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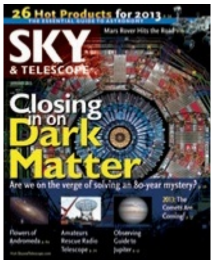

On the cover: Physicists could be creating dark matter (and its detectable signs) in particle smash-ups.

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OBSERVING JANUARY

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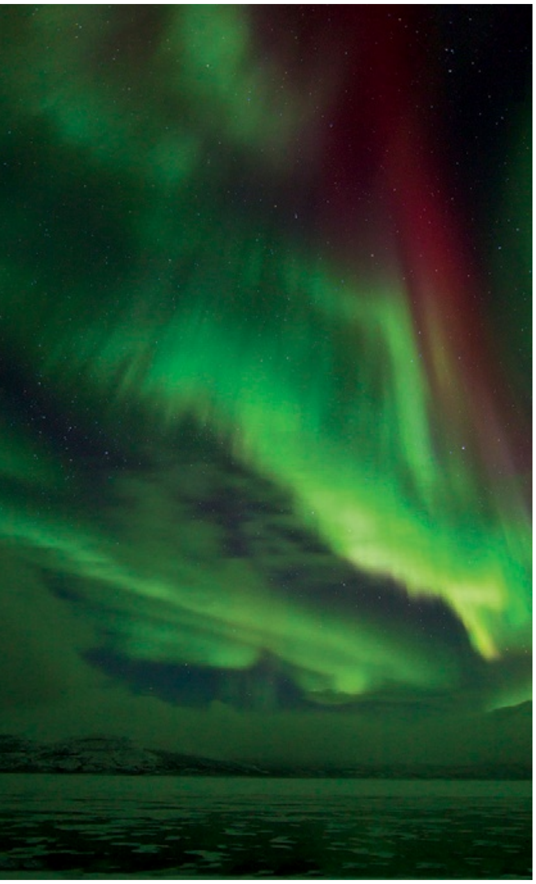
Iceland Aurora Adventure

One of the perks of working for *S&T* is the opportunity to travel to exotic places to witness spectacular sky events. I visited Iceland on aurora tours twice in the early 2000s. This beautiful island nation has fascinating volcanic geology and a unique culture that combines ultra-modern elements with customs that date back to the original Viking settlers more than 1,000 years ago. With fond memories still in my head of these previous trips, I worked with Gary Spears of Spears Travel to organize an *S&T* Iceland aurora trip from April 7 to 13, 2013. We welcome you to join us!

If you've never witnessed the aurora borealis, it should be on your must-see list. The colorful, fiery spectacle has only one rival in the sky: a total solar eclipse. Because we can't control the Sun or the weather, we can't give a 100% guarantee that we'll see an auroral display during our week in Iceland, but we chose the time and location to make sure the odds are strongly in our favor. Iceland always sits right under or near the auroral oval, the band around the far north where auroras are most common. Solar activity triggers the northern lights, and the 11-year cycle is expected to peak in 2013. Early spring is a time of year when auroras occur most frequently. And we selected a week around new Moon.



BABAK TAFRESHI / TWAN

We'll stay at a premium hotel in downtown Reykjavik and eat in fine restaurants. Iceland's tourist infrastructure is modern, and the nation is one of the cleanest and safest in the world. We'll stroll through a rift valley where the Eurasian and North American tectonic plates are splitting apart. We'll see an active geyser (Strokkur) and several hot springs. We'll see dramatic waterfalls and black-sand beaches. And no trip to Iceland would be complete without a visit to the Blue Lagoon, a geothermal spa with mineral-laden waters. Once you start relaxing in the Blue Lagoon, you'll never want to leave!

For more information on what is sure to be a fun and exciting trip, please visit **skyandtelescope.com/traveliceland**.

Robert Naeye
Editor in Chief

SKY & TELESCOPE

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

The Essential Guide to Astronomy

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Doug Reilly has merged bicycles and astronomy to create a no-headlight, carbon-neutral means of star party transportation.

DOUG REILLY

Bicycle Astronomy

My long-time passion for bringing astronomy to the public has led to a new outreach project that I would like to share with *Sky & Telescope* readers. The Bicycle Astronomy project combines my desire to introduce people to the universe's wonders and spur them to think about sustainable transportation. I throw spontaneous star parties all around town using a longtail cargo bike called a Yuba Mundo to carry my observing gear (including a lightweight telescope) and sandwich-board signs that I set up in town the morning of an event.

The project started when I asked a local bike-store owner how he would define the bicycle. He said, "It's the most perfect tool for social transformation ever invented." I thought to myself, that's how I feel about the telescope. What if I put both technologies together?

To do so, I teamed up with a local NGO and used the crowdsourcing website Kickstarter to raise funds for the bicycle and lightweight telescopes. Many of my supporters are cyclists who had never considered the bicycle as a tool for outreach, let alone a platform for astronomical observations.

My first star party this past October drew more than 40 people to one of our city's tiny "pocket" parks — quite a good turnout, considering the drizzle we had experienced all week. The sky awed them, and the bike intrigued them. I let these things speak for themselves, confident in my mission to make the universe accessible to everyone and curious about what we might achieve if we approach our shared challenges with a slightly more cosmic perspective. At the very least, my project might get more cyclists looking up, and more astronomers on bikes.

Learn more about Bicycle Astronomy at **www.bicycleastronomy.org**. Maybe you'll want to start your own people-powered stargazing project!

Doug Reilly
Geneva, New York

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

Astrophotography Musings

You probably receive letters all the time from us "astrophotography old-timers" grumbling about how today's imagers don't realize how easy they have it, but I thought I'd write anyway and repeat the sentiment.

I read with some amusement the September issue's review of the Canon 60Da camera (page 38). The comparison shots of the North American Nebula in particular struck me as a case of "polishing the cannonball," at least compared with my film attempts in the late 1970s and early '80s. I was using a state-of-the-art Minolta XK camera with interchangeable view screens, which brought focusing a half-step down from totally impossible. I put it first on a Criterion Dynascope 6-inch Newtonian, then on a Dynamax 8-inch SCT. My experience was such a frustrating mess of trial and error — with plenty of the latter — that I was lucky to produce anything remotely recognizable as an astronomical object. If it was in focus and well-guided, I was ecstatic. That almost never happened.

So I just had to give a good-natured chuckle at the concerns over the color balance of nebulae. If that had been the level of things I had to worry about back then, I'd have kept at it instead of returning, with relief, to eyes-only astronomy.

Brant Nelson
Swanton, Vermont

Sit in an astronomy club meeting these days, and you'll likely hear a discussion dominated by astrophotography and Go-To technology. So it was refreshing to read Gary Seronik's article about binocular Messier observing in the October issue (page 68). No matter how skillful you might be as an astrophotographer, someone else's image will best yours. (Heck, just look at an album of images created from observations by the Hubble Space Telescope.) On the other hand, seeing a deep-sky object with your own eyes, an object you've found by following stellar road maps instead of punching coordinates into a keypad or computer, affords in my opinion a unique and personal sense of satisfaction that is unparalleled.

Jack Kramer
Saint Charles, Illinois

Call for Jovian Event Observers

My collaborators and I have undertaken an amateur observing program to map Jupiter's dust and magnetic fields, and I would like to solicit help from *S&T* readers for this endeavor. We are using conjunctions and occultations of one object by another — usually, both are Galilean moons — to time and measure how Jovian system targets dim the light of objects passing behind them. We have dubbed these phenomena Jovian Extinction Events (JEEs).

Comparing the times of the extinctions to JPL ephemerides of the Jovian system, we "invert" our photometric light curves into a physical representation of the extinction. Our past campaigns have turned up some interesting data that appear to be related to the tenuous atmosphere surrounding Io, as well as other features of the Jovian system. But extraordinary claims require extraordinary evidence, and our preliminary results need follow-up observations for verification.

We're looking for observers to contribute photometric data, both unfiltered and in various colors, to help with this effort. Photometric data can be taken with standard CCD cameras, but video remains the best way to capture these fast transient events, as we are finding some repeating JEEs that are only a few minutes in duration. Spectroscopic data is also highly desirable, but it's difficult to obtain.

We will have multiple opportunities to probe JEEs throughout 2013, and the orbits of the Galilean moons will continue tilting toward an edge-on alignment with our line of sight into late 2014.

Predictions, past results, papers, and FAQ docs can be found on the main JEE Program page at **http://scottysmightymini.com/JEE**.

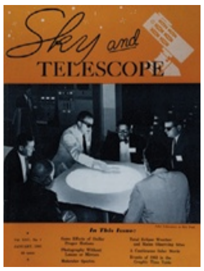
Scott Degenhardt
Santa Fe, New Mexico
scotty@scottysmightymini.com

75, 50 & 25 Years Ago

Roger W. Sinnott

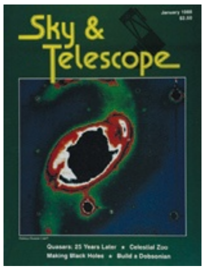
January 1938
Meteorite Impacts
"Prior to 1927 the famous Meteor Crater near Flagstaff, Arizona, was the only known feature of its kind. Within the last decade, however, four similar craters or groups of craters have been discovered in such widely separated localities as Arabia, Australia, Argentina, and Texas. Thus it appears that such features are far more common and widely distributed than has been generally supposed."

John D. Boon and Claude C. Albritton, Jr., were right. The Earth Impact Database maintained at the University of New Brunswick in Canada now lists 182 confirmed sites. They are as old as 2.4 billion years (Suavjärvi in Russia) and up to 160 kilometers across rim-to-rim (Vredefort in South Africa).



January 1963
New Distance to M31
"One of the fundamental units of cosmic measure is the distance to Messier 31, the Andromeda nebula. Recently, Henrietta Swope, research fellow at Mount Wilson and Palomar Observatories, revised this value. Her new determination of 2.2 million light-years is based on a study of 20 Cepheid variables in an outlying region of that galaxy."

In 1929 Edwin Hubble placed M31 much closer at 0.9 million light-years. Today's best value is about 2.5 million light-years.



January 1988
Are Quasars Nearby?
"How will this episode be seen 50 years from now? Everything depends, of course, on how far astronomy has advanced. If, as I suspect, the 'Arp effect' is only the tip of the iceberg, then it will look very similar to the case of Alfred Wegener and the theory of continental drift. If not, then all that will be remembered and still used will be the atlases [of galaxies] Arp has provided to the community. Those alone are no small legacy."

Geoffrey Burbidge was reviewing Halton Arp's 1987 book, Quasars, Redshifts, and Controversies. *Now age 85, Arp has long argued that quasars are associated with fairly nearby galaxies and are not as far away as suggested by their very large redshifts (when interpreted as due to an expanding universe). Burbidge himself, who died in 2010, never entirely opposed Arp's stance, but the number of Arp's adherents continues to decline.*

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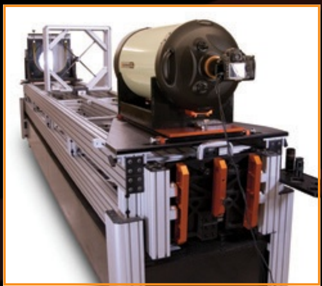

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EXOPLANET | The Earth-Mass Planet of Alpha Centauri B

European astronomers claim in the October 18th *Nature* that they have discovered an Earth-mass planet tightly orbiting Alpha Centauri B, a yellow-orange *K*1 star about 85% as luminous as the Sun in the closest stellar system to ours.

The exoplanet whips around its sun in 3.2 days, hugging it at one-tenth the distance Mercury orbits the Sun — nowhere near Alpha Cen B's habitable zone, which lies where Venus's orbit would be. The star should heat the planet to about 1,200°C, implying that it's a sea of lava.

Astronomers have found plenty of low-mass planets zipping around stars, even in binary star systems (December issue, page 12). But several planet-hunting teams have spent years focusing on Alpha Centauri's three stars because they're so close to Earth. The system consists of two stars (A and B) that are similar to the Sun and orbit each other every 80 years, and a red dwarf (Proxima, or Alpha Cen C) that revolves around the pair in an extremely distant orbit of at least 100,000 years.

"There is not a more exciting result for an individual star, even with the long line of spectacular results from the last two decades," says Debra Fischer (Yale), who leads one of the Alpha Centauri teams but was not involved with the new study. Researchers might be able to observe such a nearby world especially well in the coming years. In addition, Fischer adds, rocky planets usually come with siblings, meaning the possibility of a habitable terrestrial planet around Alpha Cen B just went up.

Detecting the candidate planet's tiny signal was truly a triumph. The European team observed Alpha Cen B for four years using the HARPS planet-hunting spectrograph on the European Southern Observatory's 3.6-meter telescope at La Silla Observatory in Chile. The astronomers were looking for slight Doppler shifts in the star's light caused by an orbiting planet's pull. The periodic shift they announced amounts to much less than the uncertainty of any single HARPS measurement; it only begins to show itself in averages of many readings (see graph on facing page). Moreover, the team had to subtract false Doppler shifts, three times larger, caused by activity on the star itself.


ESO / LUIS CALÇADA / NICK RISINGER (SKYSURVEY.ORG)

An Earth-mass planet (crescent at right) apparently orbits Alpha Centauri B, just 4.4 light-years from our solar system. In this artist's illustration, Alpha Cen B is the most brilliant object and Alpha Cen A is in the lower left. The Sun is the tiny golden speck in the upper right. Seen from the Alpha Centauri system, the Sun would make Cassiopeia's W into a longer zigzag, and at magnitude 0.4 it would be the brightest star in the constellation.

After combining all the data, the team came up with a whiff of a planet signal — a periodic stellar wobble of a mere 0.51 meter (20 inches) per second. Field tests suggest that our web editor's 1-year-old son crawls nearly this fast.

The tiny speed of the Doppler shift leads Artie Hatzes (Thuringian State Observatory, Germany) to wonder whether the planet is actually there. But study coauthor Stéphane Udry (Geneva Observatory, Switzerland) says that there is only one chance in 1,000 that the signal is a statistical fluke.

Greg Laughlin (University of California, Santa Cruz) also thinks the result will hold up. The European team used only one instrument in its observations, which reduces scatter in the data, and the planet's orbital period is distinct from any pattern from the star itself, he says.

Everyone agrees that outside confirmation is needed. The HARPS team has made its raw data public to help in this effort, but independent confirmation will take time. Fischer and her team are checking for the planet in their own observations, but although recent upgrades to the spectrograph they use at Cerro Tololo in Chile have allowed them to match HARPS's precision, their five-month string of new data is a small fraction of the European team's four-year stretch.

The star is throwing its own wrenches into the effort. Alpha Cen A and B follow eccentric orbits, and they're now approaching each other on the sky, meaning A's light will more easily contaminate obser-

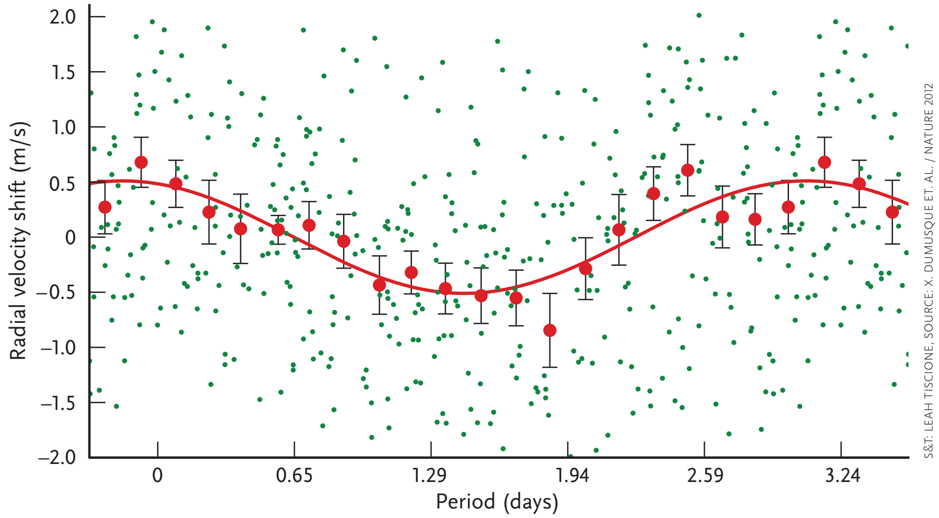
To get astronomy news as it breaks, visit skypub.com/newsblog.

vations of B. The stars won't start moving away from each other until 2016. B is also near the maximum of its 8-year starspot cycle, adding additional noise.

"I see this as the last dramatic play before halftime in a football game," Laughlin says. "We just put points on the board, we're going into halftime, and it looks like a very exciting second half is coming."

Catching a dip in Alpha Cen B's light as the planet passes in front of it would shorten this wait. Depending on how the planet's orbit aligns with the binary's orbit and our line of sight, the chance of it transiting the star's face is between 10% and 30%, Laughlin says. Udry and his team have already applied for time on the Hubble Space Telescope to observe the system. The Canadian MOST satellite could also do the trick; NASA's Kepler spacecraft looks in the wrong direction.

■ **CAMILLE M. CARLISLE**

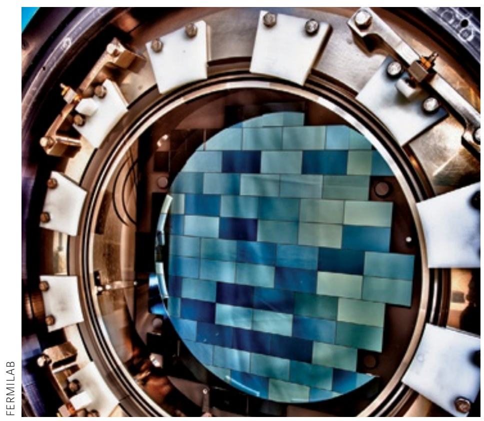


Each green dot is one corrected radial-velocity measurement of Alpha Cen B. The graph is plotted by orbital phase, assuming a period of 3.2357 days. That is, the team cut their four-years-long strip of observations into 3.2357-day segments and stacked them, so that all the green points in any vertical strip were taken when the planet was at the same point in its orbit. (The dots within vertical strips are averaged to make the red points.) The curve is a best fit to the green dots, revealing the subtle Doppler signature that the planet induces in Alpha Cen B's spectrum.

FIRST LIGHT | Cameras Open Their Eyes

Four of the newest, largest eyes in astronomy opened to the sky in August and September. Their creators hope that the gigantic images they produce will help answer some equally large questions about the universe's fate, the largest-scale cosmic structures, and the nature of dark energy and dark matter.

Three of the cameras — the Dark Energy Camera on the 4-meter Blanco Telescope on Cerro Tololo, Chile; the Hyper Suprime-Cam on the 8.2-m Subaru telescope on Mauna Kea; and the One Degree Imager on the 3.5-m WIYN telescope on Arizona's Kitt Peak — are among the largest digital cameras ever made.



One of the largest digital eyes pointed at the sky, the Dark Energy Camera houses 62 CCDs and records 570 megapixels per shot.

A typical major observatory telescope might have a handful of CCDs tiling its focal plane, but the Dark Energy Camera and One Degree Imager each have more than 60 CCDs in their arrays, and the Hyper Suprime-Cam has 116. As a result, these cameras are behemoths. The largest, Hyper Suprime-Cam, stands 3 meters (10 feet) high and weighs 3 tons.

Each camera contains hundreds of millions of pixels, making the images some of the largest ever taken. The cameras were designed for efficient sky surveys covering very wide fields with each exposure.

The Dark Energy Camera, for example, will survey about an eighth of the sky (5,000 square degrees) over five years. It will measure the universe's large-scale structure in 3-D, detect far-away supernovae, record the effects of the large-scale sound waves that rippled through the very early universe, and detect dark matter's distorting effect on the shapes of faraway galaxies. Each of these measurements will help astronomers constrain the properties of dark matter and dark energy.

The fourth new eye is the Large Monolithic Imager on the newly opened Discovery Channel Telescope (*S&T:* February 2012, page 28). Unlike the other three, which depend on vast CCD arrays, the LMI is one of the largest single CCDs in astronomy, with 36 megapixels covering a field of view nearly 13 arcminutes on a side. The single chip is sensitive to light across the optical spectrum and will enable the study of large faint objects.

These imagers pave the way for the next generation of astronomical cameras and surveys. The most ambitious planned is the Large Synoptic Survey Telescope (LSST), an 8.4-meter scope to be built in Chile. Using a camera the size of a small car, it will image half the celestial sphere to magnitude 24 in six filters every three or four days for at least 10 years.

■ **JOHN BOCHANSKI**

METEORITE | Fresh Mars Rock Hints at Water

A meteorite that fell in Morocco last year contains the freshest evidence for water on Mars, according to a study published online October 11th in *Science*.

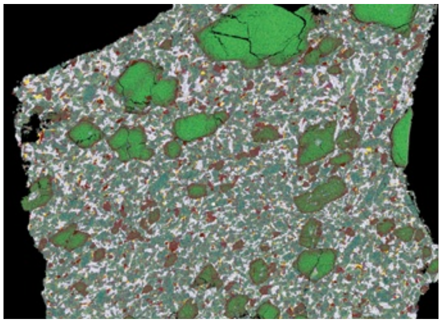
The Tissint meteorite was identified as a Mars rock a year ago. Now, Hasnaa Chennaoui Aoudjehane (Hassan II University of Casablanca, Morocco) and her colleagues report that it contains evidence of Martian dirt altered by Martian water.

Meteorites from Mars are nothing new. Over the last 4 billion years giant meteorites that have struck the Red Planet have blasted Martian rocks into space. Some of these rocks eventually hit Earth; meteorite hunters have found more than 60. Researchers can identify them as Martian by traces of atmosphere trapped inside.

But Tissint is special. Most Mars meteorites found on Earth sit on the ground for years before discovery, encountering rain and humidity that confuse any evidence of water they might contain. Tissint is fresh: eyewitnesses saw it fall at 2 a.m. on July 18, 2011, and, because the Moroccan desert is dry and rainless, Tissint likely touched no water during the two months collectors took to recover all the pieces. This makes Tissint the freshest, least-contaminated sample of Mars we have.

Tissint originally formed when lava erupted onto the surface of Mars and cooled quickly in the cold Martian air. Then 700,000 years ago, an impact blasted Tissint from Mars, melting some of the rock into tiny veins of black glass that now crisscross the meteorite.

Analyses of these veins revealed evidence of melted soil, perhaps melted by the heat of the impact. The chemical signature found in the soil can only be explained by water interacting with the dirt and depositing minerals long, long before the impact blasted the rock off Mars.


SCIENCE / AAAS

Large green crystals of olivine in this color-coded slice of Tissint grew as lava cooled underground. Reddish rims around them hint that the lava's composition changed as the olivine formed. This slice closely resembles slices of Hawaiian basalt.

Interestingly, the water appears to have been highly acidic, unlike most Earth water. Work with the Spirit and Opportunity rovers and orbiting spacecraft also suggest that ancient water on Mars was acidic, at least for a time. Why, when, and for how long that acidity existed remains unknown.

■ **SELBY CULL**

BLACK HOLES | Astronomers Knock on Leviathan's Door

The Event Horizon Telescope team (*S&T:* February 2012, page 20) reported online September 27th in *Science* that its radio array has peered at the very base of the jet rocketing from the giant black hole in the elliptical galaxy M87. The astronomers used four radio telescopes in Hawaii, Arizona, and California, part of the still-developing EHT network.

Last year another group, led by Kazuhiro Hada (National Astronomical Observatory of Japan), used the Very Long Baseline Array to observe as close to the base of M87's jet as they could. The team found that, as it observed at higher frequencies, the jet's origin seemed to walk backwards toward the black hole, as though converging on a fixed point.

Sheperd Doeleman (MIT Haystack Observatory) and his colleagues have now used the nascent EHT to observe M87's core at 230 gigahertz, a frequency five times higher than the highest used by the Japanese team. At 230 GHz the astronomers could see through the dense material bunched up in the jet, down to the point where the source stops inching backwards. When the team measured the jet's width at this scale, its diameter was about 2.3 times the size of the black hole's event horizon.

"We have now arrived at the black hole itself," Doeleman says. "It's really hard to see how the black hole could not be there."

Hada agrees. "This is a very exciting result. I would like to say congratulations on the excellent work of the EHT team."

This size is smaller than might be expected. The inner edge of the gas disk feeding M87's black hole — which has about 6 billion solar masses — should look like a ring 3.7 event horizons wide, if the hole isn't spinning. (It could be smaller if the black hole and disk spin in the same direction; see *S&T*: May 2011, page 20). Even with the requisite fudge room in the observations, 2.3 is not 3.7.

So the EHT team made two assumptions. One, the emission observed comes from where the jet's spaghetti-noodle-like magnetic field lines pick up most of their material. Two, this loading dock is anchored in the gas disk's inner edge. If both are true, M87's black hole is spinning in the same direction as the disk around it, at 20% the speed of light or higher.

Not everyone's convinced. Jet theorist Alexander Tchekhovskoy (Princeton University) says the key emission the EHT detected might not be from the disk's inner edge but from the second jet shooting from the black hole's other pole, a jet astronomers have only seen hints of because it points away from us. If so, the spin deduction goes out the window.

Doeleman agrees with these concerns. But he says what's important is that, with only three sites, the EHT can already nearly resolve what's happening at the jet's base. With more sites — most notably the Atacama Large Millimeter/submillimeter Array, which will join the EHT in 2015 — astronomers will finally have real data to help them crack the mystery of black hole jets.

■ **CAMILLE M. CARLISLE**

IN BRIEF

Astronomers have added another star to the group of rowdy stellar children dashing around the Milky Way's central black hole. The star S0-102 has the shortest orbital period yet for any star discovered looping around the hidden beast, completing its orbit in just 11.5 years, Leo Meyer (University of California, Los Angeles) and his colleagues report in the October 5th *Science.* The previous record-holder, S0-2, takes 16 years. Used with S0-2 and other nearby stars, S0-102 and its orbit might help researchers test Einstein's theory of gravity in the hole's vicinity. Planned upgrades to the Keck telescopes on Mauna Kea, and future super-telescopes such as the Thirty Meter Telescope, should enable detection of general-relativity-induced tweaks in the stars' orbits.
■ **CAMILLE M. CARLISLE**

Using a galaxy cluster as a cosmic magnifying glass, astronomers have found one of the most distant galaxies ever detected, at redshift 9.6. The galaxy, MACS J1149+2223, appears as a faint red smudge in Hubble and Spitzer Space Telescopes images. This light left the galaxy just 490 million years after the Big Bang, Wei Zheng (Johns Hopkins University) and colleagues report in the September 20th *Nature*. The galaxy is the second seen during the so-called "cosmic dawn," the reionization era when the universe changed from being dark and filled with neutral hydrogen to lit up with stars and quasars. The discovery matches other studies' estimates of when the cosmic dawn occurred.
■ **MONICA YOUNG**

Two astronomers at the University of California, Santa Cruz, have firmed up our picture of the Sun's natal star cluster. Radioactive-decay products in meteorites show that our solar system was hit by fresh supernova debris during or just after its birth, implying that our stellar cradle was a rich, massive cluster (*S&T*: March 2012, page 30). But theorists thought that passing stars in such a cluster would tug away the solar system's outer planets. A more detailed analysis published in the July 5th *Astrophysical Journal* finds that the gravitational pinball effect is actually mild enough for the outer planets and Kuiper Belt to have survived, thus removing the paradox.
■ **ALAN MACROBERT**

SKY EVENTS | No Boomerang Meteroid

DAMIEN STENSON PHOTOGRAPHY

Lucky skygazer Damien Stenson was photographing O'Briens Tower atop Ireland's Cliffs of Moher when a brilliant, fragmenting bolide passed behind it. Stenson used LEDs to illuminate the tower in this 30-second exposure.

On the evening of September 21, 2012, a dramatic fireball appeared over the British Isles, breaking into dozens of pieces as it glided east to west across the sky. Dirk Ross, who tracks bright meteors and meteorite falls worldwide, logged 564 eyewitness reports from England, Scotland, Ireland, France, Belgium, the Netherlands, and Norway.

Just three hours later, Ross received *another* burst of 126 bolide sightings — this time from southeastern Canada and the U.S. Northeast.

Were the two events related? At first, Finnish mathematician Esko Lyytinen said yes. He concluded that a single large body grazed the upper atmosphere over Ireland, dipping to an altitude of 33 miles (53 km) before escaping back to space. Because the object arrived traveling only about 8 miles (13 km) per second, barely above Earth's escape velocity, it took more than a minute to cross the sky. As the meteoroid broke apart its velocity dropped by 30%, too slow to make an escape back to solar orbit. Instead, Lyytinen suspected, the biggest chunk of this Earth-grazer ended up in a temporary loop around Earth and came down over North America one "orbit" later.

But later analyses by Lyytinen and others have concluded that, against all odds, the same-night sightings were just coincidental. Using two all-sky videos from Ontario, Canada, meteor expert Robert Matson determined that the timing for a "reentry" could have been right but the entry angles and placement were too far off.

Another analysis, by John Mason and Nick James of the British Astronomical Association, confirms that the brightest fragments seen over the U.K. exited the atmosphere too slowly to loop around Earth and return over North America at the reported times.

There have been widely seen grazers before, though nothing quite like this. On the evening of October 9, 1992, thousands witnessed a bolide that broke apart as it took its time moving far up the East Coast (*S&T:* August 1994, page 16). A piece of it struck a parked car in Peekskill, New York. An even larger meteoroid streaked across the Rocky Mountain sky in broad daylight on August 10, 1972, coming as close as 35 miles before returning to interplanetary space (*S&T:* July 1974, page 4). ✦
■ **J. KELLY BEATTY**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Curiosity Hits the Road

The newest, most capable, and most expensive rover ever launched is just beginning its two-year exploration of Mars and the planet's suitability for life.

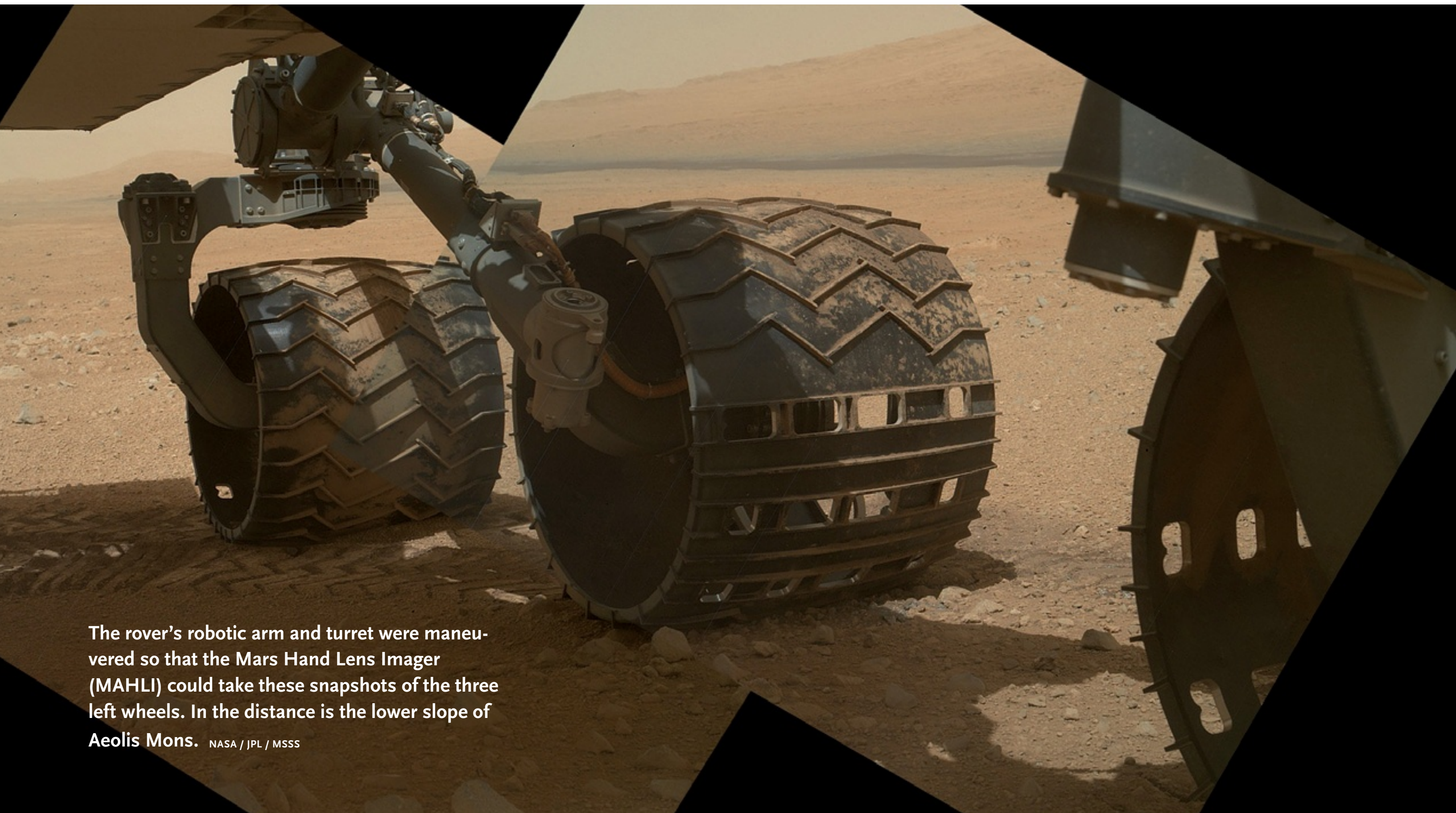
J. Kelly Beatty

Space-exploration aficionados have become accustomed to the "90-sol" rule. That's how many Martian days (called *sols*) NASA managers have expected most of their rovers and landers — going all the way back to the twin Viking touchdowns in 1976 — to operate on the planet's inhospitable surface. Yet by mid-November, when the Sun rose over NASA's new Curiosity rover for the 90th time, the craft was still a couple of months from reaching its primary objective: a towering mound of sedimentary layers stacked inside Gale Crater.

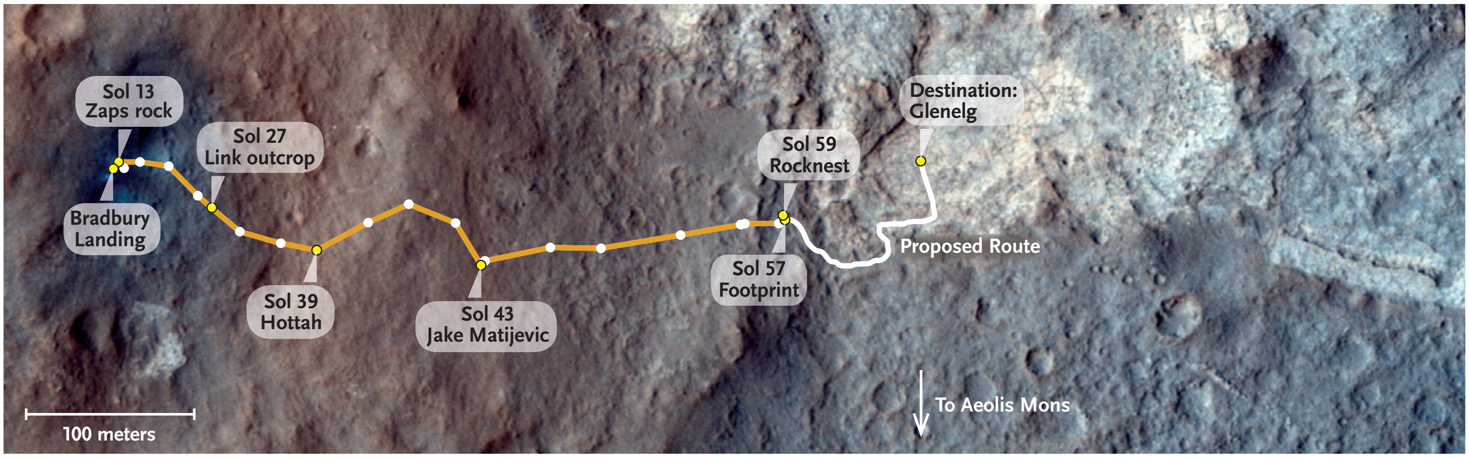
Then again, Curiosity is unlike any of the smaller surface scouts that preceded it. Nearly the size of a Mini Cooper and powered by 11 pounds (5 kg) of plutonium dioxide, the $2.5-billion Mars Science Laboratory (as it's known officially) was built for the long haul. This time the ground game is to last at least an entire Martian year, 669 sols or 687 Earth days, which should afford it plenty of time to complete the rover's complex mission.

The bulk of that time will be spent making its way up the slopes of Aeolis Mons, more widely known as "Mount Sharp" in honor of pioneering planetary geologist Robert P. Sharp (1911–2004). Rising 3½ miles (5½ km) from the floor of Gale, Aeolis Mons is a huge stack of sediments that were emplaced early in Martian history.

Just as the Grand Canyon in Arizona exposes ancient strata at the base of its walls and younger ones higher up, it's thought that the lowest layers within Aeolis



The rover's robotic arm and turret were maneuvered so that the Mars Hand Lens Imager (MAHLI) could take these snapshots of the three left wheels. In the distance is the lower slope of Aeolis Mons. NASA / JPL / MSSS



NASA / JPL / UNIV. OF ARIZONA / EMILY LAKDAWALLA

Curiosity's touchdown site, now known as Bradbury Landing, is only a short distance from Glenelg, an intriguing confluence of three terrain types and the rover's first destination. Labels on this color-inhanced image taken by the Mars Reconnaissance Orbiter's HiRISE camera mark points of interest noted in this article.

Mons were laid down about 3.8 billion years ago, when geologists suspect that the Red Planet's climate was warm enough to permit liquid water to flow abundantly across the surface. Based on spectral scans by spacecraft in Martian orbit, these beds appear to contain lots of clay minerals. Higher up, the younger sediments exhibit no clays but are instead enriched in sulfates, much like the soils sampled by the rovers Spirit and Opportunity, implying a dramatic shift to a more acidic environment.

"With Gale, we've got hundreds and thousands of meters of strata to look at," explains project scientist John Grotzinger (Caltech). "Now we'll be able to look at what happened a long time ago over tens or even hundreds of millions of years." This ability to probe what Grotzinger calls the "dimension of deep time" might reveal what caused such a downturn in the planet's habitability early in its history.

Practice Runs

As detailed in the November issue (page 20), Curiosity reached Gale's broad, flat floor in dramatic fashion after an 8½-month, 350-million-mile journey from Earth. The craft's initial panoramas showed Aeolis Mons looming nearby and a foreground landscape that bristled with geologic promise. NASA officials decided to name the touchdown site "Bradbury Landing," a tribute to renowned science-fiction author Ray Bradbury, who died just two months prior to Curiosity's arrival in August.

Before the rover could get down to some serious science, however, the mission's 200 engineers and 400 scientists had to complete an extensive series of checkouts and calibrations. As the illustration on page 24 shows, Curiosity is a complex geologic laboratory equipped to watch, grind, sift, sniff, zap, taste, and digest the Martian surface and atmosphere as never before.

Bradbury Landing is about 5 miles (8 km) from those beckoning clay sediments, but Curiosity didn't head directly there once it started rolling in late August. Instead, the team decided to make a detour to explore a site nearby, dubbed Glenelg, where three terrain types come together.

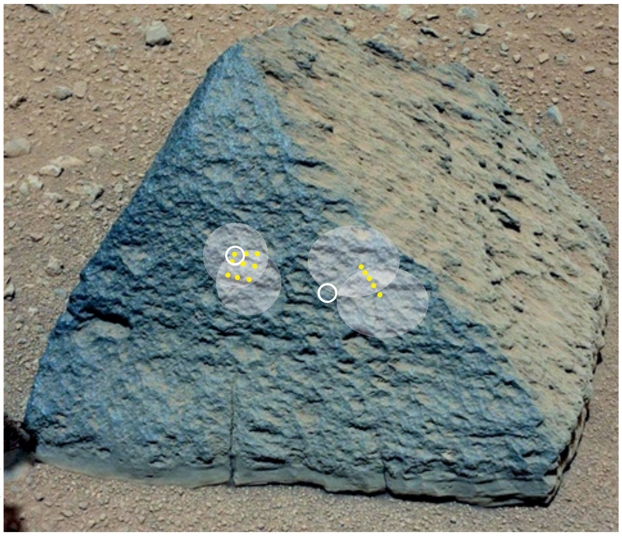
The most intriguing of these is a light-toned rock that, based on scans from orbit, is layered sediment. That's where the rover will use its arm-mounted drill for the first time, grinding down far enough to extract an unweathered sample for two key geochemical experiments. The Chemistry and Mineralogy experiment (CheMin) can accurately reveal the rock's elemental abundances and the specific minerals in its makeup, while the Sample Analysis at Mars (SAM) package will seek organic compounds relevant to life.

The rover got an opportunity to test some of its capabilities even before it started rolling toward Glenelg. Its Chemistry and Camera (ChemCam) instrument fired a burst of 30 laser pulses at a fist-sized rock lying about 10 feet away. ChemCam's telescope-aided spectroscopes (see box, page 24) recorded the resulting puffs of incandescent vapor to determine the rock's composition.

Compare Curiosity's image of the outcrop called Link *(left)* with a typical sedimentary conglomerate formed by gravel fragments in a stream on Earth *(right)*. The largest Martian pebbles are about 1 inch (2½ cm) across.



NASA / JPL / MSSS / PSI (2)



NASA / JPL / MSSS

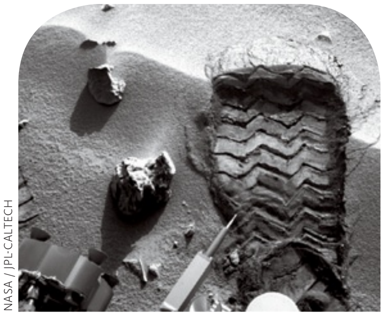
Yellow dots on this image of the igneous rock “Jake Matijevic” indicate where ChemCam vaporized small spots with bursts of laser energy. Circles correspond to the instrument’s images to record pits made by the laser, and white outline circles indicate where the Alpha Particle X-ray Spectrometer trained its view.

In mid-September, the rover passed near a jutting outcrop of rock that the team nicknamed Hottah. “It looks like someone came along on the surface with a jackhammer and lifted up a sidewalk at a construction site,” says Grotzinger. Curiosity took close-up images with one of the two imagers in its Mast Camera (Mast Cam), homing in on the outcrop with a 100-mm-focal-length lens. The images revealed that Hottah is a layer of loosely cemented gravel and sand, strikingly similar to geologic features common in dry streambeds on Earth.

“The rounded gravel tells us the particles have been transported by water or wind, which wears away the edges to yield a smooth surface,” explains investigator Rebecca Williams (Planetary Science Institute). But most of Hottah’s particles are too large to be windblown, which means the sand-and-pebble mix was most likely deposited by a vigorous Martian stream flowing across the crater’s floor.

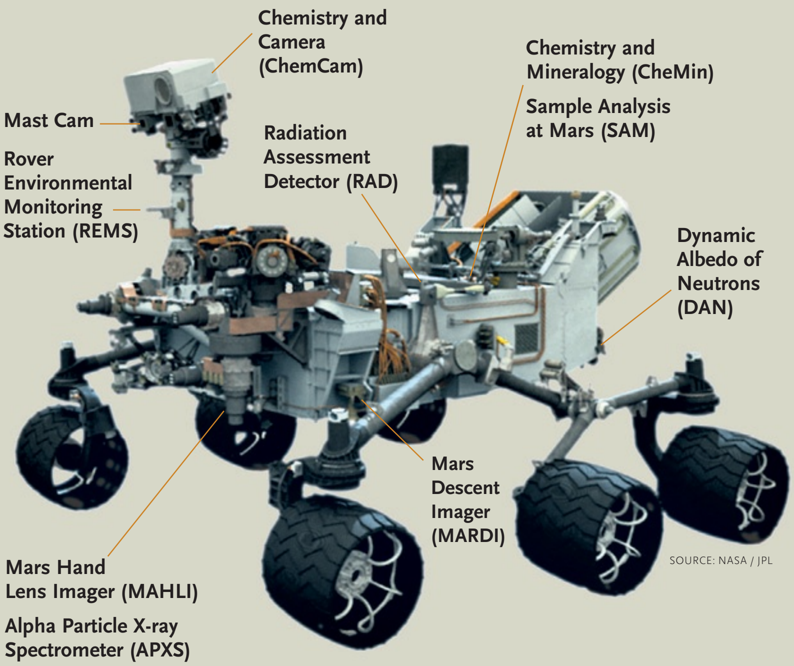
It’s an important find, though not an unexpected one. Mission scientists dropped Curiosity near an extensive fan-shaped deposit at the end of a half-mile-long channel, named Peace Vallis, that runs downslope from the crater’s inner wall. This sediment fan turned out to extend to the landing site.

As it rolled farther along the route toward Glenelg in late September, Curiosity encountered a foot-long rock (dubbed



NASA / JPL-CALTECH

On October 3rd, the mission’s 57th sol, Curiosity scuffed a wind-formed ripple at the Rocknest site with its wheel to allow researchers to examine the range of particle sizes. The width of the wheel track is about 16 inches (40 cm).



Also includes: Collection & Handling for-Site Martian Rock Analysis (CHIMRA) (scoop, not instrument)

A Roving Geological Laboratory

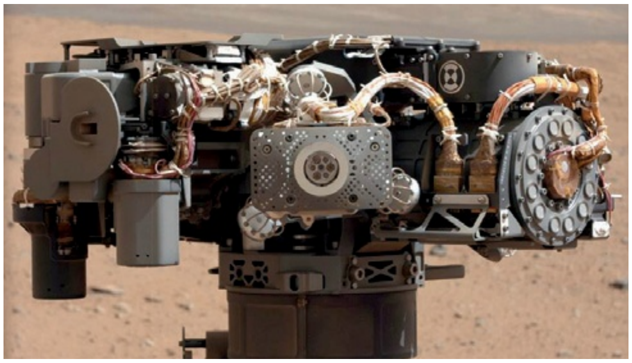
Curiosity carries 10 instruments that together total 165 pounds (75 kg), nearly half the total mass of Spirit or Opportunity. Here are snapshots of these experiments’ roles and capabilities:

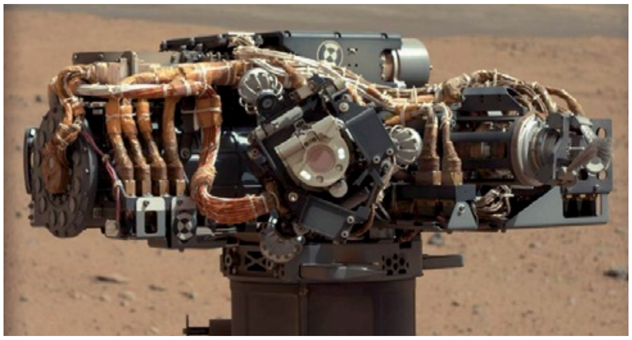
- **Alpha Particle X-ray Spectrometer (APXS)**, at the end of Curiosity’s arm, is placed directly against rocks and soils to identify their chemical elements.
- **Chemistry and Camera (ChemCam)** combines a near-infrared laser that can vaporize a pinhead-size spot up to 23 feet (7 m) away with a telescope that directs the momentary flash of light to a trio of spectrometers.
- **Chemistry and Mineralogy (CheMin)** beams X-rays at a powdered sample delivered by the robotic arm and records how they scatter — a first for an interplanetary lander — to identify specific minerals.
- **Dynamic Albedo of Neutrons (DAN)** detects water in minerals buried up to 20 inches (50 cm) beneath Curiosity’s path.
- **Mars Descent Imager (MARDI)**, though most active during the rover’s atmospheric descent, is still being used to look at the ground under the rover at different locations.

"Jake Matijevic" after a former Mars rover engineer) that was darker than the dust-covered terrain around it. It certainly *looked* like an igneous rock, but was it really? To find out, mission scientists zapped it repeatedly with ChemCam's laser and studied the resulting incandescent plasma with the camera's spectrometers. They also put the rover's Alpha Particle X-ray Spectrometer, mounted on a turret at the end of its robotic arm, directly on the rock's face to determine its composition.

"Jake" turned out to contain relatively little iron and magnesium, elements commonly found in igneous rocks, but it has high levels of sodium and potassium. "The spectrum is not what I expected," admits Ralf Gellert, the APXS's principal investigator. "It's igneous, but it seems to be a new type of Martian rock that we haven't seen yet" — a mix of minerals, uncommon on Earth, that solidifies from the water-infused molten residue left behind after most of the magma has already crystallized. According to Caltech geologist Edward Stolper (Curiosity's original project scientist), a rock like this likely formed under pressure about 5 miles below the surface.

More practice runs came in early October. Curiosity passed a small drift of fine sand, exactly what the team needed in order to test the scoop at the end of its robotic arm. "Scoop" doesn't really do this device justice. Called CHIMRA, short for Collection and Handling for In-situ Martian Rock Analysis, it sifts samples using a small vibrating cup to yield little piles of tiny particles no bigger than 150 microns across. These fine powders will then travel down tubes to a pair of instruments housed inside the rover that will analyze the samples' elemental and isotopic abundances, identify specific minerals, and test for the presence of organic compounds.





NASA / JPL / MSSS (2)

These views show the complex turret of instruments and sampling mechanisms at the end of Curiosity's robotic arm. The Alpha Particle X-ray Spectrometer is centered in the upper view and the Mars Hand Lens Imager (MAHLI) in the bottom one.

On the Road to Glenelg

These are the kinds of sampling procedures and detailed geochemical results that will be crucial in unraveling the Red Planet's complex geologic history. More pointedly, the rover will need to bring all these capabilities to bear when it finally reaches the clay- and sulfate-rich strata of Aeolis Mons — far and away the most likely candidates for preserving evidence of life, Grotzinger says.

But first Curiosity must complete its inspection of the intriguing rock outcrops exposed at Glenelg. That diversion should take no more than a few weeks. After that, the rover will double back along its earlier tracks, sidestep a field of dark dunes, and start to ascend the big mound itself. ✦

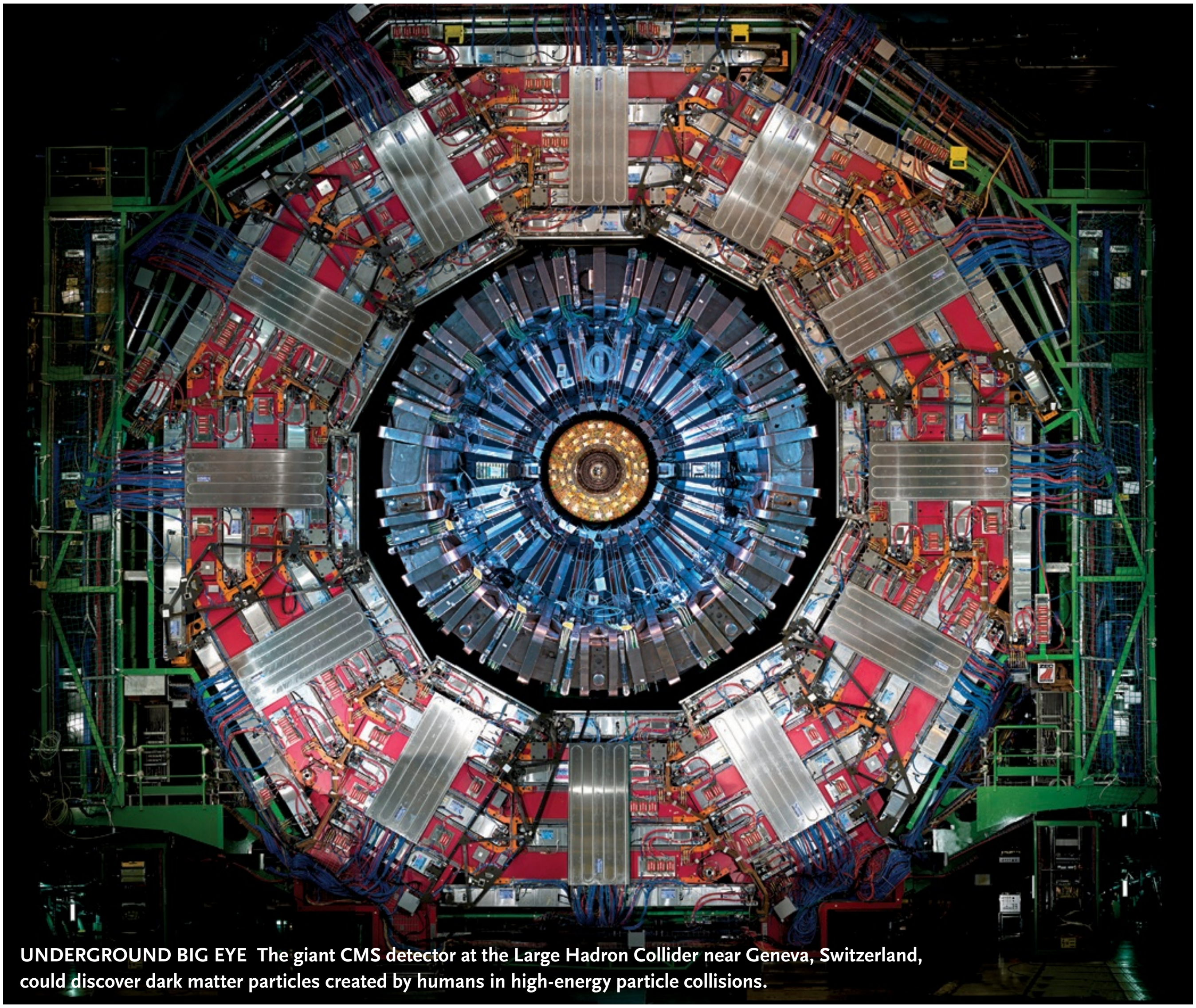
Senior contributing editor ***J. Kelly Beatty*** *has covered missions to the Red Planet since the mid-1970s and cheered at JPL in Pasadena when Curiosity nailed its dramatic landing.*

- **Mars Hand Lens Imager (MAHLI)**, also on the robotic arm, is a color camera that can resolve details down to 0.001 inch (14 microns). Two LEDs allow it to take images in shadow or at night.
- **Mast Camera (Mast Cam)** is a pair of 2-megapixel color imagers with focal lengths of 34 and 100 mm. They are mounted about 6½ feet (2 meters) above the ground.
- **Radiation Assessment Detector (RAD)** monitors high-energy atomic and subatomic particles from the Sun and cosmic sources.
- **Rover Environmental Monitoring Station (REMS)** measures air temperature and pressure, wind speed and direction, relative humidity, and ultraviolet intensity of sunlight.
- **Sample Analysis at Mars (SAM)** heats rock powders to 1800°F (1000°C) and then determines their elemental and isotopic composition (including organic content) by ionizing them and watching how they behave in electric and magnetic fields. A gas chromatograph also analyzes atmospheric composition.

For more images and updates about Curiosity, visit **skypub.com/Curiosity**.

Dark Matter in the

Using a variety of experiments, scientists might be on the



UNDERGROUND BIG EYE The giant CMS detector at the Large Hadron Collider near Geneva, Switzerland, could discover dark matter particles created by humans in high-energy particle collisions.

CERN / CMS COLLABORATION

Dan Hooper This year marks the 80th anniversary of the first evidence for dark matter. But after eight decades, we still don't know what makes up this elusive material. Although astrophysicists are more confident than ever that most of our universe's mass consists of dark matter, we have so far come up nearly empty-handed in our quest to understand its nature.

The story of dark matter began in 1933, when the brilliant but eccentric Caltech astrophysicist Fritz Zwicky recognized something strange in the Coma Cluster of galaxies. Although Coma's galaxies appear to be bound together by gravity, they are moving far too fast to avoid flying apart and breaking up the cluster. And yet some-

Discovery Age

verge of cracking one of their most perplexing mysteries.

how Coma remained intact. Were the stars in this distant cluster heavier than those in our galaxy? Do the laws of physics vary from place to place? Are we witnessing Coma in the act of breaking apart even though the odds of catching such a rare event are vanishingly small? After considering various possibilities, Zwicky speculated that if Coma contains huge quantities of invisible matter, this could explain the puzzle. With that idea, the dark matter hypothesis was born.

Since the 1930s, the possibility that invisible matter is abundant in our universe has taken many turns. Zwicky's papers on Coma failed to persuade many scientists at the time, but by the late 1970s, the body of evidence in favor of dark matter had become compelling enough to convince much of the astronomical community that there really is a "missing mass" problem. Detailed observations by Vera Rubin, Kent Ford, and others of galaxy rotations made it clear that the matter we can see in our telescopes — stars and gas — cannot by itself explain the motions of many galaxies and clusters of galaxies. Physicists currently estimate that about five-sixths of our universe's mass consists of dark matter.

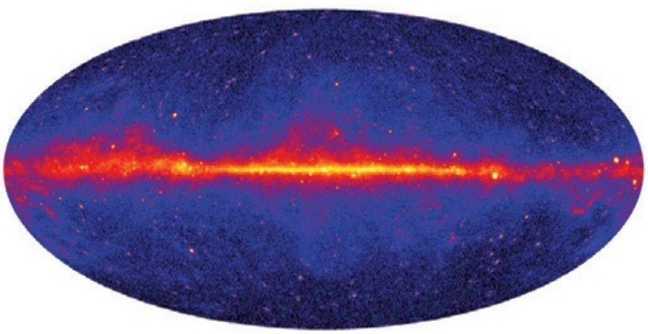
Possibilities for what might constitute this missing mass include exotic stars that are too faint to be easily detected with telescopes. But astronomical searches for white dwarfs, neutron stars, and other dim objects failed to find enough of them to solve the problem. Recent searches have also ruled out the idea that dark matter is made up of planets, brown dwarfs, and massive black holes. Whatever the dark matter is, it's not made up of atoms — or of any other known form of matter.

As a more radical alternative, some physicists considered the possibility that gravity might work differently than Isaac Newton or Albert Einstein had predicted, altering how galaxies should rotate and removing the need for dark matter. And while this idea — called MOND, for modified Newtonian dynamics — seemed initially prom-

COMA CLUSTER: NOAO; F. ZWICKY: S&T ARCHIVE; V. RUBIN: CARNEGIE INSTITUTION; GALAXY NGC 1232: ESO / NAOJ / ROBERT GENDLER

DARK MATTER DISCOVERERS There was no single "eureka moment" that convinced the scientific community to accept the idea that the universe contains huge amounts of invisible mass. But Fritz Zwicky's studies of the motions of galaxies in the Coma Cluster *(top)* and Vera Rubin's measurements of the rotation rates of spiral galaxies were pivotal pieces of evidence that there's much more to the universe than meets the telescopic eye.

FERMI IMAGE: NASA / DEPT. OF ENERGY / INTERNATIONAL LAT TEAM; ABELL 520: NASA / ESA / CFHT / CXO / M. J. LEE (UC DAVIS) / A. MAHDAVI (SFSU)



MAPPING THE INVISIBLE *Above:* By carefully measuring how background galaxies are gravitationally lensed by mass in foreground clusters of galaxies, astronomers have been able to map how dark matter is distributed. In this composite image of the cluster Abell 520, dark matter appears blue, hot X-ray emitting gas (mapped by Chandra) appears green, and starlight is orange.

GAMMA-RAY SKY *Left:* NASA's Fermi Gamma-ray Space Telescope acquired this map showing the intensity of gamma rays across the entire sky. The bright horizontal band is emission from the galactic plane. Bright dots mark the locations of pulsars and supermassive black holes. Some scientists have suggested that certain regions of excessive gamma-ray emission (particularly toward the galactic enter) might come from dark matter particles annihilating one another, but as yet there is no consensus.

ising, more recent observations of galaxy clusters and the cosmic microwave background have come down strongly in favor of dark matter and against MOND.

All indications point to the conclusion that galaxies and clusters of galaxies are embedded within enormous clouds (halos) of invisible dark matter particles, known as *WIMPs* (short for weakly interacting massive particles). Although these particles are likely to be all around us, they interact so little with familiar forms of matter that they entirely evade our direct observation. That is, until now.

Can You See a Discovery Coming?

Many of the most important discoveries in the history of science seem to have come like a thief in the night, taking almost everyone utterly by surprise. Occasionally, however, a major scientific achievement can be foreseen. Consider the recent discovery of the Higgs boson at the Large Hadron Collider (LHC) near Geneva, Switzerland (*S&T*: October 2012, page 16). Particle physicists had a pretty good idea of the Higgs boson's properties and what kind of experiments could observe it. Although the Higgs turned out to be too heavy to be seen definitively in earlier experiments, the physics community was all but certain that if the Higgs exists, the scientists operating the LHC should be able to discover it unambiguously. You could see it coming.

By similar reasoning, if dark matter consists of WIMPs, then we have a pretty good idea of what types of experiments we will need to carry out in order to observe these particles directly. For decades, scientists have developed and improved these experiments, moving closer and closer to the sensitivity likely required to detect WIMPs. These technologies include deep underground experiments that are designed to detect the impacts of individual dark matter particles. They also include telescopes that are searching for the energetic particles and radiation that are produced when dark matter particles interact; NASA's Fermi Gamma-ray Space Telescope is arguably the most promising of these experiments (*S&T:* April 2009, page 22). And lastly, the prospect of actually creating and directly inferring the existence of dark matter particles has become a major goal of the LHC.

Although theoretical research hasn't given us as much guidance about the detailed characteristics of WIMPs as it did about the Higgs boson, most dark matter theories have a great deal in common and lie well within the reach of this triad of experimental strategies. If dark matter takes the form of a WIMP, as many of my colleagues and I think is probable, then the WIMPs are unlikely to remain hidden for much longer. The discovery of dark matter seems almost imminent.

Going Deep (Underground)

Over the past 25 years, physicists have carried out numerous experiments in deep underground mines in the hopes of observing the weak collisions of incoming dark matter particles. These subterranean experiments are largely protected from cosmic rays, which on Earth's surface make it impossible to observe the occasional signal of a dark matter particle. Unlike cosmic rays, and unlike most familiar forms of matter, dark matter can travel through Earth without being deflected or absorbed. Once a WIMP penetrates through the crust to reach an underground detector, there's only a tiny chance it will strike an atomic nucleus within a detector. Like a cue ball on a billiard table, such a collision causes some of the WIMP's energy to transfer into its target — producing a tiny but measurable thermal or light signal. The various teams use different materials in their detectors, making them sensitive to different ranges of WIMP masses. These experiments sit patiently for years, waiting for those elusive WIMPs to come by and reveal their presence.

One of the most sensitive of these many experiments is XENON-100. It makes use of 161 kilograms (355 pounds) of liquid xenon as a target for WIMPs, and is located 1.5 kilometers (0.9 miles) below Earth's surface in Italy's Gran Sasso National Laboratory. If the dark matter takes the form of particles that are between about 10 and a few thousand times as massive as the proton, then XENON-100 should be able to detect their impacts. In July 2012, the XENON team announced very impressive

DARK MATTER: ONE OR MANY PARTICLES?

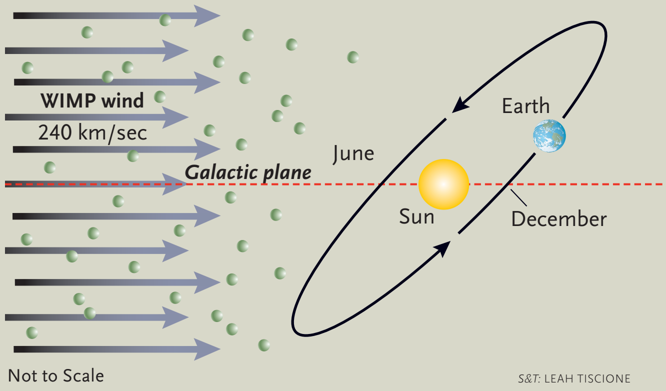
At first glance, the familiar types of matter that make up the many different elements of the Periodic Table may seem complicated. But the 118 known elements are, in fact, all combinations of only three types of particles: electrons, up quarks, and down quarks. Because these three types of particles interact strongly and electromagnetically with one another, they can combine in a wide variety of forms. In contrast, dark matter particles must not experience these kinds of interactions or else we would have detected them already. So unlike the particles that make up atoms, dark matter particles interact too feebly to bind together into many different combinations. For this reason, it seems likely that the dark matter is comparatively simple, consisting mostly of only one type of particle.

XENON COLLABORATION

SEARCHING FOR WIMPS The XENON-100 team looks for dark matter particle interactions with a 161-kilogram detector containing chilled liquid xenon buried deep underground at Italy's Gran Sasso National Laboratory. This image shows team members working on the detector's inner structure.

WIMP WIND

Due to Earth's motion around the Sun and the solar system's motion around the center of our galaxy, our planet is expected to collide with dark matter particles more often in the early summer than in the winter. For 13 years, the DAMA experiment has seen a seasonal modulation in particle detections consistent with this picture, and another team has seen a similar effect. But other experiments have not seen such a signal, so the scientific community has not yet reached a consensus on whether DAMA has actually detected dark matter particles.



S&T: LEAH TISCIONE

new results from its ongoing search. Although XENON-100 does not appear to have detected any WIMPs yet, its lack of a detected signal has ruled out many hypothetical kinds of WIMPs.

In recent years, underground detectors have been increasing in sensitivity at a steady and impressive rate. Much like Moore's law, which describes how computer chips have approximately doubled in speed every 18 months since the early 1970s, dark matter detectors have doubled in sensitivity every 15 months over the past dozen years or so. This trend will probably continue for at least another decade, making it likely that these experiments will soon become powerful enough to test the vast majority of WIMP theories. I would be surprised if another 5 or 10 years pass without the appearance of signals from WIMPs.

In fact, the scientists behind an experiment called DAMA have been claiming to have actually detected such particles. DAMA's target consists of 250 kg of sodium iodide crystals, and is also located underground at Gran Sasso. For the past 13 years DAMA has observed a seasonal variation in its signal, with more events occurring in summer than in winter. According to the DAMA team, this annual modulation is due to Earth's orbital motion around the galactic center and the Sun. In the Northern Hemisphere summer, Earth's orbit around the Sun causes it to plow headlong into the invisible cloud of galactic WIMPs, increasing the rate at which WIMPs hit DAMA's detector.

More recently, two other collaborations — CoGeNT and CRESST — have reported observations that seem to support DAMA's claim, while others have failed to see the signals we would've expect from a DAMA-like WIMP. At the moment, no consensus has been reached on whether DAMA, CoGeNT, and CRESST are seeing dark matter particles or are merely being tricked by some poorly understood background that somehow manages to mimic the signal we have long expected to see from WIMPs.

The Swiss Dark Matter Factory

Almost all the matter in our universe — dark or otherwise — can trace its origin to the first fraction of a second after the Big Bang. In that brief instant, all of space was filled with an incredibly hot, dense plasma of matter and energy. Particles were constantly being created and destroyed, flashing in and out of existence. And because energy was so plentiful in this primordial soup, many forms of exotic matter were created alongside those that we're more familiar with.

Dark matter and other exotic particles were created in the Big Bang inferno thanks to $E = mc^2$. With a mere five symbols, Einstein's equation captures the fact that energy (E) can be transformed into mass (m), and vice versa. But the exchange rate between mass and energy is pretty steep — it requires a great deal of energy to create even modest amounts of mass. Spontaneously creating electrons, for example, requires temperatures about

CDMS-II AND SUPERCDMS COLLABORATIONS

UNDERGROUND EXPERIMENTS ***Above:*** **Members of the CDMS-II team install a six-detector tower in 2004.** ***Right:*** **The XMASS detector in Japan, inside this sphere, contains 800 kilograms of liquid xenon.**

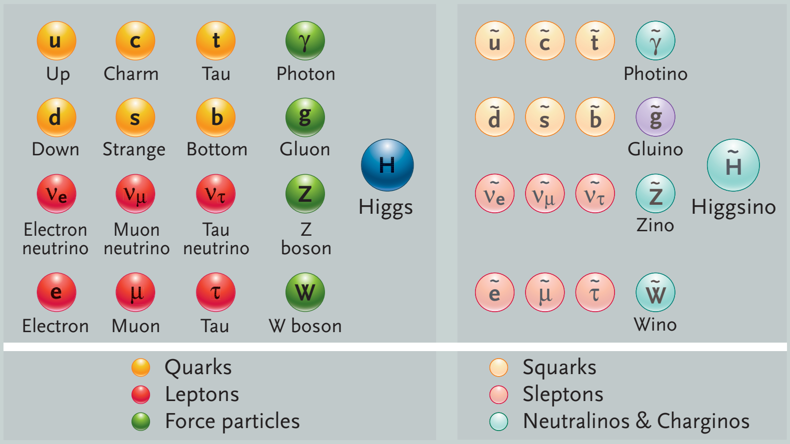
1,000 times hotter than the Sun's core. In the Big Bang's intense heat, the temperature was so high that electrons and other familiar forms of matter were created in vast numbers, but so were WIMPs. Although theory predicts that most of those WIMPs quickly annihilated one another, a small fraction managed to survive and remain in existence today in the form of dark matter.

In a circular tunnel 27 kilometers (17 miles) in circumference, the Large Hadron Collider re-creates the conditions of the Big Bang. The LHC accelerates beams of protons to velocities in excess of 99.999999% of the speed of light. When these beams are directed head-on into one another, the proton collisions contain as much energy as those that took place during the first trillionth of a second of our universe's existence. It's likely that the LHC is creating dark matter particles — our very own WIMP factory. LHC operations may represent the first time since the Big Bang that significant quantities of dark matter have been created anywhere in our universe.

But even if the LHC is busy creating WIMPs, it may be difficult to prove it. This machine smashes hundreds of millions of pairs of protons together in a second, and only a tiny fraction of those collisions are expected to produce dark matter particles. So looking for signs of WIMPs in these collisions can be like looking for a needle in a haystack. Making matters worse, the detectors cannot see the WIMPs directly — these particles are invisible to the LHC for the same reason they are invisible to our telescopes. So instead of being observed directly, the presence

KAMIOKA OBSERVATORY / INST. FOR COSMIC RAY RESEARCH / UNIV. OF TOKYO

How Particle Physicists Learned to Stop Worrying and Love WIMPs



S&T: LEAH TISCIONE; SOURCE: DAN HOOPER

SUPERPARTNERS According to supersymmetry, and as depicted above, every familiar matter particle has a supersymmetric counterpart. Theory predicts that most of these particles are unstable, so the ones produced in the Big Bang have long since decayed. But the lightest superpartner, the neutralino, is thought to be stable, and its predicted properties make it an ideal candidate for dark matter.

Astrophysicists and particle physicists often see dark matter through different lenses. As a group, astrophysicists tend to focus on the observational evidence for dark matter and on the findings of computer simulations designed to study how dark matter halos form and evolve (*S&T:* July 2012, page 28). Although astrophysicists generally agree that a new type of particle (or particles) is needed to solve the dark matter problem, they tend to shy away from hypothesizing new varieties of exotic matter.

In contrast, particle physicists were initially less willing to accept the evidence for dark matter's existence, but they have no hang-ups about hypothesizing new types of particles. Over the years they have literally proposed hundreds (if not thousands) of theories predicting the existence of new particles or forces. A substantial fraction of these theories predict the existence of new particles with the characteristics required of a WIMP, and thus could potentially solve the dark matter problem. The most compelling and popular idea among particle physicists is *supersymmetry*.

Supersymmetry postulates a fundamental relationship between the classes of particles known as *fermions* and *bosons*. Fermions are particles such as quarks and electrons, which make up what we normally think of as matter. In contrast, bosons are the particles responsible for the forces of nature. Photons, for example, are the bosons that transmit the electromagnetic force. Without photons, there would be no electromagnetism — no light. According to supersymmetry, for every type of fermion, there must also exist a boson with many of the same properties. Every kind of particle thus has a supersymmetric counterpart, called its "superpartner." The electron, for example, has as its partner the super-electron, just as the photon has its photino. Bosons and fermions are intertwined, unable to exist without each other. A boson in a supersymmetric world without its fermion counterpart would be like a one-sided coin.

To date, none of the predicted superpartners have been observed in any

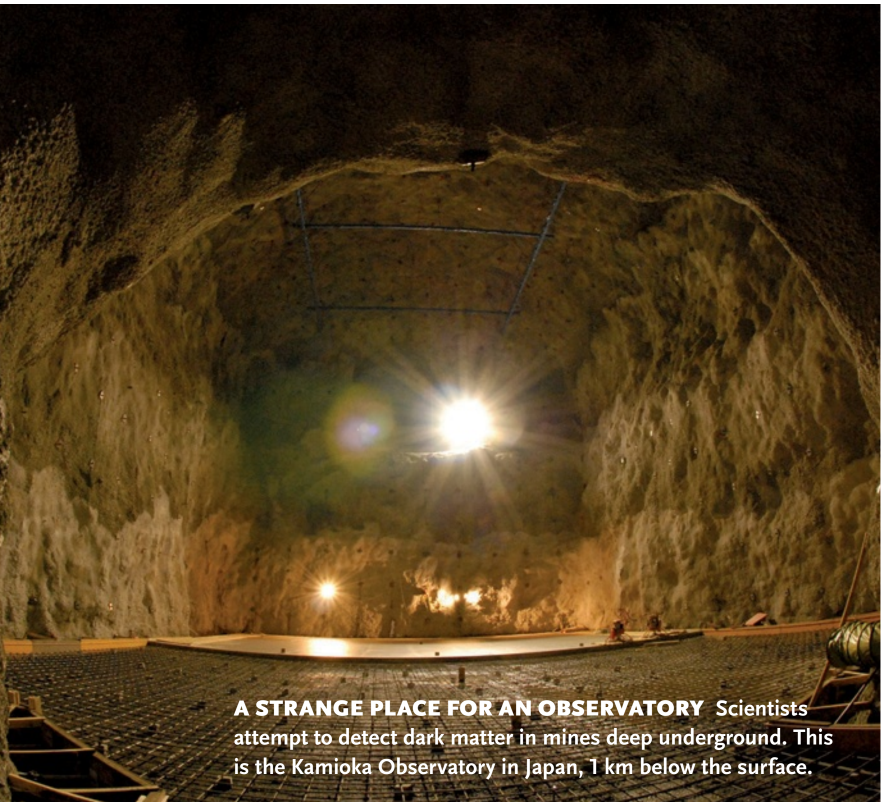
Continued on page 32

of dark matter particles can only be inferred by noticing a conspicuous absence of energy coming out of a tiny fraction of the collisions. LHC scientists are looking for an invisible needle in a very complicated haystack.

No signs of WIMPs have yet appeared at the LHC, but we have only seen the tip of the data iceberg. The LHC is scheduled for a temporary shut down in February for a planned upgrade that will almost double the amount of energy in every collision. An entire generation of physicists has been waiting decades to finally learn what the LHC is going to teach us. I, for one, will be quite surprised if it does not reveal many new, exciting, and unexpected things about the universe. If we're a little lucky, it may even reveal to us what Zwicky's dark matter is made of. ✦

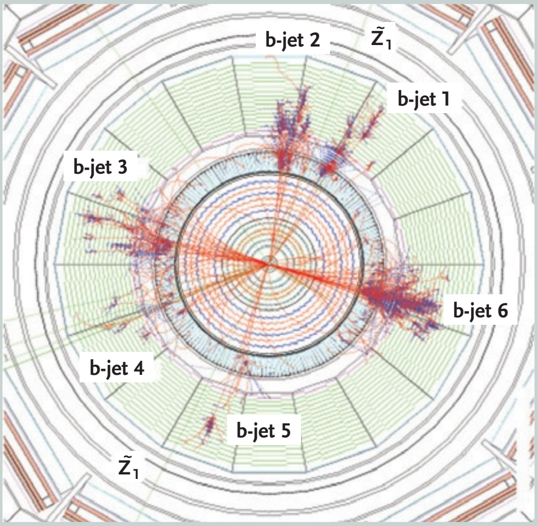
Dan Hooper is a theoretical physicist at Fermilab and an Associate Professor of Astronomy and Astrophysics at the University of Chicago. He is the author of Dark Cosmos: In Search of Our Universe's Missing Mass and Energy *and* Nature's Blueprint: Supersymmetry and the Search for a Unified Theory of Matter and Force. *His research investigates topics including dark matter, supersymmetry, neutrinos, extra dimensions, and cosmic rays.*

To view a table listing underground dark matter experiments and their characteristics, visit skyandtelescope.com/darkmatter.



KAMIOKA OBSERVATORY / INST. FOR COSMIC RAY RESEARCH / UNIV. OF TOKYO

A STRANGE PLACE FOR AN OBSERVATORY Scientists attempt to detect dark matter in mines deep underground. This is the Kamioka Observatory in Japan, 1 km below the surface.



HOWARD BAER (UNIV. OF OKLAHOMA) / SALAVAT ABDULLIN (FERMILAB)

SUPERSYMMETRY SIGNATURE Physicists produced this simulation of the aftermath of a proton-proton collision at the LHC that has sufficient energy to create two supersymmetric particles. Those particles quickly decay, releasing six jets and two additional dark matter particles. The LHC detector will not actually "see" the dark matter, but physicists can infer its presence by noting an amount of "missing" energy.

Continued from page 31

experiment. Despite this lack of evidence, many particle physicists find supersymmetry so compelling that they remain fairly confident that these particles exist — just waiting to be discovered. If supersymmetry is woven into the fabric of nature, then a number of long-standing problems in theoretical physics can be easily solved. In particular, without supersymmetry, it's very difficult to understand why the weak nuclear force is a whopping 10^{32} times stronger than the force of gravity. Efforts to build a Grand Unified Theory that connects the four forces of nature into a single force also seem to require that nature be supersymmetric. Furthermore, the only forms of string theory that seem workable are those including supersymmetry.

Supersymmetry can also provide us with a solution to the dark matter problem. In many supersymmetric models, the lightest of the superpartners is stable, and is unaffected by the strong or electromagnetic forces — *exactly* the properties required of the particle that makes up dark matter. This superpartner, the *neutralino*, has for decades been the single most popular WIMP candidate for dark matter.

It's been disappointing that the LHC has not yet seen copious neutralinos and other superpartners pouring out of its detectors. Perhaps we will observe the first superpartners sometime in the years after the accelerator is upgraded to higher energy (from 8 to 14 tera-electron volts). If supersymmetry exists, the LHC should ultimately produce and observe at least some of the superpartners. If, after several more years of searching, no such evidence emerges, then the theoretical physicists will be humbly sent back to their chalkboards, tasked to find some other solution to the problems that now only supersymmetry seems able to address. — *D. H.*

Hot Products for 2013

Each year since 1998, S&T's editors have surveyed the astronomical marketplace and selected what they consider the year's most interesting new products. From telescopes and eyepieces to books and globes, our 2013 roundup is one of the most varied in recent memory. And with costs ranging from a $2 weather app to a $13,000+ telescope mount, it spans the price gamut as well. As always, we hope you enjoy reading about the new products that intrigued us the most for 2013.

▲ WEATHER APP

Egg Moon Studio From the iTunes store

U.S. price: $1.99

There's no shortage of weather-related apps for the iPhone, but there's only one specifically made for amateur astronomers. *Scope Nights* gives a 5-day "snapshot" summary of nighttime conditions in the United States and United Kingdom. Our resident weather maven, who uses more than a half dozen apps and websites to prepare similar predictions, gives *Scope Nights* two thumbs up for its consistent accuracy.

▼ REDBEAM USB LED KEYBOARD LIGHT

Orion Telescopes & Binoculars oriontelescopes.com

U.S. price: $29.99

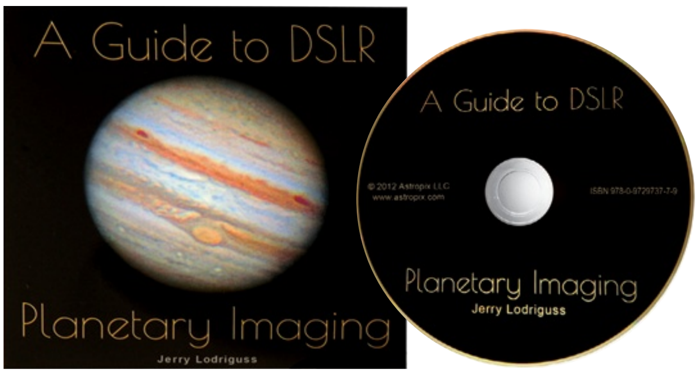
Here's a nifty alternative for those of us who are tired of clenching a flashlight between our teeth while using a computer in the dark. Powered by a computer's USB port, Orion's Keyboard Light offers multiple brightnesses and a flexible neck for easy positioning of the red LED illumination to where it's needed.

▼ *A GUIDE TO DSLR PLANETARY IMAGING*

Astropix astropix.com

U.S. price: $39.95

This CD-ROM book by veteran astrophotographer Jerry Lodriguss tells all you need to know about capturing and processing stunning images of the Sun, Moon, and planets using the live video feed from modern DSLR cameras. You can check out Jerry's overview of this topic in our May 2012 issue, page 72.



▼ TEMP-EST

Deep Space Products
deepspaceproducts.com
U.S. price: from $135
The TEMP-est cooling system for Celestron EdgeHD telescopes is different from other cooling systems. Small, custom-fitted fan assemblies replace the telescope's standard cooling vents. They are designed to run while the scope is in use, helping maintain the scope's optics at ambient temperature during the night. Another fan, which temporarily mounts in place of the scope's removable secondary mirror, assists with initial cool down of the optical tube assembly.

▲ PENTAX LENS ADAPTER

Quantum Scientific Imaging qsimaging.com
U.S. price: $289
Cooled, astronomical CCD cameras fitted with conventional camera lenses can capture dramatic wide-field views of the heavens. QSI has adapters for Canon and Nikon lenses that fit some of its cameras, but they don't work with the company's WSG models, which require added back focus for the off-axis guider port. That changes with the new lens adapter made for Pentax 67 (medium-format) lenses. Fitted to any WSG camera body, the adapter allows all Pentax 67 lenses to reach focus. An added bonus is that Pentax 67 lenses are renowned for their astronomical performance, especially in light of their reasonable price tags.

▲ LX600 TELESCOPES

Meade meade.com
U.S. price: from $4,499
Fork-mounted Cassegrain telescopes have been amateur astronomy's undisputed workhorse instruments for a quarter century. Meade's new LX600 series represents a major update to the design, bringing the company's latest optical, mechanical, and electronic innovations to the genre. Among the most noteworthy enhancements is Meade's new StarLock technology, which automatically begins precision guiding the scope each time it is pointed at a new target.

▲ MOON GLOBES

Sky & Telescope shopatsky.com

U.S. price: Moon Globe, $99.95; Topographic Moon Globe, $109.95

We would have picked these 12-inch globes even if they weren't our own products! Based on 15,000 images from the Lunar Reconnaissance Orbiter (LRO), the Moon Globe is the first to portray the entire lunar surface with true photographic detail. The Topographic Moon Globe goes a step further, adding color-coded altimetry data from LRO. This highlights dramatic variations in lunar elevations, revealing features such as huge impact basins that are all but invisible on other Moon globes.

▼ 1600GTO MOUNT

Astro-Physics astro-physics.com

U.S. price: $11,700

After more than 30 years of experience building some of the industry's finest telescope mounts, Astro-Physics has unveiled a replacement for its highly acclaimed 1200GTO German equatorial mount. The new heavy-duty 1600GTO features more than a dozen major mechanical improvements, including larger gears, more powerful motors, and the option to install high-resolution shaft encoders that can deliver virtually error-free tracking. The encoders can be ordered with the mount or added at a later date. The 1600GTO has a rated load capacity of about 220 pounds (100 kg).

▲ SV50A ED APO REFRACTOR

Stellarvue stellarvue.com

U.S. price: $499

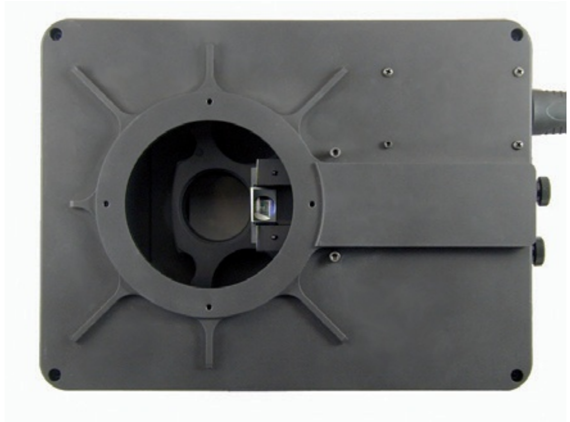
This little apo refractor created quite a buzz among amateur astronomers when it was introduced at last year's Northeast Astronomy Forum in New York (see our August 2012 issue, page 38). The 50-mm f/6.6 doublet objective has one element made from extra-low dispersion glass for superb color performance. The SV50A comes with a dual-speed, 2-inch, rack-and-pinion focuser. A package deal that includes the scope plus a 2-inch star diagonal, clamshell mounting ring with a Vixen-style dovetail bar, and padded carrying case costs $599.

◀ POLAR SCOPE

Astro-Physics astro-physics.com

U.S. price: $390

This right-angle polar-alignment scope has a 6° field of view, high-quality optics, and an illuminated reticle. To achieve precision polar alignment you simply move your telescope mount until Polaris (Northern Hemisphere) or Sigma Octanis (Southern Hemisphere) is properly positioned on the scope's unique reticle. This position is graphically displayed by Astro-Physics's software, including an iPhone app (an Android app is in the works). While the polar-alignment scope is designed for Astro-Physics mounts, do-it-yourselfers could adapt it to others.



▲ AUTOGUIDING FILTER WHEEL

SBIG sbig.com

U.S. price: $1,995

By placing the off-axis autoguiding system in front of the filters in their new 8-position filter wheel, the folks at SBIG have solved a long-standing problem. With starlight used for autoguiding no longer dimmed by the filters, it's much easier to find a suitable guide star. The autoguider's focus is adjustable as is the pick-off mirror's radial distance from the optical axis. Made for the STT line of SBIG cameras, the filter wheel accepts 1¼-inch and 31-mm filters. It also places filters in precisely the same location each time they are returned to the imaging position, thus ensuring that any dust specks appearing in light and flat-field images will properly align during image calibration.

▶ NIGHTSCAPE 8300

Celestron celestron.com

U.S. price: $1,699

What do you get when you combine one of astrophotography's most popular CCD chips with a camera system that received high praise in a recent *S&T* review (May 2012 issue, page 64)? In our view, you get a Hot Product. One of this camera's biggest features is its supplied software, which transforms the typically complex routines involved with taking and processing astronomical images to a series of simple steps with default selections that create stunning results.

▶ EOS 60Da CAMERA

Canon usa.canon.com

U.S. price: $1,499

For only the second time in history, a major camera company has introduced a DSLR camera modified specifically for astrophotography. Like its discontinued EOS 20Da predecessor, the new Canon EOS 60Da employs a special filter in front of its CMOS sensor, which transmits a greater percentage of deep red hydrogen-alpha light than the filters used in conventional cameras. As our in-depth review of the 60Da explained (September 2012 issue, page 38), this makes the camera much better for recording bright emission nebulae.

▲ DELOS EYEPIECES

Tele Vue Optics televue.com

U.S. street price: $335 each

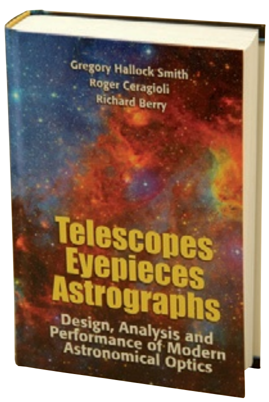
When Tele Vue introduced its 6- and 10-mm Delos eyepieces in 2011, the design, at least on paper, didn't push the optical envelop in the same way that many of the company's previous introductions had. What didn't show on paper, however, was the remarkably pleasurable observing experience that came with each look into the new eyepieces. Accolades quickly began rolling from observers around the world, and Tele Vue responded by expanding the Delos line. There are now eight models ranging in focal length from 3.5 to 17.3 mm. All include the same 72° apparent field of view, 20 mm eye relief, and large eye lens as the originals.

► iEQ30

iOptron ioptron.com

U.S. price: $1,299

The iOptron iEQ30 German equatorial mount stood out in our mind not because it broke any records, but rather because it hit so many sweet spots. Its relatively compact size, light weight, excellent Go To performance, smooth tracking, and moderate load capacity make it an ideal mount for meeting the needs of today's typical observers and astrophotographers. See our review in the October 2012 issue, page 60.



◄ *TELESCOPES, EYEPIECES, AND ASTROGRAPHS*

Willmann-Bell willbell.com

U.S. price: $39.95

If you've ever gotten the urge to look under the hood and find out what makes your telescope tick, this is the book for you. Authors Gregory Smith, Roger Ceragioli, and Richard Berry provide an overview of what it takes to make good optics for visual and imaging applications. They then go on to analyze many of today's designs to see how they perform.

▶ NANO TRACKER

Sightron available in U.S. from hutech.com

U.S. price: $299

Small motorized mounts for wide-field astrophotography with DSLR cameras are becoming increasingly popular. Just attach a camera to the tracker (a ball head mount helps with framing photos), place the tracker on a camera tripod for quick polar alignment, and you're ready to shoot short exposures of the night sky. The fist-size Nano Tracker is the smallest and least expensive model we've seen so far. In addition to its sidereal tracking rate, there's a half-speed rate that balances motion blur between the foreground and sky.

◀ ETX-90

Meade meade.com

U.S. price: $399

The Autostar version of the ETX-90 telescope revolutionized observing when it was introduced in late 1999. Priced at $750, it was the first telescope to offer Go To pointing for less than several thousand dollars. The retooled ETX-90 unveiled last year goes further; its $399 price is well below half the cost of the original in today's dollars. While the new scope still features the same high-quality 90-mm f/13.8 Maksutov-Cassegrain optics as the original, it adds a host of internal improvements, both mechanical and electronic. The supplied tripod makes it a ready-to-use scope without additional accessories.

▼ FOCAL REDUCER

Celestron celestron.com

U.S. price: $599

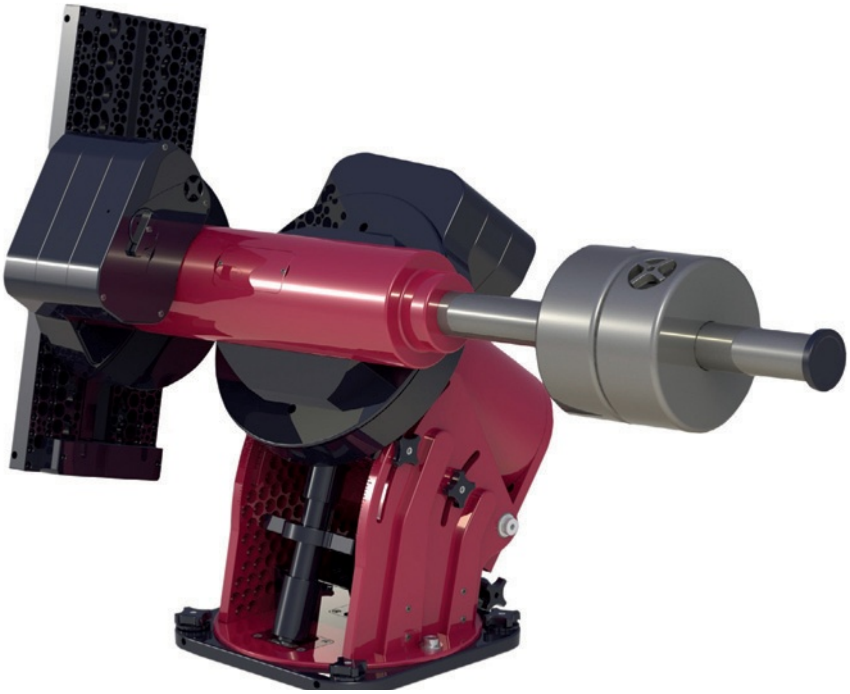
Celestron made major advances in the imaging capability of its venerable Schmidt-Cassegrain telescopes when it introduced its EdgeHD models (see our detailed review of the 14-inch EdgeHD scope in the February 2011 issue, page 52). The new 5-element, custom-designed EdgeHD 0.7x Focal Reducers for the 11- and 14-inch scopes take those advances yet another step forward, making the scopes a full photographic stop faster without sacrificing image quality.

▼ MINI MOUNT

iOptron ioptron.com

U.S. price: $399

A relative newcomer to the astronomical market, iOptron has grown to become a major supplier of telescope mounts. Its latest release, the SmartEQ, is the most portable Go To German equatorial mount we've yet seen. It features a retractable counterweight shaft, self-contained battery power, and a Vixen-style dovetail saddle. The 6¼-pound equatorial head couples with an included 5¾-pound tripod to form an extremely portable package suitable for cameras and small telescopes. Our review appears in the October 2012 issue, page 60.



▲ MAXI MOUNT

Software Bisque bisque.com

U.S. price: $13,500

The recognized industry leader in robotic telescope mounts, Software Bisque has totally redesigned its flagship German equatorial mount. The Paramount ME2 builds on the success of the company's smaller Paramount MX (reviewed in our July 2012 issue, page 64). The ME2 is engineered to accept optional high-resolution shaft encoders that will enhance the Paramount's already legendary tracking performance.

▸ WIRELESS LINK

Celestron celestron.com

U.S. price: $99.95

Celestron takes control of its latest Go To telescopes to the next level with the wireless SkyQ Link module. Just plug it into the scope to create a WiFi connection that allows operating the mount with the company's SkyQ app running on an iPhone or iPad, or with its *NexRemote* software running on a PC. You can generate custom sky tours with the software or tap on any object displayed on the app's sky maps to automatically point the scope to the target. See the company's website for a list of currently supported telescopes.

▼ GO TO DOBSONIAN

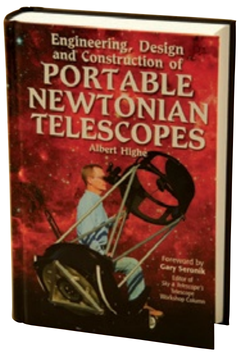
Orion Telescopes & Binoculars
oriontelescopes.com
U.S. price: $3,599.99
Orion's line of SkyQuest GoTo Truss Tube Dobsonian telescopes grew literally and figuratively with the introduction of this 16-inch f/4.4 model. Although the assembled scope weighs nearly 200 pounds (about 90 kg), it breaks down into manageable pieces for easy transportation to observing sites. The Go To system requires 12-volt DC power from batteries or an AC adapter, which are optionally available. Our review of the 8-inch SkyQuest Go To Dobsonian is in the May 2011 issue, page 52. ✦

▼ LOW-PROFILE FOCUSER

Orion Telescopes & Binoculars
oriontelescopes.com
U.S. price: $249.99
This low-profile, dual-speed, 2-inch focuser (it's only 58 mm tall when fully racked in) boasts numerous features, including the smooth operation of the Crayford design coupled with a lockable rack-and-pinion drive with helical gears that prevents slipping. The drawtube rides on eight roller bearings and the fine-focus knob offers an 11:1 speed reduction for precise focus control. Supplied with a 1¼-inch adapter, the focuser is rated for a load of more than 17 pounds (8 kg).

► STT CAMERAS

SBIG sbig.com
U.S. price: from $3,695
For nearly 25 years SBIG has built CCD cameras specifically for amateur astrophotographers. Its new STT line "represents the culmination of everything that the amateur has asked for in an imaging system," including Ethernet connectivity for remote access over the internet without having a computer directly connected to the camera.



◄ *PORTABLE NEWTONIAN TELESCOPES*

Willmann-Bell willbell.com
U.S. price: $39.95
Willmann-Bell's dedication to publishing material for telescope makers maintains a tradition begun a century ago when Russell W. Porter penned articles that launched the telescope-making movement in North America. Its latest release will help telescope builders design and construct instruments that are perfect for their needs. Included computer software lets you explore how various design parameters affect performance.

Look who made the "Nice List"
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In This Section

With the Sun now near the peak of its 11-year activity cycle, the long nights of winter are ideal for observing auroras at high latitudes.
PHOTOGRAPH: BABAK TAFRESHI / TWAN

Sky at a Glance

JANUARY 2013

2 **EARTH** passes through perihelion, its closest point to the Sun for the year (just 3% closer than at aphelion in July).

5, 6 **DAWN:** In the Americas, the Moon appears close to the right of Spica on the 5th and lower right of Saturn on the 6th.

10 **DAWN:** Venus shines a few degrees from the thin crescent Moon very low in the southeast 60 to 30 minutes before sunrise. See page 50.

12, 13 **DUSK:** A very thin crescent Moon is visible well to the right of 1st-magnitude Mars low in the southwest 30 to 60 minutes after sunset on the 12th. A thicker crescent Moon is well above Mars on the 13th.

20 **NIGHT:** Algol is at minimum brightness for roughly two hours centered on 9:48 p.m. PST (12:48 a.m. on the 21st EST); see page 53.

21 **EVENING AND NIGHT:** Jupiter is spectacularly close to the waxing gibbous Moon. They're closest — less than 1° apart as seen from most of the U.S. and Canada — around 11 p.m. EST (8 p.m. PST). The Moon occults (hides) Jupiter for much of South America.

23 **EVENING:** Algol is at minimum brightness for roughly two hours centered on 9:37 p.m. EST (7:37 p.m. MST).

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

◄SUNSET — MIDNIGHT — SUNRISE►

Planet	Visibility
Mercury	Invisible to the unaided eye all month
Venus	SE
Mars	SW
Jupiter	E S NW
Saturn	E S

Moon Phases

Last Qtr Jan. 4 10:58 p.m. EST

New Jan. 11 2:44 p.m. EST

First Qtr Jan. 18 6:45 p.m. EST

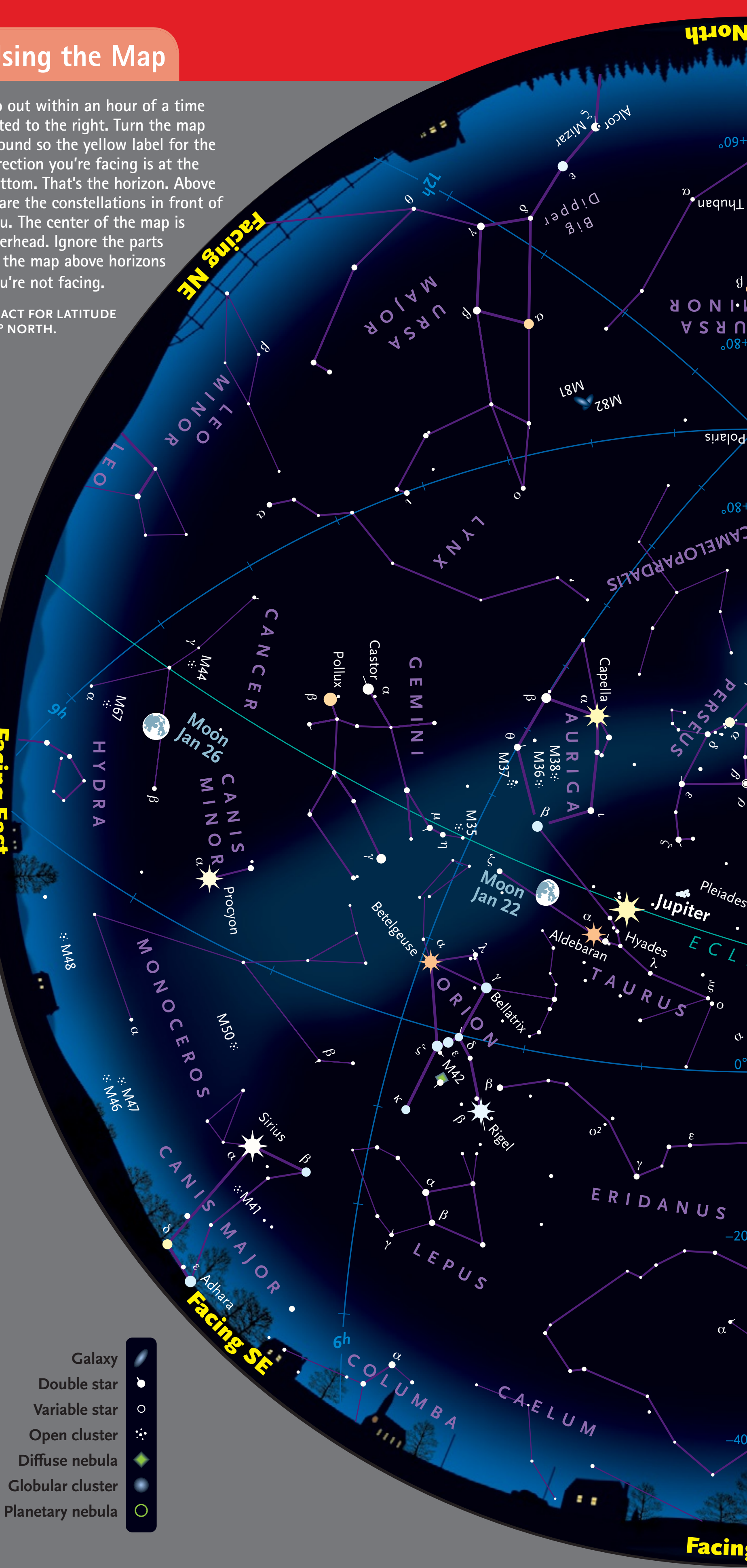
Full Jan. 26 11:38 p.m. EST

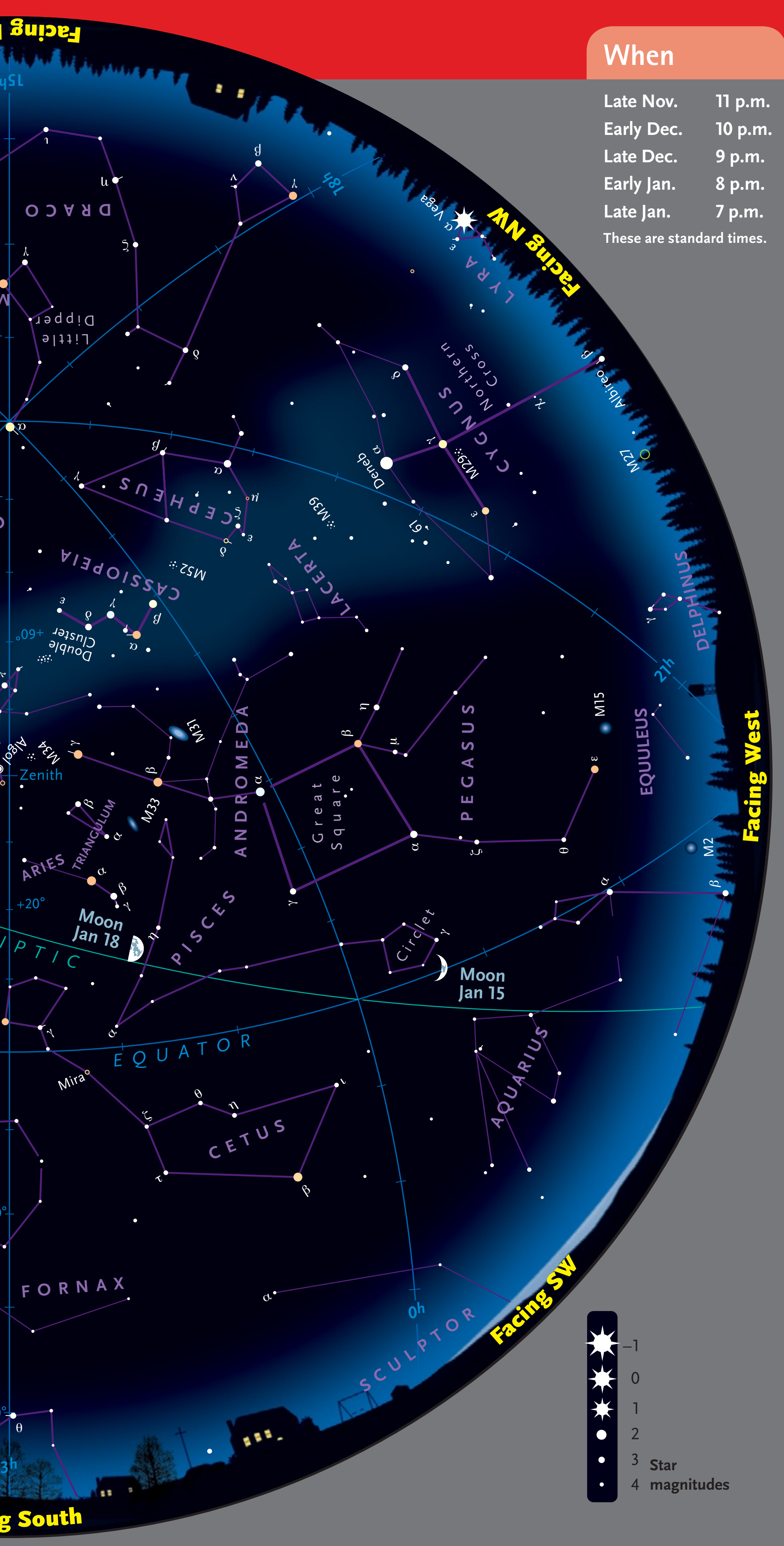
SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Using the Map

Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. Above it are the constellations in front of you. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.

EXACT FOR LATITUDE 40° NORTH.





When

Late Nov.	11 p.m.
Early Dec.	10 p.m.
Late Dec.	9 p.m.
Early Jan.	8 p.m.
Late Jan.	7 p.m.

These are standard times.

A Messier Miss

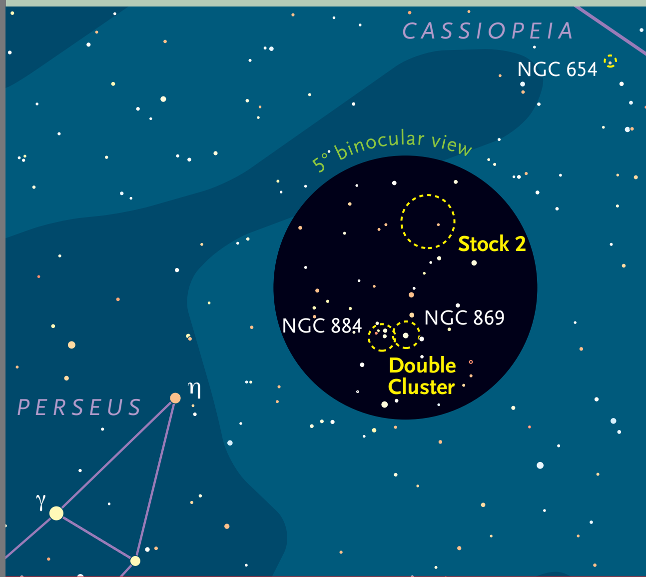
Here's a fun cloudy night activity. Take a moment and list your 10 favorite binocular sights. It doesn't have to be the 10 most spectacular — just the top 10 objects you find yourself returning to again and again. I'm willing to bet your list will have two things in common with mine. First, it'll be dominated by open clusters. Second, it'll include the Double Cluster in Perseus.

The Double Cluster goes by several names. The duo is listed as **NGC 884** (the easternmost clump) and **NGC 869**. They're also marked on some old charts as h and Chi (χ) Persei, or with their Herschel numbers (34^6 and 33^6). But more interesting than the designations they have is the one they lack — neither cluster made it into Charles Messier's catalog. It seems certain that Messier knew about the pair, but perhaps he didn't include them because he simply couldn't imagine anyone mistaking them for a comet.

In 10×50 binoculars the Double Cluster is full of non-cometary sparkle. Although quite similar in size and brightness, each grouping has its own character, and the longer you look the more distinct they appear. To my eyes, 884 seems richer than its neighbor, whose grainy glow is dominated by a pair of 7th-magnitude stars. The Double Cluster isn't the area's only delight. I also find my attention invariably drawn to the curving row of 6th-magnitude stars extending northward from 869 to the big, diffuse splash of faint starlight known as open-cluster **Stock 2**. This whole region is wonderful in any pair of binoculars.

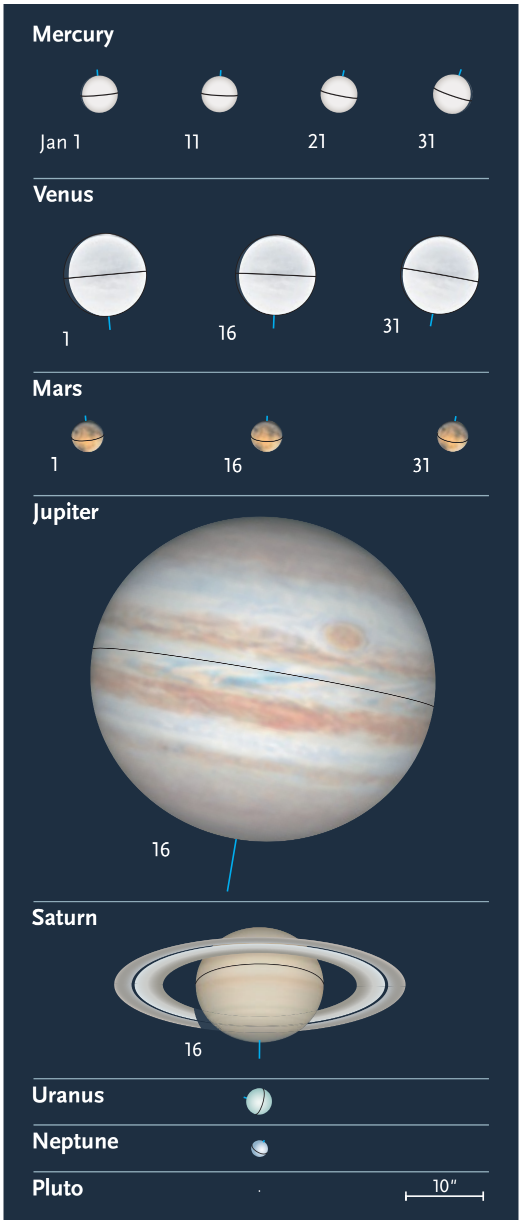
And if you want to share your top 10 list with me, I'd love to see it. You can reach me through my website, **www.garyseronik.com**. ✦

— ***Gary Seronik***



Watch a SPECIAL VIDEO

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

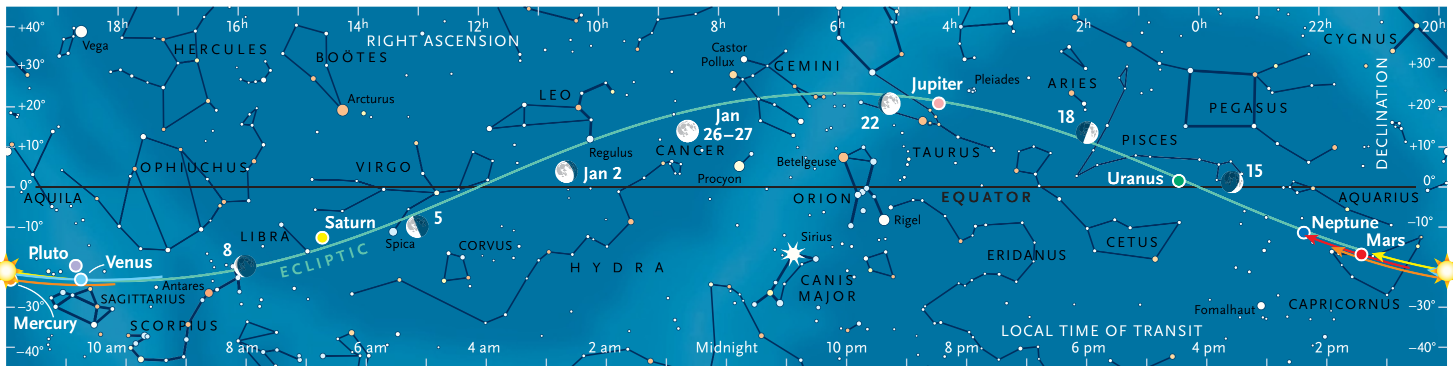


Sun and Planets, January 2013

	January	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h\ 45.9^m$	–23° 01′	—	–26.8	32′ 32″	—	0.983
	31	$20^h\ 54.2^m$	–17° 27′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$18^h\ 02.0^m$	–24° 15′	10° Mo	–0.6	4.8″	96%	1.400
	11	$19^h\ 11.1^m$	–24° 07′	5° Mo	–1.0	4.7″	99%	1.433
	21	$20^h\ 21.8^m$	–21° 35′	3° Ev	–1.4	4.8″	100%	1.409
	31	$21^h\ 31.9^m$	–16° 32′	9° Ev	–1.2	5.1″	96%	1.315
Venus	1	$17^h\ 14.9^m$	–22° 20′	21° Mo	–3.9	10.8″	94%	1.551
	11	$18^h\ 09.2^m$	–23° 09′	19° Mo	–3.9	10.5″	95%	1.586
	21	$19^h\ 03.6^m$	–22° 47′	16° Mo	–3.9	10.3″	96%	1.617
	31	$19^h\ 57.3^m$	–21° 16′	14° Mo	–3.9	10.1″	97%	1.644
Mars	1	$20^h\ 28.5^m$	–20° 15′	24° Ev	+1.2	4.2″	98%	2.225
	16	$21^h\ 16.5^m$	–17° 00′	21° Ev	+1.2	4.1″	98%	2.260
	31	$22^h\ 02.8^m$	–13° 05′	17° Ev	+1.2	4.1″	99%	2.293
Jupiter	1	$4^h\ 23.7^m$	+20° 53′	147° Ev	–2.7	46.8″	100%	4.210
	31	$4^h\ 17.5^m$	+20° 45′	115° Ev	–2.5	43.1″	99%	4.577
Saturn	1	$14^h\ 30.9^m$	–12° 24′	61° Mo	+0.6	16.2″	100%	10.228
	31	$14^h\ 37.6^m$	–12° 49′	90° Mo	+0.6	17.0″	100%	9.749
Uranus	16	$0^h\ 19.1^m$	+1° 19′	69° Ev	+5.9	3.5″	100%	20.387
Neptune	16	$22^h\ 14.3^m$	–11° 34′	36° Ev	+8.0	2.2″	100%	30.786
Pluto	16	$18^h\ 41.1^m$	–19° 47′	16° Mo	+14.2	0.1″	100%	33.311

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

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



The Sun and planets are positioned for mid-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). "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

***Fred Schaaf** has authored 13 books on astronomy.*

Fred Schaaf

The Depths of Space and Time

Astronomy and chronology walk hand in hand.

In Time like glass the stars are set,
And seeming-fluttering butterflies
Are fixéd fast in Time's glass net,
With mountains and with maids' bright eyes.

All these like stars in Time are set,
They vanish but can never pass;
The Sun that with them fades is yet
Fast-fixed as they in Time like glass.
— W. J. Turner, *In Time Like Glass*

How time flies! I have now completed two decades writing monthly stars and planets columns for *Sky & Telescope*, and this article begins my 21st year.

But time is strange — as conveyed so fascinatingly in the lines of poetry above. The start of a new calendar year gets all of us thinking about time. But astronomers have a perspective on time unlike anyone else's. We can see that by making some observations of the winter stars.

Touring space and time in the winter sky. It's often said that a telescope is a time machine. A good amateur telescope can even show you views of things as they were before the formation of the Sun and Earth — pre-solar light. (See, for instance, *S&T*: July 2012, page 57.)

But even a casual naked-eye glance at the bright winter constellations shows you stars as they looked decades, centuries, or even millennia ago.

There's a birthday, or rather, birth-year star, for everyone up there. If you're a child 8 or 11 years old, the light that you see from Sirius or Procyon left that star the year you were born. If you're 25, the light from Vega, now setting in the northwest, started its journey when you were born. The light we see this year left Pollux around 1979, Capella around 1970, Castor around 1961, and Aldebaran around 1947.

Look farther out into the winter night and you can see history. The light of the Pleiades left the cluster when Galileo was first turning a telescope upon the heavens. The Orion Nebula tonight is a medieval sight — the radiance that you see is more than a thousand years old. The light of the Double Cluster took flight from the Perseus Arm of our galaxy around 5,000 B.C. And we see M31, the great Andromeda Galaxy now high in the west, as it was more than 2 million years ago.

Astronomy gave birth to history. Studying the motions of the Sun, Moon, and stars allowed ancient peoples to know when to plant and harvest. Agriculture led to civilization, which in turn led to history — keeping written records. As Carl Sagan once said, we're all descended from astronomers.

Telling time has always been one of astronomy's main functions. Compare Stonehenge (*top*) with two sundials from contemporary craftsmen: a classic design by John Carmichael and a hypermodern precision model by Hoffmann Albin.

CLOCKWISE FROM TOP: F. VINCENT / WIKIMEDIA COMMONS; HOFFMANN ALBIN; JOHN CARMICHAEL

An instant and near-eternity. When I see a star twinkling —especially Sirius, the star of stars — I think how this beauty of an instant (light ruffled by Earth's turbulent atmosphere) comes from an object that may endure for billions of years. It was also Carl Sagan who helped us grasp such vast time periods by imagining a "cosmic calendar" — the entire 13.7-billion-year lifetime of the universe compressed into one year. Each second in this calendar is 434 years, and all the events of human history have occurred in the last quarter-minute of December 31st.

Average life expectancy in the rich countries is now about 80 years — 0.18 second on this scale. That's almost as fast as I used to average in double-clicking a stopwatch when timing meteors and grazing occultations.

Depressing? No! Carl Sagan also pointed out that what we do with our brief lives will have a powerful effect on what happens in the next second of the cosmic calendar — which begins now. ✦

Venus and Mars Edge Sunward

The planets of love and war start to vanish into twilight.

As darkness falls on January evenings, dim Mars is low in the southwest, and superbright Jupiter is well up in the east or southeast. Jupiter remains high, inviting telescopic observation for most of the night. Saturn rises a few hours after midnight but is best seen high in the southeast to south as dawn begins. Dawn is also the time to catch brilliant Venus low in the southeast — while you still can.

DUSK & EARLY EVENING

Mars starts 2013 setting about 2 hours after the Sun at mid-northern latitudes. Mars has been doing this ever since the end of July, but in January it finally begins to disappear into the sunset. Look for it about 10 high in the southwest 45 minutes after sunset on New Year's Day, and about 6 high at the corresponding time on January 31st.

Mars glows at magnitude +1.2, fairly dim when seen through the twilight glow. Telescopes show it as a tiny, blurry, 4″-wide dot. Though very far from Earth now, Mars reaches perihelion, its nearest to the Sun in space, on January 24th.

Neptune, in Aquarius, is still reasonably high at the end of twilight on January 1st, but by month's end it sets before the sky is fully dark. **Uranus**, in Pisces, is much farther east and north, so it sets almost three hours after Neptune. Both planets are best viewed as early in the evening as you can locate them using the finder charts in the September issue (page 50) or at **skypub.com/urnep**.

Pluto was in conjunction with the Sun on December 30, 2012, so it isn't viewable in January. Pluto's next conjunction is on January 1, 2014, so 2013 is the only year in a quarter-millennium when Pluto does not come to conjunction with the Sun.

FROM DUSK THROUGH MUCH OF NIGHT

Jupiter was at opposition to the Sun at the beginning of December, so in January 2013 the mighty gas-giant planet is still very bright, very large in telescopes, and extremely well placed in the evening sky. Jupiter's next opposition will be on January 5, 2014; it will have no further oppositions in 2013.

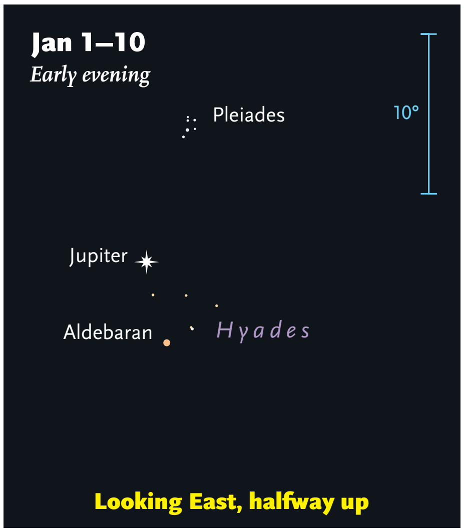
Jupiter fades a little in January (from magnitude –2.7 to –2.5), but it still far outshines any star, even the dazzling stars of winter. Jupiter is near the northern outskirts of the Hyades cluster — a splendid scene through binoculars. It retrogrades westward very slowly until January 30th, when it becomes stationary just 10′ from 4.9-magnitude Omega (ω) Tauri.

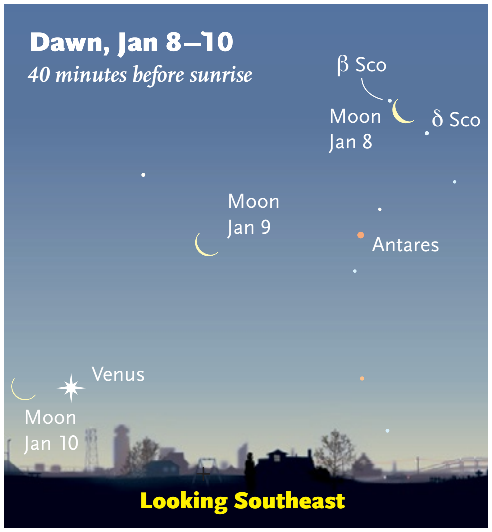
This is a wonderful month to view Jupiter in telescopes (see the observing guide on page 52). Its apparent width shrinks from 47″ to 43″ during January. But 43″ is still quite large, and Jupiter is unusually high above the horizon from dusk until midnight or later for observers at northern latitudes.

AFTER MIDNIGHT

Saturn rises in Libra around 2 or 3 a.m. on New Year's Day but about two hours earlier at month's end. It's highest in the sky, and so best placed for telescopic observing, in morning twilight.

Saturn is still fairly far from Earth, shining only at magnitude +0.6 and with an equatorial diameter of 17″ or less. How-

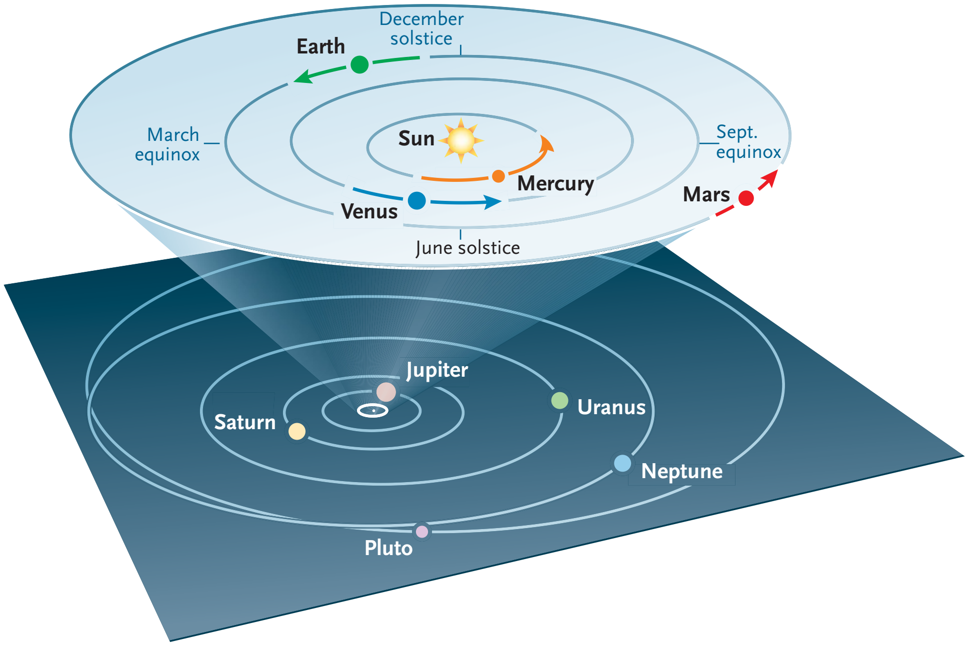




***Fred Schaaf** welcomes your comments at fschaaf@aol.com.*

ORBITS OF THE PLANETS

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



ever, this is a great time to observe Saturn's rings, which are now tilted 19 from edge-on — the best view we've had since 2006. Saturn reaches western quadrature (90 west of the Sun) on January 30th. That means that Saturn is most side-lit in January and February, making this the best time to view the shadow of the planet on the rings.

This month the distance between Saturn and Spica increases from about 16 to 18 , while the gap between Saturn and Alpha Librae (the wide double star Zubenelgenubi) decreases from 6 to 4½ .

DAWN

Venus is nearly at the end of its morning apparition. Observers at latitude 40 north see Venus 9 above the southeast horizon a half hour before sunrise on New Year's Day but just 1½ above the horizon at the corresponding time on January 31st.

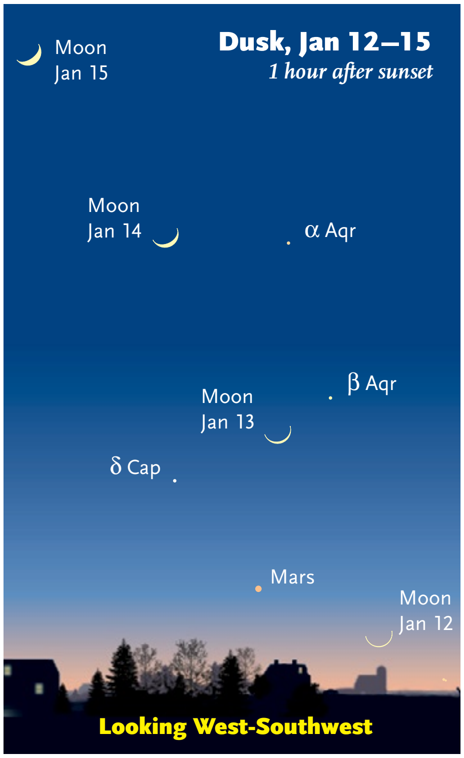
Mercury is invisible to the unaided eye all month. But binoculars might show it far lower left of Venus just before sunup on New Year's Day, and far lower right of Mars shortly after sunset in the last days of January.

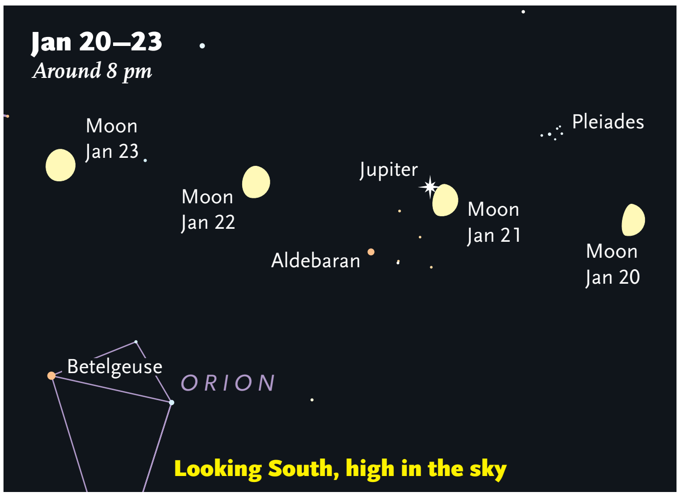
MOON & EARTH

The waning **Moon** is slightly less than half lit when it poses right of Spica at dawn on January 5th, and it's lower right of Saturn on the 6th. A very thin crescent forms a spectacular pair with Venus at dawn on January 10th.

Back in the evening sky, the waxing lunar crescent is well to the lower right of Mars on January 12th and above Mars on the 13th. On the evening of January 21st, the waxing gibbous Moon is stunningly near Jupiter for observers in the Americas — in fact it occults the planet for much of South America.

Earth is at perihelion, nearest to the Sun in space, around 5h Universal Time on January 2nd, when we're 0.98329 a.u. from the Sun. ✦





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

Observing Dynamic Jupiter

Make the most of the season's star telescopic attraction.

After months of creeping up late in the night, Jupiter now rules the evening sky high and bold, glaring down from amid Aldebaran, the Hyades, and the Pleiades. It remains 48 or 47 arcseconds wide all December, following its opposition on December 2nd, then shrinks from 47″ to 43″ in January — while climbing high into steady air earlier and earlier in the evening. Jupiter culminates at its very highest around midnight at December's start, 10 p.m. at year's end, and 8 p.m. by late January.

Jupiter has been called "the amateur's planet." It shows more apparent surface area (more square arcseconds visible) than all the other planets at their best put together. And its features are ever changing. Jupiter can show its major dark belts in the smallest telescope. In high-quality, well-collimated scopes of at least 6 inches aperture, it can display rich (though subtle) detail during good seeing.

There's always something new on Jupiter, especially lately. For the last few years observers have followed the planet's biggest upheavals since 1990-91. The massive South Equatorial Belt vanished completely and then reappeared, first narrow and red, now wide and back to its normal pale brown. In 2012 the North Equatorial Belt, which had narrowed more than at any time in living memory, widened hugely to merge with a reviving North Temperate Belt, whose return to visibility was heralded by a brilliant, almost pointlike outbreak of white material. For more on these goings-on and the weather patterns that may have caused them, see the November issue, page 56.

In September, Jupiter watchers saw Oval BA ("Red Spot Junior"), and its dark little tag-along barge, passing south of the Great Red Spot (just above it in these south-up views). Nothing seemed disturbed by the event. The bright point on October 7th is Io.

Windy Chaos

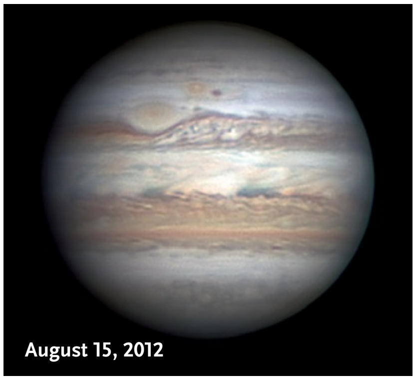
Jupiter is a gas planet whose cloud decks are torn by east-west winds. The first look in a small telescope shows a disk that's flattened at the poles by fast rotation, slightly dimmer around the edges, and crossed by at least two tawny *belts* parallel to the equator separated by brighter white *zones*. With continued scrutiny, more belts usually appear, and in moments of good seeing with a medium or large scope, turbulent swirls and knots flicker into view.

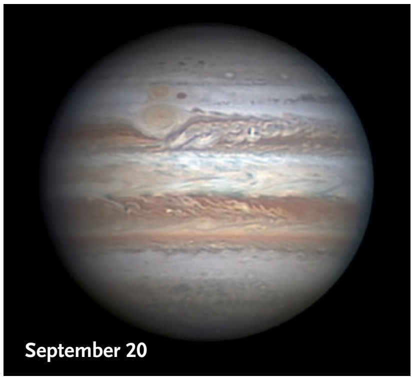
Jupiter rotates fast, in a little less than 10 hours. If you watch for 30 minutes you'll see features at the middle of its disk shift 20% of the way to the planet's edge. They move from celestial east to west, or from "following" to "preceding" in planet-observing language. The words refer to the sides of an object drifting across the field of an undriven telescope. They're used in order to avoid confusion with a planet's own geographic east and west, which are generally opposite from celestial east and west.

Different parts of Jupiter rotate at slightly different speeds, with the equator going fastest. As a result, tremendous winds circle the planet at different latitudes, pulling features along at different rates and often causing one to overtake another. An example appears below; in September observers watched pale-orange Oval BA, affectionately known as Red Spot Junior, and the dark dot following it pass just south of the Great Red Spot.

Understanding the planet requires tracking and recording all these goings-on, which amateur astronomers have done for more than 100 years.

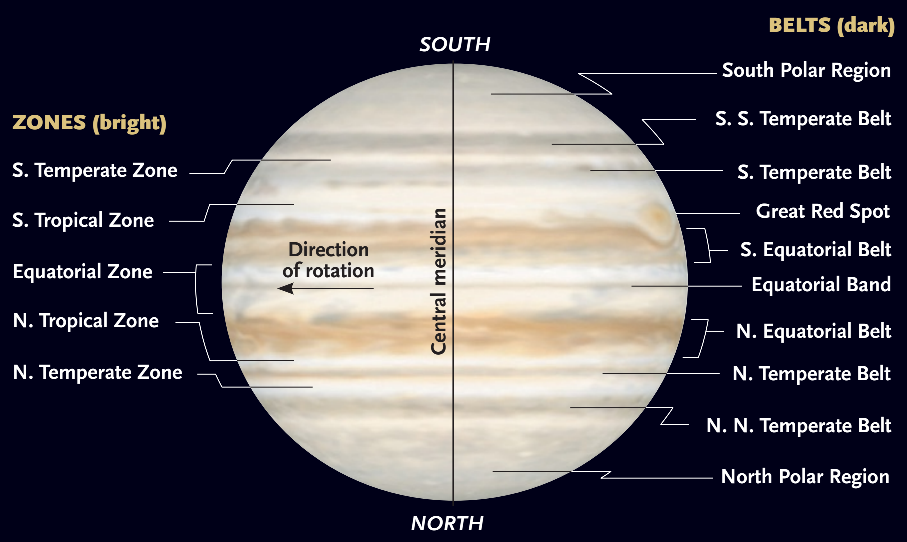
Jupiter's bright zones are high clouds of ammonia crystals and possibly ammonium hydrosulfide (NH_4SH), an ingredient in stink bombs. The orange and brown shades are caused by contaminants welling up from below,


August 15, 2012


September 20


October 7

CHRISTOPHER GO (2)
JIM PHILLIPS



Not all the belts and zones of Jupiter are always present, and often they change width. South is up to match the view in many telescopes. Features rotate from celestial east to west.

perhaps involving sulfur, phosphorus, or hydrocarbons. Bluish markings are openings where we see deeper down through the clear hydrogen-helium air; the blue arises from the same clear-air scattering of sunlight that makes the sky blue on Earth.

Jovian Sights

The diagram above identifies Jupiter's main markings, though they often change size and visibility. The famous Great Red Spot slowly changes color; it's currently pale orange-tan. It stays squeezed like a watermelon seed between the South Equatorial Belt (SEB) and the South Tropical Zone (STrZ), nestled in an indentation in the SEB named the Red Spot Hollow.

The irregular whirls, knots, and storms that churn the belts and zones can be grouped into categories. Various terms have been applied to these; here are some of the most common.

Ovals, either white, gray, or red, are similar in shape to the Great Red Spot but smaller. They occur in both belts and zones. White ovals, often seen in the South Temperate Belt, can be the planet's brightest features. The biggest long-enduring oval (after the Great Red Spot) is the one that goes by the name BA; it resulted from the dramatic merger of two smaller ovals, BE and FA, in 2000 — and then turned from white to reddish. Now, in the finest images, it appears ring-like.

White spots are smaller and rounder than white ovals. They appear about as large as the shadows of Jupiter's four Galilean satellites.

Festoons are thin, dark streamers, often bluish, extending diagonally from a belt into a zone. The Equatorial Zone is especially prone to them.

Rifts are long bright lines inside a belt.

Bars, rods, or *barges* are distinctively dark and more like line segments than ovals.

Knots are lumpy thickenings in a belt.

For links to many Jupiter sites, including some with recent images and instructions for uploading yours, see www.britastro.org/jupiter/links.htm.

Making Observations

Of all the tricks to visual astronomy, the most important is this: the more you look, the more you see. This is not just because it takes time at the eyepiece to catch brief moments of good seeing. It also takes time to build up impressions of difficult, fleeting details, to confirm in your mind whether they are real, and to fix them in your pic-

Minima of Algol

Dec.	UT	Jan.	UT
3	11:50	1	4:02
6	8:40	4	0:52
9	5:29	6	21:41
12	2:18	9	18:30
14	23:07	12	15:20
17	19:56	15	12:09
20	16:45	18	8:58
23	13:35	21	5:48
26	10:24	24	2:37
29	7:13	26	23:26
		29	20:16

Courtesy Gerry Samolyk (AAVSO). For a comparison-star chart, see SkyandTelescope.com/algol.

The Great Red Spot in December and January

Following 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. The Red Spot appears closer to Jupiter's central meridian than to the limb for 50 minutes before and after these times:

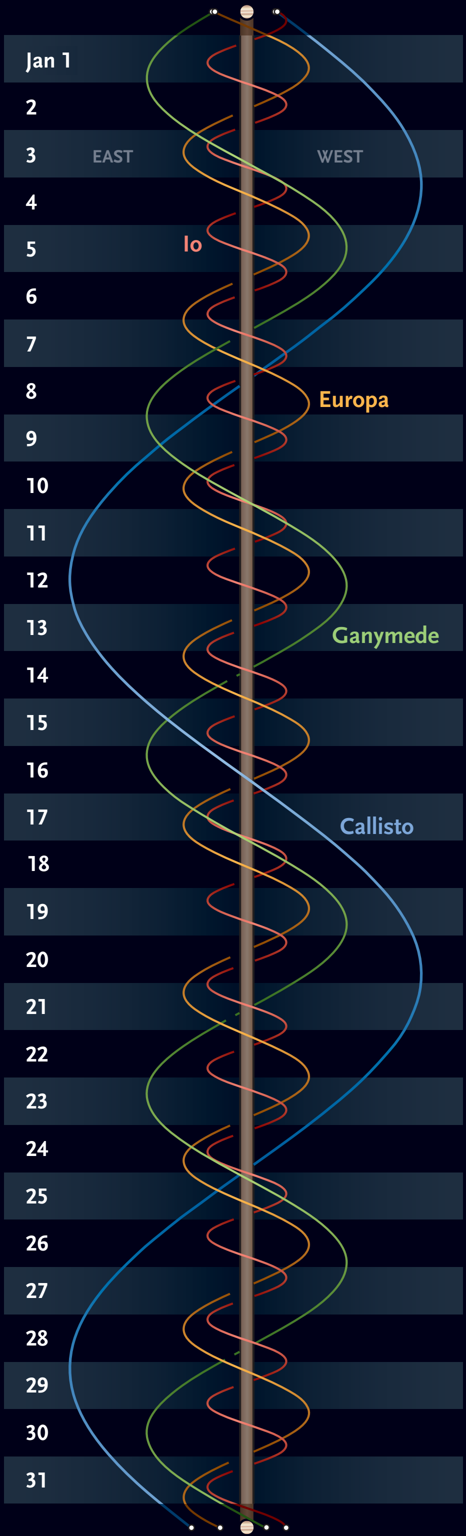
December 1, 9:47, 19:43; **2**, 5:38, 15:34; **3**, 1:30, 11:25, 21:21; **4**, 7:16, 17:12; **5**, 3:07, 13:03, 22:59; **6**, 8:54, 18:50; **7**, 4:45, 14:41; **8**, 0:37, 10:32, 20:28; **9**, 6:23, 16:19; **10**, 2:15, 12:10, 22:06; **11**, 8:01, 17:57; **12**, 3:53, 13:48, 23:44; **13**, 9:39, 19:35;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

January 1, 0:29, 10:25, 20:20; **2**, 6:16, 16:11; **3**, 2:07, 12:03, 21:58; **4**, 7:54, 17:50; **5**, 3:45, 13:41, 23:37; **6**, 9:32, 19:28; **7**, 5:24, 15:19; **8**, 1:15, 11:11, 21:06; **9**, 7:02, 16:58; **10**, 2:53, 12:49, 22:45; **11**, 8:40, 18:36; **12**, 4:32, 14:27; **13**, 0:23, 10:19, 20:14; **14**, 6:10, 16:06; **15**, 2:01, 11:57, 21:53; **16**, 7:48, 17:44; **17**, 3:40, 13:36, 23:31; **18**, 9:27, 19:23; **19**, 5:18, 15:14; **20**, 1:10, 11:05, 21:01; **21**, 6:57, 16:53; **22**, 2:48, 12:44, 22:40; **23**, 8:35, 18:31; **24**, 4:27, 14:22; **25**, 0:18, 10:14, 20:10; **26**, 6:05, 16:01; **27**, 1:57, 11:53, 21:48; **28**, 7:44, 17:40; **29**, 3:35, 13:31, 23:27; **30**, 9:23, 19:18; **31**, 5:14, 15:10.

To obtain Eastern Standard Time from UT, subtract 5 hours; for Pacific Standard Time subtract 8. The times above assume the spot is centered near System II longitude 185°.

Two bright comets may wow the world in 2013. See page 57 for Comet ISON next December, and the next two issues of S&T for Comet PANSTARRS, due to put on a fine display at dusk in March.

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.

ture of the scene. Taking this kind of time is the difference between an accomplished observer and a casual sightseer who wonders why his telescope doesn't show very much.

The most productive form of planetary observing these days, however, is stacked video imaging. That's how modern pictures crawling with features were taken. Video frames are fast enough to "freeze" the seeing. Hundreds of the sharpest frames can be electronically selected from the thousands you film in a few minutes, and these can be automatically aligned and stacked to vastly improve contrast and clarity and bring out even the weakest real features. Inexpensive, lightweight planetary videocams, free analysis software, and abundant online help make this technology available to everyone — though it takes time, patience, and attention to develop the skills of a master.

So don't expect to see views in any telescope as clear as printed images. For planetary astronomy, the eye remained better than the camera for a century and a half after photography's invention. No more. Digital imaging and processing have finally left the eyeball behind.

Even so, there's still nothing like actually watching the real thing. ✦

Phenomena of Jupiter's Moons, January 2013

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 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.

GOTO

Lens Making at GOTO INC

GOTO INC has been in the lens grinding business for nearly a century. In fact, even before there was a GOTO INC, there was a Goto grinding glass for a famous Japanese camera company. That man was Seizo Goto, founder of GOTO INC. Seizo soon mastered the skills necessary to grind quality lenses and set off to start his own business - making telescopes.

Over the years, GOTO moved from telescopes, to periscopes, to planetariums and fisheye movie camera and projection lenses. Today, one of the main lines of business for GOTO is the production of quality video projection lenses. This business is so good that GOTO's optical lab is working full time to keep up with video lens orders!

The dome environment is a challenging one for most lens manufacturers. Especially at the outer edges of a projected image, many dome systems show lack of focus, asymmetrical star images, or chromatic aberration. Likewise, internal reflections can cause contrast loss, and a poorly designed lens can lose light output.

All of these challenges have been met by GOTO for decades now, since GOTO began designing and manufacturing wide angle and fisheye lenses for GOTO Astrovision large format film projectors. In fact, every lens produced for use inside a planetarium is optimized for use on spherical, not flat, surfaces.

Special anti-reflective coatings and internal, motorized irises keep contrast extremely high, and help realize GOTO's goal of inky-black skies with tiny, beautiful stars.

GOTO's line of video projection lenses include models designed for the latest SONY and JVC 4K projectors, as well as many projectors which can be used in 2K applications. Future lens development continues, so users are encouraged to contact GOTO if they have specific questions or requests for lenses to match any new projectors.

JVC 4K projector lens

CHIRONⅡ star plate

Mr. Ikeda has been grinding and polishing lenses at GOTO for 40 years. From roughing out shapes to final testing and polishing, he and several other optical craftsmen do it all.

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John E. Bortle

A Great Comet Coming?

Comet ISON may grow into a truly incredible sight. Or not.

A faint and distant comet discovered by Russian amateur astronomers Vitali Nevski and Artyom Novichonok in September is going to be big news in late 2013. But whether it will become a great comet remains unclear.

From the outset, Comet C/2012 S1 (also known as Comet ISON after the International Scientific Optical Network involved with its discovery) was wrapped in a swirl of hype and controversy. The initial orbital elements, indicating that the comet will pass just 0.01 astronomical unit (a.u.) from the Sun, generated a firestorm of wild speculation across the internet. Poor understanding of how comets typically behave led people to post early comments suggesting that Comet ISON would become 100 times brighter than the full Moon and unfurl the longest tail ever seen. One internet wag even claimed that Comet ISON would be "the brightest comet in human history!"

Comet ISON is still nearly a year from its hairpin turn around the Sun, and though it indeed carries considerable potential for becoming a spectacular object, comets are notoriously unpredictable. Observers need only recall the dismal failure of Comet Elenin in 2011, which was also touted to become a grand spectacle.

As this is being written, only a few weeks after the discovery with Comet ISON still 6 a.u. from the Sun, it's unclear whether the comet's orbit is parabolic or very highly elliptical — an important factor for the comet's future performance. A parabolic orbit suggests that the comet is coming in from the Oort Cloud for a first-time swing by the Sun. Such objects often brighten very early, raising high hopes, but once they come within about 1½ a.u. of the Sun their brightening can radically slow. Such was the case for the notorious Comet Kohoutek in the early 1970s. Some Oort Cloud comets even disintegrate completely, as did Elenin. Conversely, a clearly elliptical orbit would imply that the comet has previous journeyed past the Sun and had its surface heated before, making

The last great comet was Comet McNaught C/2006 P1, which put on a memorable show for Southern Hemisphere observers during early 2007. Will Comet ISON match expectations in 2013?

AKIRA FUJII

John Bortle has long observed comets, variable stars, and lunar eclipses from his home in Stormville, New York.

its current brightness likelier to indicate a very grand display in late 2013.

A reliable prediction may have to wait until next autumn, but let's be optimistic and assume that Comet ISON is a repeating comet that's been through the inner solar system in the distant past. Possible encouragement for this idea comes from the similarity between ISON's orbit and that of the Great Comet of 1680; they could be related. If Comet ISON is indeed old, here's how its apparition may play out.

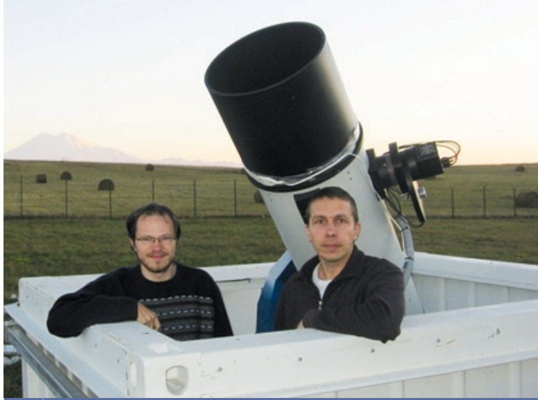
Comet ISON begins 2013 at 15th magnitude in Gemini and could brighten to 13th before disappearing into the June twilight. In mid-August it will emerge from the pale azure light of dawn at magnitude 11. On October 3rd Comet ISON will pass less than 0.1 a.u. from Mars. In late October it will attain its greatest morning elongation (53° from the Sun) as a 7th-magnitude object in reach of binoculars.

From then on it will develop rapidly. It's likely to be visible to the naked eye in the morning sky as November opens, attaining 2nd magnitude with perhaps a 10° tail by the 20th as it descends toward the Sun.

Perihelion occurs on November 28th, when, using extreme caution, experienced observers might be able to spot the comet less than 2° from the Sun's blazing disk at midday, when it will appear like star of perhaps magnitude –5 to –7 with a short tail.

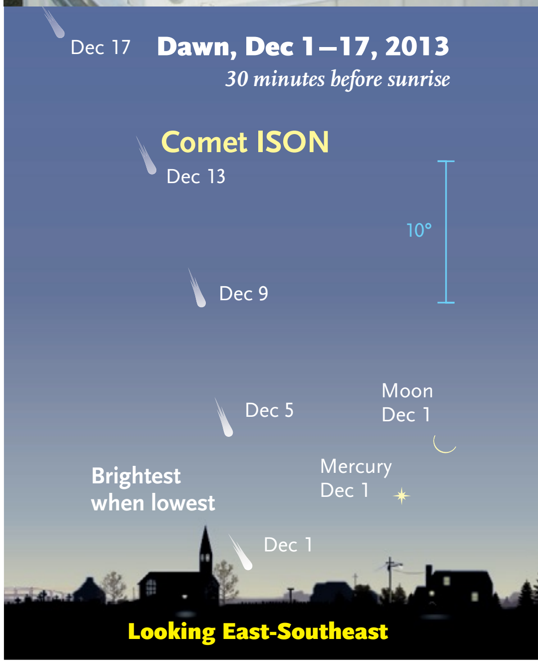
As grand as that sight may be, Comet ISON's greatest performance could be yet to come. During December 2013 it will race almost due northward. As it just begins to emerge from bright twilight — in both the morning and evening skies — it may shine like a star of magnitude –1 or –2 with a short tail, which will dramatically lengthen each day. The most impressive views could come just before dawn around or just after mid-December or just after. On those cold, clear, mornings, the tail projecting from Comet ISON's magnitude +2 or +3 head could *potentially* span an incredible 40° to 60°!

But will it? We'll just have to wait to see. ✦



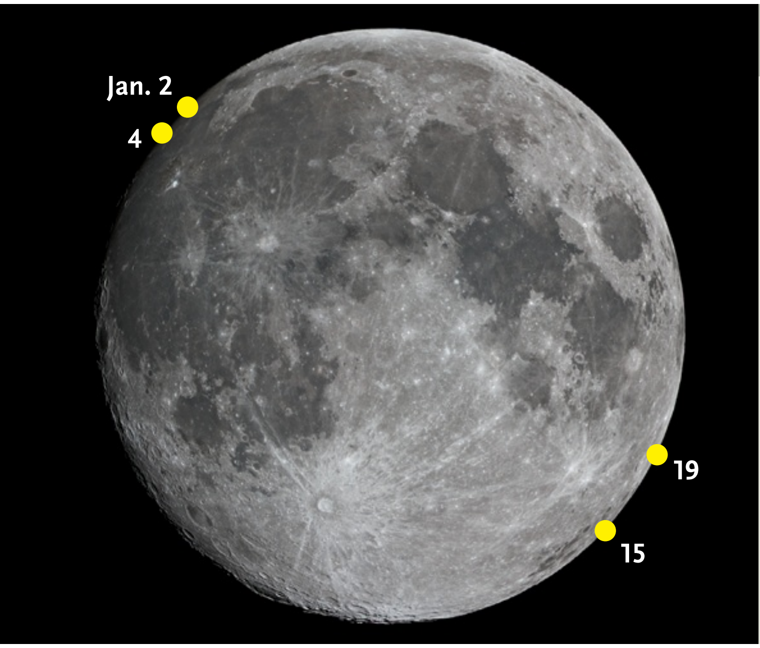
VITALI NEVSKI

Comet ISON discoverers Artyom Novichonok (left) and Vitali Nevski (right) with the 16-inch Santel reflector used in their discovery in Russia.



Comet PANSTARRS Too!

Meanwhile, *another* bright comet could put on a grand display this March. Comet PANSTARRS (C/2011 L4) is on track to shine as bright as magnitude –2 low in the west in evening twilight when at perihelion March 10th. Its finest showing should be in the 10 days after that. More in next month's issue!



S&T: DENNIS DI CICCO

The Moon • January 2013

Phases

LAST QUARTER
January 5, 3:58 UT

NEW MOON
January 11, 19:44 UT

FIRST QUARTER
January 18, 23:45 UT

FULL MOON
January 27, 4:38 UT

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

Distances

Perigee	January 10, 10^h UT
224,299 miles	diam. 33′ 6″
Apogee	January 22, 11^h UT
253,218 miles	diam. 29′ 19″

Librations

Pythagoras (crater)	January 2
Lavoisier (crater)	January 4
Peirescius (crater)	January 15
Humboldt (crater)	January 19

Maiden Flowers

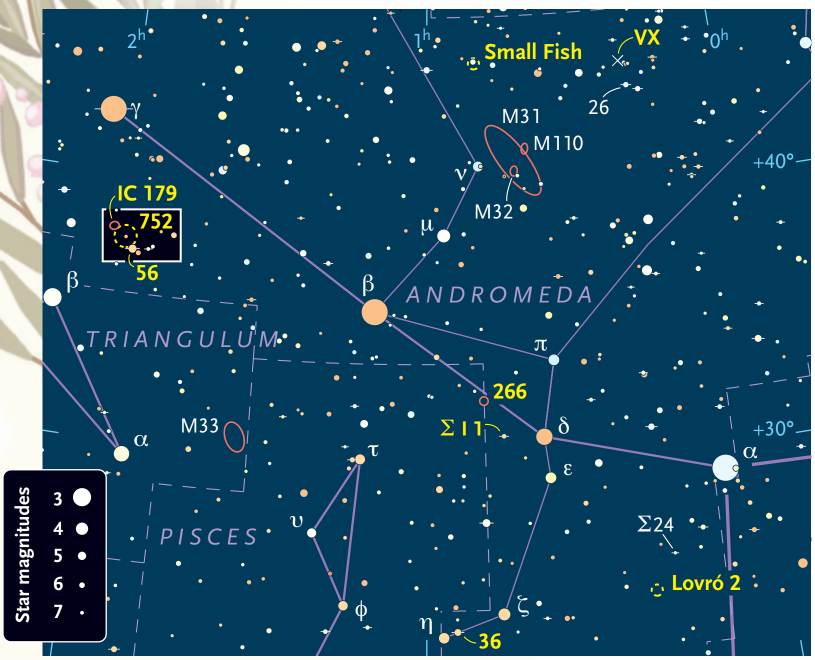
Many little-known blossoms adorn this well-known constellation.

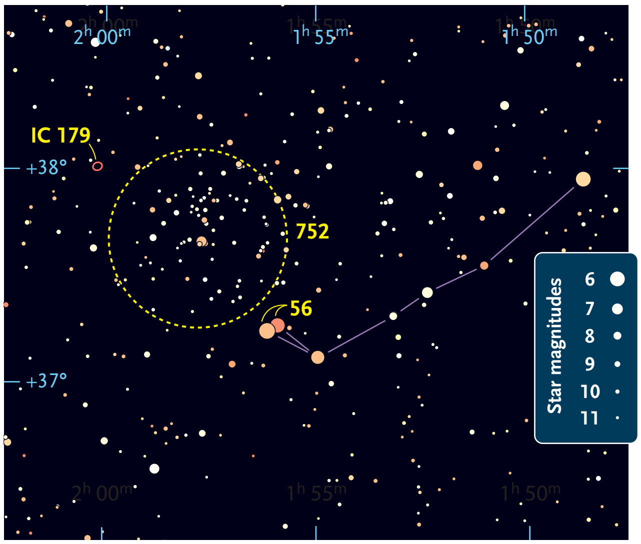
Skygazers know Andromeda as a graceful sweep of stars depicting a beautiful maiden cruelly chained to a rock and awaiting her doom at the jaws of a terrifying sea monster. Inspired by the myth of this hapless maid, the renowned Swedish naturalist Carl Linnaeus bestowed her name on a lovely marsh shrub, *Andromeda polifolia*. Linnaeus likened its drooping rosy blossoms to the cheeks of a young girl with her head bowed in grief. He wrote that the plant always grows on little hillocks in swamps with its roots bathed in water, much as Andromeda was set upon a rock with the sea lapping at her feet. Linnaeus even made a field sketch showing Andromeda and *Andromeda polifolia* side by side.

For those who wield a telescope, the constellation Andromeda bears many splendid flowers in the form of the deep-sky wonders she holds. Let's begin with **NGC 752**, one of the prettiest blooms in Andromeda, flaunting sprays of stars exploding outward like the specks adorning the petals of a stargazer lily. NGC 752 and a bright asterism known as the **Golf Putter**, named by Massachusetts amateur John Davis, make a striking combo in my 9×50 finderscope. The putter's three-starred head sits close south-southwest of NGC 752, sharing one star with the five-starred shaft that stretches 1.5° northwest. NGC 752 is a nice collection of moderately faint to diamond-dust stars. We might imagine that someone made the mistake of using the Golf Putter while in a sand trap, kicking up a splash of crystalline grains for his trouble.

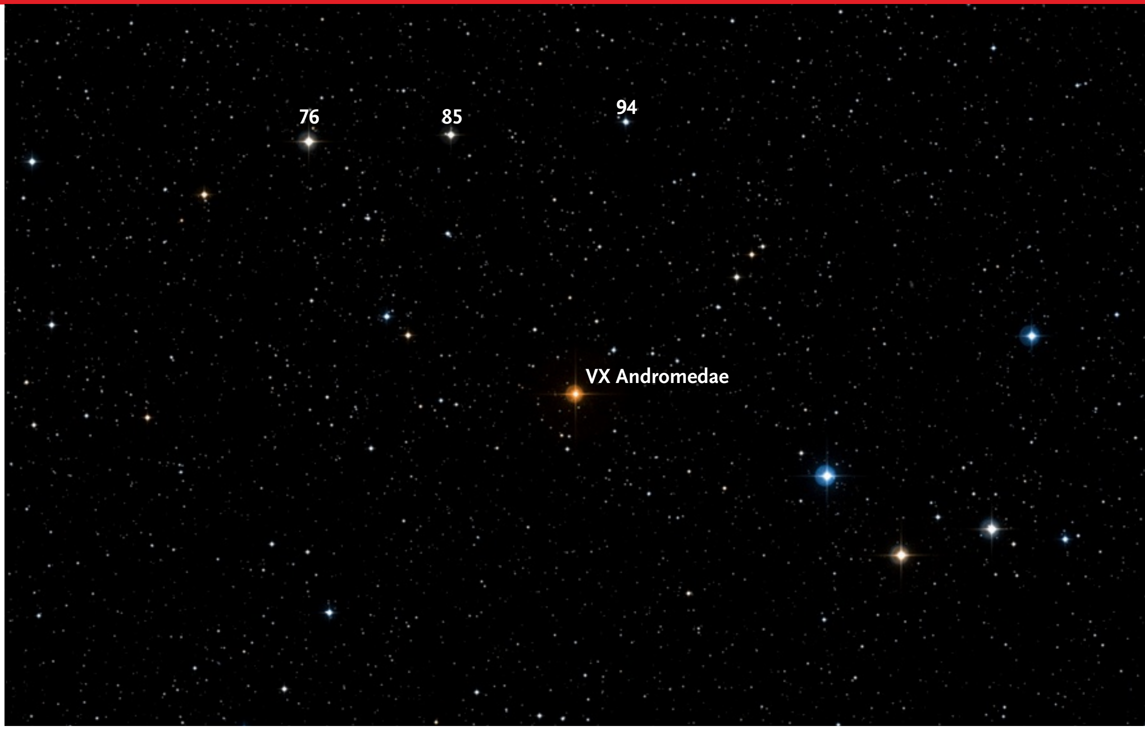
The Putter stars are clad in tulip shades of orange and yellow through my 130-mm refractor at 23×. The pair at the end of the Putter's blade is the very wide double **56 Andromedae**. Its 5.7-magnitude primary is deep yellow, and the slightly fainter companion glows orange. Some of the brightest stars in NGC 752 show color as well, most notably a yellow-orange star south of center and a deep yellow one in the western edge. This attractive group enfolds about 75 stars within a 50′ diameter, loosely sprinkled in clumps and chains.

Several galaxies lie behind NGC 752 as viewed from Earth. **IC 179** is the brightest one within the 75′ diameter attributed to the cluster in some databases. It unveils its presence in the cluster's sparsely populated, northeastern fringe when subjected to scrutiny with my 10-inch reflector at 68×. IC 179 marks the southernmost corner of the 5.9′-tall trapezoid it forms with three stars, magnitudes 10.5 to 10.9. At 166× the galaxy appears very slightly oval,





The ultrawide double star 56 Andromedae marks the tip of the Golf Putter, open star cluster NGC 752 is the ball, and the galaxy IC 179 might be an insect resting on the ball.



POSS-II / CALTECH / PALOMAR OBSERVATORY

Estimate the brightness of the variable star VX Andromedae by comparing it with the stars to its north. These are labeled with their magnitudes, omitting the decimal point.

tipped east-southeast. The galaxy brightens toward the center and is only ½′ long.

A beautiful carbon star with the red-orange hue of a Chinese poppy sits 57′ north-northeast of 6th-magnitude 26 Andromedae. **VX Andromedae** is a semiregular variable that goes from about magnitude 7.5 to 9.7 and back in roughly 375 days. It's currently near maximum light, and it appears quite striking in a starry field through a small telescope at low power. The star is approximately 500 light-years distant and 60 times the diameter of our Sun.

One of my favorite asterisms, the **Small Fish**, lies 5.4° east of VX Andromedae and 3.9° north of Nu (ν) Andromedae. Astronomy author John A. Chiravalle told me about this finny friend of his, and I had lots of fun showing it to folks at the Peach State Star Gaze with my 130-mm refractor at 91×. Outlined by 6th- to 14th-magnitude stars, this very cute fish swims north-northeast and covers 13.0′ × 7.3′. With the bright star on his brow, we might be looking at a flowerhorn fish (see page 62).

Let's plunge southward to a richly tinted double star dwelling 1.5° east of Delta (δ) Andromedae. Its designation is variously written **Struve I 1**, Σ I 1, or STFA 1. These names indicate that this is the first newly listed pair in the first supplement to Friedrich Georg Wilhelm Struve's 1827 Dorpat Catalogue. Discovery of the duo is credited to Christian Mayer, who measured the separation and position angle of its stars in 1777. Mayer's 1779 publication enjoys the honor of being the first double-star catalog in the history of astronomy.

The nearly matched components of Struve I 1 are widely split even at 23× in my 130-mm scope. The golden-rod primary watches over a slightly deeper-hued companion to the northeast. Pretty though they may be, these stars are thought to lie at significantly different distances and share only a line-of-sight coincidence.

Climbing 1.5° north-northeast, we come to an interesting barred spiral galaxy that straddles the Andromeda-Pisces border. **NGC 266** is small, faint, and brightens toward the center when seen through the 130-mm refractor at 63×. An orange 8.2-magnitude star stands guard 3.7′ to

Flowers of Andromeda, the Chained Maiden

Object	Type	Mag. (v)	Size/Sep.	RA	Dec.
NGC 752	Open cluster	5.7	75′	$1^h\ 57.6^m$	+37° 50′
56 And	Optical double	5.7, 5.9	3.3′	$1^h\ 56.2^m$	+37° 15′
IC 179	Galaxy	12.6	1.8′ × 1.5′	$2^h\ 00.2^m$	+38° 01′
VX And	Carbon star	7.5 – 9.7	—	$0^h\ 19.9^m$	+44° 43′
Small Fish	Asterism	—	13.0′ × 7.3′	$0^h\ 50.2^m$	+44° 56′
Σ I 1	Optical double	7.3, 7.4	47″	$0^h\ 46.4^m$	+30° 57′
NGC 266	Galaxy	11.6	3.0′ × 2.9′	$0^h\ 49.8^m$	+32° 17′
36 And	Double star	6.1, 6.5	1.1″	$0^h\ 55.0^m$	+23° 38′
Lovró 2	Asterism	—	18′ × 16′	$0^h\ 22.1^m$	+24° 49′

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

the south-southeast. At 117× NGC 266 shows a bright core with east-west extensions indicating the galaxy's bar. This is enveloped in an oval, east-west halo about 1.6′ long. In my 10-inch scope at 166× the galaxy appears more detailed. The oval core holds a starlike nucleus, whereas its protruding bar is somewhat fainter. The gauzy halo is 2′ long, a little more than half as wide, and tipped south of west.

In 2005 amateur astronomers Tim Puckett and Peter Ceravolo discovered a supernova in NGC 266 on CCD images taken with the 24-inch automated supernova patrol telescope at the Puckett Observatory in Georgia. It was confirmed by Canadian amateur Doug George with a 16-inch scope. Now known as SN 2005gl, this was a Type IIn supernova, which results from the core collapse and subsequent explosion of a star. The progenitor may have been a very massive type of star known as a luminous blue variable. Such a star is born with more than 40 times the mass of our Sun, but it sheds much of this material by way of fierce stellar winds. Late in its life, the star becomes highly unstable and suffers violent outbursts before submitting to its spectacular demise. A well-known example of a luminous blue variable in our own galaxy is the primary star of the far southern binary Eta (η) Carinae.

Dropping farther south takes us to the vicinity of Eta Andromedae. In my 9×50 finderscope, dandelion-yellow Eta is accompanied by a 49′ wedge of five stars to its west.

POSS-II / CALTECH / PALOMAR OBSERVATORY (2)

Hungarian stargazer Ferenc Lovró sees this asterism as a torch flame or a double question mark.

John Chiravalle discovered the Small Fish asterism, which is outlined on this photo from the Palomar Sky Survey.

The wedge is aimed west-northwest with its brightest star, **36 Andromedae**, marking the point. 36 Andromedae is a very tight double whose sunflower gold stars are a colorful treat. The components of this visual binary are currently separated by only 1.1″, with the companion star north-northwest of its primary. When the seeing (atmospheric steadiness) is good, they're nicely split through my 130-mm refractor at 234×. The orbital period of the pair is 167.5 years, and the stars will reach their maximum apparent separation of 1.3″ in the year 2040.

Our last stop will be the eye-catching asterism **Lovró 2**, noted by Hungarian amateur Ferenc Lovró. To locate it, sweep 2.4° southeast from Alpha (α) Andromedae (Alpheratz) to a very widely spaced pair of 6th-magnitude stars and then continue in the same direction for another 2.9°.

Describing Lovró 2 through his 12-inch reflector, Lovró writes, "It resembles either a double question mark, or the flames of a large torch." Through my 105-mm refractor at 87×, I see a remarkable daisy-chain of 20 stars meandering northward from a 7.8-magnitude star, reaching west, and then cascading back down toward the south. The asterism spans about 18′ × 16′, its long dimension tipped 10° east of north. What do you think of this unique star pattern?

Andromeda polifolia grows wild only in the world's northern regions, but the constellation Andromeda is visible from almost all the populous lands of Earth, there for the enjoyment of anyone with a love of the night sky. ✦

Hot Gas in Cass

Two intriguing nebulae — the Bubble and the Pac-Man — shine overhead this month.

THE FAMILIAR W (or M) of Cassiopeia stands high on January evenings. Queen Cass possesses numerous open star clusters but relatively few emission nebulae. Over several velvet-dark nights in the fall of 2011, I scrutinized two of her best nebulae: the Pac-Man and the Bubble, both between 7,000 and 11,000 light-years away.

The term Bubble Nebula is used to mean two different things: the emission nebula NGC 7635 and a small, slightly oblate spherical structure inside NGC 7635, which gives the Bubble its name. I will use **NGC 7635** to denote the larger nebula —roughly 15′ by 8′, oriented north-south — and **Bubble** for the 3′ sphere.

NGC 7635 is being shaped by powerful winds from the massive, ultrahot, 8.7-magnitude star SAO 20575 (BD +60° 2522). The 6-light-year-wide Bubble (curiously, not centered on SAO 20575) is expanding fast; its rim is the edge of a shock wave that's plowing into the surrounding H II region. Little of that broader nebulosity is visible in amateur telescopes, and most of the embedded Bubble is dark. Here be a challenge!

The Bubble conveniently floats about 30′ southwest of the bright open cluster M52. Inconveniently, the ghostly sphere is almost swamped by the glare of a 7th-magnitude field star just 6′ farther westward. Employing my 10-inch Dobsonian at 200× with a contrast-enhancing O III filter, I detected two fuzzy features near SAO 20572. One was

ROBERT GENDLER

The open cluster Messier 52 is in the upper left (northeast) corner of the 1.5°-wide view. NGC 7635 and the Bubble are left of center, and NGC 7538 is at far right.

JOSEF PÖPSEL / STEFAN BINNEWIES

This false-color image of NGC 7635 shows the Bubble in exquisite detail. It uses the "Hubble palette" popularized by the iconic Pillars of Creation image, showing hydrogen, oxygen, and sulfur as green, blue, and red, respectively.

a concentrated nebulosity fanning northwestward from that star and the other was a narrow haze east of the star trending southward. That wispy streak was the only evidence of the Bubble's unevenly illuminated rim.

My 17.5-inch Dobsonian amplified this detail even without filters. In addition, my averted vision caught a diffuse outer portion of NGC 7635 northeast of the Bubble. I then added a UHC filter and began working the field at 222× and 285×. Right away I noted some mottling in the isolated outer portion. The fanlike structure beside the primary star turned into a "comet" whose broad tail issued westward, then curled northward. On the other side of the star, the wispy streak sharpened into an arc extending southward almost as far as a 13th-magnitude star, which appears a hair's width east of the Bubble in the image to the right. In all, I traced perhaps one quarter of the shell's circumference.

Our second object, **NGC 281**, lies 1.3° southeast of the pretty binary star Eta (η) Cassiopeiae. When I centered Eta in my 50-mm finderscope, the pale target nearby showed as a mist enveloping an 8.6-magnitude star — the emission nebula's main energizer and the gravitational anchor of a tight quadruple system. The 8.9-magnitude secondary (4″ away) and 9.7-mag tertiary (9″) showed easily in my 10-inch reflector. The fourth component, a 9.3-magnitude star 1.5″ from the primary, was a clean split at 400×. This foursome, together with a 4′-wide scatter of lesser stars (among them an 11th-magnitude pair 13″ apart), are the most obvious members of the cluster IC 1590, which is partly cloaked by the cloud. My 17.5-inch scope resolved more of IC 1590. At 285× the area around the quadruple system was a 2′-wide hive of very dim stars.

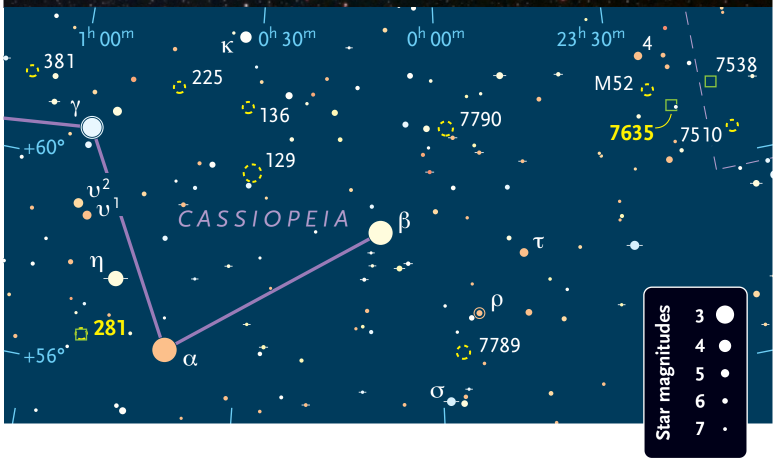
The Pac-Man Nebula really does resemble its namesake arcade-game character, especially when viewed with a UHC or O III filter. In my 17.5-inch Dob at 83× with an O III attached, the ½°-wide haze is indented on its southwest side by a wedge-like void — the mouth of the munching man. Intriguingly, the haze comprises three ragged patches of unequal size and brightness. A large patch above the mouth encloses the multiple star and fans westward. A faint jaw protrudes below the mouth. The prominent section opposite the mouth spreads northeastward and dissipates into the Milky Way. The two dark lanes creating these divisions cut like facial wrinkles from the mouth. One inky thread runs northeast and the other meanders northward past the multiple star. In my 10-inch, a UHC teased out essentially the same structure. The details were dimmer, but definite.

My most memorable view of NGC 281 was with a colleague's home-built 15-inch Dobsonian equipped with a 21-mm ultrawide ocular and a UHC filter. My notes tell all: "Incredible! Two thick lanes plus lots of curvy dark threads. Finely textured all over. The 'face' totally breaks up." So, the Pac-Man lives by the filter — and dies by it. ✦

*Contributing editor **Ken Hewitt-White** enjoys the dark skies of British Columbia, Canada.*

Here's another Hubble-palette image, this time of NGC 281, the Pac-Man Nebula.

HUNTER WILSON / WIKIMEDIA COMMONS



Dave's Dobsonian Sun Scope

This scope combines fool-proof safety with excellent solar views.

Every reader has heard of Dobsonian telescopes — the simple-but-effective design championed by John Dobson since the 1960s. An equally clever, but virtually unknown, Dobson creation is his dedicated solar telescope. You just don't see very many of them, and the last time we ran an article about building one was in the August 1989 issue (page 207). But I was recently reminded of the design when Vancouver amateur David Dodge dropped me a line about his Dobson-inspired Sun scope.

"I fell in love with the design when John Dobson showed it to me a few decades ago while visiting Vancouver," Dave recounts. "It was the simplicity of the instrument that got me, but I didn't find the time to build one until I retired recently."

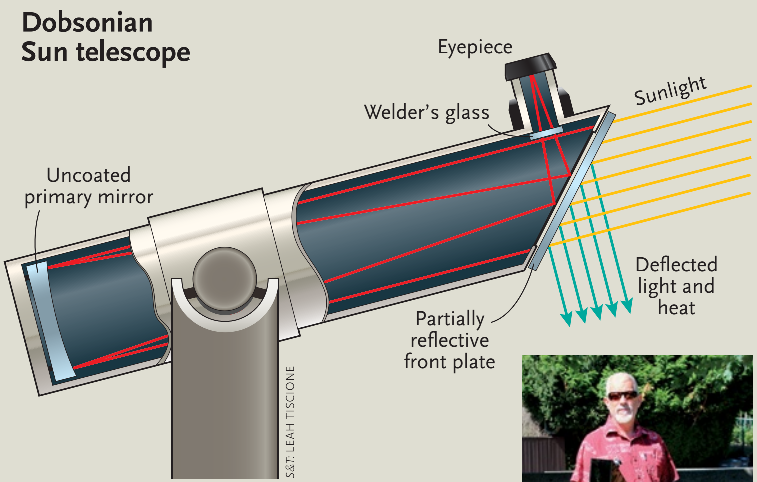
The design is indeed simple. At the most basic level, it's a Newtonian reflector, but with modifications that allow you to safely view the Sun's blinding surface. The most important modification is the lack of a diagonal mirror. In its place is a partially reflective window made from a "two-way" mirror that is sold at most large glass-supply companies. This is mounted to the front of the scope at a 45° angle, with its coated surface facing into the tube. Next, the primary mirror (in Dave's scope, a 4½-inch f/8) is left uncoated. Lastly, at the base of the focuser there is a filter made from a piece of #9 welder's glass.

Following the journey of sunlight through the scope, we see that much of the light's intensity is deflected out of the telescope when it initially strikes the front window. Of the transmitted light, only 4% is reflected by the primary mirror back to the window, which now acts as a partially reflecting diagonal mirror. It bounces a further-reduced sunbeam to the welder's glass, which filters out all harmful ultraviolet and infrared wavelengths and reduces the Sun's image to a comfortable viewing level at the eyepiece.

If you've put together a regular Newtonian reflector, you'll find building a Dobsonian Sun scope relatively straightforward. The only important detail is to ensure that the partially reflective window is tilted as close to 45° as possible, and this was easier to do with Dave's square plywood tube than with a round one. He used silicone epoxy to glue the window in place. This adhesive is also a good choice for affixing the welder's glass to the base of the focuser, or directly to the tube under the focuser.

One of the greatest virtues of this design is that it's arguably one of the safest ways to view a magnified image of the Sun, making it well suited for public sidewalk astronomy. "If the front window breaks or falls off, you'll simply find yourself looking at the ground through a piece of welder's glass," John Dobson once commented, adding, "and that's known to be safe!"

So how are the images in Dave's scope? "At 50×, the Sun nicely fits the field of view and I can easily pick out all the sunspots shown in the daily images posted at **spaceweather.com**, as well as some of the brighter plages," he reports. Readers wanting to know more about his solar Dobsonian can contact him at **mr_astro@telus.net**. ✦




ERIC DUNN

Vancouver amateur David Dodge built his Dobsonian solar telescope in less than six hours. Two components that make it different from a standard Newtonian are its unaluminized primary mirror and the partially reflective "two-way" mirror mounted to the front of the scope that acts as a solar filter *and* the Newtonian diagonal.

*Contributing editor **Gary Seronik** has built many Dobsonians over the years, though only for viewing distant suns. He can be contacted through his website, **www.garyseronik.com**.*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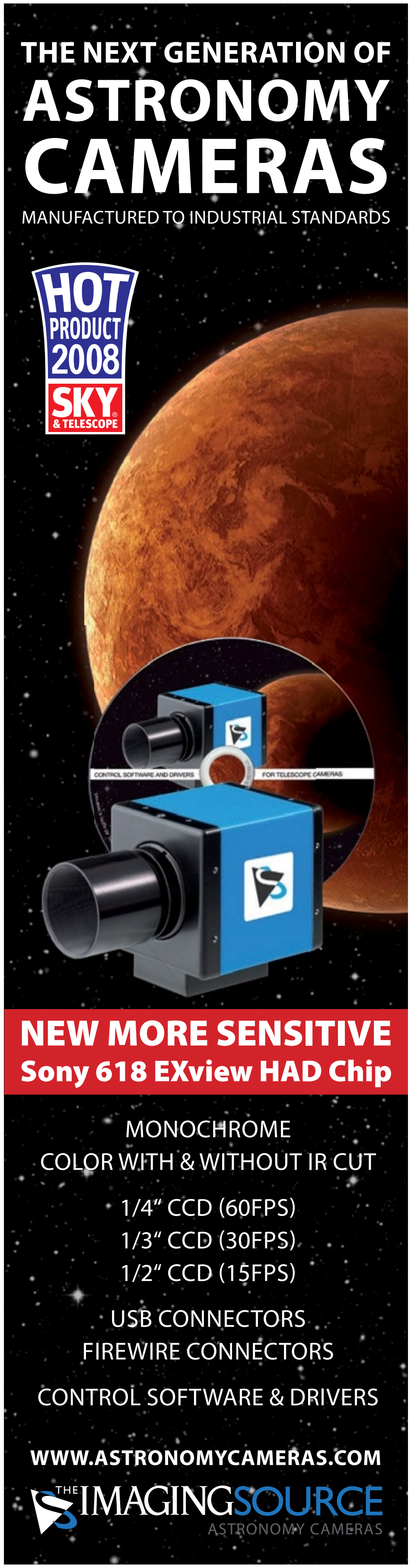
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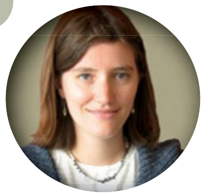
Tales from the Dwingeloo Radio Observatory



Yvette Cendes

Amateur astronomers have reclaimed a world-class radio telescope for science and outreach.

AS THE OVERCAST SKY turned to dusk, organizers normally would have called off the Leap Day star party. For days, persistent clouds and mist had enshrouded the countryside of tidy farms and wild heather, but the amateur astronomers remained undaunted. After all, signals pierce through clouds as if they weren't even there when you use the Dwingeloo Radio Observatory, the world's largest amateur radio project.

"What you're hearing right now is the pulsar B0329+54," operator and educational coordinator Harm Munk explained in Dutch to curious members of the public. Deep, throbbing pulses filled the control room like beats from a relentless clock. "This object is one of the brightest radio sources in our night sky. It completes one rotation every 0.71 second — quite slow for a pulsar." A computer screen similar to an EKG monitor showed the real-time strength of the pulsar's ceaseless signal.

As Munk moved on to the next radio source, the 82-foot-wide radio dish continued to monitor the heavens as it had for more than half a century. Though the observatory languished in a state of disrepair for almost a decade, amateur astronomers have now taken the helm of what was for a short time the world's largest radio telescope. The story of Dwingeloo weaves together the potential of radio amateur initiatives and the scientific history of a nation.

AMATEUR EXPERTISE *Top:* The C. A. Muller Radio Astronomy Station (CAMRAS) foundation runs Dwingeloo Observatory; with a diameter of 25 meters (82 feet) it was once the largest radio dish in the world. The telescope laid the foundation for Dutch participation in radio astronomy when it was built in 1956. Now it continues its legacy under the guidance of amateur astronomers. *Far left:* Radio operators experiment in the telescope's control room. *Center:* A CAMRAS volunteer builds a new control unit that will guide the telescope as it slews across the sky. *Near left:* Another volunteer leads a public tour of Dwingeloo's control room.

The Birth of Dutch Radio Astronomy

The Netherlands, flat and cloudy, does not host ideal sites for optical telescopes, so perhaps it's only natural that the Dutch have been heavily involved in radio astronomy since the field's infancy. Astronomer Jan Oort realized the potential of radio waves in the early 1940s. Unlike visible light, radio penetrates the dust obscuring much of the Milky Way and can reveal its underlying structure.

Oort was particularly interested in measuring our galaxy's rotation, but to do that he needed a spectral line to reveal the velocities of gas clouds across the Milky Way. As the clouds move toward or away from Earth, the signal they emit Doppler shifts to shorter or longer wavelengths. So when another Dutch astronomer, Hendrik van de Hulst, calculated that neutral hydrogen atoms emit a spectral line at a radio frequency of 1420 megahertz (a wavelength of 21 centimeters), he discovered the tool that he and Oort, and many astronomers after them, would use to measure the rotation of the Milky Way.

Though World War II delayed their experiments, Oort and van de Hulst began observations with an old German radar antenna soon after the war ended. They produced some of the first measurements of Milky Way rotation, publishing their results in 1954. But it soon became clear that to obtain better observations, they would need a new instrument dedicated to radio astronomy: the Dwingeloo Radio Observatory.

Named after the nearby village of Dwingeloo and the Dwingelderveld National Park in which it resides, the

SUNNY STAR PARTIES Dwingeloo's star parties typically take place in the daytime. And until renovations began in June 2012, visitors were required to wear hard hats due to the danger of falling parts. *Lower left:* Children sing a Dutch version of the popular song "Are You Sleeping?" as a musical round with the echo of their voices bounced off the Moon.

Dwingeloo Radio Observatory began observations in 1956 as the world's largest radio telescope. Though it was surpassed in size a year later, Dwingeloo remained productive into the 1990s. Astronomers measured the spiral structure of the Milky Way, cataloged the radio sky in unprecedented detail, and discovered two galaxies only 10 million light-years away — galactic dust had obscured the visible light from the subsequently named Dwingeloo 1 and 2.

Dwingeloo became the center of radio astronomy research in the Netherlands. Both ASTRON (the Netherlands Institute for Radio Astronomy) and JIVE (Joint Institute for VLBI in Europe) are headquartered in the Dwingelderveld National Park, only a stone's throw away from the telescope. Two newer radio arrays lie a few miles farther afield. The Westerbork Synthesis Radio Telescope (WRST), an array of 14 dishes each as wide as the 82-foot Dwingeloo, was built in 1970, and the world's largest astronomy array, the Low Frequency Array (LOFAR), officially opened in 2010. LOFAR's 20,000 antennas lie scattered across France, Germany, Sweden, and the U.K., but the array's core stations are located just 20 miles from Dwingeloo, near the village Exloo (*S&T:* May 2011, page 26).

By 1998 advances in radio astronomy had outpaced the capabilities of the aging observatory, so the telescope was decommissioned. It sat idle for several years — the price of scrap metal at the time was too low to make demolition worthwhile. Then in January 2005, two amateur radio operators, Robert Langenhuysen and Maarten Dijkstra, wondered whether they could use the telescope for amateur projects. Together with other interested amateurs, they founded the C. A. Muller Radio Astronomy Station (CAMRAS) foundation to operate and maintain the telescope. ASTRON agreed to lease the telescope to CAMRAS for a nominal fee, and sponsors were found to buy new equipment and begin refurbishing the telescope. Finally in 2007, after nearly a decade of sitting idle, the Dwingeloo telescope restarted operations under CAMRAS's jurisdiction.

A New Lease on Life

An amateur astronomer's 18-inch dish can listen for the Sun, and a 10-foot dish can hear the hiss of the 21-centimeter line in the Milky Way. But such modest projects pale in comparison to the CAMRAS project at Dwingeloo. "We were lucky enough to take advantage of a unique opportunity," explains André van Es, chairman of CAMRAS. "The size of the dish alone makes our capabilities truly exceptional."

Before Dwingeloo could listen to the radio sky, the CAMRAS group first had to install the telescope's receiving equipment — from scratch. The process required establishing the pointing parameters, improving sensitivity, reducing noise in the receiver, and even dealing with the occasional pesky RFI source nearby. Now CAMRAS operators can lock onto radio signals from rapidly spinning pulsars throughout the galaxy and listen to radio galaxies millions of light-years away.

Several pulsars in the northern sky are relatively easy to observe, and their clock-like signals make them popular targets for amateurs and the public. Radio galaxies such as Cygnus A and Virgo A emit a more irregular signal created by relativistic jets of particles streaming away from supermassive black holes. And harking back to the dish's original purpose, the CAMRAS team has also constructed Doppler maps of galactic hydrogen.

"We are sensitive enough that we made a rotation plot of the hydrogen in the Andromeda Galaxy at different angular offsets from its center," says frequent observer Paul Boven, "and in the rotation curve you can see which side of Andromeda is coming toward us and which is going away."

The telescope has found success not just with amateur astronomers but also with members of the general public. Education about astronomy and technology is a key element of CAMRAS's mission. "We've had schoolchildren of all ages come visit for class projects and events such as Girls' Day, where we encourage girls interested in science," explains Munk. "We usually observe pulsars with such groups, and the kids are amazed when they realize what they're hearing."

The CAMRAS team also observes major meteor showers such as the Perseids, listening for "meteor scatter," the snippets of faraway radio broadcasts that reflect off the ionized trails left in a meteor's wake.

In addition to astronomy, the CAMRAS team runs the telescope in association with several amateur (ham) radio operators, who use the facilities once a month under the call sign PI9CAM. They engage in Earth-Moon-Earth (EME) bounce, reflecting radio signals off the Moon to communicate with other amateur stations around the world. The wall is filled with confirmation cards from stations as far away as Brazil, California, and even Australia. The team also assisted an Italian artist, Daniela de Paulis, as she moonbounced several astronomy-related images as performance art — the first time in history that color images were bounced off the Moon.

© A.GRAFFI (PORTRAIT PHOTO) / D. DE PAULIS / CAMRAS (MOON-BOUNCED PICTURE)

SPACE ART Artist Daniela de Paulis collaborated with CAMRAS volunteers to moonbounce several color images, including this photograph of herself, as performance art.

RENOVATIONS BEGIN On June 6, 2012, construction workers lifted Dwingeloo's dish from its foundation to begin refurbishing the aging structure holding it in place. Rusty parts will be replaced, and all steel sections will be sandblasted and repainted. The restoration is expected to be complete by mid-2013.

Challenges for the Future

Reclaiming the observatory has come with its share of difficulties, such as finding people with radio expertise. "My best advice to anyone considering a similar project in radio astronomy is to get in touch with a local amateur radio club," advises Boven. "They're really the ones who have the expertise in electronics to get such a project off the ground." Some clubs have already sprung up in Germany and Ireland with the aim of using old, large communication-relay dishes that are now obsolete and often abandoned. These dishes aren't fully steerable, Boven says, but there is still good potential for amateur radio astronomy.

A more serious problem for CAMRAS has been the telescope's age. The dish has rusted over the decades, to the point where hard hats are required when standing underneath the structure due to the danger of falling bolts and other small pieces. Fortunately, in 2009 the Dwingeloo Radio Observatory was declared a National Monument by the Dutch government in recognition of its historical importance and its legacy in science. This event allowed CAMRAS and ASTRON to apply for subsidies for the telescope's renovation, which began on June 6, 2012.

"We are essentially lifting the entire dish from its foundation, and refurbishing the parts that have been too corroded by the elements," explains van Es. "The entire renovation should last about a year."

The renovations will preserve an important piece of astronomical history for future generations. In many ways, however, what is most exciting is the knowledge that the Dwingeloo Radio Observatory has a future as an active instrument that will continue to probe the heavens. The members of CAMRAS have given this old professional a new lease on life, opening new horizons for those interested in the radio sky. ✦

Originally from Pittsburgh, Pennsylvania, ***Yvette Cendes*** *is now a Ph.D. student in radio astronomy at the University of Amsterdam. She chronicles her adventures around the universe at* ***www.whereisyvette.com****.*

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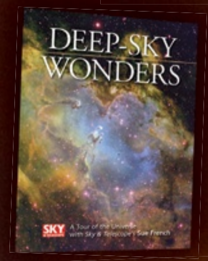

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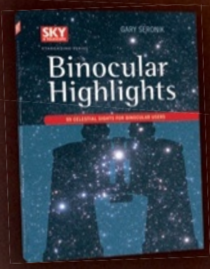

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Sean Walker
Gallery

▶ **TRAILS OF A LONG NIGHT**

Greg Brush

Thousands of stars trace their nightly path around the North Celestial Pole as seen from Flagstaff, Arizona, on the night of September 18, 2012.

Details: *Canon EOS Rebel T2i DSLR with 18-55-mm zoom lens. Total exposure was more than 7 hours.*

▼ **GALACTIC SPIDER**

Lorenzo Comolli

The Tarantula Nebula (NGC 2070), in the Large Magellanic Cloud, is one of the finest targets to observe from Southern Hemisphere skies.

Details: *Takahashi FS-152 refractor with a modified Canon EOS 5D DSLR camera. Total exposure was 4⅙ hours recorded in Namibia, Africa.*

CASSIOPEIA'S STELLAR OFFSPRING

Bob Fera

The large H II region NGC 281 in Cassiopeia is an active star-forming region surrounding the young star cluster IC 1590.

Details: *Officina Stellare RC360AST 14-inch Ritchey-Chrétien telescope with Apogee Alta U16M CCD camera. Total exposure was 14½ hours through Astrodon color and Hα filters.*

▶ **A NEBULOUS CLAW**

Craig & Tammy Temple

The large nebula Sh2-157 in Cassiopeia resembles a claw of an American lobster in deep photographs such as this.

Details: *Stellarvue Raptor SVR80 refractor with QSI 583wsg CCD camera. Total exposure was 11 hours through Astrodon Hα and O III narrowband filters.*

▼ **EMERGING RED PLANET**

Doug Zubenel

Mars reappears from behind the day-old Moon after a rare occultation on the evening of December 6, 2010.

Details: *Half-second snapshot captured with a modified Canon EOS Rebel XTi and 300-mm lens.* ✦

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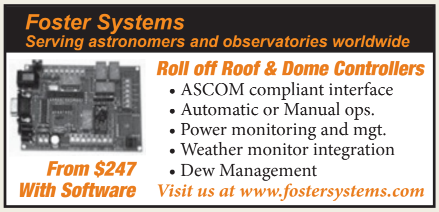

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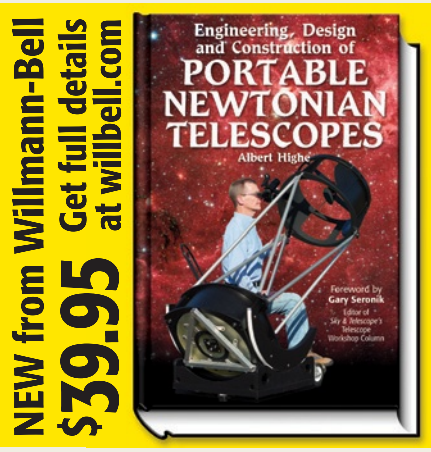

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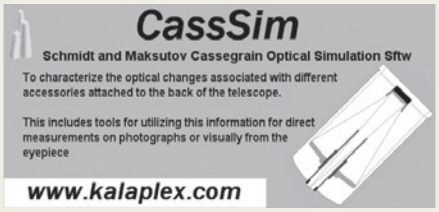

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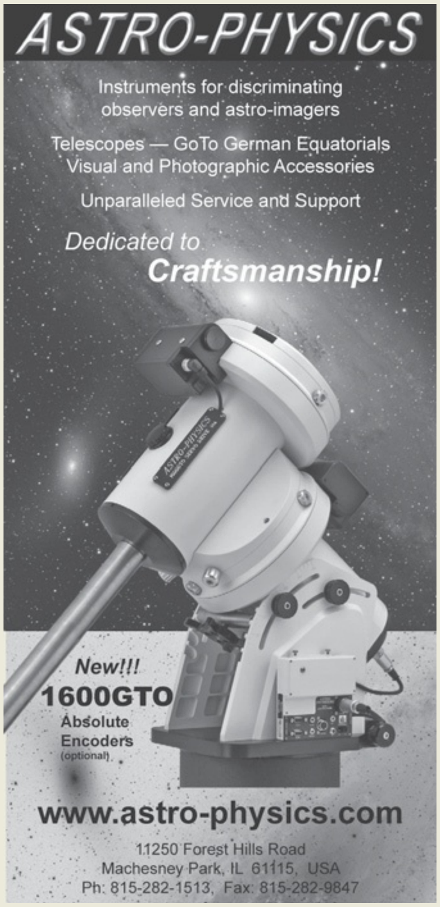

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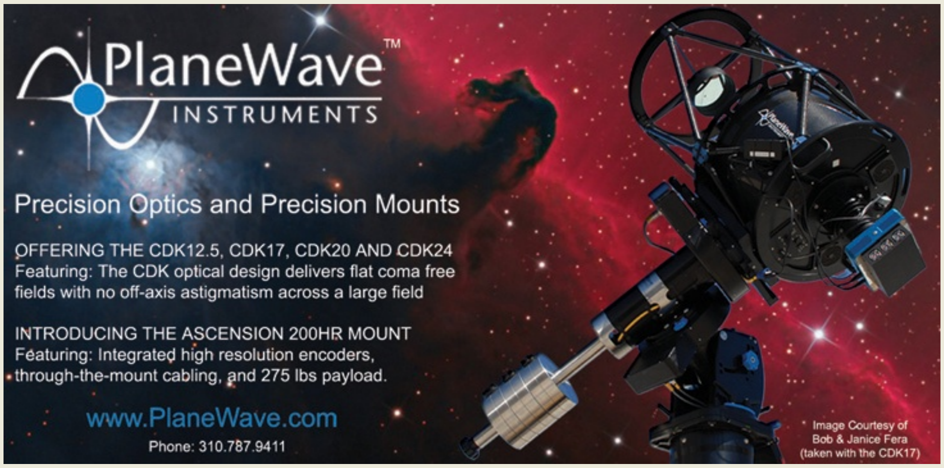

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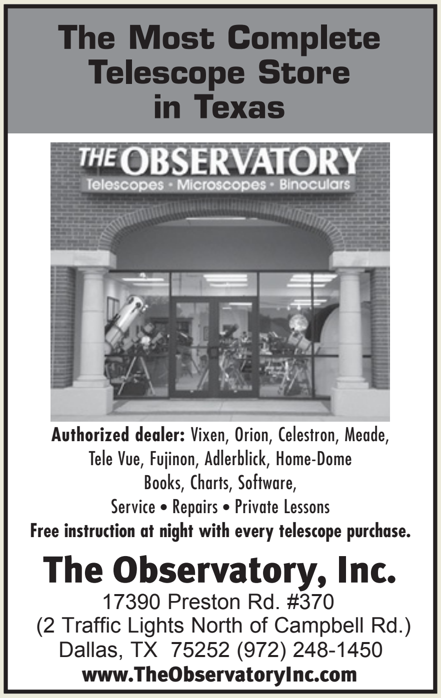

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IN THE NEXT ISSUE

Secrets of the Northern Lights

Scientists mostly understand how auroras are created, but mysteries still linger for this mesmerizing phenomenon.

Video Astronomy

A veteran deep-sky observer shares his experiences making the leap into video-assisted astronomy.

The Moon and the *Hunley*

The Moon and tides played pivotal roles in one of the U.S. Civil War's most famous naval encounters.

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A century ago this month, observers all over the Western Hemisphere saw a spectacular "parade" of fireballs.

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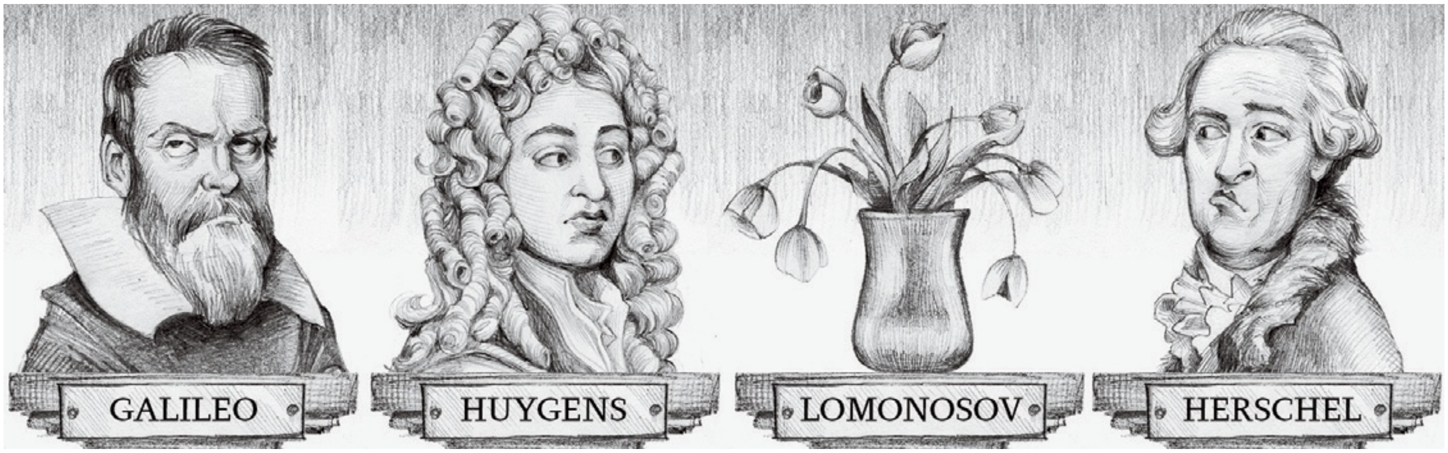
By Jay M. Pasachoff & William Sheehan

A Major Discovery in Doubt

Transit observations suggest that Mikhail Lomonosov never saw Venus's atmosphere.



S&T: LEAH TISCIONE

The great Russian 18th-century scientist Mikhail Lomonosov has been widely credited with the discovery of Venus's atmosphere during the 1761 transit of Venus that he observed from St. Petersburg. However, just as many convictions have been recently overturned by DNA evidence, the transits of Venus in 2004 and 2012 have convinced us that he didn't discover the planet's atmosphere after all.

When Glenn Schneider and one of us (J.M.P.) looked at observations of the 2004 transit made by NASA's TRACE spacecraft, we were surprised at how easily visible Venus's atmosphere was. Based on these observations, the two authors of this article wondered whether the "hair-thin luminous sliver" Lomonosov had seen and attributed to sunlight refracting through Venus's atmosphere could possibly be the arc of sunlight that had appeared so dramatically in TRACE imagery.

We commissioned an expatriate Russian librarian to translate the key parts of Lomonosov's 1761 article. Lomonosov indeed mentioned a "hair-thin luminous sliver," but it appeared for "not more than a second." Also, he wrote, "During Venus's egress ... a small blister ... appeared on the edge of the Sun." Neither of those events resembled what the atmosphere really looked like in 2004, as we point out in an article in the *Journal for Astronomical History and Heritage*, or in 2012.

Most of Lomonosov's article was concerned not about his observations but about religious and philosophical reasons for Venus having an atmosphere. He concluded that "the planet Venus is surrounded by an extensive atmosphere of air." He surmised, though on the basis of that incorrect conclusion, that the blister "could only be due to refraction of solar rays by the atmosphere surrounding Venus." Lomonosov himself produced a German translation of his article, in which he quoted only the philosophical part.

Historians of science have thoroughly documented how widespread the notion was in Lomonosov's time that the Moon and planets had to have atmospheres to serve the inhabitants of those worlds. Lomonosov was thus a man of his time.

Lomonosov's report just doesn't match what we now know Venus's atmosphere looks like during a transit. The "hair-thin sliver" lasting 1 second at ingress doesn't match the many minutes during which the atmosphere is visible, something that the two of us and Glenn Schneider each saw during the 2012 transit (*S&T:* October 2012, page 20). And the bulge at egress seems to match observations reported in 2012 by Canadian amateurs as resulting from the blurring of the bit of Venus's black silhouette that sticks out between bright bits of the solar limb on either side, without needing an atmosphere. Though the actual atmosphere was much fainter than the nearby solar disk, Lomonosov's drawings do not show any such difference.

Nothing Lomonosov wrote indicates that he actually saw Venus's atmosphere. Even if his telescope was good enough to see it, and the atmospheric conditions at St. Petersburg were exceptionally steady, Lomonosov apparently didn't notice it or he would have mentioned the faint "whisker" or "arc" instead of depicting a bulge.

Our view is that Lomonosov is given credit for something he assumed and analyzed but did not actually observe. If "History is an agreed upon fable," Lomonosov's discovery is a fable about which we and our critics must agree to disagree. ✦

Jay Pasachoff *is a solar and planetary astronomer currently on sabbatical at Caltech. Minnesota-based* ***William Sheehan*** *is author of many books on the history of astronomy.*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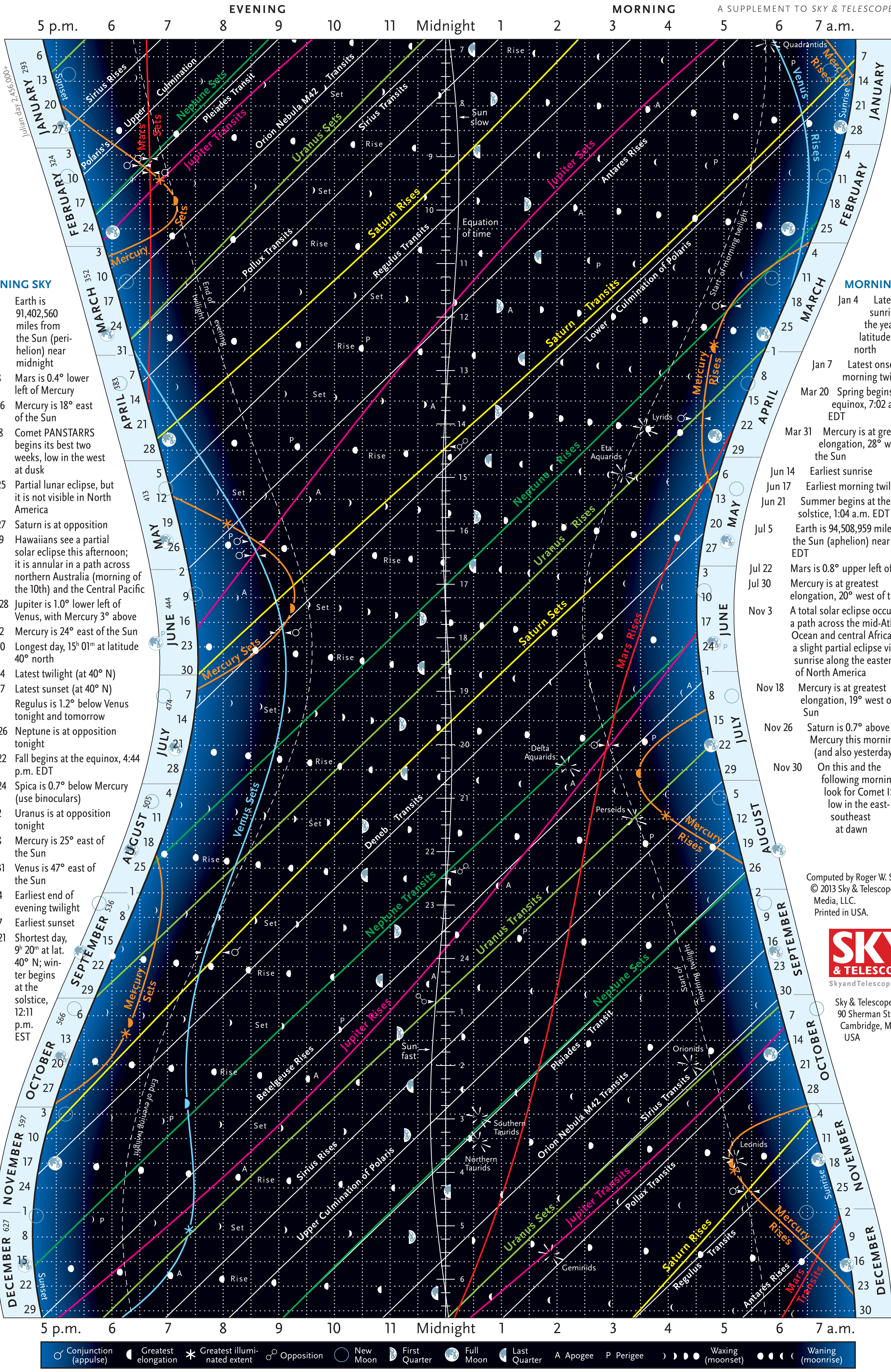

EVENING SKY

- Jan 1 — Earth is 91,402,560 miles from the Sun (perihelion) near midnight
- Feb 8 — Mars is 0.4° lower left of Mercury
- Feb 16 — Mercury is 18° east of the Sun
- Mar 8 — Comet PANSTARRS begins its best two weeks, low in the west at dusk
- Apr 25 — Partial lunar eclipse, but it is not visible in North America
- Apr 27 — Saturn is at opposition
- May 9 — Hawaiians see a partial solar eclipse this afternoon; it is annular in a path across northern Australia (morning of the 10th) and the Central Pacific
- May 28 — Jupiter is 1.0° lower left of Venus, with Mercury 3° above
- Jun 12 — Mercury is 24° east of the Sun
- Jun 20 — Longest day, 15ʰ 01ᵐ at latitude 40° north
- Jun 24 — Latest twilight (at 40° N)
- Jun 27 — Latest sunset (at 40° N)
- Jul 21 — Regulus is 1.2° below Venus tonight and tomorrow
- Aug 26 — Neptune is at opposition tonight
- Sep 22 — Fall begins at the equinox, 4:44 p.m. EDT
- Sep 24 — Spica is 0.7° below Mercury (use binoculars)
- Oct 2 — Uranus is at opposition tonight
- Oct 8 — Mercury is 25° east of the Sun
- Oct 31 — Venus is 47° east of the Sun
- Dec 4 — Earliest end of evening twilight
- Dec 7 — Earliest sunset
- Dec 21 — Shortest day, 9ʰ 20ᵐ at lat. 40° N; winter begins at the solstice, 12:11 p.m. EST

MORNING SKY

- Jan 4 — Latest sunrise of the year at latitude 40° north
- Jan 7 — Latest onset of morning twilight
- Mar 20 — Spring begins at the equinox, 7:02 a.m. EDT
- Mar 31 — Mercury is at greatest elongation, 28° west of the Sun
- Jun 14 — Earliest sunrise
- Jun 17 — Earliest morning twilight
- Jun 21 — Summer begins at the solstice, 1:04 a.m. EDT
- Jul 5 — Earth is 94,508,959 miles from the Sun (aphelion) near 11 a.m. EDT
- Jul 22 — Mars is 0.8° upper left of Jupiter
- Jul 30 — Mercury is at greatest elongation, 20° west of the Sun
- Nov 3 — A total solar eclipse occurs in a path across the mid-Atlantic Ocean and central Africa, with a slight partial eclipse visible at sunrise along the eastern coast of North America
- Nov 18 — Mercury is at greatest elongation, 19° west of the Sun
- Nov 26 — Saturn is 0.7° above Mercury this morning (and also yesterday)
- Nov 30 — On this and the following mornings, look for Comet ISON low in the east-southeast at dawn

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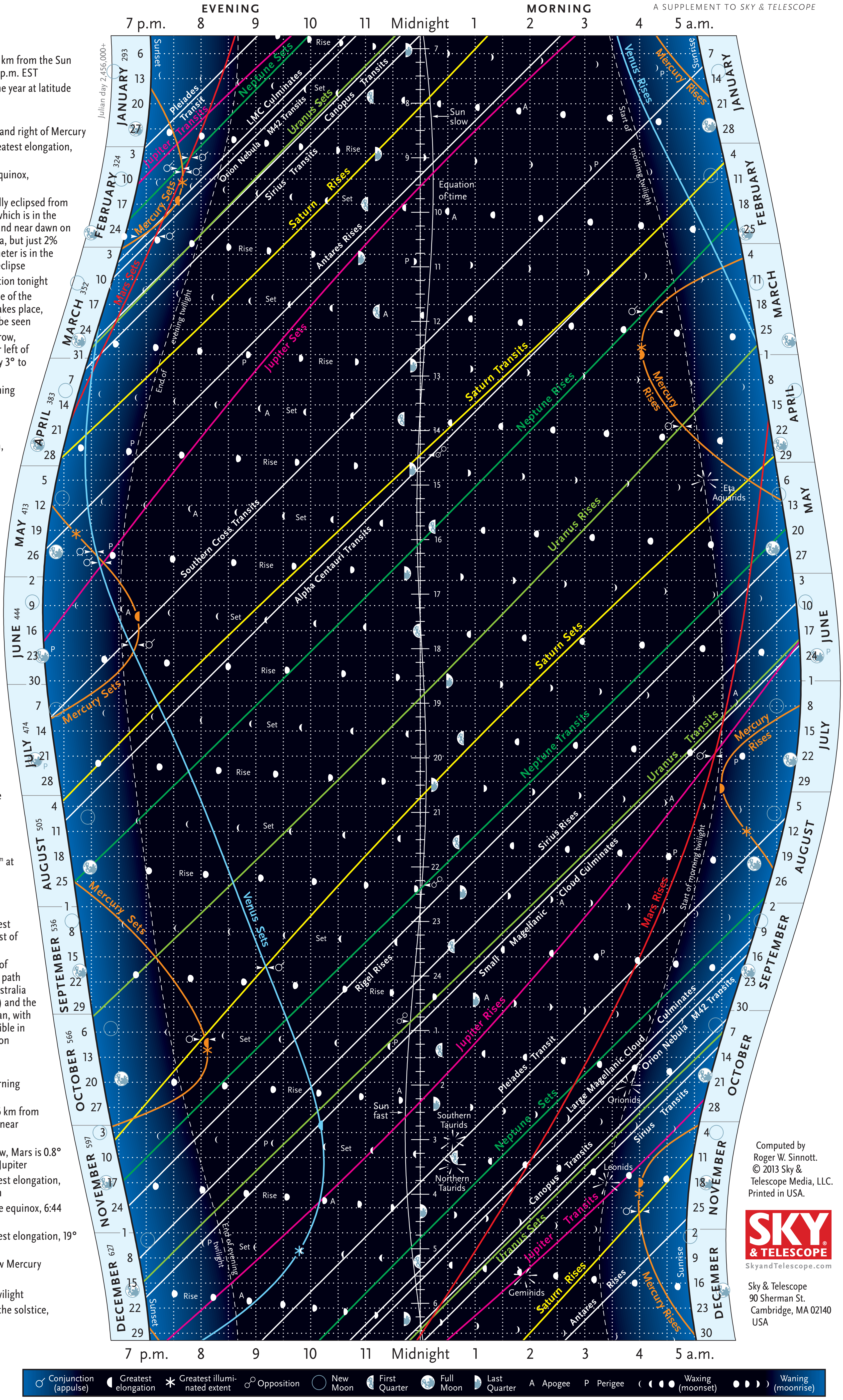
- Jan 2 Earth is 147,098,161 km from the Sun (perihelion) near 3 p.m. EST
- Jan 4 Latest twilight of the year at latitude 30° south
- Jan 9 Latest sunset
- Feb 8 Mars is 0.4° above and right of Mercury
- Feb 16 Mercury attains greatest elongation, 18° east of the Sun
- Mar 20 Fall begins at the equinox, 9:02 p.m. EST
- Apr 25 The Moon is partially eclipsed from 19:52 to 20:23 UT, which is in the evening for Africa and near dawn on the 26th in Australia, but just 2% of the Moon's diameter is in the umbra at greatest eclipse
- Apr 28 Saturn is at opposition tonight
- May 25 A penumbral eclipse of the Moon technically takes place, much too slight to be seen
- May 28 Tonight and tomorrow, Jupiter is 1.1° upper left of Venus with Mercury 3° to the right
- Jun 7 Earliest end of evening twilight
- Jun 10 Earliest sunset
- Jun 12 Mercury stands at greatest elongation, 24° east of the Sun
- Jun 21 Shortest day, 10^h 13^m at latitude 30° south; winter begins at solstice, 3:04 p.m. EST
- Jul 22 Regulus is 1.1° upper left of Venus
- Aug 26 Neptune comes to opposition
- Sep 25 Spica is 0.8° lower left of Mercury (use binoculars)
- Oct 3 Uranus is at opposition
- Oct 9 Mercury is at greatest elongation, 25° east of the Sun
- Nov 1 Venus attains greatest elongation, 47° east of the Sun
- Nov 3 A total solar eclipse occurs in a path across the mid-Atlantic Ocean and central Africa
- Dec 22 Longest day, 14^h 05^m at latitude 30° south

MORNING SKY

- Apr 1 Mercury is at greatest elongation, 28° west of the Sun
- May 10 An annular eclipse of the Sun occurs in a path across northern Australia (soon after sunrise) and the central Pacific Ocean, with a partial eclipse visible in Hawaii (afternoon on the 9th)
- Jul 1 Latest sunrise
- Jul 4 Latest onset of morning twilight
- Jul 6 Earth is 152,097,426 km from the Sun (aphelion) near 1 a.m. EST
- Jul 22 Today and tomorrow, Mars is 0.8° to the lower left of Jupiter
- Jul 31 Mercury is at greatest elongation, 20° west of the Sun
- Sep 23 Spring begins at the equinox, 6:44 a.m. EST
- Nov 18 Mercury is at greatest elongation, 19° west of the Sun
- Nov 26 Saturn is 0.4° below Mercury
- Dec 3 Earliest sunrise
- Dec 9 Earliest morning twilight
- Dec 22 Summer begins at the solstice, 3:11 a.m. EST



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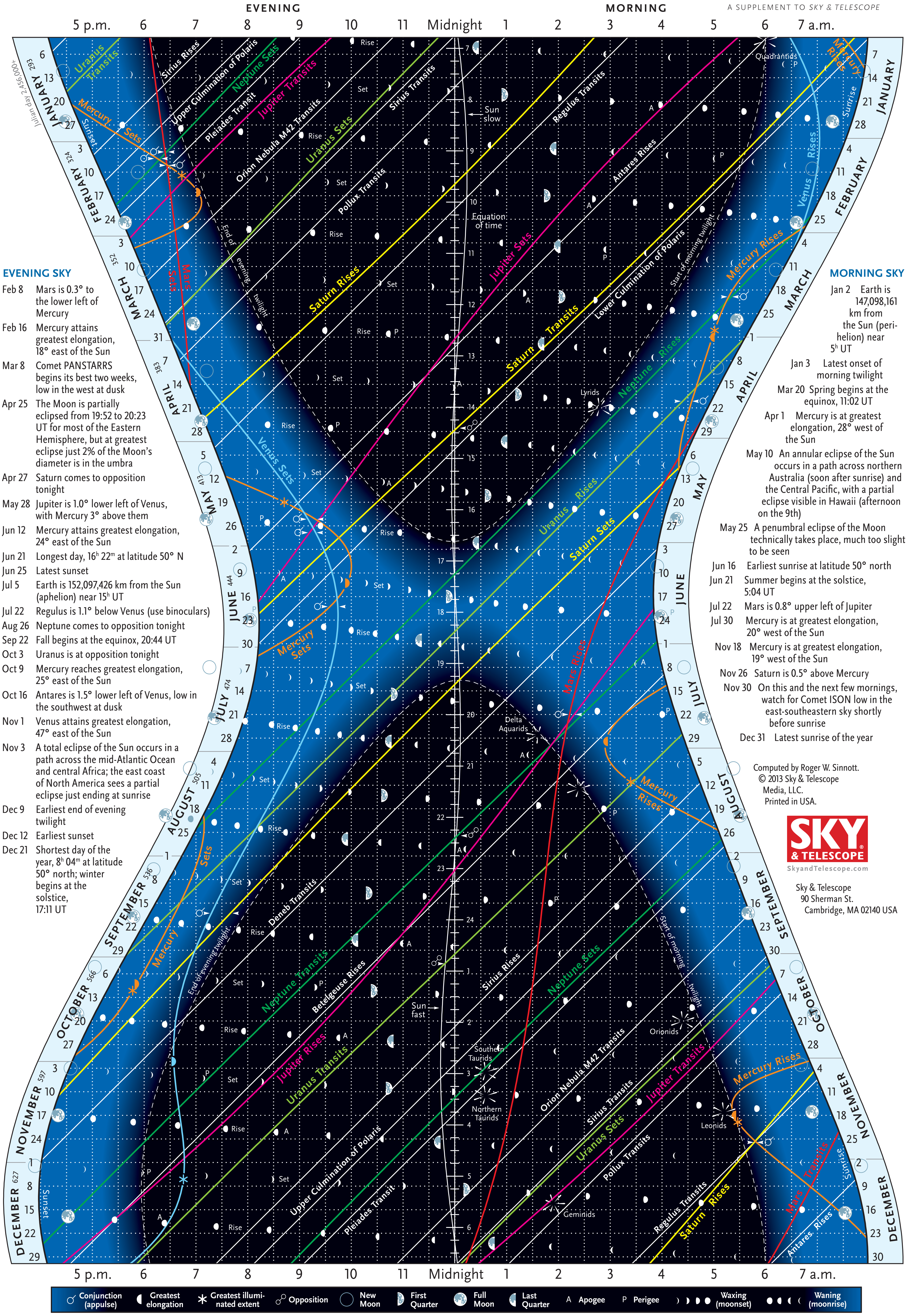

EVENING SKY

- **Feb 8** Mars is 0.3° to the lower left of Mercury
- **Feb 16** Mercury attains greatest elongation, 18° east of the Sun
- **Mar 8** Comet PANSTARRS begins its best two weeks, low in the west at dusk
- **Apr 25** The Moon is partially eclipsed from 19:52 to 20:23 UT for most of the Eastern Hemisphere, but at greatest eclipse just 2% of the Moon's diameter is in the umbra
- **Apr 27** Saturn comes to opposition tonight
- **May 28** Jupiter is 1.0° lower left of Venus, with Mercury 3° above them
- **Jun 12** Mercury attains greatest elongation, 24° east of the Sun
- **Jun 21** Longest day, $16^h\,22^m$ at latitude 50° N
- **Jun 25** Latest sunset
- **Jul 5** Earth is 152,097,426 km from the Sun (aphelion) near 15^h UT
- **Jul 22** Regulus is 1.1° below Venus (use binoculars)
- **Aug 26** Neptune comes to opposition tonight
- **Sep 22** Fall begins at the equinox, 20:44 UT
- **Oct 3** Uranus is at opposition tonight
- **Oct 9** Mercury reaches greatest elongation, 25° east of the Sun
- **Oct 16** Antares is 1.5° lower left of Venus, low in the southwest at dusk
- **Nov 1** Venus attains greatest elongation, 47° east of the Sun
- **Nov 3** A total eclipse of the Sun occurs in a path across the mid-Atlantic Ocean and central Africa; the east coast of North America sees a partial eclipse just ending at sunrise
- **Dec 9** Earliest end of evening twilight
- **Dec 12** Earliest sunset
- **Dec 21** Shortest day of the year, $8^h\,04^m$ at latitude 50° north; winter begins at the solstice, 17:11 UT

MORNING SKY

- **Jan 2** Earth is 147,098,161 km from the Sun (perihelion) near 5^h UT
- **Jan 3** Latest onset of morning twilight
- **Mar 20** Spring begins at the equinox, 11:02 UT
- **Apr 1** Mercury is at greatest elongation, 28° west of the Sun
- **May 10** An annular eclipse of the Sun occurs in a path across northern Australia (soon after sunrise) and the Central Pacific, with a partial eclipse visible in Hawaii (afternoon on the 9th)
- **May 25** A penumbral eclipse of the Moon technically takes place, much too slight to be seen
- **Jun 16** Earliest sunrise at latitude 50° north
- **Jun 21** Summer begins at the solstice, 5:04 UT
- **Jul 22** Mars is 0.8° upper left of Jupiter
- **Jul 30** Mercury is at greatest elongation, 20° west of the Sun
- **Nov 18** Mercury is at greatest elongation, 19° west of the Sun
- **Nov 26** Saturn is 0.5° above Mercury
- **Nov 30** On this and the next few mornings, watch for Comet ISON low in the east-southeastern sky shortly before sunrise
- **Dec 31** Latest sunrise of the year

Computed by Roger W. Sinnott.

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