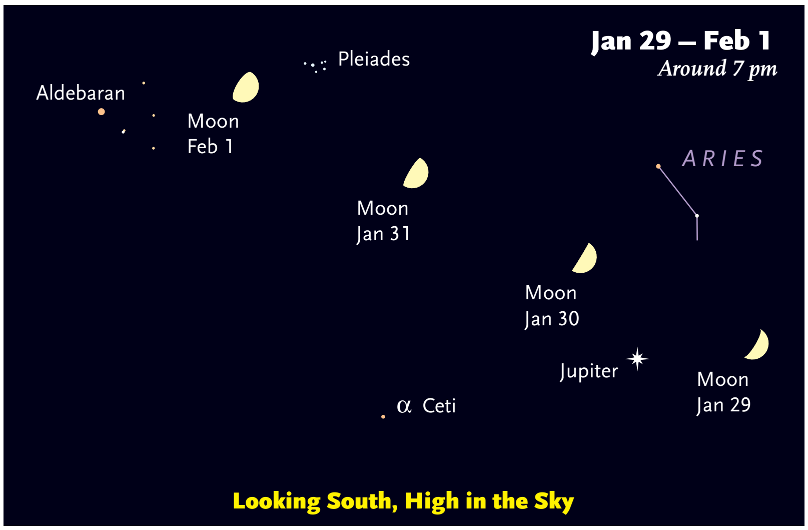
**Jupiter** begins January blazing at magnitude –2.6 more than halfway up the southeastern sky at nightfall. During the month, the giant world fades slightly (to magnitude –2.4), and the time it transits the meridian advances from about 7 p.m. local time to about 5 p.m. (around sunset). Jupiter's globe shrinks from 43″ to 39″ wide in January. The planet passes through quadrature (90° east of the Sun) on January 22nd.

Jupiter nudges from Pisces back into Aries in the second week of January. But the most dramatic change in Jupiter's position is in its separation from Venus. The two planets start the month 75° apart and end it just 41° apart. They will continue to approach each other until they cross paths in mid-March.

## NIGHT AND PREDAWN

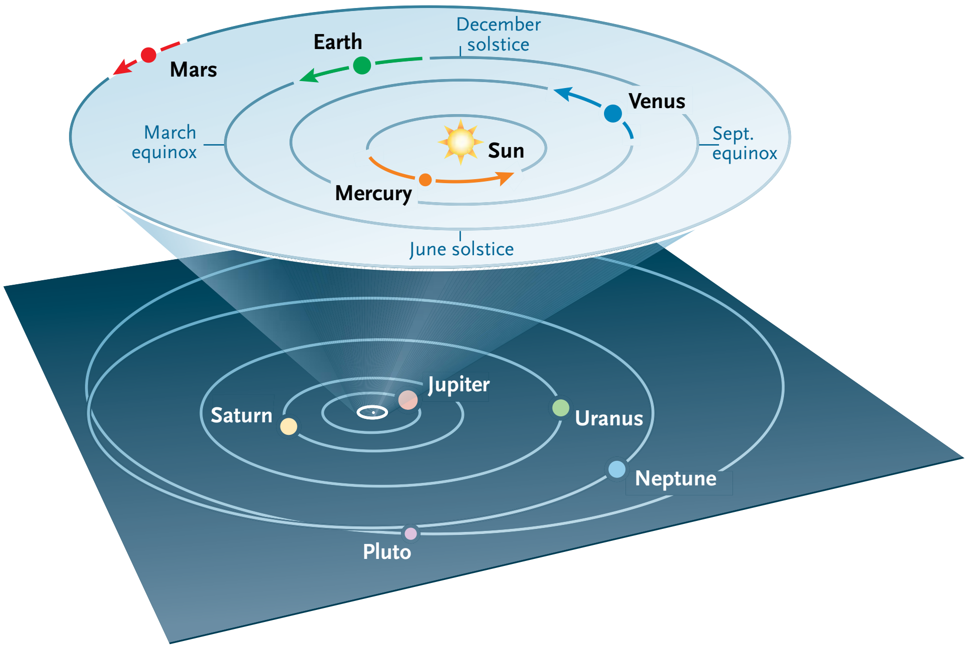
**Mars** rises after 10 p.m. on New Year's Day but before 8:30 p.m. by month's end (depending where you live in your time zone). The tiger-colored point of light doubles in brightness during January, kindling from magnitude +0.2 to –0.5. Mars creeps east from Leo into Virgo in mid-January, halts on January 24th, then starts retrograding back westward toward Leo. Mars reaches its highest in the south around 3 or 4 a.m., and it's still well up in the southwestern sky as dawn begins to brighten.



## ORBITS OF THE PLANETS

**The curved arrows indicate each planet's movement during January, as if you were looking down on the solar system from the constellation Ophiuchus. (The outer planets don't change position enough in a month to notice at this scale.)**




Through a telescope the disk of Mars grows from 9.0″ to 11.7″ wide in January. That's challengingly small for seeing any surface and atmospheric features, but Mars will only be a little bigger (13.9″) at opposition on March 3rd. For more on observing Mars telescopically, see the November issue, page 50.

**Saturn** nudges above the east horizon around 1:30 a.m. local time as January starts and about 11:30 p.m. as January ends. It brightens marginally, from magnitude +0.7 to +0.6, as it crawls east away from slightly fainter Spica. The separation between the planet and the star increases from 6° to 7° in January.

The best time to observe Saturn telescopically is just before morning twilight, when it's almost halfway up the southern sky. Saturn's globe is only 17″ or 18″ wide, but the rings are tilted a healthy 15° from edgewise, making features such as the Cassini Division relatively easy to spot.

## DAWN

**Mercury** shines at magnitude –0.4 a half hour before sunrise on January 1st, but it's barely visible in the bright glow about 8° high in the east-southeast. It appears lower each morning and becomes unviewable by the naked eye during the second week of January.

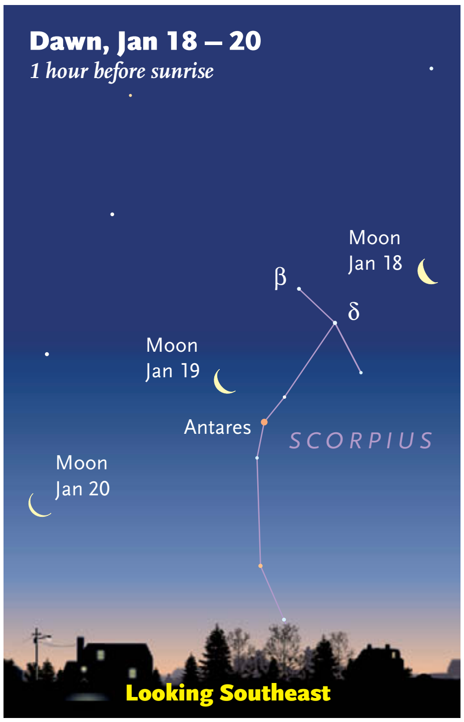
## MOON AND EARTH

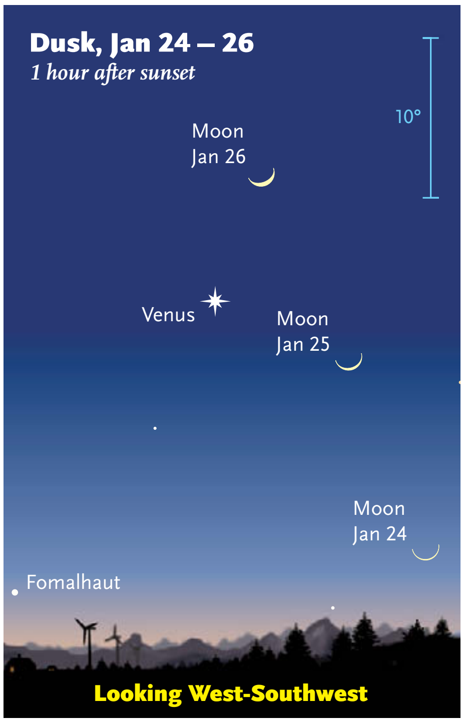
The **Moon** is waxing gibbous just a few degrees below Jupiter in the early evening of January 2nd.

The waning gibbous Moon is well to the lower left of Mars before sunrise on January 14th, and it forms a fairly compact triangle with Spica and Saturn at dawn on the 16th. The waning crescent is upper left of Antares at dawn on January 19th.

Back in the evening sky, the waxing lunar crescent passes Venus on January 25th and 26th, and it poses right of Jupiter on the 29th and 30th.

**Earth** comes to perihelion, its closest approach to the Sun for the year, around $0^h$ UT on January 5th. The two bodies are then about 98.33% of their average distance apart. ✦




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

# A Fine Year for the Icy Quads

*Here's a chance to catch the richest meteor shower you've never seen.*

Have you ever seen a single Quadrantid meteor? The Quads are supposed to be one of the richest annual showers, with peak rates of 60 to 200 meteors visible per hour under ideal conditions. But many lifelong skywatchers have never even seen one.

The Quads have two problems. First, the shower is brief. Peak activity usually lasts just a few hours, and if the peak doesn't fall between midnight and dawn for your part of the world, you miss out. The duration of the peak (when meteor rates are at least half the maximum) is variously quoted as 2 to 4 hours, or 14 hours. And the strength of the shower may vary less from year to year than the sometimes spotty observations suggest. Clearly the Quads could use more study.

The second problem is that you're watching in the night's coldest hours in the year's coldest time, under a wide-open clear sky that will also expose you to maximum radiational cooling. And if you're lying still in a reclining chair or on the ground (or the snow), you're not generating much heat.

So, make it an adventure. This year the morning of January 4th offers very good circumstances for North Americans, especially in the East. The Quadrantids are predicted to peak around $7^h$ or $8^h$ Universal Time; 2 or 3 a.m. Eastern Standard Time. The waxing gibbous Moon sets about 3 a.m. local time, leaving the sky fully dark until dawn begins around 6.

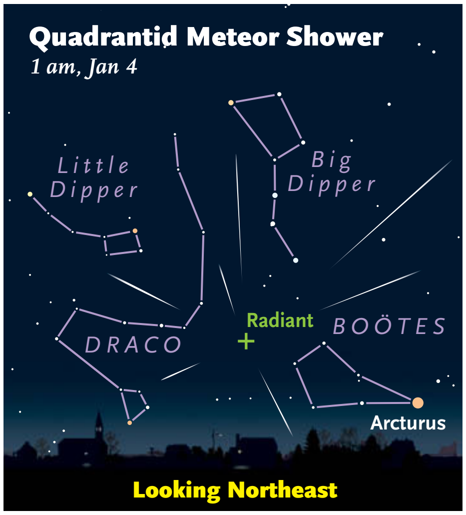
Plan a proper expedition. You want to be snug in many layers from head to feet with no pinches or thin spots. An electric hot pad buttoned inside your clothing will help. Meteor watching is especially fun if you take notes to make a proper count using standardized methods for reporting to the International Meteor Organization. (For instructions on how to do this, see "Advanced Meteor Observing" at **SkyandTelescope.com/meteors**). If you use a voice recorder for notes, practice beforehand so you can work it in the dark with mittened hands. Batteries fail in the cold, but a pencil and clipboard won't. Your mittened pencil notes don't need to be pretty, just clear enough to

**"It was definitely one cold night of shooting, but I was happy with this result," writes photographer Eric Stoike. He caught this distant Quadrantid fireball before dawn on January 4, 2008, from a frigid site east of Hart, Michigan. The brightest star is Arcturus, with Boötes extending to its left. The Big Dipper's handle is at top left, and Coma Berenices is at top right. Expect to take many, many images before you get this lucky! Experiment with exposure times. They should be long enough to record stars well, but short enough to keep the sky dark.**

read the next day. And be sure you can get to your watch and read it to mark off time intervals every half hour or so for separate counts. Many digital voice recorders offer the convenience of automatic time stamps.

The shower's radiant, its apparent perspective point of origin, is in the antique constellation Quadrans Muralis about halfway from the end of the big Dipper's handle to the head of Draco, as seen at right. It's rising in the north-east by about 1 a.m. local time and climbs higher until dawn. The higher a shower's radiant, the more meteors appear all over the sky. Watch whatever part of your sky is darkest, probably straight up.

The meteors that arrive late in this shower tend to be brighter than the early ones. Minor activity has been reported as much as a week before and after the peak date; this needs to be monitored too.




Not until early morning does the radiant of the Quadrantid meteor shower start to rise high. (And don't expect to see several at once!)

## Asteroid Occultations

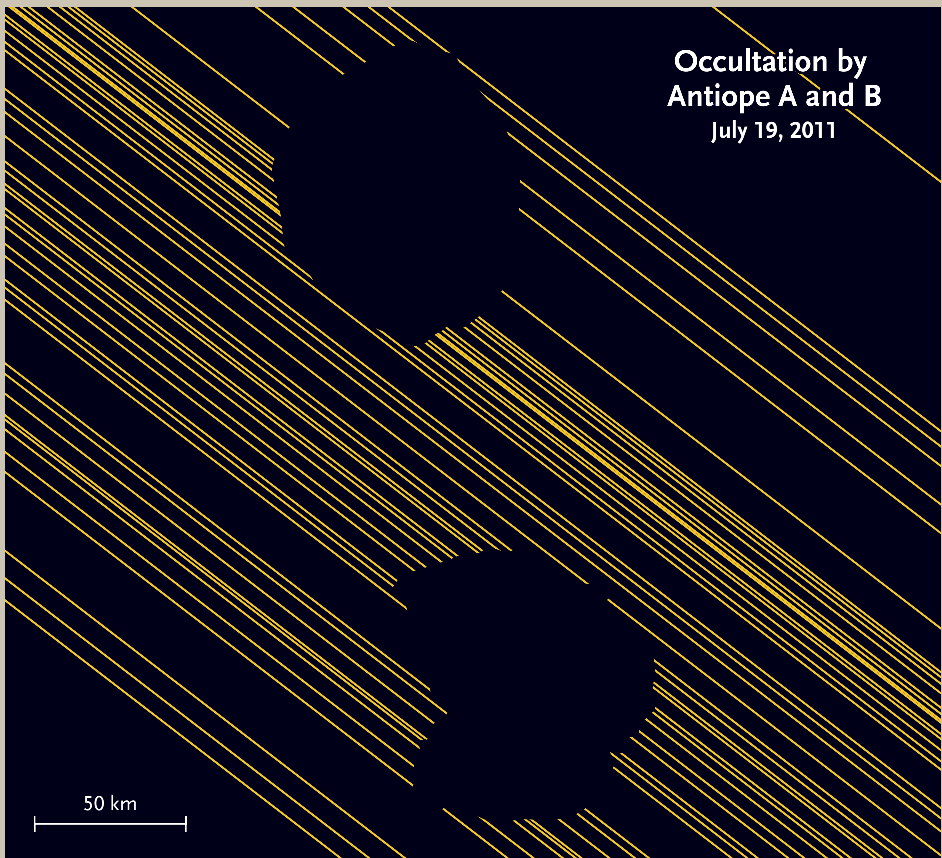
Among the asteroid occultations that will cross North America in January, just waiting for you to time them, three stand out for the brightness of the stars that will wink out:

- On the evening of January 8th, the faint asteroid 75 Eurydike will cover up an 8.3-magnitude star in Auriga for up to 5 seconds along a track from North Carolina through Texas.
- On the morning of January 19th, 911 Agamemnon will occult an 8.0-magnitude star in Lynx for up to 9 seconds along a track from the Washington, D.C. region northwest across most of the Great Lakes.
- On the evening of January 29th, 1746 Brouwer will occult a 7.0-magnitude star in Aries for up to 4 seconds along a path from Oregon through the Minneapolis/St. Paul area to Massachusetts. ✦

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

**For all about observing and timing these events, see asteroidoccultation.com/asteroid_help.htm.**

**For more past results, see asteroidoccultation.com/observations/Results.**




Two for one! Last July 19th, 24 people timed the binary asteroid 90 Antiope occulting a 6.7-magnitude star in Aquarius as seen from 56 different locations. Most observers used video timing setups on small telescopes. Some placed automated setups several miles apart along the sides of roads. Each line is the star's path with respect to the asteroid as seen from one site; north is up. The line vanishes and resumes at the points corresponding to when the star winked out and back on. The campaign resolved the silhouettes of Antiope A and B in stunning detail. Both components are seen to be about 90 km (55 miles) wide, and a huge crater makes one look like Pac-Man.

# Action at Jupiter

January finds Jupiter high in the south at dusk, a still time of day when the atmospheric seeing often steadies right down. The daytime solar heating of the land has ended, but the nighttime radiational chilling is not yet fully under way.

Even the smallest scope shows Jupiter's four Galilean moons. 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 January, fascinating events to watch with a small scope.

Here are the times, in Universal Time, when Jupiter's Great Red Spot should cross the planet's central meridian. The dates (also in UT) are in bold. Eastern Standard Time is UT minus 5 hours:

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

These times assume that the spot is 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 than 173°. ✦

## Minima of Algol

| Dec. | UT | Jan. | UT |
|---|---|---|---|
| 2 | 11:18 | 3 | 0:19 |
| 5 | 8:07 | 5 | 21:09 |
| 8 | 4:56 | 8 | 17:58 |
| 11 | 1:46 | 11 | 14:47 |
| 13 | 22:35 | 14 | 11:37 |
| 16 | 19:24 | 17 | 8:26 |
| 19 | 16:13 | 20 | 5:15 |
| 22 | 13:02 | 23 | 2:05 |
| 25 | 9:52 | 25 | 22:54 |
| 28 | 6:41 | 28 | 19:43 |
| 31 | 3:30 | 31 | 16:33 |

These geocentric predictions are from the heliocentric elements Min. = JD 2,452,253.567 + 2.867321*E*, where *E* is any integer. Derived by Marvin Baldwin (AAVSO), they are based on 17 timings collected from 1999 to 2003 and on the star's average period during the previous 35 years. For more about this star, visit SkyandTelescope.com/algol.

## Phenomena of Jupiter's Moons, January 2012

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

# Orion Beams!

*Orion hosts many well-known and lesser-known showpieces.*

*Orion's beams! Orion's beams!*
*His star gemmed belt, and shining blade;*
*His isles of light, his silvery streams,*
*And gloomy gulfs of mystic shade.*
— John Theodore Barker, *The Heavens*, 1831

ORION IS ONE of the brightest and most recognizable constellations. Among its many radiant beacons, none beams as brilliantly as Rigel, the seventh-brightest star in the night sky. Dwelling approximately 850 light-years from Earth, it's the nearest of a class of stars known as blue supergiants. Rigel is about 18 times as massive as our Sun and gives off 100,000 times as much light. Blue supergiants consume their nuclear fuel at a prodigious rate and suffer an astronomically brief life. Although only 0.2% the age of our Sun, Rigel will most likely die within a few million years in a spectacular supernova explosion, shining in our sky as brightly as a quarter Moon.

**Rigel** is a fascinating double star, sometimes captured by a small telescope and other times unconquerable even with a large scope. Although the components aren't exceptionally close, the secondary star is 6½ magnitudes fainter than the dazzling primary and difficult to see in its glare. Your ability to observe this lovely pair depends on good seeing (atmospheric steadiness), having your telescope at nearly the same temperature as the outdoor air, high-quality optics, and proper collimation (alignment of your optics). While it isn't necessary to have all these things working in your favor, the missing factors will conspire against you. With my 105-mm (4.1-inch) refractor at ambient air temperature, I've seen the pair flaunt a beautiful, wide split at 87× during good seeing, while it took 127× to get a decent split on a night of poor seeing.

The real charmer of Orion is the **Orion Nebula** (M42 and M43), an unforgettable deep-sky delight when seen in a moderately dark sky through almost any telescope. In fact, the entire sword of Orion is captivating through a small telescope. Its isles of light and silvery streams share a single field of view if you have an eyepiece that gives you a field of at least 2°.

At the Winter Star Party in Florida, custom optician Dan Joyce showed me an interesting arrangement of stars that he calls the **Three Radio Telescopes** of Orion's Sword. I can readily see them together in the 2.7° field of my 130-mm refractor at 23×, but some of the stars are a bit faint. The "radio telescopes" show better viewed individually at higher power or with a slightly larger scope. One of them is involved in faint nebulosity, and Joyce comments, "Using an 8-inch f/6 at a state park

DALE J. MARTIN / WWW.MASSAPOAG.ORG

**This wide-field photo stretches from NGC 1981 at top to well south of Iota Orionis on the bottom. The "Three Radio Telescopes" are outlined. *Inset:* Here's the author's impression of the Orion Nebula as seen at 68× in her 10-inch reflector.**

in December of 1973, the one in NGC 1977 was not only noticed by Wally Piorkowski and me, but we were seeing the nebulosity itself as if in the shape of a radio telescope. This prompted us to call it the Radio Telescope Nebula."

Outshone by the glory of Orion's sword, **NGC 1999** is often passed by. This little emission nebula lurks 50′ south-southeast of Iota (ι) Orionis and looks like a fuzzy star in 15×45 image-stabilized binoculars. Through my 130-mm scope at 63×, I see a faint star cloaked in a milky glow, while at 164× a tiny dark nebula materializes just east of the star. This sable spot takes on an unusual shape through 10-inch and larger scopes at 200× to 300×. Although it resembles a keyhole in its Hubble Space Telescope image, visual observers tend to see a fat T, Y, or V of darkness nudging the embedded star. If you're graced with a dark sky, look for little wisps of nebulosity jutting out from the edges of NGC 1999.

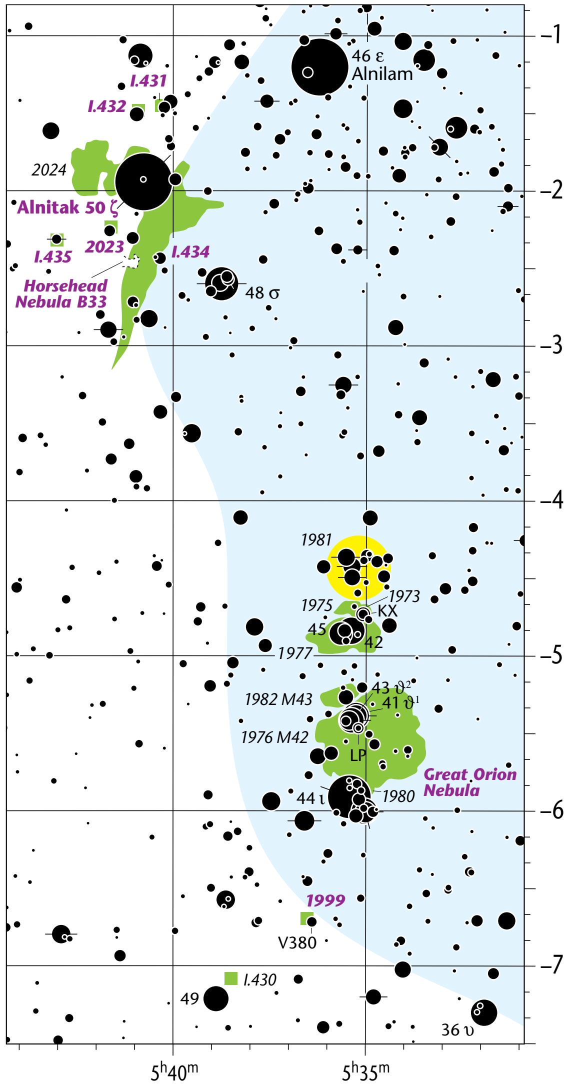
The largest telescope in the world was turned toward NGC 1999 on November 15, 1873. Built by William Parsons, the 3rd Earl of Rosse, the 72-inch "Leviathan" was then under the care of his son, Lawrence Parsons. The immense telescope bared the nebula's dark heart, and the view was described as a "9th-magnitude star with nebulosity in which there is a vacuity preceding the star."

As indicated by the word "vacuity," it was thought that some dark spots might simply be holes devoid of stars and nebulosity. The first mention of this particular ink blot as a "patch of obscuring matter" may have been in a 1946 paper by George H. Herbig of Lick Observatory. The following year, Bart J. Bok and Edith F. Reilly suggested that small, dense, dark nebulae be called globules. These relatively sharp-edged clouds, now routinely referred to as Bok globules, are concentrated knots of cold gas and dust, some of which give birth to low-mass stars.

The area around **Alnitak**, Zeta (ζ) Orionis, is also crowded with deep-sky wonders. Alnitak itself is a nice, close binary of blue-white stars. The 1.9-magnitude primary is accompanied by a 3.7-magnitude companion 2.2″ to the south-southeast, the pair split at 153× in my 105-mm refractor.

Alnitak surveils the western side of wonderfully intricate **NGC 2024**, also known as the Flame Nebula. Since its complexity is difficult to capture in words, I made the sketch at on page 56 while at the Winter Star Party in the Florida Keys. Although the Flame Nebula is the only part I drew, the 74′ field of view in my 130-mm refractor at 63× also included NGC 2023, IC 435, and the Horsehead Nebula. I didn't use a filter.

While NGC 2024 is seen primarily by light that it emits, NGC 2023 shines chiefly by reflection (scattering) of light, and IC 435 almost wholly so. **NGC 2023** appears fairly bright and has an 8th-magnitude gem embedded west of the nebula's center. It covers about 5′ × 3′, elongated north-south. Somewhat fainter than its neighbor and centered on




***Sky Atlas 2000.0*** **includes a detailed chart of central Orion. This excerpt shows all the objects discussed in this article except for Rigel.**

## Nebulae and Double Stars in Orion

| Object | Type | Mag(v) | Size/Sep | RA | Dec. |
|---|---|---|---|---|---|
| Rigel | Double star | 0.3, 6.8 | 9.3″ | $5^h$ 14.5$^m$ | −8° 12′ |
| Orion Nebula | Diffuse nebula | 3.0 | 70′ × 60′ | $5^h$ 35.0$^m$ | −5° 25′ |
| NGC 1999 | Diffuse/dark nebula | 9.5 | 2′ | $5^h$ 36.4$^m$ | −6° 43′ |
| Alnitak | Double star | 1.9, 3.7 | 2.2″ | $5^h$ 40.8$^m$ | −1° 57′ |
| NGC 2024 | Diffuse nebula | 7.2 | 30′ × 22′ | $5^h$ 41.7$^m$ | −1° 48′ |
| NGC 2023 | Diffuse nebula | — | 10′ | $5^h$ 41.7$^m$ | −2° 15′ |
| IC 435 | Diffuse nebula | — | 5′ × 3′ | $5^h$ 43.0$^m$ | −2° 19′ |
| IC 434 | Diffuse nebula | — | 70′ × 14′ | $5^h$ 40.7$^m$ | −2° 27′ |
| Horsehead | Dark nebula | — | 6′ × 4′ | $5^h$ 41.0$^m$ | −2° 28′ |
| IC 432 | Diffuse nebula | — | 8′ × 4′ | $5^h$ 41.0$^m$ | −1° 30′ |
| IC 431 | Diffuse nebula | — | 5′ × 3′ | $5^h$ 40.3$^m$ | −1° 28′ |

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

a lesser jewel, **IC 435** is a roundish glow roughly 3′ across.

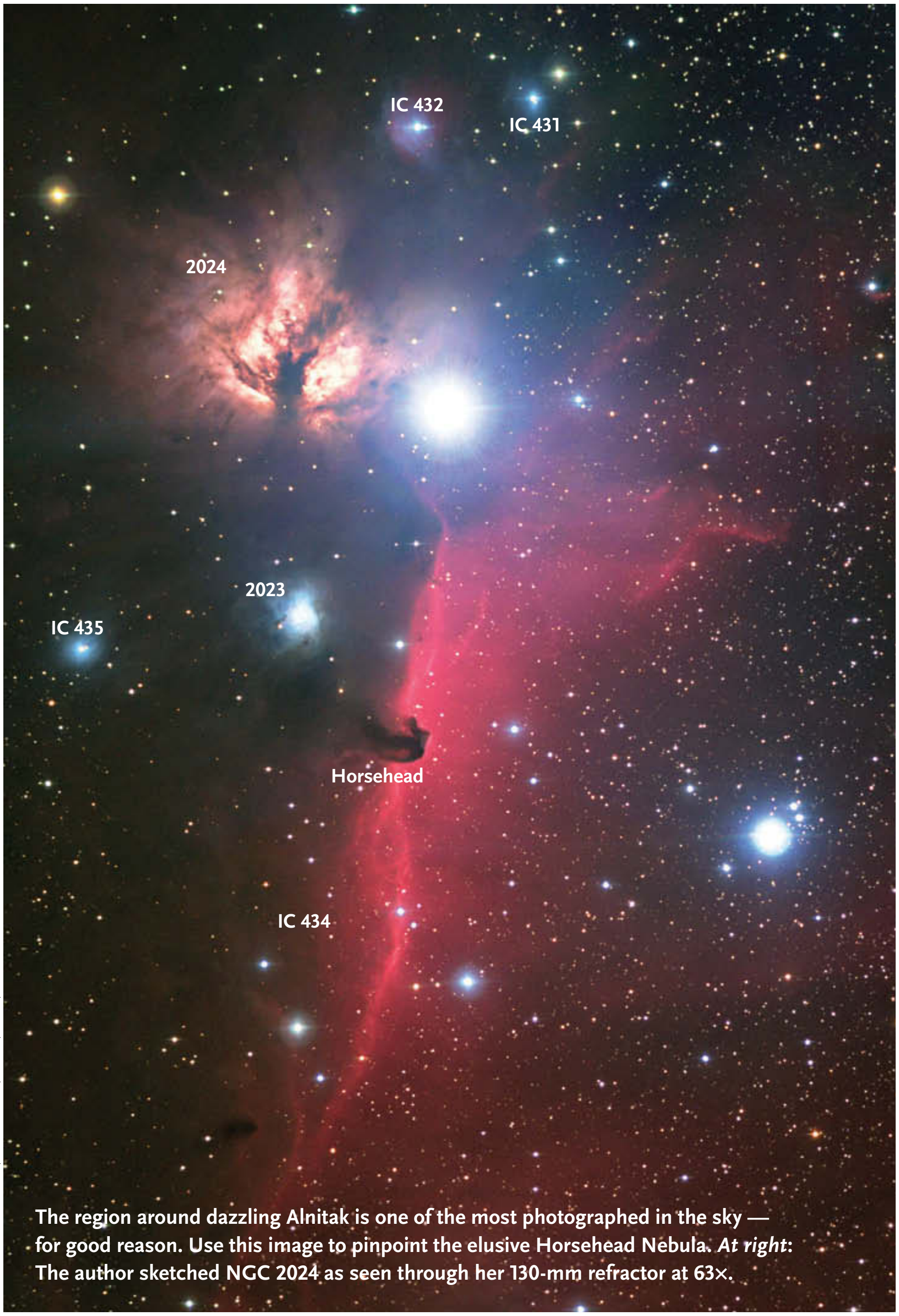
The much dimmer glow of **IC 434** is west of NGC 2023 and sprawls north-northwest to south-southeast for more than 1°. The easiest way to pick it up is to sweep your telescope east-west across it and notice the change in illumination. IC 434 is widest in the north and tapers to a narrow wisp at its southern end. The nebula's great claim to fame is the intrusion of the **Horsehead Nebula** (Barnard 33) into its eastern flank. I see the Horsehead as a dark hook, but the view is better without Zeta in the field. It also benefits from the use of a hydrogen-beta filter.

The Horsehead Nebula is notorious as an easy target for astrophotographers and a tough one for visual observers. Viewing conditions greatly affect success. I've

DAN & ERICA SIMPSON / A. BLOCK / NOAO / AURA / NSF

**The bright nebula NGC 1999 hosts a tiny, inky dark Bok globule at its heart.**

RYAN STEINBERG & FAMILY / ADAM BLOCK / NOAO / AURA / NSF




**The region around dazzling Alnitak is one of the most photographed in the sky — for good reason. Use this image to pinpoint the elusive Horsehead Nebula.** ***At right*:** **The author sketched NGC 2024 as seen through her 130-mm refractor at 63×.**

seen this gulf of mystic shade looking like a perfect horse's head at the Winter Star Party through New York amateur Joe Bergeron's 10-inch reflector, without a filter. From my northerly home, where Orion strides much lower across the sky and the light-pollution is worse, I need my 14.5-inch reflector and a hydrogen-beta filter for a comparable view. Don't be discouraged if you have difficulty spotting it. My husband had a lot of trouble with this one until he saw it in a 17.5-inch scope at a star party. Armed with a better idea of what to expect, he now views it with much smaller telescopes. It's often easier to see an object after you've finally gotten one good view.

Nudging the 130-mm scope a bit north, I see another reflection nebula. **IC 432** is an obvious oval haze about 3½′ long, sloped northeast, with a 7th-magnitude star adorning its western side. Nearby **IC 431** surrenders to my 10-inch reflector at 115×, though it eludes me in the smaller scope. This junior version of IC 432 (4¼′ × 2½′ versus 7′ × 3′) has the same slant as its big brother and also holds a beaming sun in its western edge. ✦

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

# Nebulae with Heart & Soul

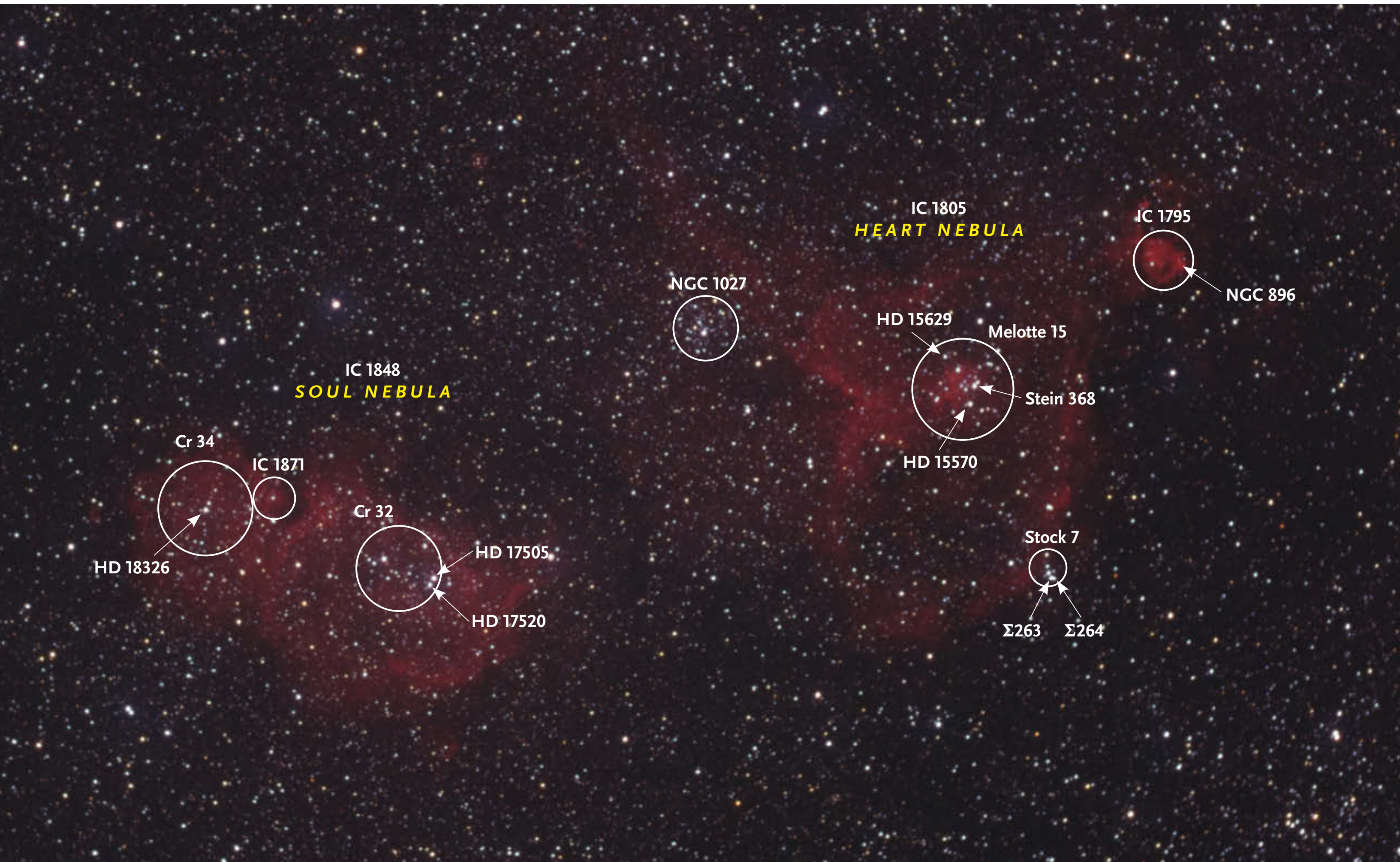
*These northern nebulae are a treat for the patient observer.*

Tucked in the southeastern corner of Cassiopeia are the immense H II regions **IC 1805** and **IC 1848**, popularly known as the Heart and Soul Nebulae. These faintly glowing clouds of gas are lit up by young, vigorous star clusters. Powerful stellar winds and intense ultraviolet radiation from blue, superluminous *O*-class stars have ionized the surrounding gas, carving out huge cavities and sculpting the remains into stunningly familiar celestial shapes.

The Heart and Soul Nebulae are part of the Cassiopeia OB 6 Association, a sprawling complex of gas, dust, and massive *O*- and *B*-class stars. Cas OB 6 resides within the Perseus arm of the Milky Way at a distance of roughly 7,500 light-years. These vast stellar nurseries, along with IC 1795, form a chain of H II regions splashed over 5° of sky.

This photogenic region is a spectacular target for astroimagers, but how much detail is visible in the eyepiece? Although challenging due to their huge dimensions and low surface brightness, the main structures are surprisingly obvious at just 13× in my 80-mm short-tube refractor equipped with an O III filter. With an 8-inch or larger scope, both nebulae are rich in subtle features. The key to success is dark skies, the use of an O III or other narrowband filter, and low magnification to provide contrast with the surrounding sky.

The cardioid-shaped outline of the **Heart Nebula** extends 1.5°, but a convenient starting point is its central cluster, **Melotte 15**. This 20′ scattered group contains twenty 8th- to 10th-magnitude stars, along with dozens



of fainter members. A striking feature is a fairly rich 4′ × 2.5′ oval ring with 30 stars including **Stein 368**, a 10″ duo of 8th- and 10th-magnitude stars. The primary is HD 15558, one of the eight *O*–class luminaries that power the nebula. At 225× my 18-inch Dobsonian resolves a swarm of 9 companions within 2′ of the pair.

Switching to 73× and adding an O III filter, Melotte 15 is encased in a prominent, 15′ ragged glow that's distinctly brighter on the east side. Fainter nebulosity flows east of the cluster for 20′ but abruptly bifurcates — the main stream curls northeast while a fainter offshoot heads toward the southeast.

The brighter nebulous wing extends 20′ northeast then dims and sharply turns due west for 35′, terminating 30′ northeast of the cluster. A weaker southern ribbon of nebulosity surrounds the cluster, forming a huge outer loop. It first heads south for roughly 40′ and then abruptly curves west a similar distance, passing near **Stock 7**, a distinctive 6′ string of five stars. At the south end of Stock 7 is a pair of doubles, Σ263 and Σ264, both easily split at 15″ and 17″ separations, respectively.

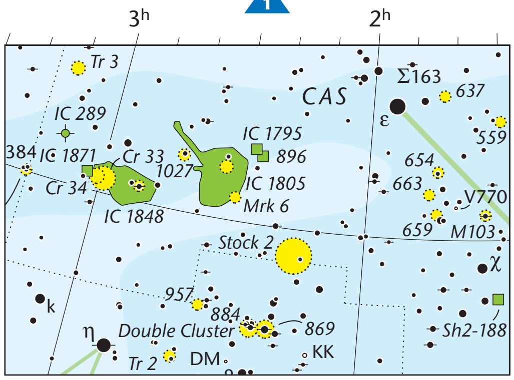
At this point, the ribbon bends north and brightens noticeably in a 10′ patch. Farther north, a dim shred passes 25′ west of the cluster and fades out. You may want to pause here, remove your filter, and search for **Tombaugh 4**, a phantom cluster discovered photographically in early 1941 by Clyde Tombaugh at Lowell Observatory. At low power it appears as a 3′ diaphanous glow with two 14th-magnitude stars on the south side.

To the northwest of IC 1805 is **IC 1795**, a 15′ irregular nebula sliced into three distinct sections by two dust lanes. At the west end is **NGC 896**, a dense 2′ knot that should grab your attention. NGC 896 is partially detached by a broad dark rift on its east side jutting northwest to southeast. East of the lane is another 8′ patch containing a 10th-magnitude star. A second dark channel running north-south defines its eastern border and beyond this lane a fainter wash of nebulosity spreads 15′ north.

Now, let's head 2.5° southeast of Melotte 15 to **Collinder 32** (Cr 32), a scattered 10′ group of stars on the west side of the **Soul Nebula** (IC 1848). The cluster is highlighted by a 2′ pair of *O*-class stars: 7.3-magnitude HD 17505 (the primary ionization source) and 8.3-magnitude HD 17520. Both of these stars have an impressive number of faint visual companions and at 220× appear as a tiny double cluster!

The view through an O III filter reveals a 1½° × ¾° starry region immersed in a low-surface-brightness mist. Based on its distinctive shape in photographs, this emission nebula is often dubbed the Baby Nebula.

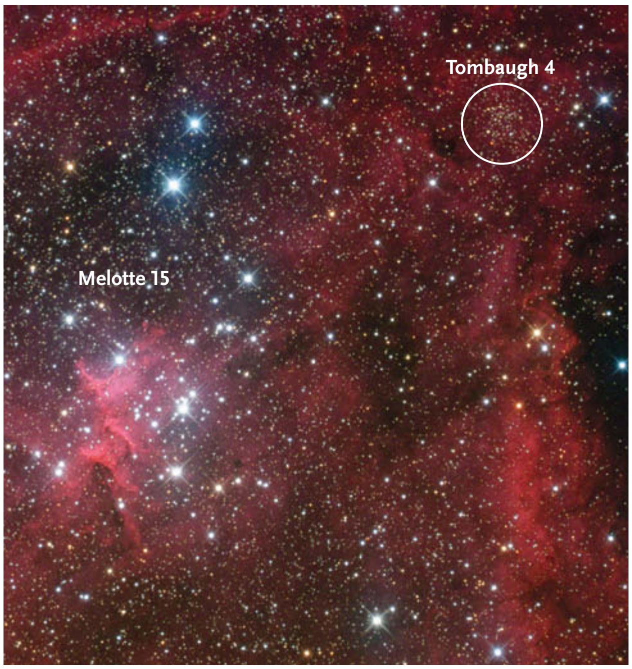
S&T ARCHIVE




Look 30′ east-northeast of the cluster for a bright patch with a sharply defined eastern border. Another 10′ east is a glowing 20′ × 10′ region that forms the face of the "Baby." An unfiltered view of the Baby's head will display **Cr 34**, a scattered stellar collection surrounding HD 18326. This 8th-magnitude *O*-class star boasts an entourage of eight close companions.

If you enjoyed the challenge of the Cassiopeia OB 6 region, check out the Cepheus OB 4 complex, which includes the H II region NGC 7822 (Sh 2-171) and the ionizing cluster Berkeley 59. I'd like to hear your results. ✦

*Steve Gottlieb (steve_gottlieb@comcast.net) explores nebulae and star clusters with all his heart and soul.*




S&T: SEAN WALKER

**Northwest of Melotte 15 in the Heart Nebula (IC 1805) resides the faint open cluster Tombaugh 4, a challenging target for observers with large telescopes.**

## Eyeball cosmology

***I've been told the ancient Greeks knew the Sun was bigger than the Earth. How could they know that?***

***— Abby Hafer, Bedford, Massachusetts***

By observing things carefully, and by using their geometry smarts.

They started from the ground up. In the 3rd century BC, Eratosthenes correctly figured out the size of Earth. He knew that on a particular date, the Sun crossed the zenith as seen from the town of Syene (now Aswan) in Egypt; people there could see the Sun shining straight down deep wells at noon. He then measured the Sun's height at local noon on the same date at his home in Alexandria, about 500 miles north. Here, he found, the Sun missed the zenith by 7.2°. That's 1⁄50 of a circle. So, 500 miles had to be 1⁄50 of the circumference of the Earth. Pretty good!

Eratosthenes published his finding far and wide, others repeated it, and the correct size of the spherical Earth remained widely known for centuries.

Next came the Moon. The Greeks knew that a lunar eclipse happens when the Moon passes through Earth's shadow. That seemed pretty obvious, because an eclipsed Moon is always exactly opposite the Sun in Earth's sky. They examined the curvature of Earth's shadow-edge when it was visible on the Moon's face. Applying some geometry, from this they figured out the Moon's size compared to Earth's. From this and the Moon's apparent diameter of ½°, they concluded that the distance to the Moon was about 50 times Earth's diameter. That's too far by half (and values quoted by ancient sources differ), but at least it was in the right cosmic ballpark.

Next the Sun: Aristarchus of Samos noted that when the Moon appeared exactly half sunlit, as best as he could judge by eyeballing it, the Moon was 87° from the Sun in the sky. This, he noted, meant the Sun was very far away: 18 or 20 times farther than the Moon. That's actually way too close. But because the Sun and Moon appear the same angular size, it still made the Sun 18 or 20 times physically larger than the Moon and thus nearly seven times larger than Earth.

The Sun's enormity may have been what inspired Aristarchus to state that the Sun, not Earth, is the real center of things — in the 3rd century BC!

Eratosthenes

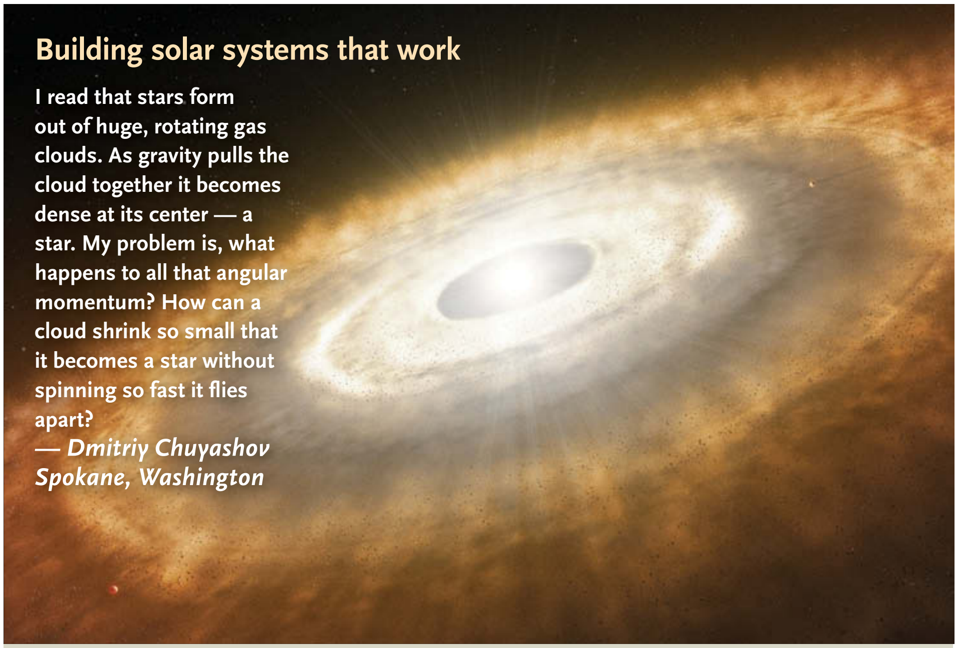
The Greeks' correct picture of the Earth, Moon, and Sun was never lost entirely; Copernicus cited Aristarchus 1,800 years later to justify proposing his own Sun-centered solar system. But for quite a few centuries these findings went ignored and unknown in cultures that had no use for people who thought like that.

PORTRAIT: TOMISTI / WIKIPEDIA

## Building solar systems that work

**I read that stars form out of huge, rotating gas clouds. As gravity pulls the cloud together it becomes dense at its center — a star. My problem is, what happens to all that angular momentum? How can a cloud shrink so small that it becomes a star without spinning so fast it flies apart?**

***— Dmitriy Chuyashov***
***Spokane, Washington***



ESO / LUIS CALÇADA

**UNAVOIDABLE OUTCOME** An artist's concept of a protoplanetary disk.

Congratulations! You've hit on a problem that flummoxed theorists for centuries, after Immanuel Kant proposed his (correct) "nebular hypothesis" of solar-system formation in 1755. But modern observations and computer modeling have confirmed the answer.

Luckily for creatures like us who live on planets, a collapsing gas cloud will feed *most* of its matter toward the center while *also* spinning off material into a large disk that carries most of the angular momentum. The result: a tiny, slow-spinning core with a large protoplanetary disk orbiting it.

As planets condense from the matter in the disk, they continue to carry its angular momentum. That's the main reason why the planets in our solar system have 99% of the solar system's angular momentum today, even though they amount to only 0.13% of its mass.

The need for someplace to dump the excess angular momentum is one reason why astronomers suspected that most stars come with planets long before exoplanets were discovered. ✦

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

# A 21st-Century RFT

*New advances in mirror making and eyepiece design change the recipe.*

RICH-FIELD TELESCOPES (RFTs) provide some of the most breathtaking views of the night sky — especially if your favorite pastime is soaking up starlight while cruising the Milky Way. You might assume that any telescope that delivers low-power, wide-field views qualifies, but in fact the parameters of a true RFT are more complex.

The term RFT first appeared in a 1916 article by British amateur S. L. Walkden. The concept came to the attention of most ATMs when a version of the article appeared in Albert G. Ingalls' *Amateur Telescope Making — Book Two* (which is currently available in Volume 3 in the Willmann-Bell revision of this telescope-making classic). In a nutshell, an RFT is an instrument that shows the greatest number of stars in a single view. That sounds simple on the surface, but there are some important subtleties involved. For instance, a larger objective lens or mirror will pull in fainter stars than a smaller instrument. And since fainter stars are more numerous than brighter ones, that's a good thing. But as a scope's aperture and focal length increase, the amount of sky you see in a single view is reduced. Less sky means fewer stars. So seeing the most stars is a balancing act between light grasp and field of view.

Two recent developments have proved to be RFT game changers. The first is the growing availability of super-fast primary mirrors — those with focal ratios faster than f/4 — which offer the potential for wider fields of view than the same-aperture instrument with a longer f/ratio. The second is modern, highly corrected, wide-field eyepieces. Used in conjunction with fast mirrors, these new eyepieces produce large apparent fields and pinpoint stars from edge to edge. One shining example of this new RFT trend is Mel Bartels's 13-inch f/3 folding Dobsonian pictured here.

What makes this scope a wonderful RFT is the amount of sky it can pull in, and its aperture. "Decades ago I built an 8 inch f/6 that I used with an oversized 38-mm Erfle eyepiece to get a 2° field of view," Mel recalls. "With my new scope I get the same field of view, but with a 13-inch mirror." The extra light gathering reaches stars a full magnitude fainter, effectively tripling the number visible in a given field.

Ironically, Mel didn't initially set out to make an RFT; rather, the 13-inch was going to be a test bed for an ultra-light 30-inch scope. "My goal is to build the largest-aperture, no-ladder scope possible," he says. "I made the 13-inch just to try my hand at a slumped, plate-glass meniscus mirror." In addition to the scope's primary mirror, a Tele Vue 21-mm Ethos eyepiece is the other piece of the puzzle. This eyepiece yields a 6-mm exit pupil and a magnification of 54× in Mel's scope, when used with a Tele Vue Paracorr Type 2 coma corrector.

Quite aside from the scope's RFT cred, Mel's 13-inch is also a model of compact portability and innovative design. The scope and mount are integrated — the side bearings also form the sides of the scope, and the "ground board" is simply a ring captured by bearings under the rocker. But the really interesting feature is the way the scope unfolds. First, the middle section of the double-strut "tube" folds out to complete the side bearings. Next,

MEL BARTELS

**This compact 13-inch RFT was crafted by Oregonian ATM Mel Bartels. The instrument features a slumped f/3 meniscus mirror that Bartels made in order to gain experience with ultra-fast optics.**

MEL BARTELS (4)

**The telescope folds in on itself for easy storage and transport. A 13-inch telescope with such compact dimensions, unthinkable only a few years ago, is now practical because of commercial coma correctors and eyepieces designed for very-fast focal ratios.**

the upper tube assembly (housing the secondary mirror and focuser) swings up, where it's locked in position by two modified monopods. Crucial to the scope's utility is its rigidity. "With a laser collimator in the focuser, I'm able to twist the upper end of the scope to the point that the mirror end lifts out of the altitude bearings without seeing the laser spot on the primary move," Mel reports.

If the idea of a super-rigid, large-aperture RFT quickens your pulse, you're probably already picturing the kinds of sights such a scope can offer under dark skies. "Views through this scope are incredible," Mel enthuses. "The combination of a 13-inch aperture and nearly 2° field of view is an experience that I cannot get enough of."

Showpiece treasures such as the Orion Nebula and Andromeda Galaxy are spectacular beyond words, and even notoriously difficult objects like the Horsehead Nebula in Orion fall to the big RFT. With a narrow-band O III filter, it only gets better. "The North America Nebula along with portions of the Pelican Nebula are visible in a single field," Mel notes. "Also eye-catching are the streaks on opposite sides of the Gulf of Mexico section — it looks just like a detailed black-and-white photo."

Readers wanting to learn more about Mel's RFT can visit his website, **www.bbastrodesigns.com/ZipDob/ZipDob.html**. ✦

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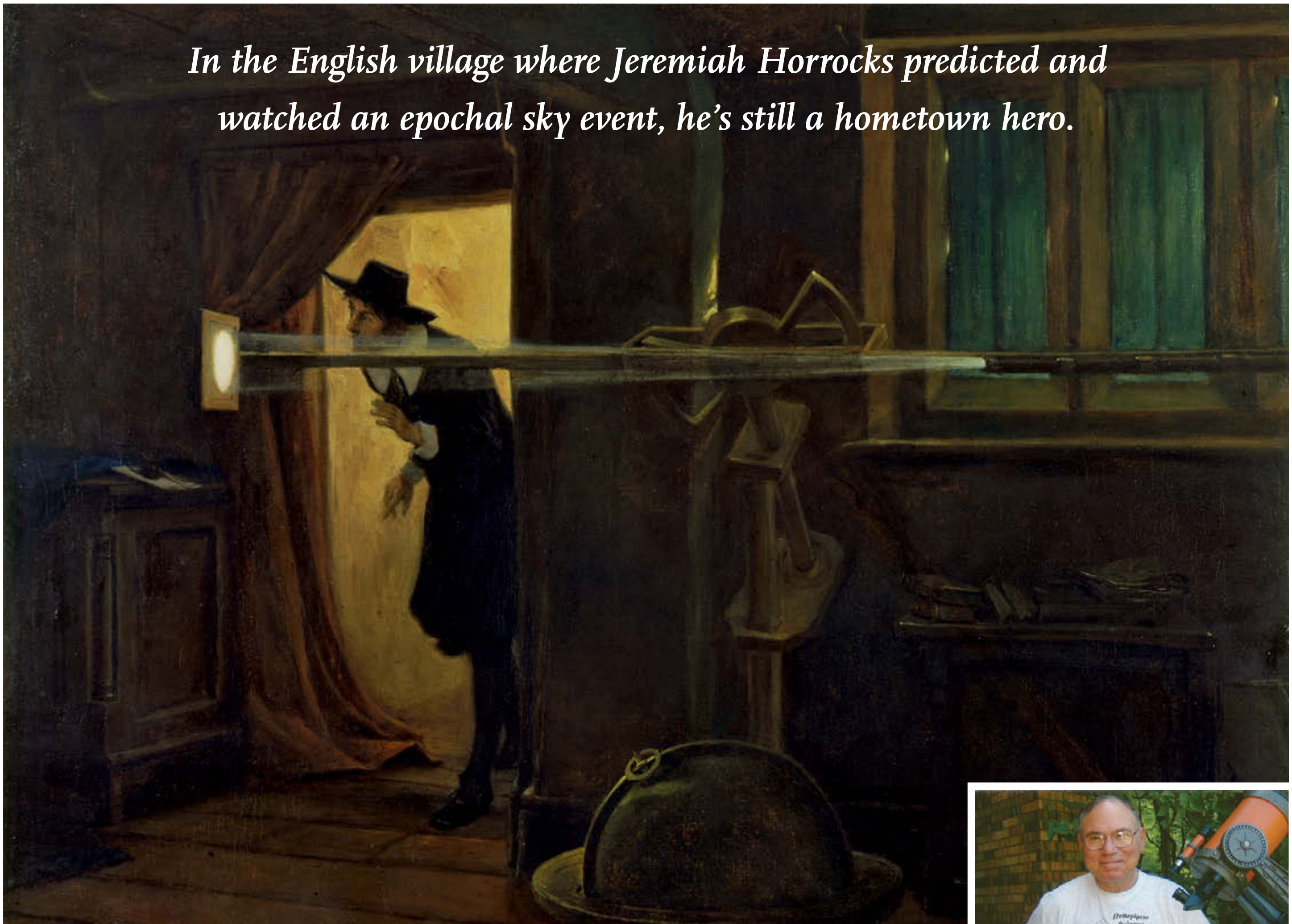
*Contributing editor* ***Gary Seronik*** *is a long-time mirror maker. Some of his scopes are featured at his website,* ***www.garyseronik.com****.*

# *In the Footsteps of the* First Recorded Transit of Venus

*In the English village where Jeremiah Horrocks predicted and watched an epochal sky event, he's still a hometown hero.*



COURTESY NATIONAL MUSEUMS LIVERPOOL

**FIRST TRANSIT OBSERVATION** This painting, *The Founder of English Astronomy*, hangs in the Walker Gallery in Liverpool. It depicts Jeremiah Horrocks watching the passage of Venus in front of the Sun on December 4, 1639. This was the first time a human saw a Venus transit while knowing exactly what was happening. Eyre Crowe created this painting in 1891, 250 years after Horrocks's death in 1641. No known painting of Horrocks was created in his short lifetime, so his appearance here is purely speculative.

ELI MAOR

ELI MAOR

**Barely eight years** after the passage of Venus in front of the Sun on June 8, 2004, a repeat of the rare celestial show is almost upon us. At 22:09 UT on June 5, 2012 (June 6th for parts of Eurasia and Africa), Venus's dark silhouette will once again enter the Sun's disk, the last such transit in our lifetime. We are privileged indeed to live in a "double transit" period in Venus's strange transit schedule. This schedule, at least for the next few millennia, calls for transits to be paired by an eight-year interval, followed alternately by a hiatus of 105.5 and 121.5 years before the cycle repeats. So if you miss the 2012 event, you'll have to wait until December 11, 2117 for the next show (see page 70).

The story of transits takes us back to the 17th century. In 1627, in his last major work, *The Rudolphine Tables*, Johannes Kepler made a startling prediction: on November 7, 1631, Mercury would pass directly in front of the Sun, and one month later, on December 6th, Venus would do the same. Aware of the opportunity these events could offer astronomers to measure the diameters of the two innermost planets, Kepler issued an "admonition" to fellow astronomers to watch the rare apparitions, urging them to begin their vigil a day early, in case of an error in his calculations.

Only three astronomers witnessed the 1631 transit of Mercury, of whom only one, Pierre Gassendi, left us a detailed report. His observation from his home in Paris marks the first documented transit of a planet across the Sun. The 1631 transit of Venus, on the other hand, occurred when the Sun had already set in Europe; it was observable from the Western Hemisphere, but there is no record that anyone actually saw it. Sadly, Kepler did not live to witness the two events he had predicted: he died on November 15, 1630, almost a year before the Mercury transit.



S&T: LEAH TISCIONE

ELI MAOR

**THE CARR HOUSE** Horrocks observed the transit from this house, which still stands proudly in the village of Much Hoole (formerly Hoole) after 372 years.

## Jeremiah Horrocks Makes History

Kepler's calculations showed that Venus's next passage in front of the Sun would not occur until 1761. Enter a young and unknown astronomer named Jeremiah Horrocks (or Horrox, as his name was then spelled). Horrocks was born in 1618 to a poor family near Liverpool, England. He showed an early interest in mathematics and astronomy and attended Cambridge University for a year or two without graduating. He then moved to the little hamlet of Hoole, 15 miles (24 kilometers) north of Liverpool, where he obtained a teaching and clerical position at the local church of St. Michael. In his free time he immersed himself in studying astronomy. He was one of the first English scientists to embrace Copernicus's heliocentric system, which even at that time, some 90 years after its author's death, was far from being universally accepted.

In 1635 the 17-year-old Horrocks started to reexamine Kepler's tables and compare them with more recent tables by Belgian astronomer Philip van Lansberge. After three years of hard work, Horrocks found that Kepler had missed an important date: the next transit of Venus would occur not in 1761, as Kepler had predicted, but on December 4, 1639 — just one year hence! Apparently Kepler had made his calculations for an imaginary observer stationed at Earth's center, from which Venus would just miss the solar disk. But as seen from Earth's surface, the planet would indeed transit the Sun on that day.


ELI MAOR

**CRABTREE MURAL** **Author Eli Maor stands in front of a mural of William Crabtree observing the 1639 Venus transit. The mural, painted by Ford Madox Brown in the late 1800s, hangs in Manchester's Town Hall. Perhaps influenced by the prevailing Victorian sentiment of his era, Brown depicted Crabtree as being much older than his actual age of 29.**

Horrocks completed his calculations in October 1639, barely a month before the transit. He hurriedly alerted a few friends, urging them to observe the rare event with utmost care. He knew that the transit would provide astronomers with an opportunity to measure Venus's apparent diameter, a task nearly impossible to achieve at any other time due to the planet's intense glare. The possibility of using the transit to measure Venus's *physical* diameter had not occurred to him: it would require a knowledge of Earth's and Venus's distances from the Sun, both of which were unknown in his time.

As it happened, only two people are known to have watched the 1639 transit: Horrocks himself, and William Crabtree, a linen draper from Manchester. The two had met at Cambridge and shared a passion for astronomy; after leaving college they maintained their friendship solely by correspondence, even though they lived just 25 miles apart.

Horrocks set up his small telescope in his room in Hoole. According to his calculations, Venus would enter the Sun's disk at 3:57 p.m. on December 4th. But just in case he might have erred, he began his vigil on the previous day. As expected, there was no transit to see. December 4th dawned: it was a Sunday. Horrocks remained at his telescope from sunrise until noon, intensely watching the Sun's image projected on a screen in his darkened room. The sky was overcast, but he managed to glimpse the Sun during short breaks in the clouds. Except for a few sunspots, however, he saw nothing unusual.

At 1:00 p.m. Horrocks left his post to attend mass at his church, apparently to serve some official duty. When he returned to his room at 3:15 p.m., he made history:

> *The clouds, as if by Divine interposition, were entirely dispersed, and I was once more invited to the grateful task of repeating my observation. I then beheld a most agreeable spectacle, the object of my san-*

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**To listen to an audio interview with author Eli Maor, visit SkyandTelescope.com/Maor.**

PHOTO: ELI MAOR

*guine wishes, a spot of unusual magnitude and of perfectly circular shape, which had already fully entered upon the sun's disc on the left, so that the limbs of the sun and Venus precisely coincided, forming an angle of contact. Not doubting that this was the shadow of the planet, I immediately applied myself sedulously to observe it.*

Horrocks had thus missed the beginning of the transit, the very moment that would become critical in future transits for attempts to determine the value of the astronomical unit, the mean Earth–Sun distance. This missed opportunity was, in the words of the 19th-century astronomer Simon Newcomb, "a circumstance which science has mourned for a century past, and will have reason to mourn for a century to come."

But Horrocks did not waste time lamenting over what he had just missed. He immediately drew a quick sketch of Venus's image on the Sun, and found the planet's diameter to be much smaller than anyone had expected: only about one minute of arc. But he was now racing against time: at 3:50 p.m. the Sun set, ending his historic observation. He had been watching it for scarcely half an hour.

In Manchester, 25 miles southeast of Hoole, Crabtree was also watching the transit. He too was beset by an overcast sky, when at 3:35 the Sun suddenly burst through the clouds. He at once began to take notes, but was so taken by the sight in front of him that for a few minutes he stood there motionless. By the time he regained his senses, the Sun had almost set. Nevertheless, his records were consistent with those of Horrocks, to the latter's great delight.

The transit now over, Horrocks was planning to write a full account of his observation, but it was not to be. He died suddenly on January 3, 1641, not yet 23 years old.

ELI MAOR

**ST. MICHAEL'S CHURCH** **Horrocks missed the first part of the transit because he was performing official functions in this church. The church was constructed in 1628 and a stone tower was added in 1720 when the church was rebuilt.**

The cause of death has never been determined. His good friend Crabtree, whom Horrocks was to meet the next day — it would have been their first meeting since their student years — survived him by only three years. He was reportedly killed in 1644 in the Battle of Naseby in the First English Civil War.

Were it not for Crabtree, who kept many of Horrocks's letters, we may have never heard of Horrocks. Many of these letters were destroyed in the war, while others went up in flames during the 1666 Great Fire of London. Of the remaining papers, many were taken by his brother and never returned. Fortunately, those papers that were in Crabtree's hands were bought by an antiquarian dealer and thus survived. German astronomer Johannes Hevelius first published Horrocks's account of the historic transit in 1662.

ELI MAOR

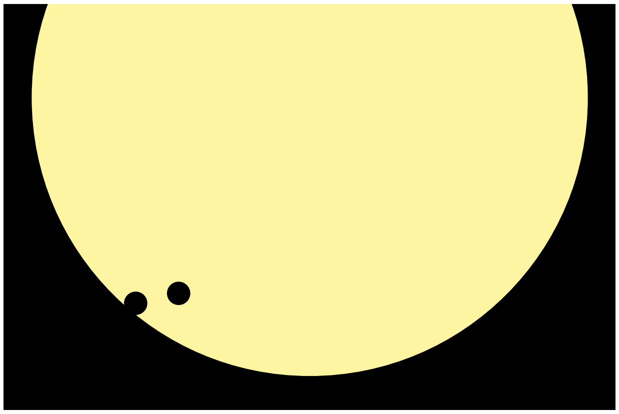
**ST. MICHAEL'S SCHOOL** **Students at St. Michael's Primary School in Much Hoole pose for the author. The students later enjoyed clear skies for the June 8, 2004 Venus transit.**

## Visit to Much Hoole

In June 2002 my wife Dalia and I traveled to Hoole — now renamed Much Hoole — to follow in Horrocks's footsteps. Our journey began at Manchester's imposing Victorian Town Hall, were there is a huge mural showing Crabtree intently observing the image of Venus on the screen in his darkened room, with his wife and children next to him. The 19th-century artist Ford Madox Brown created this painting, one of a dozen murals depicting the industrial and scientific history of the city. Brown obviously romanticized the scene, showing Crabtree to be much older than the 29 years he was at the time, but otherwise the details in the painting seem accurate.

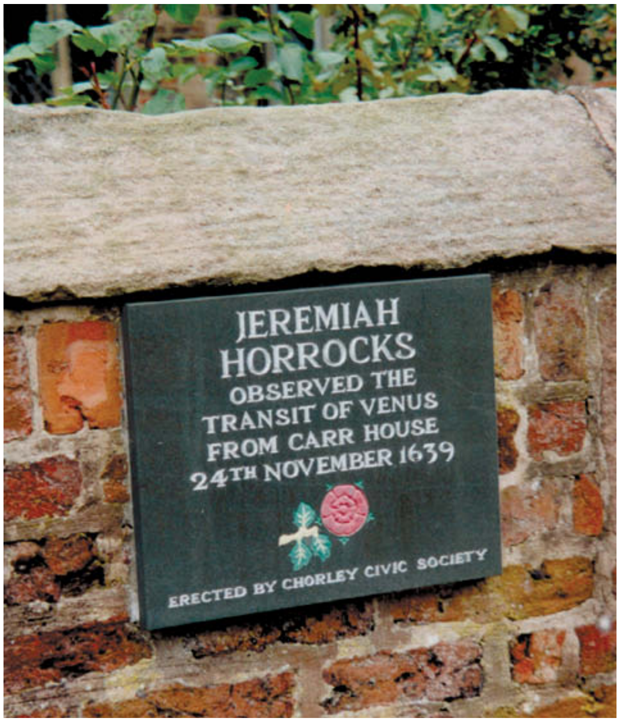
We then took a bus to the town of Preston, where we boarded a local double-decker to Hoole, a few miles to the southwest. The sleepy village of about 2,000 residents lies amidst open fields and low, rolling hills. When we got off, we tried to find someone to show us the way to St. Michael's Church, where Horrocks had to do his official duty on that fateful day in 1639. Finally spotting a man walking his dog, we stopped him and asked for directions. Sensing our foreign accent, he asked what brought us to this little place. We explained that we came to retrace an astronomical event that took place here more than 350 years ago, upon which he replied, "You mean the transit of Venus?" Horrocks was clearly a household name here.

In no time we found ourselves at the church and the adjacent St. Michael's Primary School. We introduced ourselves to the school's secretary and explained the purpose of our visit, upon which she called the headmaster, David Upton, who received us with great honor and introduced us to one of his classes. The pupils were well aware of the astronomical event that made their town famous, and they were making preparations to watch the June 8, 2004 transit from their schoolyard, despite the early hour (6:20 a.m. local time) at which it would begin. In the hallway we saw a large quilt titled "Life in Hoole," with one panel dedicated to Horrocks.



SOURCE: ELI MAOR

This illustration approximates the initial and final silhouette of Venus that Horrocks witnessed in 1639. Venus had just barely completed its ingress when he returned home from church and realized the transit was in progress. The planet had advanced about two of its diameters when sunset ended his observing.




ELI MAOR

**HORROCKS MEMORIAL** This plaque hangs at the entrance to the Carr House. The inscribed date of November 24, 1639, is from the old Julian calendar, which was still in use in England in the 1600s. On modern calendars it would have been December 4th.

At the church we found several plaques commemorating Horrocks's historic observation; an inscription engraved in marble tells the story of his brief life, and an impressive sundial on the outside wall bears the inscription *Sine Sole Sileo* ("Without the Sun I am Silent"). A clock on the opposite wall was dedicated to Horrocks in 1859, on the 220th anniversary of the historic transit.

We ended our visit with a one-mile walk to the Carr House, where Horrocks had lived and set up his telescope. We were hoping to be allowed inside, but the house — an impressive brick mansion surrounded by a beautiful garden — was up for sale and closed on that day. A plaque at the entrance briefly recounts the event that brought us there.

We briefly entertained the thought of joining the students of St. Michael's School to watch the transit on June 8, 2004, but we instead traveled to the town of Mitzpe Ramon in southern Israel, figuring we would have a better chance of clear skies. We set up our little Questar on a cliff overlooking the vast Ramon Depression in a desolate landscape that could have been on the Moon. Right on cue, Venus's black silhouette entered the solar disk and slowly moved across it for the next six hours and four minutes. We later learned that the Much Hoole students were equally lucky — they saw Venus's image on the Sun in clear skies, a sight they will surely remember for the rest of their lives. ✦

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***Eli Maor** is the author of* Venus in Transit *(Princeton University Press, 2004), on which this article is based. He is an adjunct professor at Loyola University Chicago, where he teaches the history of mathematics.*

# Transit of Venus 2012

HAWAII · JUNE 3RD – 7TH, 2012

SKY & TELESCOPE

http://InSightCruises.com/Transit

**The next Venus transit won't be until December 2117 ... 106 years from now. DON'T MISS THIS LAST-CHANCE OPPORTUNITY!**

**Experience the 2012 Transit of Venus in an Otherworldly Setting.** Join *Sky and Telescope's* Editor in Chief Robert Naeye on the Aloha State's astronomy-oriented Big Island for a memorable transit expedition. We'll stay at the four-star Waikoloa Beach Marriott Resort & Spa, home to gracious Hawaiian hospitality, exotic scenery, and classic sunsets. Naeye sets the scene with presentations on transits of Venus and the latest in planetary science. Transit day you'll head up Mauna Kea above the clouds (with excellent prospects for perfect weather) to 9,300 feet, based near the Onizuka Visitor's Center and the viewing sites of Hawaii's astronomy clubs. You can opt to ascend to Mauna Kea's observatory-clustered peak at nearly 14,000 feet, visit the Keck Observatory's giant telescopes, and take in an unforgettable view of the transit's progress. To ice the cake, June 6 we'll visit Keck Observatory headquarters in Waimea and learn about Keck's current endeavors, plus get a privileged behind-the-scenes look at Keck's command-and-control center.

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

## DAY 1: June 3

### Arrive Kona

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

## DAY 2: June 4

### Full Day of Classes Waikoloa Beach Marriott

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

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

## DAY 3: June 5

### Transit Day — Welcome to the Keck Observatory

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

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

## DAY 4: June 6

### Keck Headquarters

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

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

## DAY 5: June 7

### Fly Home

Depart from KOA Airport

### Optional Tour to the 'Imiloa Astronomy Center

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

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

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

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

InSight Cruises THE JOURNEY WITHIN

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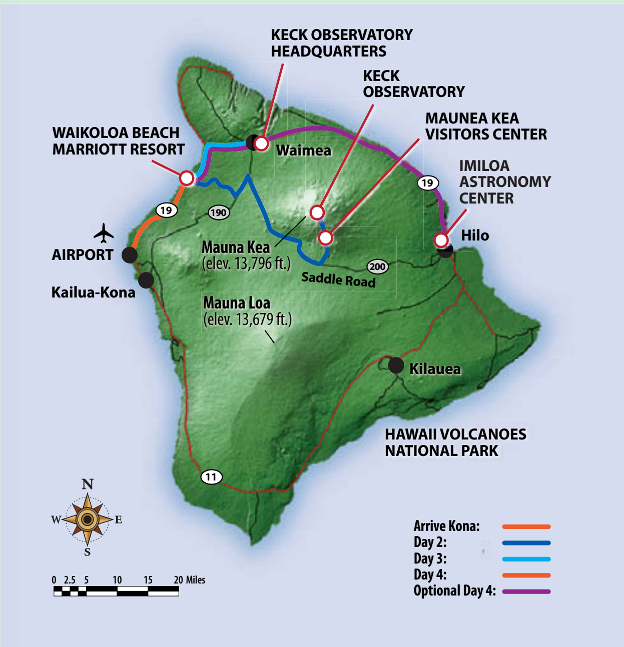


# The June Transit of Venus

Fred Espenak
& Jay Anderson

On June 5–6, Venus will cross the Sun for the last time this century. **Be prepared.**

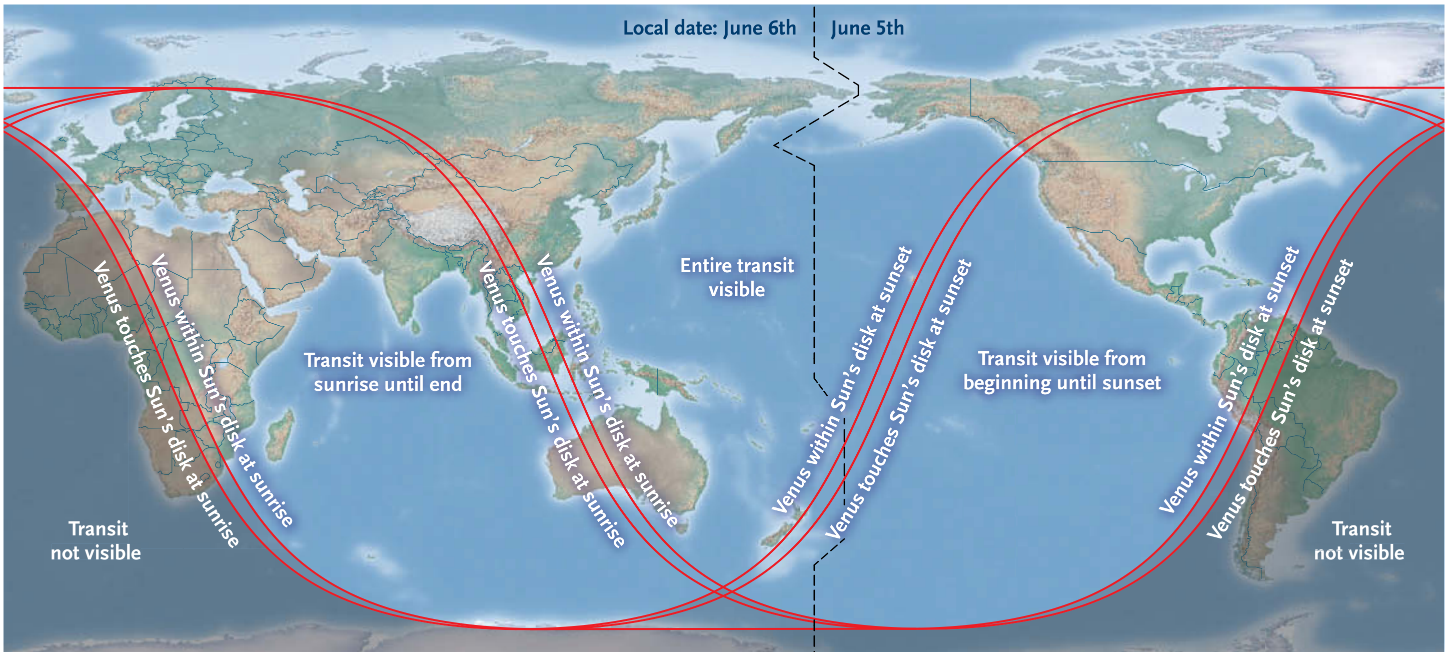
This June, Venus will pass across the face of the Sun for the second time in a decade and the last time for 105 more years. For 6 hours and 40 minutes, Venus's little black orb will be visible in silhouette as it creeps across the Sun's brilliant disk. The last time this happened was on June 8, 2004. Miss the 2012 transit and it will be a long wait until December 11, 2117.

The local date of the transit is June 5th in the Western Hemisphere and June 6th in the Eastern Hemisphere. Observers in most of North America will see the transit begin on the afternoon of Tuesday, June 5th, but the Sun will set with the transit still in progress. The entire event is visible from start to finish for Alaska, Hawaii (barely), most of the Pacific, eastern Australia, and eastern Asia.

The Sun will rise on June 6th with the transit already in progress for observers in most of Europe, eastern Africa, west and south Asia, and western Australia. Those unlucky enough to be in most of South America, western Africa, Portugal, and southern Spain will miss out completely. The map below tells the story.

## The Four Steps of the Transit

When Venus lines up between the Sun and Earth, it's as close to Earth as it ever comes. Hence it will appear 58 arcseconds wide, larger than even Jupiter ever appears. Sharp-eyed observers will be able to detect it making its way across the Sun without magnification, just a safe solar filter. Remember, looking at the Sun's face unprotected can permanently burn your retina. Plan to use the same eye protection you would for viewing a partial solar eclipse.




MICHAEL ZEILER / ECLIPSE-MAPS.COM

**WHO'S IN, WHO'S OUT** For most of North America, the transit of Venus will begin on the afternoon of June 5th and still be in progress at sunset. The western Pacific, eastern Asia, and eastern Australia see the whole show from beginning to end on June 6th local date. For South Asia, the Middle East, most of Europe, and parts of Africa, the transit is already in progress when the Sun rises on the 6th.

You will have a much better view in a 3- to 6-inch telescope with a full-aperture solar filter over its front. The newly popular narrowband H-alpha solar telescopes offer the possibility of viewing Venus against the Sun's chromosphere (upper atmosphere) or perhaps a prominence.

Although the transit lasts more than six hours, most of the action happens during the two 18-minute periods when Venus enters and exits the solar face. The beginning and end of each period occurs when the edges of Venus and the Sun just touch.

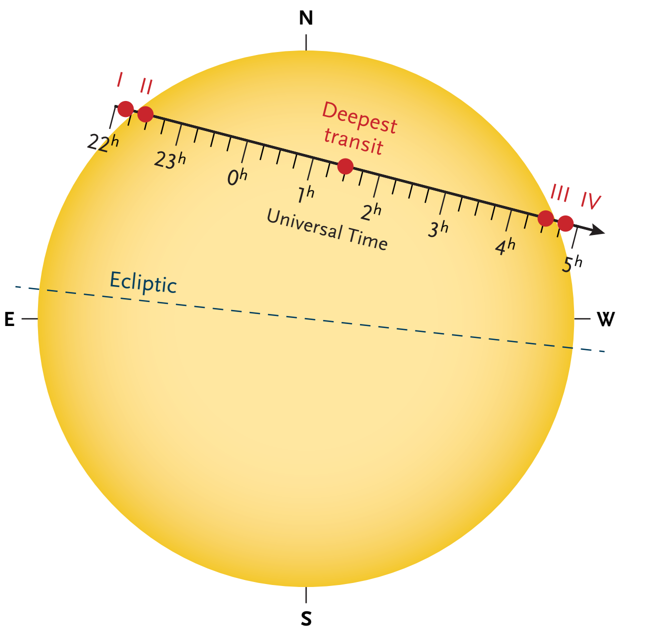
The transit begins with *first contact,* the moment when Venus first touches the edge of the Sun's photosphere (the Sun's surface as seen in white light). *Second contact* is the moment the planet becomes completely surrounded by sunlight: when Venus is entirely on the Sun's disk.

After Venus crosses the Sun's face and nears the other limb, the entry sequence repeats in reverse order. *Third contact* marks the instant Venus touches the edge of the Sun and the planet is no longer completely surrounded by sunlight. At *fourth contact* the last dark dent of the planet's silhouette vanishes from Sun's edge, and the transit is over.

Contacts I and II are referred to as "ingress," while contacts III and IV are known as "egress."

## Frequency of Transits

Transits of Venus are among the rarest of solar-system alignments. Only seven have occurred since Galileo first pointed a telescope toward the heavens. Venus goes through inferior conjunction (passing between Earth and




**THE TRAJECTORY** Venus will take about 6 hours 40 minutes to cross the northern side of the Sun as seen from Earth. This diagram is exact for an imaginary observer at Earth center ("geocentric"), but the differences at various places around the world will be small.

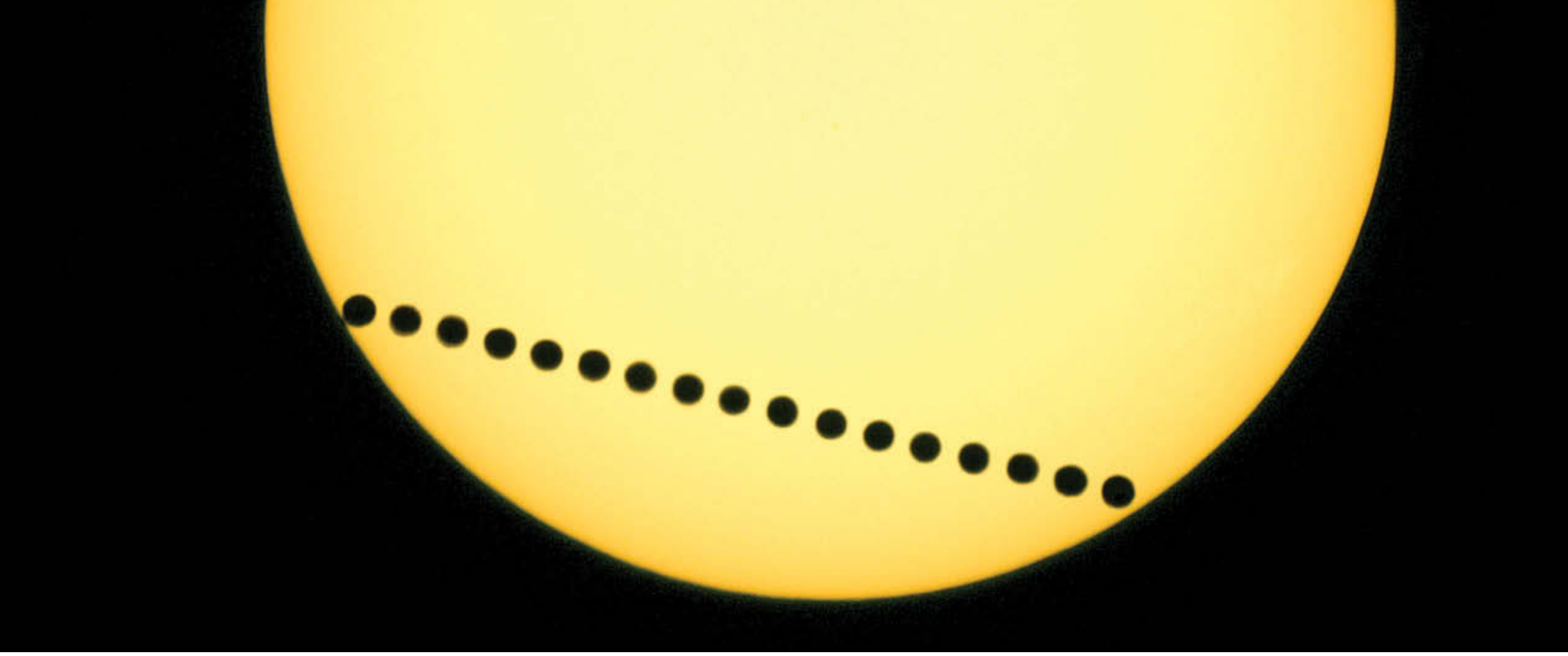
S&T: LEAH TISCIONE

**SILHOUETTE** The last time Venus transited the Sun was on June 8, 2004. Observing from Greece, author Fred Espenak shot this image with a filtered 80-mm refractor at f/16. Now more than in 2004, images like this call to mind illustrations of extrasolar planets transiting other stars!

## Transit Timetable

| Event | Universal Time, geocentric |
|---|---|
| Contact I | 22:10 June 5 |
| Contact II | 22:28 June 5 |
| Mid-transit | 1:30 June 6 |
| Contact III | 4:32 June 6 |
| Contact IV | 4:45 June 6 |

**Wherever you are**, these geocentric contact times give a good idea of when to plan to watch. The actual times for your location can differ from these times by up to 8 minutes. For instance, in most of the contiguous U.S. the events happen 3 to 6 minutes earlier. Large timetables of precise local predictions are at SkyandTelescope.com/transitofvenus. Some of these will be in our June issue.



**ORBIT PROGRESS** From the June 2004 transit, Espenak composited 17 exposures made at 20-minute intervals to create this sequence.

Sun) every 584 days, but the 3.4° tilt of Venus's orbit with respect to Earth's orbit usually carries Venus well north or south of the Sun during conjunctions. A transit is possible only when Venus is at inferior conjunction very close to where the orbital planes of Venus and Earth intersect (at the *nodes* of Venus's orbit). These transit "windows," just 8 hours long, currently occur in early June (at the descending node) and early December (ascending node). This is why transits of Venus are such uncommon events.

Venus transits recur in an interesting 243-year pattern: they come at intervals of 8, 105.5, 8, and 121.5 years in a repeating cycle. For example, the 8-year pair of transits in 2004 and 2012 both occur at Venus' descending node, with the Sun looking down on June flowers in Earth's Northern Hemisphere. After 105.5 years have elapsed, the next pair of transits in 2117 and 2125 will occur at Venus's ascending node, looking down on December scenes. Fast forward another 121.5 years later and the 243-year pattern begins again, with an 8-year pair of transits at the descending node in June of 2247 and 2255.

## Transits in History

Johannes Kepler, with the publication of his *Rudolphine Tables* in 1627, became the first person to accurately predict that a transit of Venus would occur in 1631. In spite of this achievement, uncertainty in the transit's exact time left Kepler unable to forecast the part of the world from which it would be visible. Unfortunately, the 1631 event went unobserved from Europe because the Sun was below the horizon.

During this period, the gifted young astronomer Jeremiah Horrocks was living in Hoole (now Much Hoole), a small town in Lancashire, England. Although Kepler predicted that transits of Venus would occur in 1631 and 1761, Horrocks corrected Kepler's calculations and realized that another transit was due on November 24, 1639 in the Julian calendar that he was using (the date was December 4, 1639 on the modern Gregorian calendar). Horrocks predicted that the transit should begin in England at about 3:00 p.m. Using a simple, single-lens refractor in a darkened room, he projected the Sun's image onto a white card and watched for signs of the transit throughout the day in question. In the afternoon he was called away for church business, but on his return he discovered the transit already in progress at 3:15 p.m. The Sun set a half hour later. But Horrocks's observations allowed him to estimate the apparent size of Venus to about one arcminute. Unfortunately, Horrocks died of an unknown cause shortly after his transit observation and a most promising scientific career was cut short (see page 64).

Years passed. Edmond Halley, while studying the stars of the Southern Hemisphere from the island of St. Helena in the South Atlantic in 1677, observed one of the much more common transits of little Mercury. This event inspired Halley to publish a paper decades later, in 1716, that laid out the techniques and observations needed to measure the Sun's distance accurately using future transits of Venus (see the box on page 74). He recommended that expeditions be organized to the most extreme latitudes to make careful position measurements and timings of the transit contacts. The distances between even

### VISIBILITY WITHOUT A TELESCOPE

Will you be able to see Venus on the Sun (through a safe solar filter) with your unaided eyes? This test, suggested by Herman Heyn of Baltimore, will give you an idea. Draw a black dot exactly 2 millimeters in diameter on a sheet of white paper. In good light, view the paper from 23 feet (7 meters) away. Can you see the dot?

the most widely separated observers would be small compared to the distance to Venus. But even so, the parallax difference that they observed in Venus's path across the Sun could determine the distance to Venus — and hence the distance of the Sun and the scale of the entire solar system. Halley's paper challenged future astronomers:

> I recommend it therefore again and again to those curious astronomers who (when I am dead) will have an opportunity of observing these things, that they remember my admonition... that having ascertained with more exactness the magnitudes of the planetary orbits, it may redound to their immortal fame and glory.

Halley's words launched what amounted to the international space race of the 18th and 19th centuries. No astronomical quest was more important than measuring the scale of the solar system and its fundamental measuring stick, the grandly named "astronomical unit" (the mean distance of Earth from the Sun). The major European countries (and later the U.S.) competed for the international prestige that would come with making the most precise determination.

The transits of 1761 and 1769 prompted global expeditions involving many notable scientists and explorers, such as Guillaume Le Gentil, James Cook, Charles Mason and Jeremiah Dixon, and Claude Chappe. They undertook long, arduous, and dangerous journeys to exotic locales such as India, Tahiti, South Africa, and Siberia.

Unfortunately, the results of all the 18th-century transit expeditions were disappointing. Timings of the crucial second and third contacts were marred by the mysterious "black drop effect." Instead of cleanly touching the solar limb at a precisely observable moment, the silhouette of Venus developed a narrow neck or bead, a bit like a raindrop's, that connected it to the Sun's limb, thereby making the timings imprecise. We now know that the black drop is due to blurring caused by Earth's atmosphere, the diffraction inherent to any telescope, and whatever optical imperfections the telescope may have.

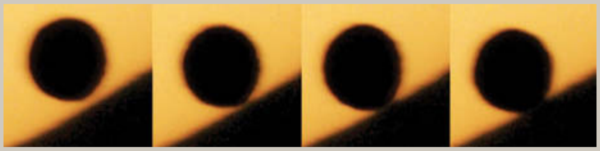
Undeterred by the problem, the great powers of the 19th century mounted new expeditions for the transits of 1874 and 1882 to claim the prize of measuring the astronomical unit. This time the United States played a major role, with the U.S. Naval Observatory organizing several expeditions. Among many other nations, France mounted an expedition led by Jules Janssen and England one by George Airy. All were armed with better telescopes and the new tool of photography to defeat the black drop effect. Unfortunately, the results were little improved over those of more than a century before.

By the end of the 19th century, better means were available for measuring the astronomical unit, including measuring the aberration of starlight (how much Earth's orbital velocity shifts the direction from which a star's light seems to arrive), and parallax measurements of near-Earth asteroids seen against the starry backdrop. The first such body, 433 Eros, was discovered in 1898.

Although a transit of Venus no longer holds the scientific value of previous centuries, it remains a remarkably rare and stunning event, one that Halley called the "sight which is by far the noblest astronomy affords."

## The Black Drop Effect

**During the 1876 Venus transit, Samuel Hunter at Suez, Egypt, made these drawings of egress using a 3-inch refractor at 126×. The first shows a thin filament forming between Venus and the Sun. The next depicts the black drop about 19 seconds before the time Hunter considered to be third contact. The next is 74 seconds after third contact, and the last shows what Hunter called "the rim of silvery light round the edge of Venus on leaving the Sun's limb" — a sign of Venus's atmosphere.**



FRED ESPENAK

**Yes, it's real. The black drop effect is not just a visual illusion; many photographed it in 2004. The smaller the telescope and the worse the atmospheric seeing, the more obvious it was.**

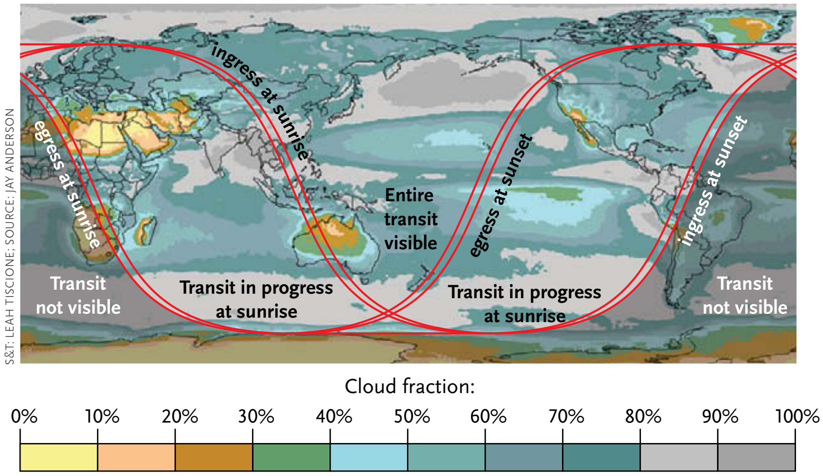
### 2012 Weather Prospects

With only one chance for success, weather forecasts will be a critical factor in viewing the 2012 transit. Fortunately, the event lasts long enough at most places to allow for lucky breaks in the clouds or for moving to a new location. Transit chasers can also travel to places with better clear-sky prospects based on past weather records.

Serious transit observers will want to be where the entire spectacle is visible, especially ingress and egress. Within that zone, one country stands out above all others for its clear weather in early June: Australia, and only northern and central Australia at that, as the start of the transit won't be visible in the west.

June is winter in the Southern Hemisphere, and Australia — "Oz" to locals — is divided between sunshine haves and have-nots. Much of the north is a "have," with some climate stations reporting that, on average, 90% or more of June daylight hours are sunny. The gloomier south struggles to reach even half that amount, so dedicated transit chasers should head for Queensland or the Northern Territory. Three places stand out in the climato-

## Predicted Cloud Cover




**CLOUDS OR CLEAR?** The American Southwest, Northern Australia, and the Middle East and surroundings offer the best chances of clear skies. For a larger map and detailed local predictions, see **SkyandTelescope.com/transitofvenus.**

logical record: Katherine and Tennant Creek in the Northern Territory and Mount Isa in Queensland, along with the region in between. Halls Creek in Western Australia also has great sunshine prospects, but lies perilously close to the sunrise limit for the start of the transit.

In North America, where the Sun sets with the transit in progress, West beats East. Excellent transit-viewing sites can be found at some places right along the California coast and in the southwest deserts. Statistics from coastal California show that sunshine averages 60% to 65% of the maximum possible — generous, but outdone by Arizona. Tucson and surroundings have 93% complete sunshine in June, comparable to the best of Oz.

To see the entire transit from North America, travel to Canada's northern regions or to Alaska is required. Yellowknife offers the most promising cloud and sunshine statistics of any northern site, with sunshine hours averaging 64% of the maximum possible.

# Measuring the Solar System

**A central problem** for astronomy in the 18th and 19th centuries was determining the true size of the solar system — just as determining the Hubble constant, giving the true scale of the extragalactic universe, was for astronomers in the 20th century.

The planets' *relative* distances from the Sun and one another were known very well, thanks to Johannes Kepler's third law of planetary motion, published in 1619. This states that the cube of a planet's mean distance from the Sun is proportional to the square of its orbital period. The orbital periods of the planets could be measured to high accuracy. So astronomers knew, for example, that Venus's mean distance from the Sun was 72.3% of the Earth–Sun distance.

But how big was that? The Earth–Sun distance, the yardstick for measuring all else, was given a sweepingly important name: the *astronomical unit* (a.u.). Its length remained embarrassingly unknown.

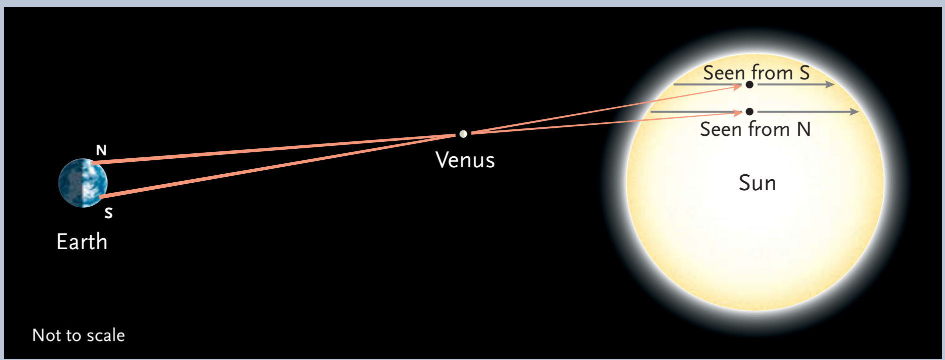
In 1716 Edmond Halley proposed a way to measure the a.u. accurately by timing the transit of a planet across the Sun, as measured from two locations as far north and south on Earth as possible. Two planets can transit the Sun: Mercury and Venus. But, Halley realized, transits by Venus should give a much better result than the more common ones by Mercury, because Venus is both nearer to us and farther from the Sun.

As shown in the diagram below (greatly exaggerated), observers widely separated north and south would see Venus following slightly different tracks across the Sun's face. The length of each track could be determined by accurately timing the transit's beginning and end. Second and third contacts offered the best chance to do so with precision. Apply some geometry, and the difference in the length of the two tracks would tell Venus's *parallax:* its difference in apparent position as seen from the two sites.

Given the latitude of each station (which could easily be determined during a transit expedition), and the diameter of Earth (known in Halley's time to better than 1%), the length of the baseline between the observers could be found in miles. This would tell the length in miles of the other sides of the thin triangles in the diagram.

The east-west separation of a pair of stations could also be used, but with greater difficulty. A transit expedition would have to measure its longitude accurately — the hard part — as well as the true local mean times when the transit contacts were observed (done by comparing the expedition's clocks with star measurements made at night).

Once the length of the a.u. was known, it would yield all the other planets' distances from the Sun — and hence from Earth at any time — and hence, using telescopic measurements of their apparent diameters, their true diameters in miles. For planets with moons, the moons' true orbital distances would become known — and thus the masses of the planets attracting them.



For more information, and detailed local predictions, see SkyandTelescope.com/transitofvenus.

Elsewhere in the U.S. and Canada, cloud prospects are worse. June is prime thunderstorm season in the late-afternoon hours, and cloudiness increases steadily eastward, reaching a maximum over the Appalachians and along the Atlantic seaboard. Nevertheless, mobility by car will probably enable almost any determined Venus-watcher to get some view of the transit. Weather forecasts can give a pretty reliable three- to five-day "heads up," lots of time to drive to a more favorable location.

The Hawaiian Islands offer a promising transit venue; the Big Island just qualifies as a site to watch both ingress and egress before the Sun lowers into the ocean. Sunshine statistics improve toward the northwest along the Hawaiian chain, but clouds vary considerably by island and by topography. In general, but not infallibly, the windward (eastern) side of the islands are cloudier than the leeward. On the Big Island, windward Hilo has an average clear-sky fraction of 33% versus 51% at leeward Kona. The same pattern on the island of Oahu gives 47% average clearness to windward Kaneohe Bay, but 61% to leeward Honolulu. For the truly determined, the finest statistics can be found at Midway Island, which boasts an 80% clear-sky figure, comparable to the best of Australia.

Some transit watchers will be tempted by the summit of Mauna Kea (access may be limited), in spite of the very low Sun as Venus exits the solar disk. Provided that no high-level cloud interrupts, the transparency and dryness of the air at that altitude will prove a considerable advantage. That advantage will be needed, as the seeing could suffer from turbulence generated by the flow of Sun-warmed air from lower levels during the course of the afternoon. Turbulence will also be a problem at lower altitudes, but this can be overcome by selecting sites along the shore that look out across the water, where cooler ocean temperatures will steady the air.

Point Venus in Tahiti has historical cachet, being the site where Cook observed the transit in June 1769. The transit in 2012 is just short of being visible in its entirety from Tahiti, but French Polynesia is in its dry season in June and the weather is cooperative. Sunshine averages 67% of the maximum at Papeete, among the better spots in the South Pacific. The Point is a popular and often-crowded park, but a surrounding sandy beach offers a good open view to the Sun. The center of the park, around the Cook monument, is heavily treed and unsuitable. The monument is not where Cook's crew performed the actual observation; that place seems to be farther down the beach, now on private property.

In Southeast Asia, China, and Japan, the news is worse. The monsoon season is in its early stages, and cloudiness is endemic. Of all of the sites along the shores of the eastern Pacific, the northern Philippines and Taiwan straddle the low-cloud regime created by the permanent high-pressure cells that inhabit that latitude.

**BEAUTY MARK** Soon after sunrise on June 8, 2004, Robert Watters at Roscoe, Illinois, caught the haze-dimmed Sun showcasing Venus. In 2012 North Americans will see the Venus-pocked Sun setting, not rising.

Over Africa, the Middle East, and India, good weather prospects stretch from the Sahara across Egypt and Turkey into Iraq and Afghanistan. For a guaranteed view of at least part of the transit, it's hard to beat the statistics for Riyadh in Saudi Arabia: a 97% clear-sky average.

Wherever you are, make every effort to see this remarkable event. It's your very last chance — unless you're very young and plan on living another 105 years! ✦

*Retired astronomer **Fred Espenak** (formerly NASA/Goddard Space Flight Center) runs two eclipse websites, **eclipse.gsfc.nasa.gov** and **MrEclipse.com**, and coauthored* Totality: Eclipses of the Sun *with Mark Littmann and Ken Willcox.*

*Meteorologist **Jay Anderson** (University of Manitoba) has prepared eclipse and transit weather forecasts since 1979 and has journeyed worldwide to confirm his predictions in person.*

▶ **COMET TAILS**
Gerald Rhemann
While Comet 45P/Honda-Mrkos-Pajdušáková remained low in the morning sky late last September, it sported a thin tail of at least 1° that was visible in binoculars.
**Details:** *ASA H-series 8-inch f/3 astrograph with FLI ProLine PL16803 CCD camera. Total exposure was 24 minutes through color filters.*

▼ **HEART OF THE SCORPION**
Babak A. Tafreshi
This deep photo captures one of the most colorfully diverse nebulous regions within the Milky Way, which straddles the borders of Ophiuchus and Scorpius.
**Details:** *Modified Canon EOS 5D Mark II with a 200-mm lens. Total exposure was 40 minutes at f/3.5, ISO 3200.*

Visit SkyandTelescope.com/gallery to see more of our reader's images online.

### ▲ GULF OF MEXICO IN CYGNUS

George East

Thick clouds of dust hide embryonic stars within the "Gulf of Mexico" region of NGC 7000, popularly known as the North American Nebula. **Details:** *Astro-Physics 155mm f7 StarFire EDFS refractor with SBIG STL-11000M CCD camera. Total exposure was 9 hours through Astrodon Generation 2 color and hydrogen-alpha filters.*

### ► JUPITER'S GAZE

Brad Hill

Jupiter's nearest Galilean moon, Io, transits in front of the Great Red Spot, giving the gas giant planet the appearance of gazing back at the viewer. **Details:** *Celestron C14 Schmidt-Cassegrain telescope with Point Grey Research Flea3 video camera. Stack of 3,200 frames each of red, green, and blue-filtered images recorded through Astronomik color filters.*

▲ **MILKY WAY IN MOTION**
Miguel Claro
The Milky Way appears to pause briefly between trees during its nightly path across the sky in this composite image.
**Details:** *Canon EOS 50D with 10-mm lens. Total exposure was 3⅓ hours at f/4, ISO 3200.*

► **CRESCENT SHELL**
David Jurasevich
This deep image of the Crescent Nebula, NGC 6888 in Cygnus, reveals a faint bluish shell of doubly ionized oxygen surrounding the popular object's familiar hydrogen-alpha nebulosity.
**Details:** *Astro-Physics 160mm f7.5 StarFire EDF refractor with SBIG STL-11000M CCD camera. Total exposure was 11 hours through Astrodon hydrogen-alpha and oxygen-III filters.* ✦

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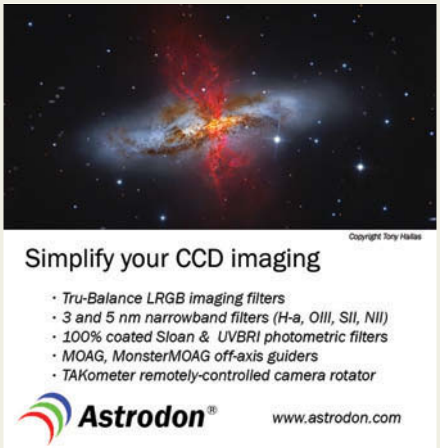



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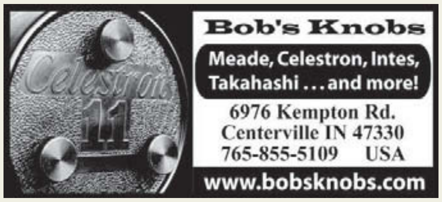

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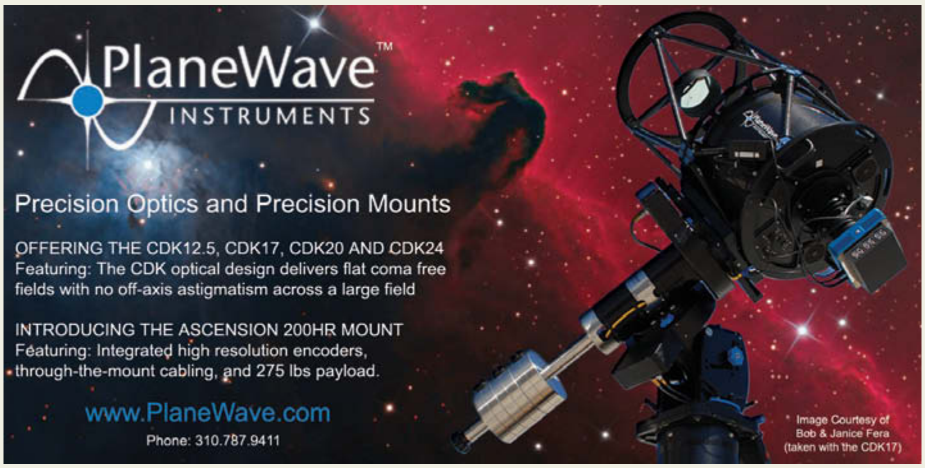

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Theo Ramakers

# Sidewalk Astro: Another Angle

*A Georgia astronomy club finds new ways to inspire students.*

THEO RAMAKERS (3)

The end of NASA's Constellation Moon program is only a small part of the fear that the United States may fall behind in space exploration. My biggest concern is that we might not have sufficiently skilled scientists to conquer the requirements for future efforts. Our astronomy club decided to do something about this.

For years we used the star-party method, using whatever the weather would allow us to show to inspire people who had no clue about astronomy. But recently we've taken a different angle: focusing on young students who are looking for that perfect future job and trying to expand their view of science.

A few of us were inspired by NASA's Night Sky Network, which provides guidance and tools for astronomy clubs to reach out to the public. We wanted a consistent and dependable way of reaching students, and this program helped us to achieve that goal.

Our club meets every month at a Mansfield, Georgia center that invites small schools to come and stay overnight to learn about wildlife. We expanded this program by offering an evening of astronomy consisting of hands-on activities and an observing session in a nearby field. In bad weather we expanded our indoor activities. For example, we have students build a tabletop "scope on a stick" and then use it to observe an artificial Moon and star, simulated by cutouts on the lens of a large flashlight. The students reach the conclusion all by themselves that a telescope inverts an image. They also explore the lunar landscape in a box with stones strewn across a flour-covered bottom by shining a flashlight from the side to observe the craters.

Because our goal is to attract students to careers in astronomy and space exploration, we also go to schools instead of asking them come to us. We established "Space Nights" and "Astronomy Nights," where we make classroom presentations and then go outside to observe. Solar telescopes allow our members to expand to daytime observing. Students often shake their heads in disbelief to see that our Earth is so tiny compared to the Sun, and they love traveling through the solar system using interactive astronomical programs.

We conducted more than 50 of these outreach sessions in 2010, and we've set a new record in 2011. Schools keep coming back to us, and new schools are inviting us in. In 2011 our club was proud to participate in the first Georgia Department of Education's STEM Festival (Science, Technology, Engineering, and Math), which allowed us to reach out to more than 1,000 science students.

It's also possible to expand a club's outreach in a formal way by making use of the excellent training NASA/JPL provides to become a Solar System Ambassador. I encourage any of you who have time to see if you can light a fire in a student who has an interest in astronomy, physics, or astrobiology. By doing so, you can help fill the need for the scientific jobs we will so desperately need this century. ✦

***Theo Ramakers*** *is a board member of the Atlanta Astronomy Club, he was Chapter director of its Charlie Elliott Chapter from 2008–2011, and its current outreach coordinator. More information can be found at:* ***http://ceastronomy.org/blog/outreach***.

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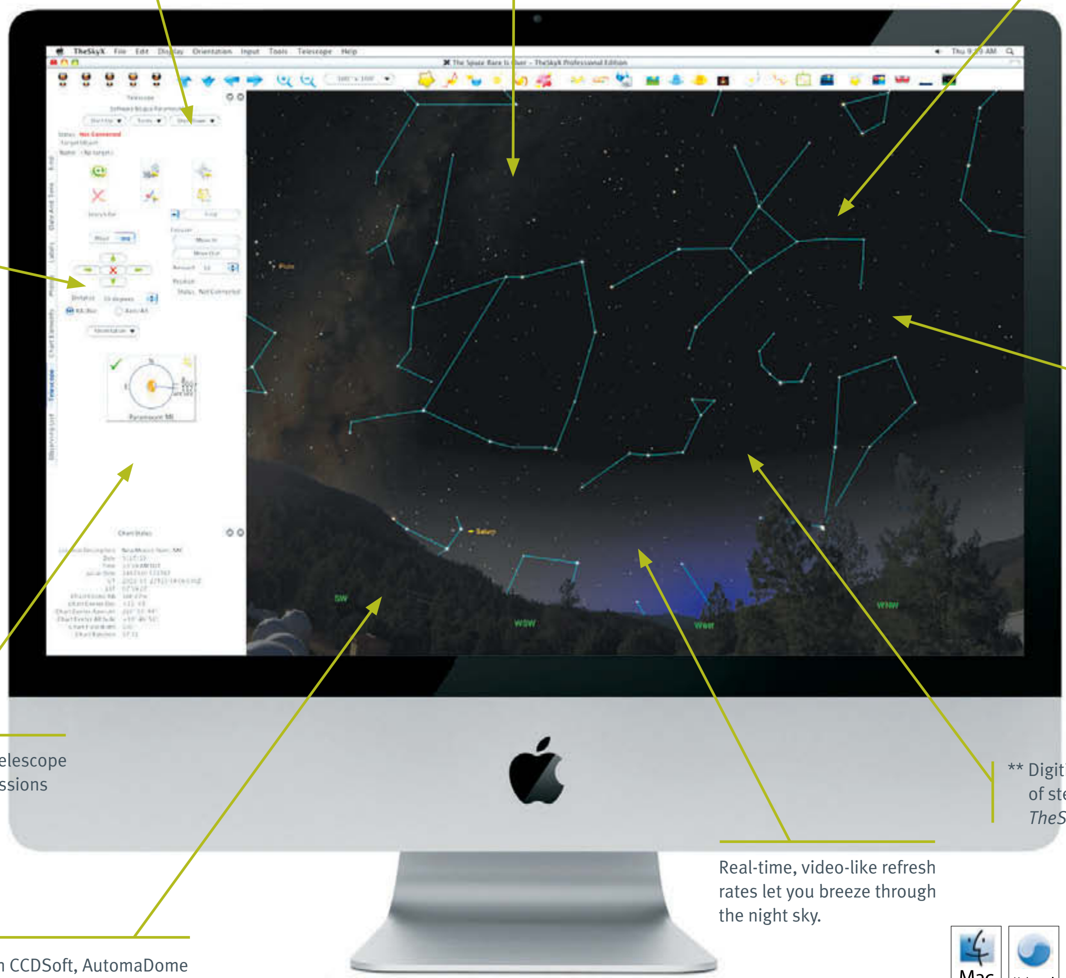

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