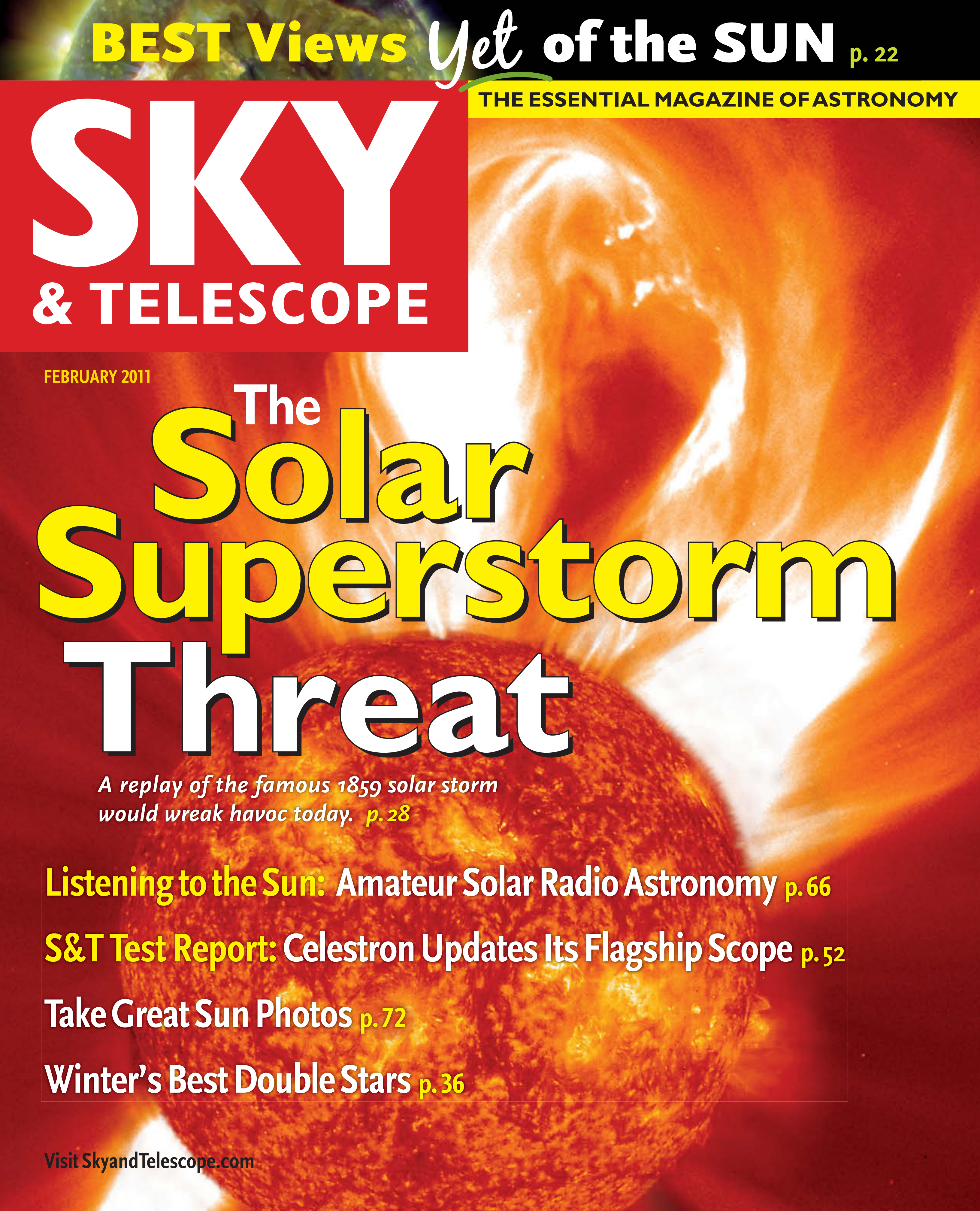

BEST Views *Yet* of the SUN p. 22

SKY & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

FEBRUARY 2011

The Solar Superstorm Threat

A replay of the famous 1859 solar storm would wreak havoc today. *p. 28*

Listening to the Sun: Amateur Solar Radio Astronomy p. 66

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Winter's Best Double Stars p. 36

SKY & TELESCOPE

February 2011

VOL. 121, NO. 2

ESA / NASA / EIT / LASCO

On the cover: This not-to-scale composite of 2 SOHO images from different instruments shows a coronal mass ejection blasting outward.

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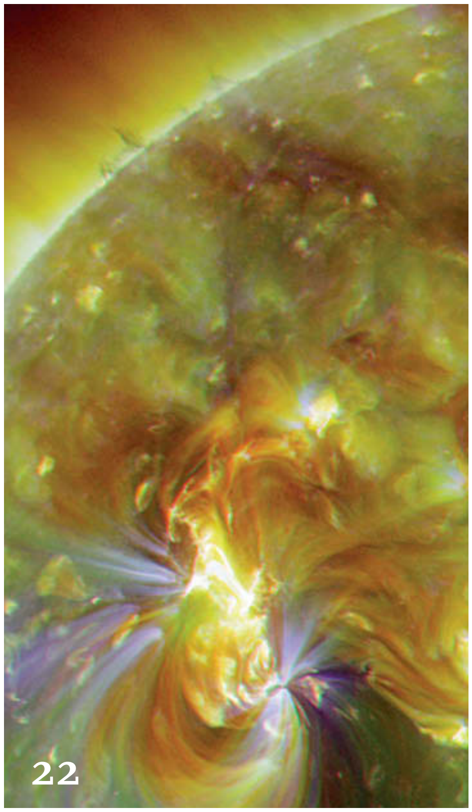
KWON O CHUL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NASA / SDO / AIA SCIENCE TEAM

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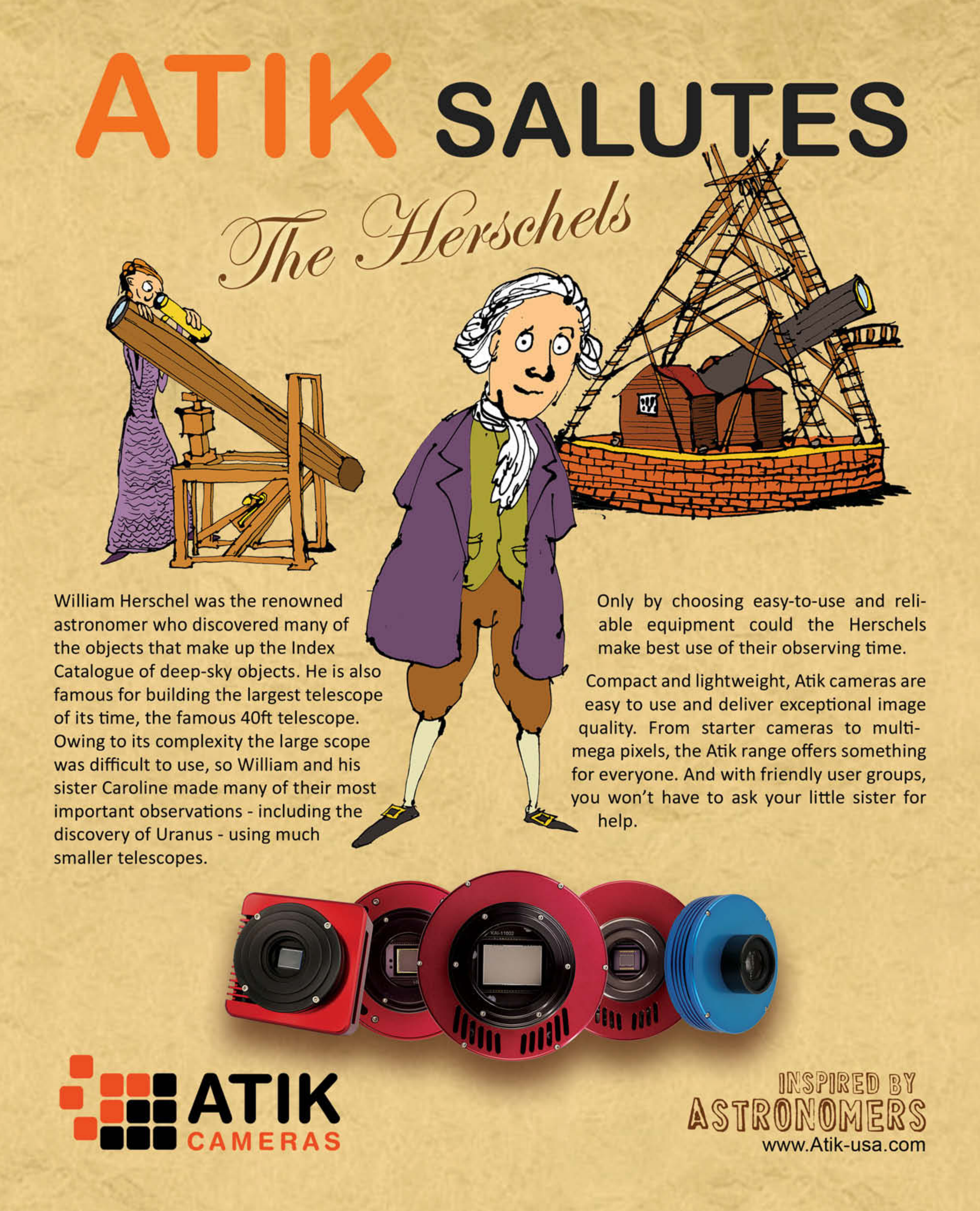
ATIK SALUTES
The Herschels
William Herschel was the renowned astronomer who discovered many of the objects that make up the Index Catalogue of deep-sky objects. He is also famous for building the largest telescope of its time, the famous 40ft telescope. Owing to its complexity the large scope was difficult to use, so William and his sister Caroline made many of their most important observations - including the discovery of Uranus - using much smaller telescopes.
Only by choosing easy-to-use and reliable equipment could the Herschels make best use of their observing time.
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Origin of an Article

IN OCTOBER 2009 I attended a three-day media workshop — The Dynamics of the Sun — at the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP). My knowledge of the Sun and space weather advanced by leaps and bounds, but a presentation by LASP Director Daniel Baker particularly caught my attention.

Dr. Baker gave a fascinating summary of the 1859 solar flare observed by British amateur astronomer Richard Carrington, and the effects on Earth of the subsequent geomagnetic storm. But I was practically jolted out of my chair when he mentioned that if a similar storm struck today, it could knock out electrical power for more than 130 million Americans, and it might take *years* to restore service in some areas. I was well aware of the 1989 solar-storm-induced blackout in Québec, but I didn't realize a larger solar storm could produce such widespread power disruptions and that it would take so long to recover. My immediate reaction was, "Yikes!!! More people need to be aware of this!" (I just violated my own rule of only one ! per article.)

My *S&T* colleagues and I feel it's our mission to provide you, the reader, with interesting, informative, and accurate articles about a wide range of astronomical-related topics. But from time to time, we think it's our responsibility to perform a public service by making you aware of astronomical phenomena that could have widespread consequences for society (or those that won't, such as the 2012 doomsday rumor). Assuming that many *S&T* readers, and certainly the vast majority of policymakers, are unaware of the severe consequences to our modern world of an 1859-level event, I asked Dr. Baker if he would be interested in writing an article for *S&T*. He quickly agreed.

Dr. Baker submitted his draft (based on a report for the National Academy of Sciences, and coauthored with James Green) about a year ago. But at that time the Sun was in the midst of an unusually prolonged minimum, so we waited until the Sun's activity was waking from its slumber before running the story. The result is the article beginning on page 28. Even knowing that it might be decades or centuries before humans face another storm similar in magnitude to the one in 1859, you might want to inform your friends about the consequences of severe space weather, and perhaps even write your legislators. Modern society needs to be better prepared for extreme geomagnetic storms, so we're hoping this article will help raise public awareness.

The solar superstorm article is one of several Sun stories in this issue, as you have probably noticed. We weren't originally planning a thematic issue about the Sun, but we've had so many recent high-quality article submissions related to the Sun that it made sense to run them together. Even if you're not a Sun aficionado, the articles cover such a diverse range of topics that we expect you'll find at least a couple of them to your liking.

Robert Naeye
Editor in Chief

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Asteroid Deflection & NEO Threats

Dan Durda's explanation of "How to Deflect a Hazardous Asteroid" (December issue, page 22) is state-of-the-art. However, I fear that it addresses only a part, and indeed the lesser part, of the NEO threat.

Durda informs the reader that "we're now focusing our concerns more on the multitude of smaller objects." His rationale is that "small impacts are common, large impacts are thankfully rare." But while that's empirically true, the conclusion drawn rests upon a double fallacy.

The first fallacy is that probability equals risk. But the standard definition of risk is probability of an occurrence times the magnitude of the projected loss. The projected loss from a large impactor — human extinction — more than compensates for its small probability. The second fallacy is that probability equals regularity. But the probability of an extinction-level impact by an errant asteroid or comet is more like the roll of a fair die than like the ticking of a clock. For instance, we have no idea when two asteroids will collide, or if two Oort Cloud objects did collide a thousand years ago, diverting one of them into the inner solar system. So even though large impacts may occur only, say, once every million years on average, they could happen two years in a row, or one could happen tomorrow.

I submit, therefore, that scientists (and politicians) should be focusing their concerns more on the larger objects than on the smaller ones.

Joel Marks
Professor Emeritus of Philosophy
University of New Haven
West Haven, Connecticut

Editor's note: *An extinction-level impactor from the Oort Cloud could not literally hit tomorrow; sky surveys would probably detect such an object 2 or 3 years in advance. But that would still give us scant time to prepare.*

Granted, a few asteroids might be "threatening," as the magazine cover declares. But to vilify all asteroids is going too far. Who knows, someday we might have to call upon one of these planetary wannabees to save our collective hides!

In a 2000 study titled "Astronomical Engineering: A Strategy for Modifying Planetary Orbits," D. G. Korycansky, Gregory Laughlin, and Fred C. Adams confront the peril faced by future Earthlings as the Sun brightens during its main sequence lifetime (*Astrophysics and Space Science* 275: 349-366, 2001). Within a billion years, the authors report, the increased solar emission will irreparably compromise Earth's biosphere. But there is a way out: use the gravitational tug of a well-placed asteroid to shepherd Earth out to a safe distance. Once coaxed into a highly elliptical orbit by an adjacent spacecraft (à la Durda's guidelines), each close encounter of the asteroid with Earth will slightly enlarge our planet's orbit; as the Sun brightens, Earth spirals away to a safe distance.

According to the authors' calculations, one such near-pass every 6,000 years or so is sufficient to maintain the present solar flux on Earth for the remainder of the Sun's main-sequence stage, around 5 billion years. Of course, deflecting an asteroid toward Earth is not without risk: a slight maladjustment of its orbit could mean catastrophe. But please don't blame the asteroid. It's only trying to help.

Alan Hirshfeld
Dartmouth, Massachusetts

Venus During the Day

Since the sky was very clear and blue yesterday (October 28th) in Palm Springs, California, I stood on the south-facing porch of the Tahquitz Canyon Visitor Center at 11 a.m. PDT, using the overhanging porch roof to block the Sun, and searched for Venus to the lower right of the Sun with my 10×50 binoculars. It took awhile, but after several minutes I spotted the crescent, horns pointing to the lower right. Once seen, it was easy to keep in view.

I next headed to Cahuilla Elementary School, where I set up my Orion SkyQuest XT4.5 Dobsonian reflector, again under an overhanging roof, to safely block the Sun, and quickly found Venus. Using the 25-mm eyepiece (36×), I remained in the schoolyard showing the crescent Venus to more than 100 students over the next few hours, ending just three hours before Venus's inferior conjunction at 6 p.m. PDT. Most of the students had no difficulty seeing the very thin crescent, which appeared oriented as a "smile."

I'm planning to set up the telescope in mornings for daytime viewing of Venus beginning November 29th, when the students return from a 4-week break in their school year. By then Venus will be very easy to spot in the daytime, even with the unaided eye. I'm especially looking forward to December 2nd, when the Moon will appear nearby, making Venus easy to locate.

This is the first time I have observed Venus on the date of an inferior conjunction to the south of the Sun. On many occasions since April 1961, I have observed Venus at or near inferior conjunctions in January or in March–April, when Venus passes north of the Sun, making it easy to block the Sun with the top of a building.

During my observations on October 28th, Venus was 6.0° from the center of the Sun's disk, and it appeared brighter and easier to see than I expected.

At the next inferior conjunction, on the afternoon of June 5, 2012 (in North America), Venus will transit the Sun's disk. It will be interesting to find out how close before and after the transit a crescent Venus can be observed. Hopefully, I'll be able to use the side of a building to hide the midday Sun. I'm reminded of a daytime comet I observed with my unaided eye and binoculars a few years ago on January 14th and 15th, by hiding the midday Sun behind the trunk of a palm tree.

Robert C. Victor
Palm Springs, California

Editor's note: *Victor penned* S&T*'s Sun, Moon, and Planets column from 1971 to 1985.*

Global Astronomy Month

Many clubs started outreach programs for the International Year of Astronomy 2009 (IYA2009), but what now?

Astronomers Without Borders (AWB) has created Global Astronomy Month (GAM) to bring together astronomy clubs and enthusiasts worldwide each April. First held in April 2010, one year after the highly successful 100 Hours of Astronomy IYA2009 Cornerstone Project, GAM consists of programs created by AWB and other organizations, all centrally organized, and linking clubs of the Astronomers Without Borders global network. Popular programs include the Global Star Party on April 9th, Lunar Week, SunDay, Saturn Watch, and online observing with interaction between participants around the world and the astronomer controlling the telescope and camera.

For more information, see the GAM 2011 website at www.gam-awb.org, or write to GAM2011@astronomerswithoutborders.com.

Mike Simmons
Agoura, California

For the Record

✷ *As several readers pointed out, Mercury and Venus were mislabeled in a diagram on page 49 of our December issue. Alas,* Sky & Telescope *does not have the power to swap planets, and we apologize for the error.*

50 & 25 Years Ago

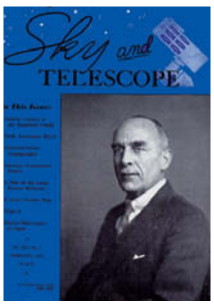
Leif J. Robinson

February 1961

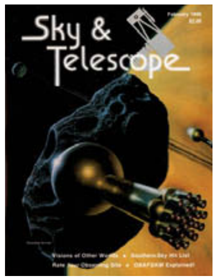
Galactic Powerhouse "M87 [Virgo A] has a very remarkable feature, shown on short-exposure photographs with large reflectors. This is a brilliant jet, extending out from the nucleus. . . .

"The jet is about 20 seconds of arc long, and averages two seconds in width. This feature is much bluer than M87 itself, and according to M. Humason its optical spectrum is continuous, without absorption or emission lines. . . .

"The physical nature of M87's bright jet remains unexplained. I. S. Shklovsky has suggested that it shines by synchrotron radiation emitted by fast-moving electrons in a magnetic field. . . ."



Shklovsky's interpretation was spot on, and the jet is now regarded as a manifestation of a supermassive black hole in the galaxy's center. The giant elliptical M87 is one of the closest active galaxies to Earth. It's the fifth-strongest radio source in the sky, and most of the radio energy comes from the jet.



February 1986

Optics News "The California Institute of Technology has awarded a $10.8-million contract to Itek Optical Systems of Lexington, Massachusetts, to fabricate 42 hexagonal mirrors for the new 10-meter (400-inch) Keck Telescope. . . . Each mirror will be about 72 inches across and 3 inches thick and weigh 1,400 pounds."

"A September, 1986, completion date has been set by Perkin-Elmer Corp. for its new optical facility in Danbury, Connecticut. One of the largest and most sophisticated of its kind, the plant will produce specialized systems for 21st-century astronomy missions. . . .

"Perkin-Elmer built the optical systems . . . for Hubble Space Telescope. . . ."

The Keck Observatory's mirrors worked right away. But the Hubble Space Telescope's primary mirror was slightly misshapen.

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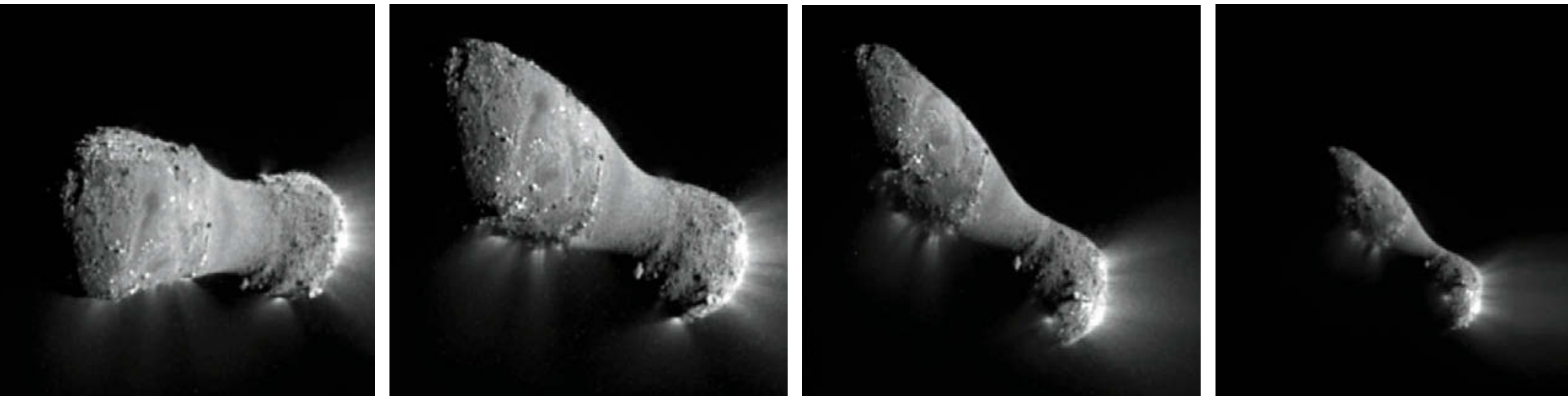
The Amazing Comet Hartley 2



NASA / JPL-CALTECH / UMD / EPOXI MISSION (4)

The nucleus of Comet Hartley 2, seen as NASA's Deep Impact spacecraft approached and flew under it.

On November 4th NASA's Deep Impact spacecraft zipped 435 miles (700 km) past Comet 103P/Hartley 2, taking pictures and spectra of its unexpectedly weird nucleus: an irregular peanut, 1.4 miles long, spraying jets from its rough, rubbly ends and girdled by a smooth zone around its middle. The smooth zone seems to be fine-grained material that drifted to fill the gravitationally lowest areas of the little body. There's no explanation yet for the smooth zone's sharp edges: lines of piled-up chunks marking the beginnings of the two caps.

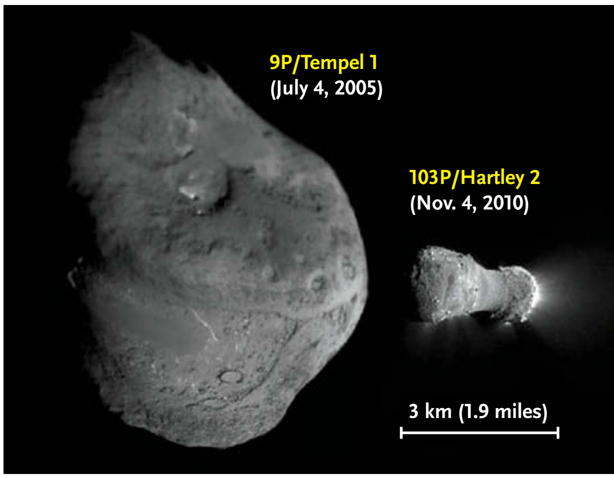
Mission scientists released raw images immediately, but more came later. It took a while to reconstruct the sharpest views from the craft's High-Resolution Imager, which was slightly out of focus and needed computer help to recover details.

The images connect individual jets of gas and dust to their sources on the surface, a cometary first. More remarkably, in the image on the next page we see that Hartley 2 is shedding discrete chunks, inches to a foot or two across, that are moving slowly away from the nucleus. Stereo pairs of these images give 3-D views looking "like a snow globe that we've shaken in space," said investigator Peter Schultz (Brown University). "The nucleus has a posse of mini-comets around it."

So was the spacecraft in danger? The clumps are apparently fluffballs of tiny grains just 1 to 10 microns wide. Says investigator Jessica Sunshine (University of Maryland), "We're seeing fluffy aggregates of very small pieces of ice, akin to a dandelion puff." Nine tiny grains struck the spacecraft during the 10 minutes it was closest — with enough kinetic energy to jiggle the structure momentarily but not enough to damage it.

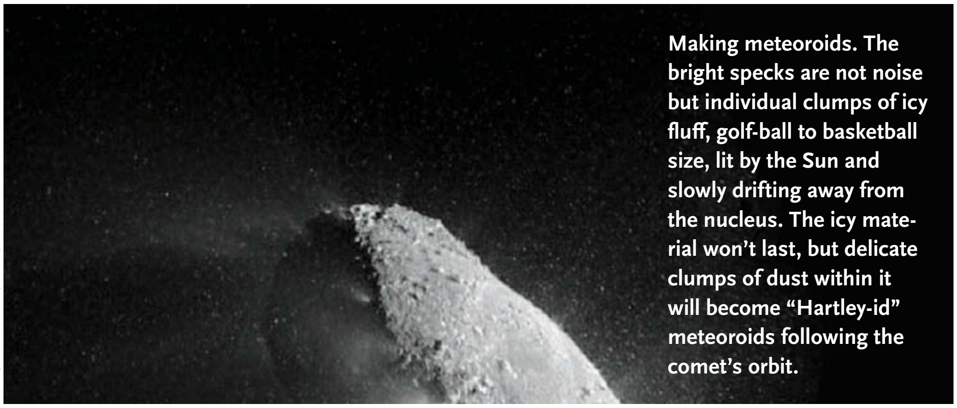
A different discovery, which could turn our current understanding of comets on its head, is that the jets spraying from the end caps are not driven by water vapor. Instead, Sunshine says, "We now have unambiguous evidence that solar heating of subsurface frozen carbon dioxide — dry ice — is powering the jets of material coming from the comet."

Since 1950 cosmic chemists have thought water was the dominant volatile frozen into these icy bodies. Part of the problem has been an inability to detect CO_2 gas directly: its strongest emission, at 4.26 microns, is too far in the infrared to be



The two comets visited by Deep Impact are shown at the same scale. With a length of about 4.7 miles (7.6 km), Tempel 1 is five times larger in average diameter than Hartley 2. But jets were obvious in views of Hartley 2's nucleus, while jets from Tempel 1 could be glimpsed only after extensive image processing.

NASA / JPL-CALTECH / UMD / EPOXI MISSION



Making meteoroids. The bright specks are not noise but individual clumps of icy fluff, golf-ball to basketball size, lit by the Sun and slowly drifting away from the nucleus. The icy material won't last, but delicate clumps of dust within it will become "Hartley-id" meteoroids following the comet's orbit.

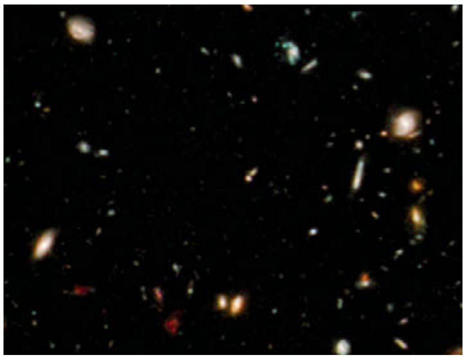
NASA / JPL-CALTECH / UMD / EPOXI MISSION

seen from the ground. But the spectrometer on Deep Impact resolved the sources of CO_2 and H_2O and found that they're in different places. The bright jets are driven by dry ice vaporizing and carrying dust out with it. Water vapor is sublimating more quietly from Hartley 2's middle zone.

Not surprisingly, the spectrometer also picked up the infrared signature of organic compounds. When the Giotto spacecraft flew through the coma of Comet Halley in 1986, one of its instruments found that some 30% of the bits it analyzed were "CHON" particles, consisting entirely of the organic building blocks carbon, hydrogen, oxygen, and nitrogen.

New Cosmic Distance Record

Using nearly 15 hours of exposure time on an 8.2-meter telescope in Chile, astronomers have measured a new record redshift — for a tiny speck of a galaxy dimly recorded in the Hubble Ultra Deep Field 09. The galaxy has a redshift of 8.6, meaning we see it as it stood 13.1 billion years ago: 600 million years after the Big Bang, when the universe was just 1⁄25 of its present age. It edges out the previous well-determined redshift record of 8.3, seen in a gamma-ray burst, and it smashes the previous definite high of 7.0 for a galaxy.



GARTH ILLINGWORTH (UCO / LICK OBS. / UC SANTA CRUZ) ET. AL.

In this bit of the near-infrared Hubble Ultra Deep Field 09, a few of the tiniest specks are small galaxies apparently shining to us from just 600 million years after the Big Bang.

Light coming from such an early time probes the *reionization epoch:* when the cold, neutral hydrogen filling the universe after the Big Bang was being lit up and ionized by radiation from the first stars and quasars.

The redshift team, led by Matt Lehnert of Paris Observatory, speculates that intense radiation from billions of young stars created a local ionized "clearing" roughly 10 million light-years across in the primordial neutral-hydrogen fog. This would have given the hydrogen-emission light from the galaxy enough running room to redshift away from its original wavelength, and thus avoid being reabsorbed by neutral hydrogen farther on its line of sight toward Earth. Yet the galaxy likely contained only a billion hot stars, way too few to create a clearing big enough. It probably had help from unseen smaller galaxies in its neighborhood.

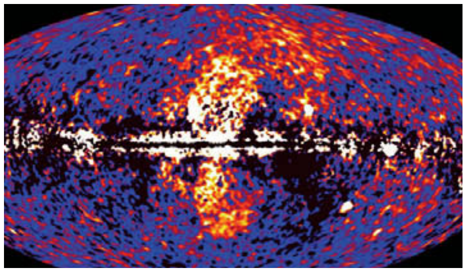
The Milky Way's Giant Gamma-Ray Bubbles

Who knew? NASA's Fermi gamma-ray observatory has revealed a pair of enormous gamma-ray-emitting bubbles, each 25,000 light-years tall, extending north and south from the Milky Way's center. They span the sky from Virgo to Grus.

In Fermi's all-sky maps of very-high-energy gamma radiation (1 billion to 100 billion electron volts per photon), the bubbles at first went unrecognized. Meng Su, Tracy Slatyer, and Douglas Finkbeiner (Harvard-Smithsonian Center for Astrophysics) coaxed them into view only after masking bright sources and subtracting the glow of high-energy gamma-ray emission that pervades the sky, especially toward the galactic plane and center.

But clues were lying around for decades. During the 1990s the German-built Rosat X-ray observatory traced two sets of cone-shaped arcs that coincide with the bubbles' edges. Later, NASA's WMAP satellite detected a "microwave haze" that corresponds to the bubbles' interiors.

Many galaxies exhibit opposing jets of matter blowing from their centers, but the "Fermi bubbles" defy easy explanation. The energy of the gamma rays is just too high. One possible source is a titanic burp within the last 10 million years from the supermassive black hole at the Milky Way's center. But the bipolar jets from such sources rarely display such



NASA / DOE / FERMI LAT / D. FINKBEINER ET. AL.

This all-sky map, centered on the plane of the Milky Way, shows curving sprays of *something* that emits very-high-energy gamma rays (1 billion to 100 billion electron volts) extending some 25,000 light-years north and south of the Milky Way's center.

symmetry or wide shapes. Another possibility is a burst of star formation at the galaxy's center. The bubbles seem to have sharp edges, perhaps marking expanding shock fronts from such an event, but the gamma-ray spectrum recorded by Fermi is again too "hard" (dominated by especially high-energy emission). "There is likely more than one thing going on here," suggests Finkbeiner.

Planet from Another Galaxy

Is there *any* kind of star that can't have planets? The latest unexpected find is a world with at least 1.25 Jupiter masses

orbiting the post-red-giant star HIP 13044, a 10th-magnitude yellow giant 2,000 light-years away in Fornax.

A European group found the planet by the radial-velocity wobble it induces in the star. At the inner end of the planet's elliptical, 16.2-day orbit, it comes within a stellar diameter of this large star's surface. The star is on the horizontal branch of the Hertzsprung-Russell diagram, meaning that it has already gone through its first excursion to red-gianthood and has since shrunk and re-heated. The planet must have been farther out during the star's red-giant phase and later worked its way in closer, perhaps by tidal interactions. Otherwise the star would have swallowed it.

The planet is also unique in two other ways. Its star has the lowest metallicity (fraction of elements heavier than helium) of any host star yet known. And this system didn't even originate in our Milky Way. The star is on a high-velocity trajec-

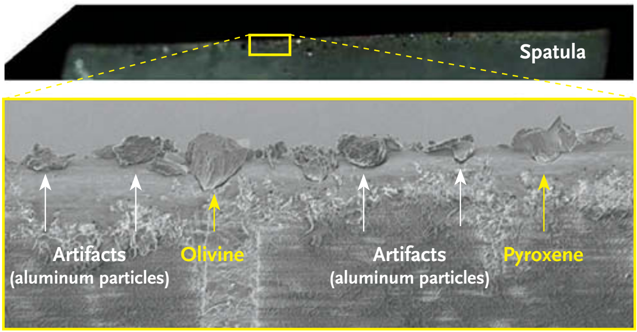
ESO / LUIS CALÇADA

tory that pegs it as member of the "Helmi stream," a moving group that originally belonged to a dwarf galaxy that fell into the Milky Way 6 to 9 billion years ago and has not yet completely dispersed.

Any planets that were closer to HIP 13044 may have been consumed already. "The star is rotating relatively quickly for a horizontal branch star," said Johny Setiawan (Max Planck Institute for Astronomy), who led the research. "One explanation is that HIP 13044 swallowed its inner planets during the red-giant phase, which would make the star spin more quickly."

Hayabusa's Asteroid Dust

After surviving a seven-year, problem-plagued trip to the tiny asteroid 25143 Itokawa and back, Japan's Hayabusa spacecraft plunged to Earth last June 13th. The



JAXA

Microscopic particles line the edge of a tiny spatula used to scrape the walls of one of Hayabusa's sample containers. Shown magnified in the lower panel, most of the particles (white arrows) are specks of aluminum from the container. The ones marked in yellow are from the asteroid Itokawa.

craft's sample gatherer had failed while on the asteroid's surface — but, it turns out, not entirely. Working in a special clean room at the Japan Aerospace Exploration Agency (JAXA), meteorite scientists have confirmed that some microscopic bits in a sample-return container are truly extraterrestrial — mostly rocky, iron-rich olivine and pyroxene.

That's consistent with the surface composition of Itokawa derived from Hayabusa's instruments and from Earth-based observations. These studies suggest that the small body — only 2,100 feet (640 meters) long — is an S-type asteroid with a rocky composition.

Scientists scraped particles from the container's walls using a tiny, Teflon-coated spatula. Many of the particles are aluminum flakes created by opening the enclosure — but several thousand are not. "The minerals are all extremely rare and never found together on Earth," explains Michael Zolensky, a NASA scientist who helped with the analysis. "But they constitute the major minerals found in some ordinary chondrite meteorites."

A Steamy Super-Earth?

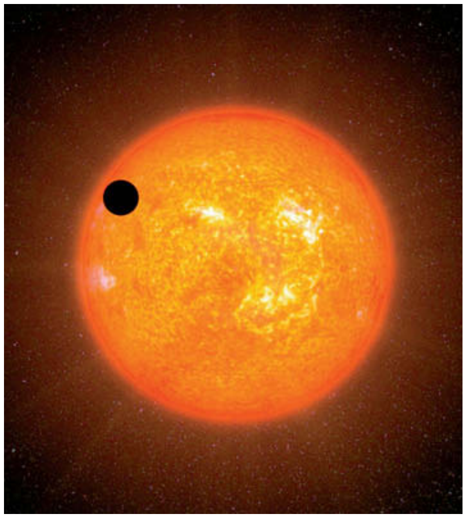
In the latest breakthrough for exoplanet science, a team using the European Southern Observatory's Very Large Telescope has obtained a crude spectrum for the upper atmosphere of a super-Earth orbiting a dim red dwarf star 40 light-years away in Ophiuchus. The planet's atmosphere is apparently dominated by steam or cloudy haze.

The star, 14.7-magnitude GJ 1214, is type *M*4.5 and 300 times dimmer than the Sun. Its planet was discovered in 2009 by its transits across the star. The planet has 6.5 Earth masses (determined by the star's wobbles) and circles the little star very closely in just 38 hours. The transits reveal the planet's diameter to be 2.6 times Earth's — making its average density very low, only about a third of Earth's.

The astronomers detected spectral signs from a tiny fraction of the star's light filtering through the planet's upper atmosphere during a transit. They found that the upper atmosphere either consists mostly of water vapor or is dominated by high-altitude clouds or haze.

"This is the first super-Earth to have its atmosphere analyzed. We've reached a real milestone on the road toward characterizing these worlds," said team leader Jacob Bean (Harvard–Smithsonian Center for Astrophysics).

Before this observation, astronomers had suggested three possible atmospheres for GJ 1214b. The planet could be shrouded by water — which, given its high



ESO / LUIS CALÇADA

GJ 1214b is small as exoplanets go. But its red-dwarf star is small too, one-fifth the diameter of the Sun, so the planet displays a sizeable profile during its transits. (Artist's concept.)

temperature so close to the star (200°C; 400°F), would be in the form of steam. Or it could be a rocky world with an atmosphere of mostly hydrogen obscured by high clouds or hazes. Or it might be a mini-Neptune, with a small rocky core and a deep hydrogen-rich atmosphere, the upper part of which would be clear.

The measurements show no signs of hydrogen and thus rule out the third option. So the atmosphere is either rich in steam or blanketed by clouds or hazes. The planet's low density, meanwhile, suggests a waterworld.

"Although we can't yet say exactly what that atmosphere is made of, it is an exciting step forward to be able to narrow down the options for such a distant world to either steamy or hazy," comments Bean. "Followup observations in longer-wavelength infrared light are needed to determine which of these atmospheres exists on GJ 1214b."

No Goldilocks Planet?!

Rarely have modern exoplanet hunters had to retract a discovery, but they almost certainly have egg on their faces regarding one of the most newsworthy exoplanets ever announced.

Last September 29th a team led by Steven Vogt and Paul Butler, longtime leaders in the field, announced that it had teased six distinct planetary orbits out of the complex wobbles of Gliese 581, a red dwarf 20 light-years away in Libra. Significantly above the noise level, they said, was the signature of an object with 3 to 4 Earth masses orbiting in the star's habitable zone, where temperatures should be right for liquid water on the surface (*S&T:* December 2010, page 16). The "Goldilocks planet" made worldwide news.

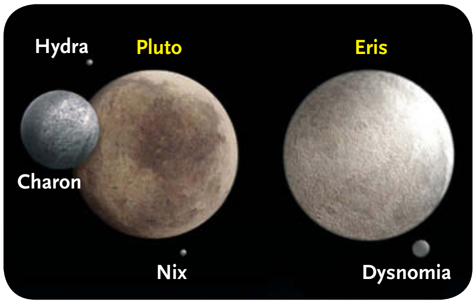
Its radial-velocity wobble emerged only when the team combined its own star-velocity measurements with others published by a different team, at Geneva Observatory in Europe. But since then, the Geneva team has made additional measurements of its own and says it cannot confirm that the planet exists — and if its signal were as strong as claimed by Vogt's group, it would have seen it by now.

More measurements should settle the issue within a year or two, but it's looking bad for Goldilocks — and for exoplanet hunters' stellar reputations.

Eris is Dwarfed; Is Pluto Bigger?

A successful campaign to time a faint star's occultation has shrunk the diameter and brightened the surface of Eris, considered to be the largest known "dwarf planet" beyond Neptune. In fact, Eris is now so close to the size of Pluto that Pluto could regain its lost title as the king of the known trans-Neptunian objects.

On November 6th three teams of astronomers in the Chilean Andes caught Eris passing in front of a 17th-magnitude star in Cetus. Still, the solution for Eris's diameter is not very exact because the star's dimness required slow-frame video exposures. Nevertheless, says Bruno Sicardy, Eris "almost certainly" has a diameter smaller than 2,340 km. Pluto is thought to be 2,344 ± 20 km wide. And Eris's final value could be pushed another 100 to 120 km lower.



NASA

Which is bigger? Now that an occultation has downgraded the diameter of Eris, it's in a tossup with Pluto. Both are shown with their moons.

Mike Brown (Caltech), who headed the team that discovered Eris in 2005, and others took images with the Hubble Space Telescope that year indicating a diameter of 2,400 km, 5% larger than Pluto. Observations of Eris's heat glow by the Spitzer Space Telescope yielded a diameter nearer 2,600 km, and another group, using the IRAM millimeter-wave telescope in Spain, upped the heat-glow value closer to 3,000 km. However, astronomers now realize that Eris's spin axis is pointing toward the Sun, an aspect that would keep the sunlit hemisphere warmer than average and skew infrared and millimeter-wave measurements toward higher values.

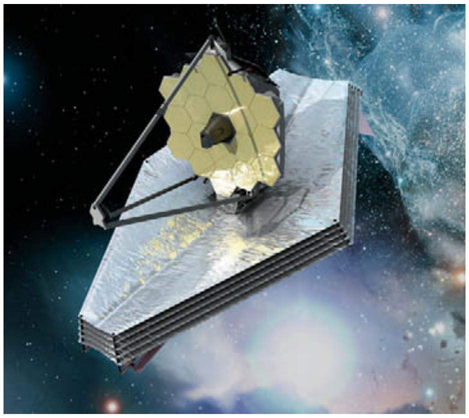
Eris's mass, well determined from the orbit of its moon Dysnomia, is about 25% greater than Pluto's — and that's unchanged. So if the occultation result holds up, Eris's density must be higher, 2.5 grams per cubic centimeter or more. And its albedo (reflectivity) must be at least 90%, as white as new-fallen snow. "A year ago I would have declared that result to be thoroughly crazy," Brown says, "as it just seems unreasonable that Eris would have a density that high." He adds, "The albedo is already so ridiculously high that just a little more ridiculousness is okay."

JWST Late and Over Budget

Unrealistic budget planning at NASA has left the 6.5-meter James Webb Space Telescope (JWST) — the keystone of big astronomy for the next generation — facing at least another $1.5 billion in cost overruns, an independent review panel announced in November. And though construction of JWST is under way ($3 billion has already been spent), the panel estimated that its launch will be delayed from June 2014 to at least September 2015.

NASA is now scrambling to scrounge the money from other projects even as the overall fiscal environment worsens. The news bodes ill for the funding of future space-based projects outlined in the recent decadal survey of U.S. astronomy goals (*S&T:* November 2010, page 14). These might have to wait until JWST is launched.

At least the panel had good news on the technical side. It found that although JWST will rely on many new and difficult technologies, it is on track to work as planned. ✦



ESA / C. CARREAU

New Scrutiny of the Sun's Secrets

The Solar Dynamics Observatory is taking continuous, fine-scale movies of every layer from the Sun's surface up.

Monica Bobra

OFF-PLANET ECLIPSE From its position in geosynchronous orbit 22,000 miles above Earth's surface, SDO sometimes sees the Moon cross the Sun. Low lunar hills are visible on the limb against gossamer loops of plasma in the solar atmosphere.

NASA / SDO / AIA SCIENCE TEAM

AUGUST 1, 2010, was a remarkably active day on the Sun. Several flares erupted, sending gusts of charged particles across the solar system. Some of these particles slid down Earth's magnetic field lines, plunged into the atmosphere, and created vivid curtains of auroral light. Further eruptions have been taking place, and it seems that a new solar-activity cycle is finally under way — providing scientists with a long-awaited opportunity to study renewed solar activity with a new suite of spaceborne instruments.

On February 11, 2010, NASA launched its most ambitious endeavor to study the Sun: the nearly $1 billion, three-instrument Solar Dynamics Observatory. SDO was designed to image the activity in every layer of the Sun simultaneously, continuously, and at high resolution and high speed (*S&T:* January 2010, page 22). SDO began observing last April. Here are some early returns from its three instruments.

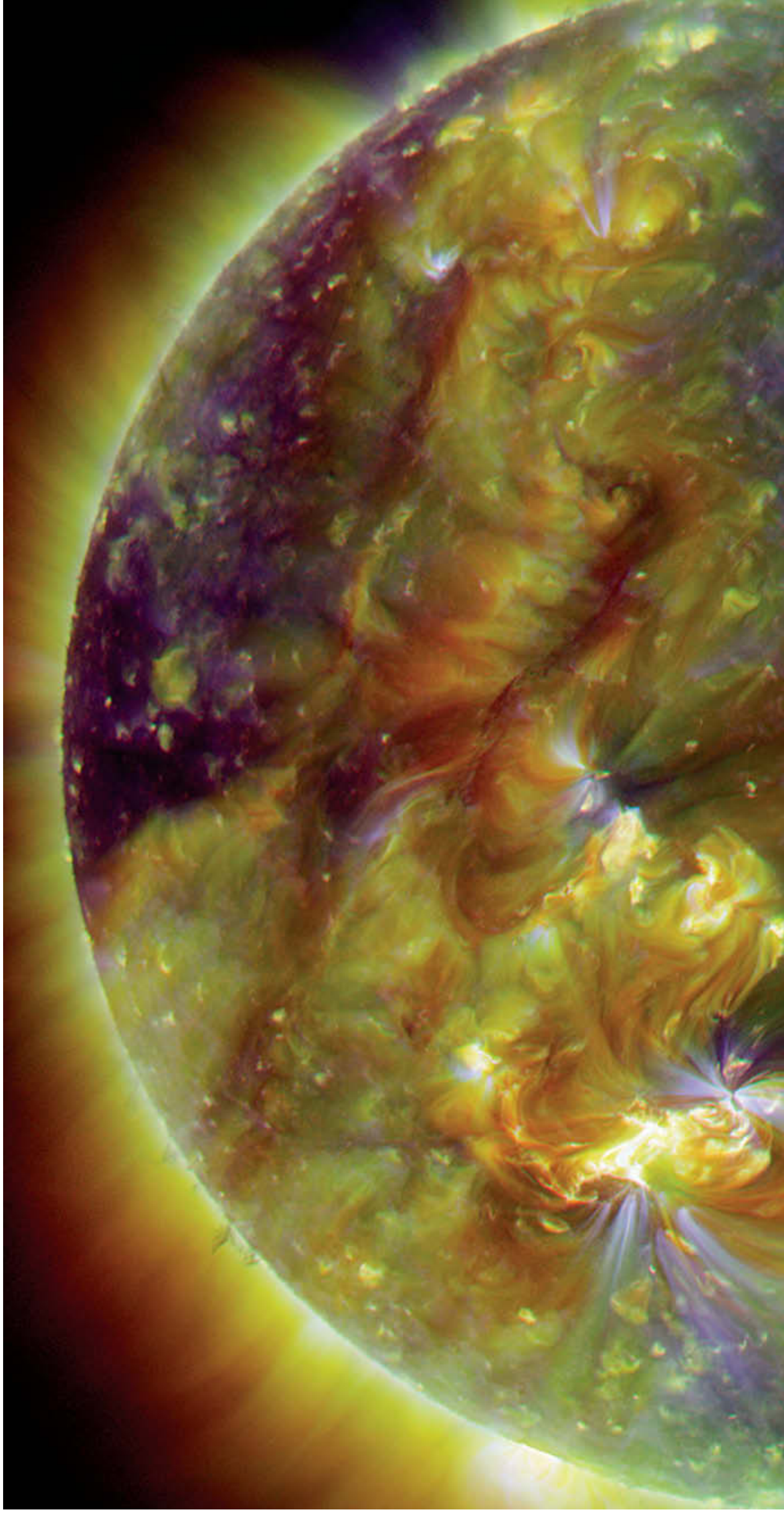
Helioseismic and Magnetic Imager (HMI)

Like swarms of needles poking up through a swath of fabric, magnetic field lines poke through the visible solar surface. In his first look at the Sun through a telescope, Galileo unknowingly viewed these field lines; they cause the Sun to be pockmarked with spots. Sunspots, regions of extremely strong, dense magnetic field, appear dark because they're about a thousand degrees Celsius cooler than the surrounding plasma (ionized gas). Such a strong magnetic field inhibits convection and turnover of surface material, allowing it time to cool.

Although people have observed sunspots for millennia (Chinese astronomers noted them around 20 B.C.), they remain bewilderingly complex and unpredictable. Take, for example, the spot at the top of the next page. Over nine days this solitary spot underwent an astrophysical mitosis, splitting into two identical offspring. Why?

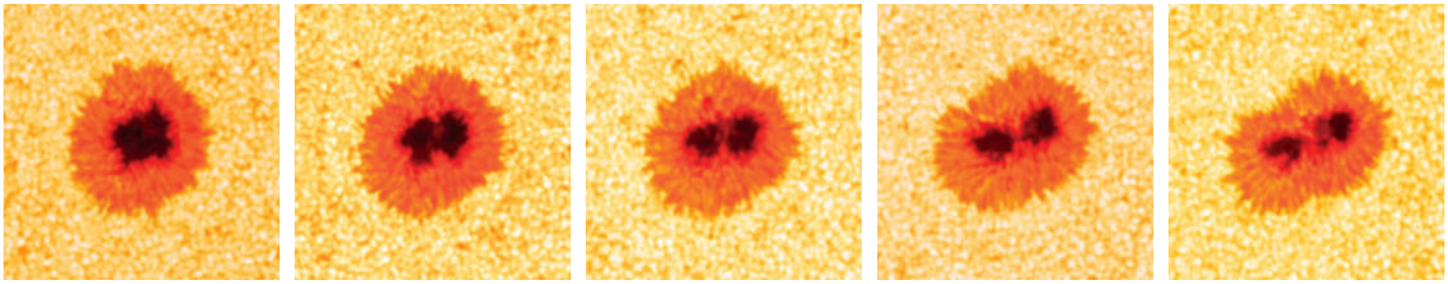
The magnetic field loops emerging from below the solar surface are far from random. Sunspots often cluster in groups, which implies some sort of common process occurring below. Thanks to HMI, scientists will be able to infer better what happens down inside. By combining HMI data with theory, they will model the flow of plasma to a depth of some 20,000 km (12,000 miles) underneath every single sunspot for the next five years. That's 5% of the way down to the Sun's center.

In addition, using a 16-megapixel camera, HMI takes images of the ubiquitous magnetic field at the solar surface. At the bottom of the next page is a high-resolution map of the solar magnetic field, constructed from HMI data. Studying the ebbs and flows of the Sun's surface

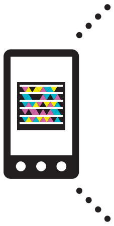


NASA / SDO / AIA SCIENCE TEAM

FAST ACTION **The resolution of SDO's AIA camera, which took this extreme-ultraviolet image, isn't new. SDO's predecessor, the Transition Region and Coronal Explorer (TRACE), began taking images at 1-arcsecond resolution some 12 years ago. But AIA takes full-disk images at about 500 times the rate ("cadence").**



NASA / SDO / HMI SCIENCE TEAM



Get the free tag-linking app for your phone at **http://gettag.mobi**.

Above: **A sunspot's umbra, or dark inner area, is held in the grip of a strong magnetic field. Nevertheless this one, for reasons not well understood, split in two.** ***Left:*** **To watch movies of the Sun in action, you can load the free Microsoft Tag app onto your phone from the URL at left. Then take a picture with your phone of the code square. A page with movies from SDO will open on your screen.**

magnetism is a key to understanding many of the frenetic things happening on and above the Sun, as told on the facing page.

Atmospheric Imaging Assembly (AIA)

The magnetic field is tightly anchored in the Sun's surface. When a flare erupts, the surface itself generally remains unperturbed. The atmosphere above, however, rapidly changes shape. The solar magnetic field is like a willow tree — the branches flail in stormy winds, but the roots stay firm in the ground.

In the AIA image of the solar atmosphere on the previous page, the colors represent different layers spanning more than 2 million degrees Celsius. Blue is the coolest, and red is the hottest. There's a lot going on: bright patches, dark holes, tiny spots ... a circular magnetic wellspring marks an active region, the source of solar flares. Dark, rope-like filaments run across the upper atmosphere. (Where filaments appear against the background of space rather than the solar surface, they glow as prominences.) After this frame was taken, several flares went off in the tangled mess of magnetic activity, sending the filaments flying off the Sun in the direction of Earth. AIA filmed the whole thing.

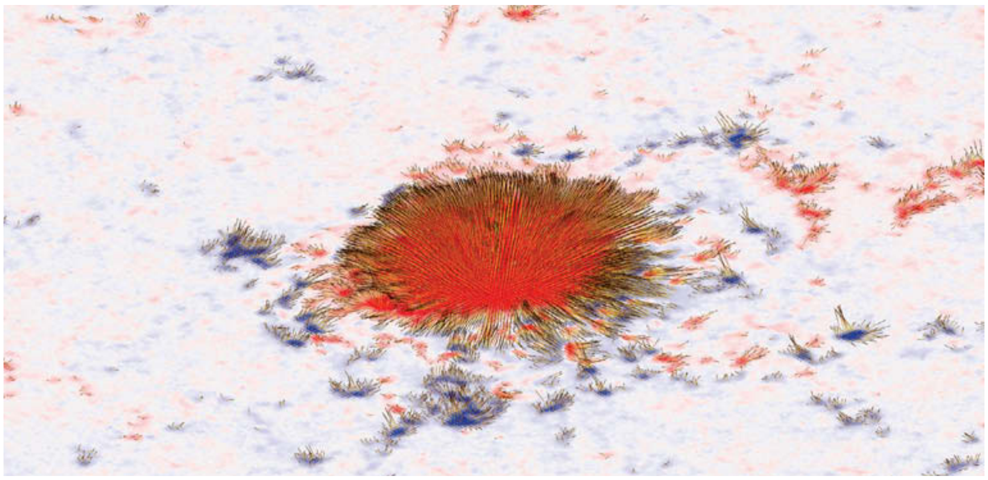
Already, AIA is challenging the notion that flares are isolated patches of activity. Instead, data show that a flare is inextricably linked to the rest of the features across the Sun's 865,000-mile-wide disk.

The AIA movies will likely give scientists clues as to how filaments form in the first place. Some think that shear motions on the churning surface are what create them. Others suspect that filaments bubble up as-is from the solar interior.

When a filament lifts off the Sun, it cools and disperses into interplanetary space. And because the four AIA telescopes take simultaneous exposures in four wavelengths, they can study how this twisted rope of magnetic material changes in temperature, structure, and mass during the beginning of its journey across the solar system.

Extreme-ultraviolet Variability Experiment (EVE)

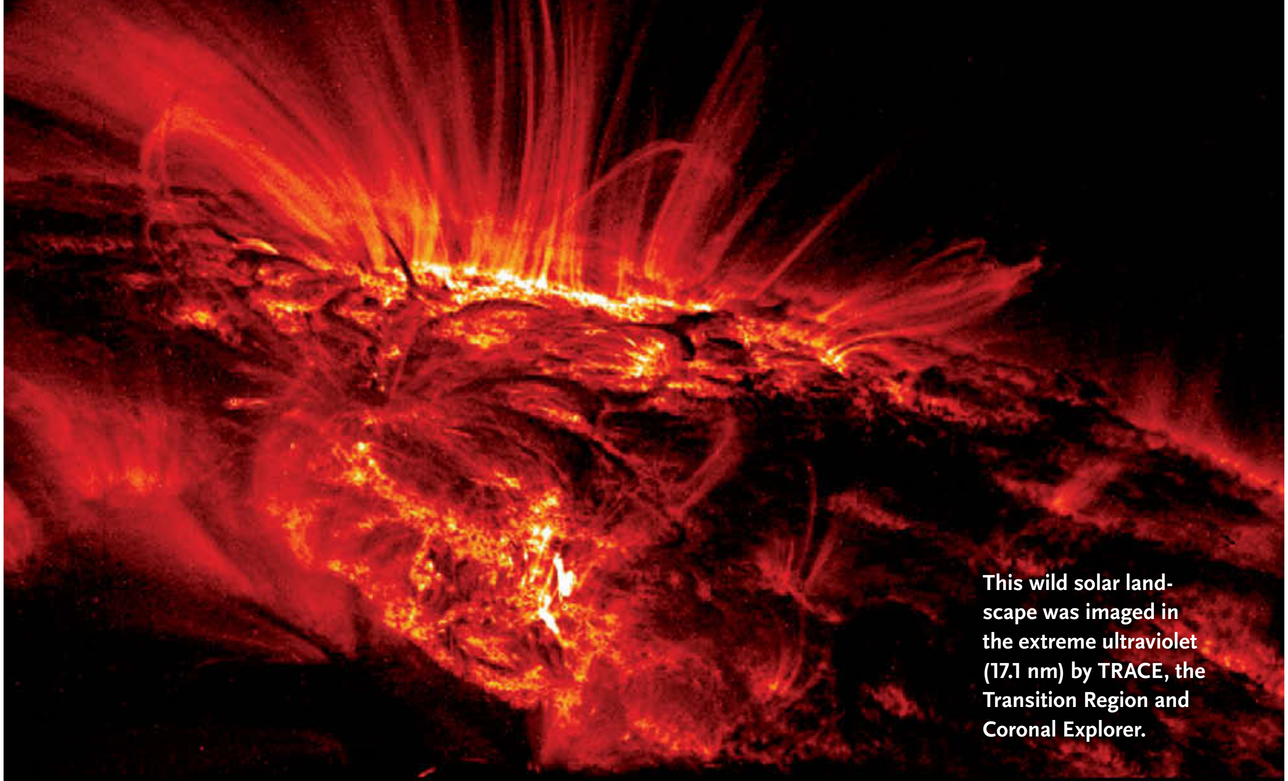
When a solar eruption hits Earth, it dumps a lot more than just particles into the upper atmosphere. It also delivers lots of high-energy, ionizing radiation, affecting the shape of Earth's ionosphere. Determining how Earth's atmosphere reacts to such energy is an outstanding prob-



NASA / SDO / AIA SCIENCE TEAM

MAGNETIC MAP This is a frame from an SDO movie that maps the swarming magnetic activity in the Sun's light-emitting layer, or photosphere. The photosphere is strangely cooler than the tenuous corona; a mere 6,000°C, compared to the corona's millions of degrees. Magnetic structures leading up from the surface are likely a major part of the coronal heating mechanism.

Why Is the Sun So Complicated?



This wild solar landscape was imaged in the extreme ultraviolet (17.1 nm) by TRACE, the Transition Region and Coronal Explorer.

NASA / TRACE

THE SUN IS JUST A BALL OF GAS, mostly hydrogen. How can something so simple produce such complex, bizarre, unpredictable structures and behavior?

The key is that the Sun's gas is hot enough to be *ionized*: some of its atoms have had an electron knocked off. These free electrons can move around. Any substance with freely movable electrons conducts electricity; metal is an example. So for this purpose, you can think of the Sun as like a churning ball of liquid copper.

The slightest electric current in a conductor creates a magnetic field. Magnetic field lines try to stay fixed in a conductor, like strings in clay. It takes energy to drag the lines sideways through the material, like dragging strings sideways through clay. Instead, if the field lines move they'll tend to drag the conducting material — the gas of the Sun — along with them.

But the Sun's ionized gas doesn't want to cooperate. It has its own agenda: churning and boiling, driven by heat flowing up from below. So the gas sometimes overpowers the magnetic field lines and carries *them* with *it*.

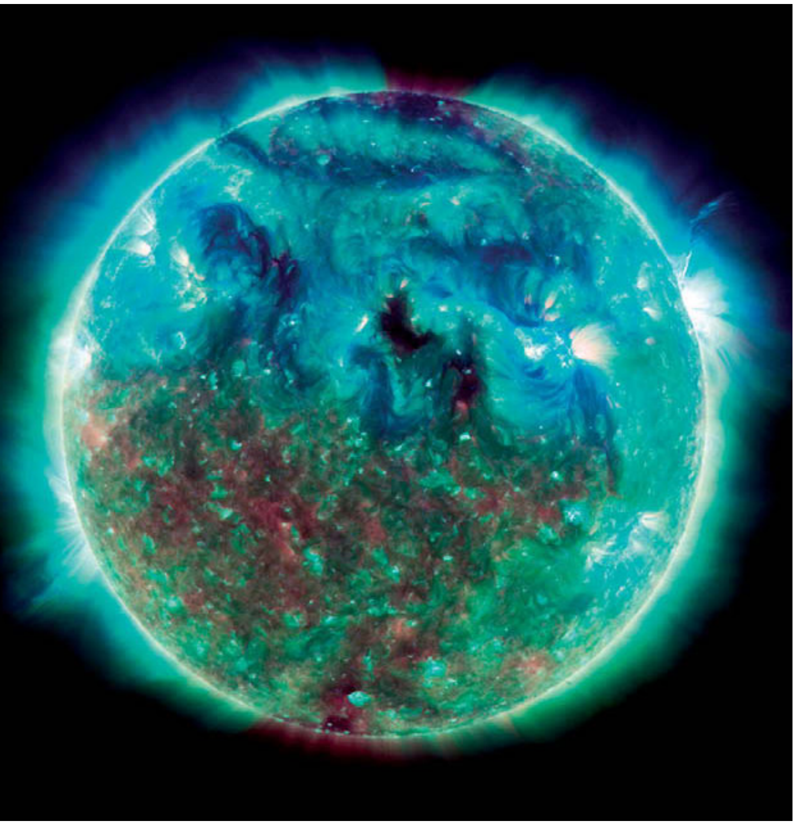
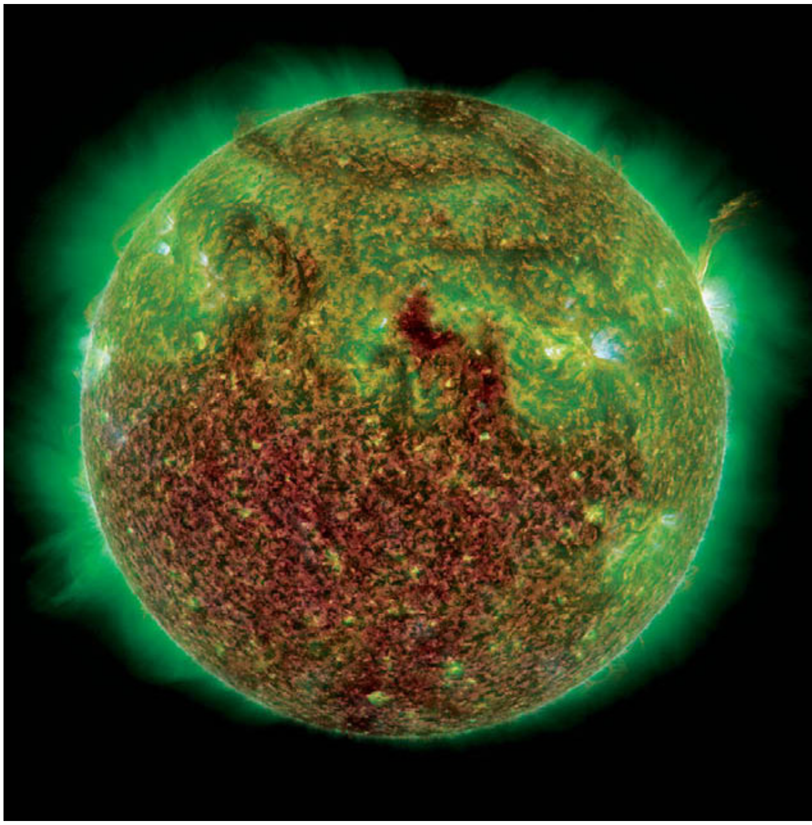
And as you learned in school, a moving magnetic field generates electric current. This current in turn creates *new* magnetic field, which generates new current, and so on.

Here comes the important part. Wherever in nature a runaway positive-feedback arrangement like this gets going, you're likely to see it spawn remarkable, chaotic, endless complexity. Unpredictable *emergent phenomena* appear from it — forms of higher-level organization and structure that you could never have predicted from first principles.

And why does *that* occur? Because — key point, now! — we live in a universe with an interesting property: *energy flowing through a system tends to organize that system* into greater complexity, producing emergent phenomena (at the expense of greater disorder, or entropy, elsewhere).

After all, that's the only kind of universe we could arise to find ourselves living in. Life is an example of this process. On Earth, the energy flow consists of sunlight arriving, driving processes and complexification on the ground, and eventually radiating away to space as waste heat. In the Sun's own case, the energy flow consists of heat coming up from the interior and radiating to space.

The interaction between magnetic fields and fluid conductors is called *magnetohydrodynamics*, or MHD. It is a notoriously difficult field, precisely because MHD systems break so easily into positive feedback, chaos, and emergent phenomena. — *Alan MacRobert*

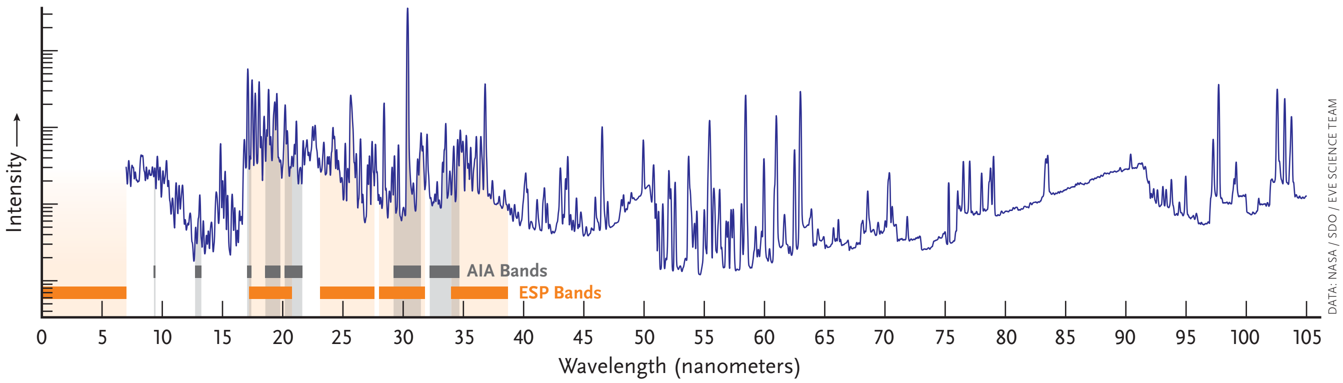
NASA / SDO / AIA SCIENCE TEAM (3)

LAYER BY LAYER These images, taken at the same time, show the Sun in different combinations of wavelengths, highlighting layers from the chromosphere just above the white-light surface (30.4 nanometers, shown red) to the upper corona (9.4 nm, blue). The temperature skyrockets in the "transition region" above the chromosphere. As a result, a lot of solar activity happens in this layer.

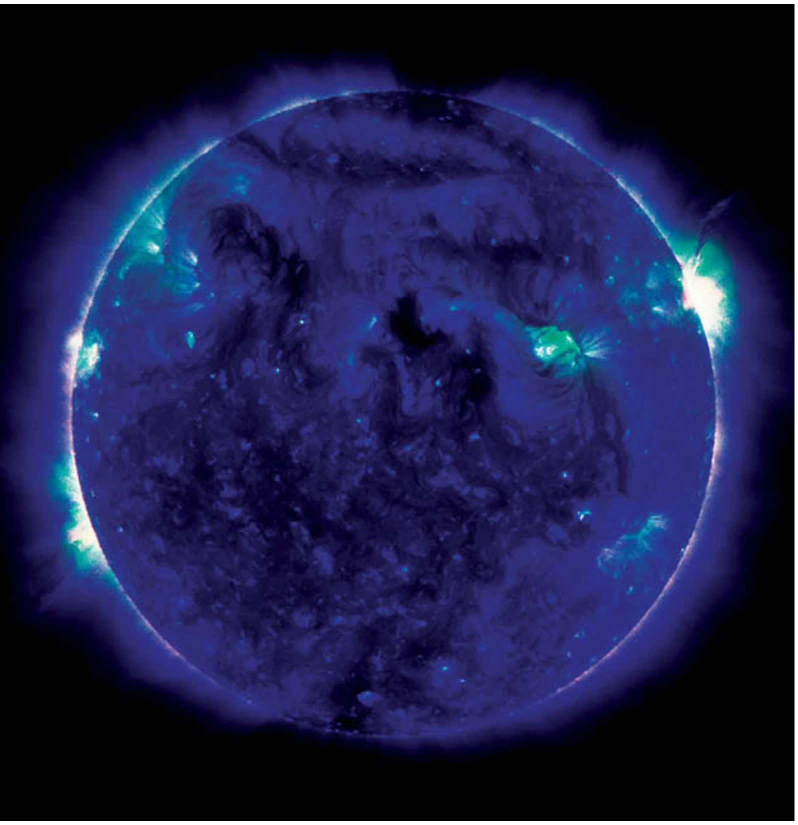
lem in space physics with many practical consequences.

EVE is helping solve this problem by monitoring the Sun's total extreme-ultraviolet output. It sees the Sun as one pixel but resolves a thousand wavelengths from 0.1 to 105 nanometers (1 to 1050 angstrom units), as seen in the spectrum below. Using EVE and AIA data, scientists found a peculiar behavior of solar flares: they shine brightest in ultraviolet when they erupt, but they almost always emit another burst of ultraviolet light some hours later, like an aftershock following an earthquake. That sort of result is integral to learning how flares affect Earth's atmosphere.

EVE scientists have also deduced that a tiny, long-duration flare dumps as much energy into Earth's ionosphere as a huge brief one. The latter ones get the press, but the former are just as important.



BROAD SPECTRUM Instead of taking images, the EVE instrument watches the Sun's ultraviolet spectrum from 0.1 to 105 nanometers. This spectrum is typical. The gray bands indicate the wavelengths that AIA can see. The orange bands show the wavelengths covered by the Extreme Ultraviolet Spectrophotometer, one of EVE's five channels.



Working Continuously

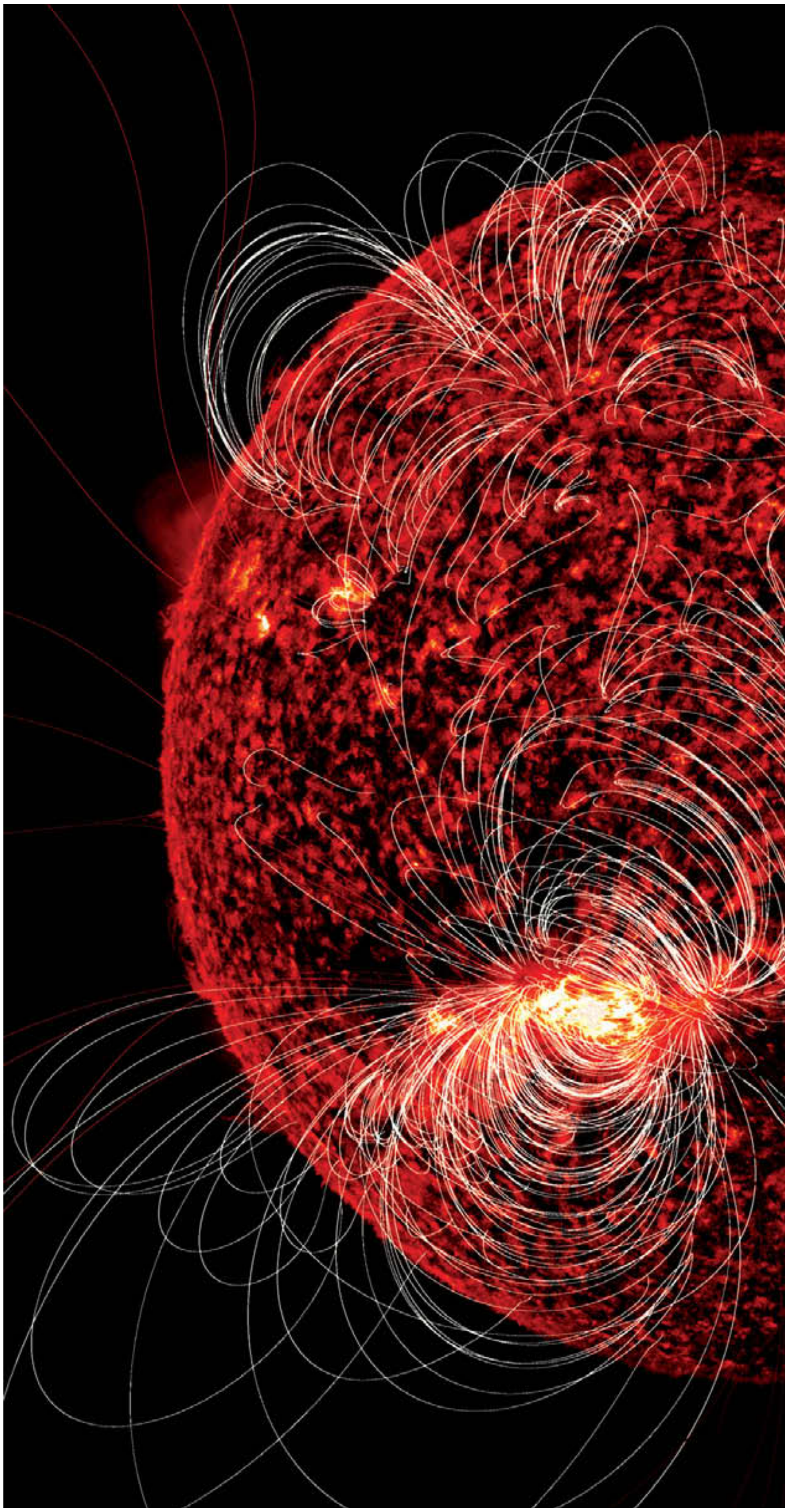
Because it's critical to study not only transient, big events but also the ever-present small ones, SDO doesn't have time to blink. Taking images nearly continuously (95% of the time for the next 5 years), SDO sends back nearly two terabytes of data a day, the highest rate of any spacecraft NASA has flown. By comparison, the Hubble Space Telescope sends down about a thousandth as much.

With so much data, solar scientists hope they can finally study the entire Sun for what it is — not just the star that gives life to Earth, but an immense untapped opportunity to view important universal phenomena up close. ✦

Former S&T *editorial intern* ***Monica Bobra*** *is now a member of the SDO HMI science team. She studies the solar magnetic field at Stanford University.*

For movies, more images, and more about SDO and its work, see SkyandTelescope.com/sdo.

NASA / SDO



NASA / SDO / AIA SCIENCE TEAM

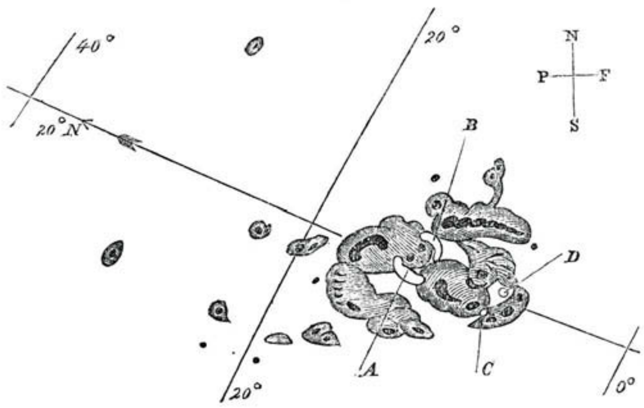
EVERYTHING IS CONNECTED Combining HMI magnetic-field data at the surface with theoretical models, scientists can predict the shape of the outer field lines and hence the solar corona. In this image, the field lines from a theoretical model (white) are added to an AIA image of the chromosphere. Active regions far apart are revealed as linked.

The Perfect Solar Superstorm

Solar storms in 1859 wreaked havoc on telegraph networks worldwide and produced auroras nearly to the equator. What would a recurrence do to our modern technological world?

Daniel N. Baker & James L. Green

SOHO / ESA / NASA / LASCO



ROYAL ASTRONOMICAL SOCIETY / © PHOTO RESEARCHERS

PRELUDE TO THE STORM **British amateur astronomer Richard Carrington sketched this enormous sunspot group on September 1, 1859. During his observations he witnessed two brilliant beads of light flare up over the sunspots, and then disappear, in a matter of 5 minutes. The next day, auroras were seen almost to the equator and telegraph systems fell silent all over the world. Carrington had observed what was probably the most intense solar flare ever recorded.**

DRAMATIC AURORAL DISPLAYS were seen over nearly the entire world on the night of August 28–29, 1859. In New York City, thousands watched "the heavens . . . arrayed in a drapery more gorgeous than they have been for years." The aurora witnessed that Sunday night, *The New York Times* told its readers, "will be referred to hereafter among the events which occur but once or twice in a lifetime."

An even more spectacular aurora occurred on September 2, 1859, and displays of remarkable brilliance, color, and duration continued around the world until September 4th. Auroras were seen nearly to the equator. Even after daybreak, when the auroras were no longer visible, disturbances in Earth's magnetic field were so powerful that magnetometer traces were driven off scale. Telegraph networks around the globe experienced major disruptions and outages, with some telegraphs being completely unusable for nearly 8 hours. In several regions, operators disconnected their systems from the batteries and sent messages using only the current induced by the auroras. Earth had just experienced a one-two punch from the Sun the likes of which have not been recorded since.

Humanity was just beginning to develop a dependence on high-tech systems in 1859. The telegraph was the technological wonder of its day. There were no high-power electrical lines crisscrossing the continents, nor were there sensitive satellites orbiting Earth. There certainly was not yet a dependence on instantaneous communication and remote sensing of Earth's surface. At present, when the Sun is ramping up its activity in Solar Cycle 24, we need to ask ourselves: What would happen to our 21st-century world if a solar storm as severe as those in 1859 were to strike today?

The Sun–Earth Connection

The 1859 auroras were the visible manifestation of two intense magnetic storms that occurred near the peak of the 10th recorded sunspot cycle. On September 1st, the day before the onset of the second storm, British amateur astronomer Richard Carrington observed an outburst of "two patches of intensely bright and white light" from a large group of sunspots near the center of the Sun's disk. The outburst lasted 5 minutes and was also observed by Richard Hodgson from his home observatory near London. Carrington noted that the solar outburst was followed the next day by a geomagnetic storm, but he cautioned against inferring a causal connection between the two events.

Contemporary observers such as American astronomer Daniel Kirkwood recognized the dazzling auroral displays, magnetic disturbances, and telegraph disruptions between August 28 and September 4, 1859 as spectacular manifestations of a "mysterious connection between the solar spots and terrestrial magnetism." Several scientists had proposed such a connection earlier in the decade based on the regular observed correspondence between changes in Earth's magnetic field and the number of sunspots. By the mid-1860s, Hermann Fritz in Zürich and Elias Loomis at Yale University would furnish convincing evidence of a link between auroras and the sunspot cycle.

Although the link between solar, geomagnetic, and auroral phenomena was recognized by 1859, the nature of this link was not understood. The Carrington and Hodgson flare observations provided a vital clue. But scientists would not fully appreciate their significance until well into the 20th century. Only then would a full picture emerge of the phenomena that constitute "space weather."

Large-Scale Storms

A breakthrough came in the 1970s with the discovery of coronal mass ejections (CMEs). Scientists came to recognize that CMEs, rather than eruptive flares, are the cause of nonrecurrent geomagnetic storms. Solar flares are sudden eruptions of intense high-energy radiation from the Sun's

SOLAR ERUPTION **This image, from the Large Angle and Spectrometric Coronagraph (LASCO) aboard the Solar and Heliospheric Observatory (SOHO), shows an enormous coronal mass ejection (CME) blasting a cloud of particles into space on December 2, 2003. An occulting disk blocks the Sun. CMEs can contain 10 billion tons of gas and travel as fast as 6.7 million miles per hour. CMEs (not flares) cause the severe geomagnetic storms that affect modern society. This CME shows a preferred direction, meaning it was not aimed toward Earth.**


SOURCE: JAMES L. GREEN / NASA

AURORA REPORTS During the first 90 minutes of the September 2, 1859 solar superstorm, observers recorded auroras (red dots) nearly to the equator. Normally, auroras are only seen at high latitudes.

visible surface, producing X-rays, radio emission, and energetic particle bursts. In contrast, CMEs are enormous eruptions of plasma and magnetic fields from the corona. They can contain 10^{16} grams (10 billion tons) or more of coronal gas and travel as fast as 3,000 kilometers/second (6.7 million mph). This translates into a kinetic energy equivalent to almost 10,000 megatons of TNT.

Flares and CMEs usually occur most frequently around solar maximum and result from the release of energy stored in the Sun's magnetic field. CMEs and flares can occur independently of each other, but both are generally observed at the start of a space weather event that leads to a large magnetic storm at Earth. To drive a magnetic storm, a CME must: (1) be launched onto a trajectory that will cause it to impact Earth's magnetic field; (2) be fast (at least 1,000 km/second) and massive, thus possessing large kinetic energy; and (3) have a strong magnetic field whose orientation is opposite that of Earth's magnetic field.

The magnetic storm that began on September 2, 1859 was not caused by the highly energetic white-light flare observed by Carrington and Hodgson the previous morning. Instead, it was a fast CME launched just above and near the same giant sunspot region that produced the flare. The CME tore off an enormous section of the surrounding corona and hurled it into the solar wind.

If the ESA/NASA Solar and Heliospheric Observatory (SOHO) had been operating in 1859, its Large Angle and Spectrometric Coronagraph (LASCO) would have observed the CME perhaps 20 minutes after the flare's peak emission. The CME would have appeared as a bright "halo" of material surrounding the occulted solar disk, indicating that it was headed directly toward Earth. About 17.6 hours elapsed between the time of the flare/CME eruption on September 1st and the onset of the magnetic storm the next morning. This implies a speed of approximately 2,300 km per second (about 5 million mph), making this CME the second fastest on record. Solar physicists think the auroral storm observed on August 28th was also generated by an enormous CME that probably cleared a path in the solar wind, thereby facilitating the great speed of the September 2nd event.

Fast CMEs move much quicker than the surrounding medium, creating a shock wave that generates powerful electromagnetic forces that accelerate slow, lower-energy coronal and solar wind particles to a significant fraction


JOHN BOUDREAU

RED AURORA A red aurora lit up the sky over eastern Massachusetts on October 30, 2003. Auroras that made the sky appear "stained with blood" showed up as far south as Cuba as a result of the 1859 solar superstorm.

of the speed of light. Such large solar energetic particle (SEP) events can also include particles accelerated by flares. Traveling so rapidly, SEPs begin arriving at Earth within an hour of the flare eruption and any associated CME release. The particles are channeled along our planet's magnetic field lines into the upper atmosphere above the poles. There they enhance the ionization of the lower ionosphere over the entire polar regions. This sequence of events sometimes lasts several days.

Humans in the 1850s lacked the means to detect solar particles, and the most sophisticated technologies were unaffected by them. Thus, the September 1859 particle radiation storm went essentially unnoticed. But there is a natural record of the storm. Nitrates (NO_3^-), produced by SEP bombardment of the atmosphere above the poles, precipitate out of the atmosphere within weeks of a solar storm and are preserved in polar ice. Analysis of anomalous nitrate concentrations in ice-core samples indicates that the 1859 storm was the largest SEP event known, with flux levels several times that of the August 1972 storm — the largest solar particle event in the space era.

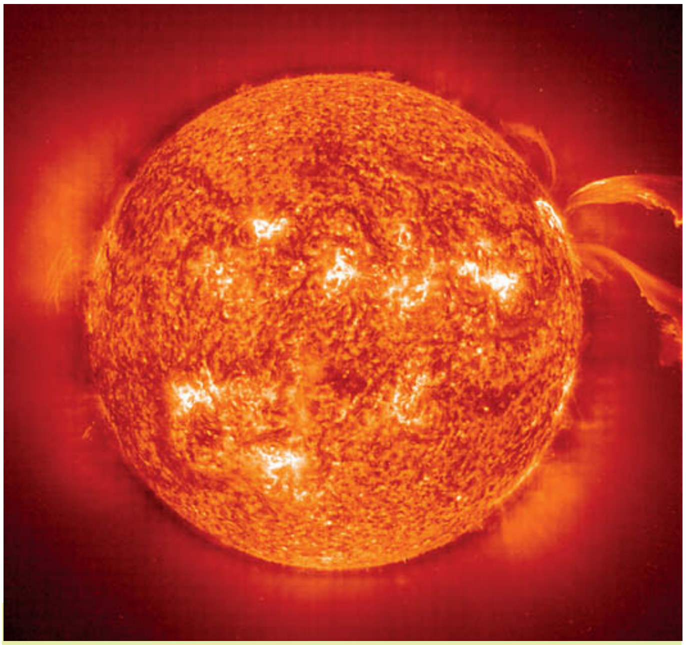
The shock wave responsible for the 1859 radiation storm hit Earth's magnetosphere at 04:50 GMT on September 2nd. It dramatically compressed Earth's magnetic field, triggering an almost instantaneous brightening of the entire auroral oval. Earth's magnetic field took several days to recover. Balfour Stewart, the director of the Kew Observatory near London, reported at that time that Earth's magnetic properties "remained in a state of considerable disturbance until September 5, and scarcely attained their normal state even on September 7 or 8."

Space Weather Effects

Contemporary observers recognized the 1859 auroral and magnetic storms as extraordinary events. But given the state of technology, the societal impact was limited to the disruptions of telegraph service, the telegraph companies' loss of income, and the associated effects on commerce and railroad traffic control.

Today, the story would be quite different. Modern society depends heavily on a variety of technologies that are vulnerable to the effects of intense geomagnetic storms and SEP events. We have turned Earth's surface, oceans, atmosphere, and near-Earth space into a tangled web of interconnected technologies. Knocking out a critical component such as electric power can ripple through society like a falling row of dominoes, triggering short- and long-term disruptions.

Strong auroral currents, which wreaked havoc with 1859 telegraph networks, can knock out modern electrical transformers and power grids. Electric power is our society's cornerstone technology on which virtually everything else depends. Although the short-term probability of a widespread blackout resulting from an extreme space weather event may be low, the consequences would



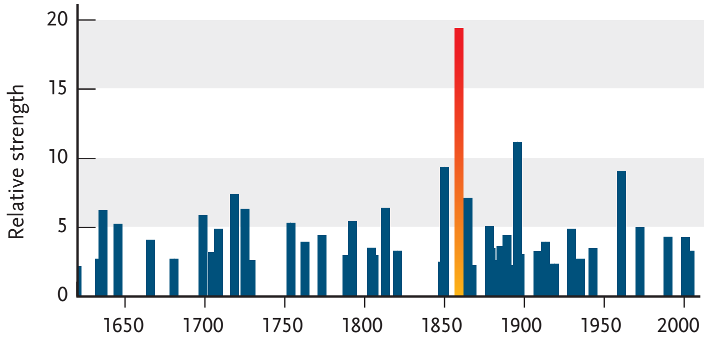
SDO / NASA / AIA SCIENCE TEAM

The Sun Ramps Up

Over an approximately 11-year period, the number of observed sunspots increases from near zero to perhaps 100 or more, and then decreases back to near zero again as the next cycle gets underway. Solar minimum of our current cycle (number 24) occurred on January 4, 2008, when a sunspot group with Cycle 24's correct magnetic-field polarity appeared at high solar latitudes. Interestingly, the Sun in the past few years has undergone the deepest minimum of activity that has been observed in more than a century (*S&T:* August 2009, page 26).

The underlying cause of a sunspot cycle remains one of the great mysteries of solar physics. While we know many details, we still have not yet developed a reliable predictive modeling capability. Scientists currently predict that Cycle 24 will peak in the summer of 2013, with a smoothed sunspot maximum of about 60 with fluctuations that may be as high as 90. Predicting the behavior of a sunspot cycle is fairly reliable once we have been in the cycle for about 3 years after sunspot minimum. Since it's still early in Cycle 24, forecasters might need to slightly revise the predicted timing and sunspot number of the next maximum.

Despite the recent modest increase in sunspot numbers and relatively weak solar flaring, this approaching maximum still appears to be one of the least-active cycles since Cycle 19, whose sunspot maximum occurred in the late 1920s. But the sunspot number is not always a reliable indicator of solar storm intensity, because the 1859 superstorm occurred during a sunspot maximum that was less than the previous 7 cycles. We must therefore wonder if this upcoming maximum will produce a series of events similar to those of the 1859–60 maximum.



POLAR SPIKE Geoscientists have identified a big spike in nitrate concentrations in polar ice dating to the 1859 solar superstorm.

be very high — its effects would cascade through other dependent systems like a space weather Katrina.

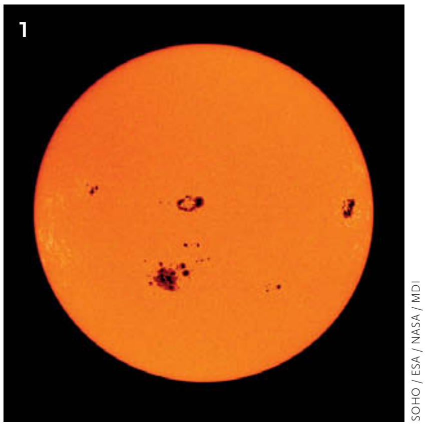
A March 13, 1989 power-grid blackout in Québec and the consequent forced power outages in the northeastern United States remain the classic example of severe space weather's impact on the electric-power industry. According to a thorough study by the Metatech Corporation, the occurrence today of an event like the May 1921 solar storm would result in large-scale blackouts affecting more than 130 million Americans and would expose more than 350 extra high-voltage (EHV) transformers to the risk of permanent damage. Because of the limited manufacturing capacity for EHV transformers in the U.S. and the rest of the world, large areas of our nation could be without electricity for *months or years,* as power companies struggle to purchase and replace damaged hardware.

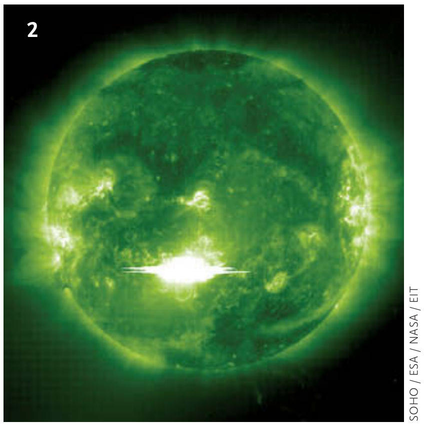
A long power outage would disrupt transportation, communication, banking, medical care, financial systems, and government services. The distribution of potable water would break down because of pump failure, and we would experience the loss of perishable foods and medications because of the lack of refrigeration. The resulting loss of services for weeks, months, or years in even one region of the country would have enormous national and international repercussions.

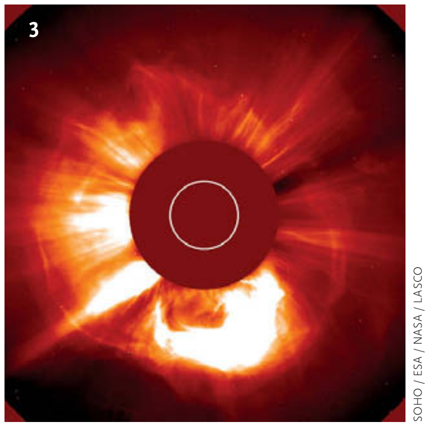
Even less-severe storms can affect various industries. Magnetic-storm-driven ionospheric disturbances interfere with radio communications and GPS navigation signals. Radiation events can degrade or completely black out high-frequency radio communications along transpolar aviation routes, requiring aircraft to be diverted to lower latitudes and/or lower altitudes — costing airlines money and inconveniencing passengers. Spacecraft exposed to SEP events can suffer temporary anomalies, damage to critical electronics, degraded solar arrays, and blinded cameras and star trackers. Intense SEP events pose a significant radiation hazard for International Space Station astronauts during the high-latitude segment of the orbit, and energetic particles would threaten the lives of astronauts beyond the protection of Earth's magnetosphere.

Industries have responded to space weather threats by improving procedures and technologies. Alerted to an impending geomagnetic storm by NOAA's Space Weather Prediction Center and monitoring ground currents in real-time, power-grid operators can take defensive measures. For example, they can temporarily divert power flow from the most severely affected parts of the grid to protect the entire grid against geomagnetically induced currents.

If warned of an upcoming 1859-level geomagnetic storm, operators could shut down a few EHV transformers to avoid burnouts. But that would concentrate dangerous current flows into the remaining transformers. Nobody has the authority to shut down the entire national electric grid. But even if someone did, the resulting widespread blackout

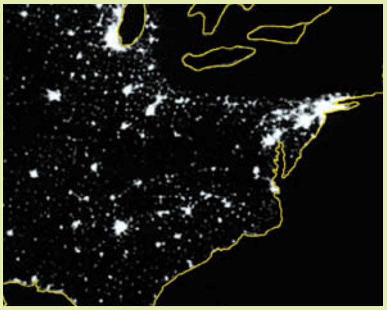






SOLAR STORM EVOLUTION *Left to right, both pages:* These SOHO images trace the evolution of the powerful October 28, 2003 solar storm, which caused satellite anomalies and power-grid disruptions in northern Europe. *1.* SOHO's Michelson Doppler Imager (MDI) captures a large sunspot group at 6:24 UT. *2.* At 11:12 UT, the Extreme ultraviolet Imaging Telescope (EIT) caught an X-ray flare emanating from the sunspot group. The flare was so intense that it saturated the detector. *3.* This LASCO image, taken at 11:30 UT, shows a large CME expanding outward. *4.* This "difference" image subtracts EIT and LASCO images taken around 11:24 to 11:30 UT

How Space Weather Causes Blackouts



NASA

Auroral currents from space weather induce powerful, fluctuating direct currents (DC) in electrical power grids. These currents flow through large extra high-voltage transformers and can cause the transformers to saturate and overheat. This saturation can be severe enough to cause network-wide voltage-regulation problems, which can lead to widespread blackouts. The most intense current flows can burn out transformers in a matter of minutes. The problem can quickly spread because power grids barely recognize political borders. The North American grid links the U.S. and Canada in very important ways. When the March 13, 1989 blackout occurred in Québec, it naturally propagated throughout the entire Northeast region. It was only good luck that the disruption was stopped as effectively as it was and relatively minor effects were felt in the U.S.

WIDESPREAD BLACKOUT This artwork simulates what a satellite would have seen during the power outage of March 13, 1989. The blackout knocked out power in all of Québec for 12 hours, and affected the grid in the northeastern U.S. for a shorter time interval. An 1859-level event would cause more severe and widespread disruption to the grid.

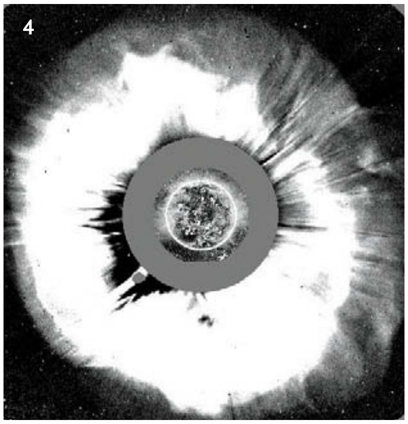
could cost tens of billions of dollars, and it could turn out to be a false alarm. According to Metatech, hardening the national grid against the effects of a severe storm would be much cheaper than a single false alarm or forced blackout.

As for other industries, space agency officials can delay a launch and satellite operators can postpone critical operations. The aerospace industry has designed satellites to operate under extreme conditions. GPS modernization through the addition of two new navigation signals and codes will help lessen space weather effects.

Future Vulnerabilities

Extreme space weather disturbances are low-frequency/high-consequence (LF/HC) events. Public and private institutions require different budgeting and management capabilities to deal with the collateral impacts of such events. Space weather challenges the basis for conventional policies and risk-management strategies, which normally assume constant or reliable conditions. It's difficult to understand, much less to predict, the consequences of future LF/HC events. Sustaining preparedness and planning for such events in future years is crucial. Without being unduly alarmist, we contend that policy-makers must address space weather as a key LF/HC matter of vital importance to our modern society.

Our understanding of the vulnerabilities of modern infrastructure to severe space weather and the measures developed to mitigate those vulnerabilities are based largely on experience gained during episodes such as the geomagnetic storms of March 1989 and October–November 2003. The 1859 and 1921 superstorms suggest that such extreme events, though rare, will almost certainly occur in the future. It's sobering to recognize that a large flare and CME in November 2003 occurred on the Sun's



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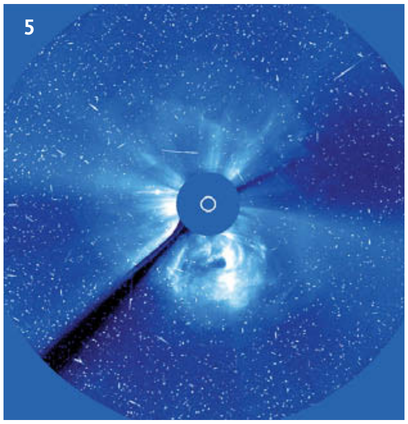
SOHO / ESA / NASA / EIT / LASCO



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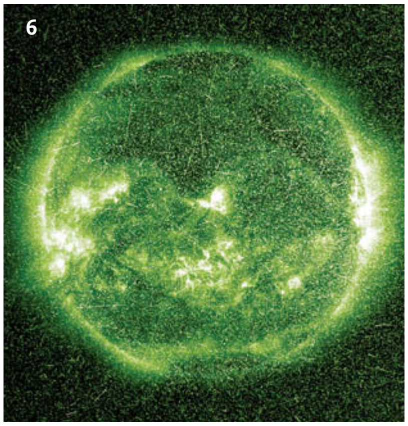
SOHO / ESA / NASA / LASCO



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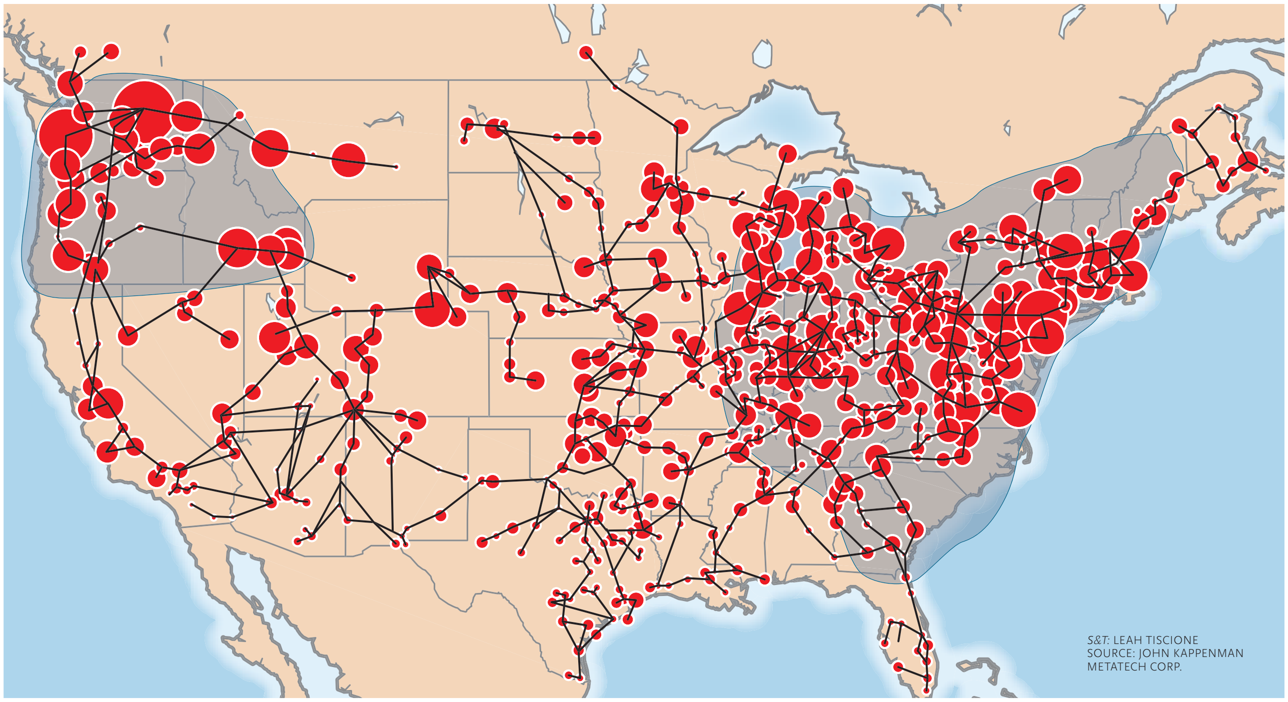
SOHO / ESA / NASA / EIT

from earlier images to reveal changes. This "halo" illusion (ejected material appears to be spreading in all directions), coupled with the fact that the active region was almost directly facing Earth, informed scientists that the CME was heading our way. *5.* At 12:42 UT, a shower of energetic solar protons produced the "snow" effect in this LASCO image. *6.* Later in the day, at 23:54 UT, the shower of particles was so intense that it made this EIT image look like it was in the midst of a blizzard. Combined, these six images give us a sense of what a SOHO-like spacecraft would have seen if one was operating in 1859. But the 1859 storm was considerably more powerful.



THE GRID This map is based on a study by Metatech Corporation. Dark lines show routes of extra high-voltage (EHV) transmission lines and major power substations. Geomagnetic electric currents from a solar storm will flow through these lines to major transformers, marked by red dots. The relative sizes of the dots indicate the magnitude of the current. Due to the powerful flows of current, 300 large EHV transformers would be at risk of permanent damage or failure. The electric grid and transformers in the gray shaded regions could suffer a catastrophic collapse, leaving more than 130 million people without electricity. Because of the limited manufacturing capability for these large EHV transformers, it could take *months or years* to restore power in some areas.

limb and were therefore not aimed directly at Earth. Had they occurred at a more central solar longitude, we probably would have experienced an 1859-level event. We figuratively and literally dodged a major bullet. With a new solar maximum approaching around 2013, a giant event could occur during this developing cycle.

Despite the lessons learned since 1989 and their successful application during the 2003 storms, the United States's electric power grid has become even more vulnerable in terms of both widespread blackouts and permanent equipment damage requiring long restoration times. What emerged from a recent U.S. National Academy of Sciences study is that industry experts understand well the effects of moderately severe space weather on specific technologies. In many cases they know what is required to mitigate space weather through enhanced forecasting and monitoring capabilities, new technologies, and improved operations. Limited information also emerged on the socioeconomic costs of power outages: $4–10 billion for the August 2003 blackout, which was not caused by space weather, and an estimated $1–2 trillion during the first year alone for a "severe geomagnetic storm scenario" with recovery times of 4 to 10 years. Many other nations share similar vulnerabilities.

While our recent work has organized much of what is currently known or suspected about socioeconomic impacts, it has perhaps been most successful in illuminating the scope of the myriad issues involved, and the gaps in knowledge that remain to be explored in greater depth. It's difficult to fathom how damaging an 1859-type event might be in today's world. We need to prepare better for such a possibility and help policymakers understand what can and should be done to mitigate possible effects. ✦

To read the entire National Academy of Sciences report "Severe Space Weather Events — Understanding Societal and Economic Impacts," visit www.nap.edu/openbook.php?record_id=12507&page=R1.

Daniel N. Baker *is Director of the Laboratory for Atmospheric and Space Physics at the University of Colorado–Boulder. He has published more than 700 scientific papers concerning plasma physics and energetic particles at Earth and other planets. He also chaired the National Research Council panel that authored the report from which this article is adapted.*

James L. Green *is Director of the Planetary Science Division at NASA headquarters. He has written more than 100 scientific articles on various aspects of Earth's and Jupiter's magnetospheres and over 50 technical articles on various aspects of data systems and networks.*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Great Winter

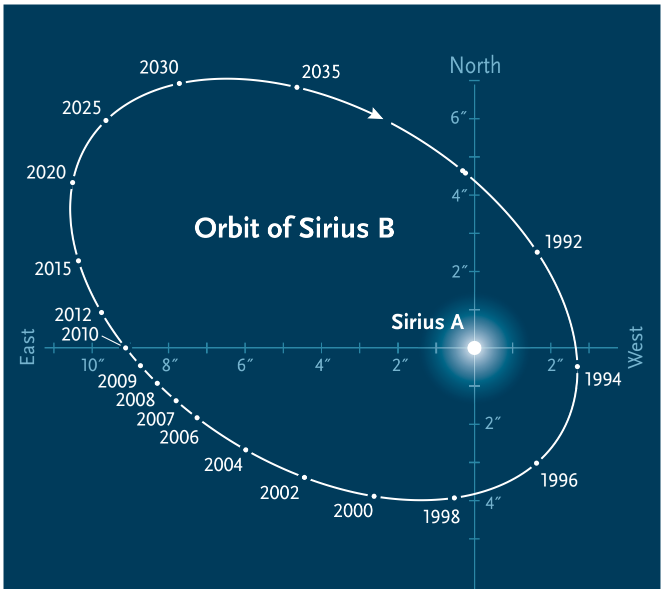
This season is as notable for its doubles, triples, and quadruples as for

James Mullaney

Observing double stars is one of the most pleasurable aspects of stargazing — and yet, sadly, also one of the most neglected. Thousands of these tinted jewels lie within reach of even the smallest of telescopes, and no two of them look exactly alike! Best of all, they can be enjoyed on nights that are all but useless for viewing other deep-sky wonders due to haze, bright moonlight, or light pollution. Showcased below is a sampling of these gems well placed for viewing in the winter evening sky.

Rigel (β Ori) is one of the most spectacular magnitude-contrast pairs in the heavens. This radiant supergiant shines like a blue-white diamond and has a bluish 7th-magnitude sun just 9.6″ to its south. The pair was described by one observer as "a blue boy with a companion on its shoulder." On a steady night, a 3-inch (76-mm) scope at 75× shows the small star half hidden within the primary's glare, and the duo becomes ever more striking as aperture increases. The view in 12- to 14-inch telescopes at 150× is never to be forgotten!

In this article, we will bypass the famed Trapezium in the heart of the Orion Nebula in favor of another beautiful but lesser-known multiple star just to its north. **Sigma Orionis** (σ Ori) is a lovely clan of colorful stars strung out in an irregular line that's anchored by the blue-white primary near the western end. Among the various hues reported for its companions are red, grape red, orange, yellow, ash, gray, and off-white. Adding to the beauty of the scene is the dim triple star **Struve 761** (Σ761) lying close by in the same field, as shown below. A 3-inch scope at 50× has just enough light grasp and magnification



Showpiece Double Stars of Winter

Name		Mag.	Sep.	PA	RA	Dec.
Rigel		0.2, 6.8	9.6″	203°	5^h 14.5^m	–8° 12′
σ Ori	AB-C	3.7, 8.8	12″	238°	5^h 38.7^m	–2° 36′
	AB-D	3.7, 6.6	13″	84°		
	AB-E	3.7, 6.3	42″	62°		
Σ761	AB	7.9, 8.4	68″	203°	5^h 38.6^m	–2° 33′
	BC	8.4, 8.6	9″	268°		
β Mon	AB	4.6, 5.0	7.1″	133°	6^h 28.8^m	–7° 02′
	AC	5.0, 5.4	2.9″	108°		
γ Lep		3.6, 6.3	97″	350°	5^h 44.5^m	–22° 27′
Sirius		–1.5, 8.5	9.2″	88°	6^h 45.1^m	–16° 43′
h3945		5.0, 5.8	27″	52°	7^h 16.6^m	–23° 19′

Dog and Pup

Sirius has been called the Dog Star since classical times, so its faint companion was dubbed The Pup after its discovery by famed telescope maker Alvan Clark in 1862. Its existence had been predicted some decades earlier due to the wobble that it induces in the brighter star's motion across the sky.

The Pup baffled scientists; it's as massive as our Sun, but just one-millionth of its volume. It glows white hot but puts out only 2% as much light as the Sun due to its small size. It's now know to be a white dwarf, a stellar core that has exhausted its nuclear fuel and is glowing from residual heat.

— Tony Flanders

Double Stars

its nebulae and star clusters.

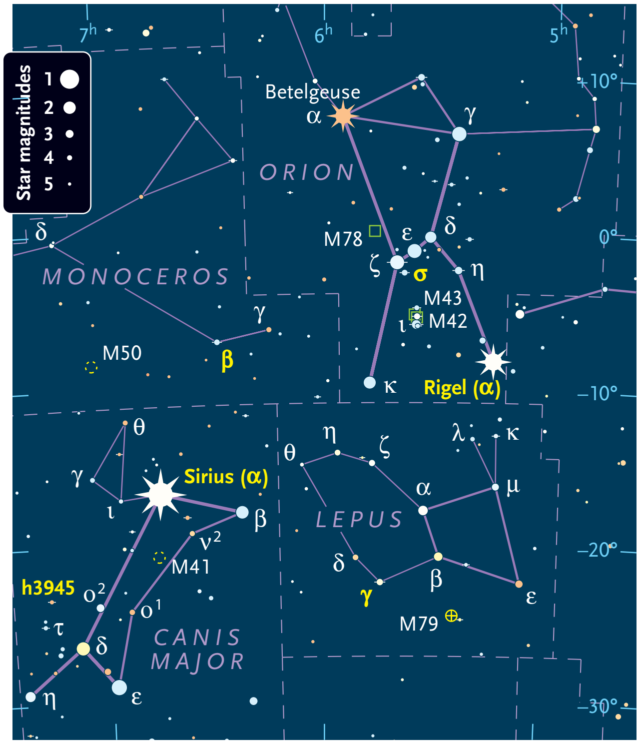
to reveal the whole group clearly, while an 8-inch at 80× transforms the overall scene into a memorable sight.

Beta Monocerotis (β Mon, also called Herschel's Wonder Star) appears to be a cozy matched double at low power. A good 3-inch scope at 50× elongates the eastern star, and at 100× a lovely trio makes its appearance — three blue-white suns in a tight slender triangle. I rank this gem as perhaps the finest triple system in the sky when viewed at 100× or more in 10- to 14-inch telescopes.

Dropping south of Orion, **Gamma Leporis** (γ Lep) is an attractive wide pair for binoculars and low-power scopes displaying a yellowish primary and garnet secondary. "Awash in color" is how one observer described the view — and indeed it is! While a very pretty sight in a 2-inch refractor at 25×, it's way too spread out for optimum effect in an 8-inch at 80×. Larger apertures often dilute wide bright doubles, reducing contrast by unduly separating the components, and muting colors due to light "saturating" the eye, like an overexposed photograph. I find that a 4-inch scope at 16× gives the best overall effect here.

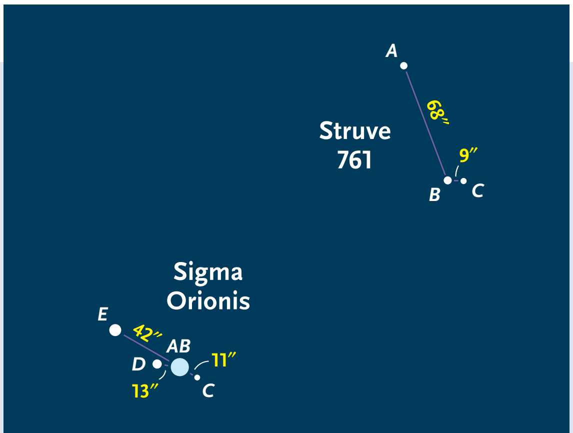
Sirius (α CMa) is the brightest star in the sky, so this dazzling blue-white gem technically ranks as the brightest double. But that description is misleading, because Sirius is also among the most challenging doubles to split. Faint Sirius B tends to be swamped by the overpowering glare of Sirius A, which shines 10,000 times brighter.

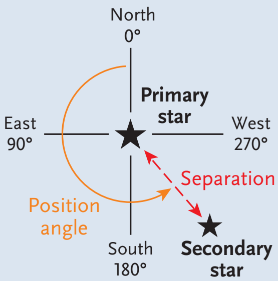
The stars are locked in a 50-year orbital embrace; their separation varies from less than 3″ to 11″. Splitting the pair at minimum separation requires an optically perfect telescope with at least 12 inches of aperture, high magnification, and superb seeing conditions. The pair has been opening since its last minimum in 1994, and at its current separation of 9″, it can be split by telescopes as small as 3 or 4 inches if the seeing is excellent.



The magnificently colorful double star **John Herschel 3945** (h3945) lies in Canis Major 10° southeast of Sirius. This once-neglected jewel has been growing in popularity since I dubbed it the "Winter Albireo" in this magazine several years ago. The colors of this combo are perhaps best described as fiery-red and greenish-blue. They're vividly striking in a 3-inch scope at 30× and superb in a 6-inch at 50×. If you haven't seen this exquisite object, you simply must seek it out the very next clear night. It will surprise and delight you — guaranteed! ✦

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





VITAL STATISTICS FOR DOUBLES

Double stars are described by their separation and the position angle (PA) of the dimmer star with respect to the primary. PA is measured from north around through east — counterclockwise in binoculars and most reflecting telescopes, clockwise in the mirror-reversed views of most refractors and SCTs.

New Product Showcase

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www.oriontelescopes.com

▸ GO TO TRUSS DOB

Orion Telescopes & Binoculars now offers Go To slewing with its new SkyQuest XX12g GoTo Truss Tube Dobsonian ($1,899.95). The scope features a 12-inch (305-mm) f/4.9 primary mirror with a built-in cooling fan contained in a rigid, eight-segment truss-tube assembly. The Go To system includes a database of more than 42,000 objects to automatically slew to and observe, and the system won't lose its sky alignment when you manually move the telescope. The XX12g reflector comes with a dual-speed, 2-inch Crayford-style focuser and 1¼-inch adapter, an EZ Finder II unit-power red-dot finder, a DeepView 35-mm 2-inch eyepiece, and an illuminated 12.5-mm 1¼-inch Plössl eyepiece to aid in alignment. A free copy of *Starry Night* software is also included with purchase.

S&T: SEAN WALKER

PREMIUM GRAB-AND-GO MOUNT

Deep Space Products introduces the T-REX Apex Alt-Azimuth T-Mount (starting at $1,665 for the mount head). This heavy-duty mount is capable of bearing telescopes as large as a Celestron C11. It features smooth slow-motion gears controlled by long aluminum handles on both axes for accurate pointing and manual tracking even at high magnification. The base model T-REX Apex mount head includes built-in encoders, allowing plug-and-play capability for most digital setting circles. Together with optional equipment including a sturdy tripod, flexible slow-motion handles, and dovetail saddle plate, the T-REX is a portable observing platform able to handle most small to mid-sized telescopes. The entire mount with optional tripod and case weighs only 43 pounds (19.5 kg), making set up and take down effortless, even in the dark.

Deep Space Products
22851 N. 53rd St., Phoenix, AZ 85054
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▾ DUAL-SPEED SCT FOCUS Continuing with its long tradition of developing useful accessories, JMI Telescopes introduces its new Dual Speed Micro-Focus for Schmidt-Cassegrain telescopes ($189). The unit simply slides over the shaft of all popular SCT focuser knobs (or the knob itself), and adds two-speed manual focus ability to your scope. It has separate knobs for coarse and fine adjustments, with a numeric dial indicator for improved accuracy and repeatability. See the company website for ordering the specific Micro-Focus unit for your telescope model.

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The Hour of Wonder

February evenings are magnificent beyond compare.

I CAN'T THINK OF a more thrilling phrase for stargazers than "the Orion-Sirius Hour."

Orion isn't just the brightest constellation, and the one with the most eye-catching asterism — Orion's Belt. It is, building around the Belt, the most striking constellation pattern. And what accompanies the best and brightest constellation? Sirius, the brightest star of the night sky.

The hour of supreme stellar splendor. So what is the Orion-Sirius Hour? It's the time when Orion the Hunter is reaching his highest, his gigantic glittering form marched right up to the north-south meridian of the sky. Sirius, Orion's Dog Star, follows close behind. And these are only the beginning of what you can see.

Other wonders of the Orion-Sirius Hour. The naked-eye observer will marvel at the constellation canopy that floats above Orion and Sirius. This arc includes Taurus the Bull, Auriga the Charioteer, Gemini the Twins, and Canis Minor the Little Dog. There is also a bright spur from this canopy or arch, extending from Auriga to Perseus and Cassiopeia in the northwest sky. And the constellation of Sirius — Canis Major the Big Dog — is second only to Orion in brightness.

ARON CHARAD / ADAM BLOCK / NOAO / AURA / NSF

Messier 42, the Great Orion Nebula, is widely considered to be the most magnificent deep-sky spectacle of all for telescope owners at mid-northern latitudes.

Glow-clouds of birth and death. What can you do with a telescope at the Orion-Sirius Hour? You could spend the whole time studying just one magnificent object: Messier 42, the Great Orion Nebula. It's the nearest major cloud of star birth to Earth. And near Zeta Tauri, the dimmer horn-star of Taurus, you can find the result of star death: M1, the Crab Nebula. M1 is much, much fainter than M42. But a little less than a thousand years ago, the Crab supernova probably outshone even Venus for a few weeks.

The greatest chain of open clusters. At the Orion-Sirius Hour, binoculars show that Cassiopeia in the northwest is overflowing with open star clusters. Next comes Perseus with three naked-eye clusters (the Double Cluster, M34, and the Alpha Persei group), then Taurus with the overwhelmingly big and bright Hyades and Pleiades. Near the zenith are the three great telescopic clusters of Auriga: M38, M36, and M37. And then we head down the southeast sky to big, bright M35 at Gemini's northwestern foot, the wonderland clusters of Monoceros the Unicorn and Puppis the Poop-Deck, and, finally M41, the bright wonderful cluster just below Sirius.

Dim glows of wonder at brightest star hour. February and the Orion-Sirius Hour don't just offer brightness. Travel far away from city lights on a moonless evening, and you have your best chance at seeing the subtle winter Milky Way glow and the zodiacal light.

I recall an incredibly clear February night at a place called Polestar Farm. Those of us out that night could see the band of the Milky Way as though it were etched in the sky, flowing from Auriga on down between Sirius and Procyon, the Little Dog Star. Even more notable was the tilted but tall tower of zodiacal light — sunlight scattered off countless micrometeoroids — bright all the way up to the Pleiades. Equally memorable was stepping into our host's observatory dome and seeing the great Auriga Messier clusters become easy naked-eye glows as the dome shielded the rest of the sky from sight. ✦

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


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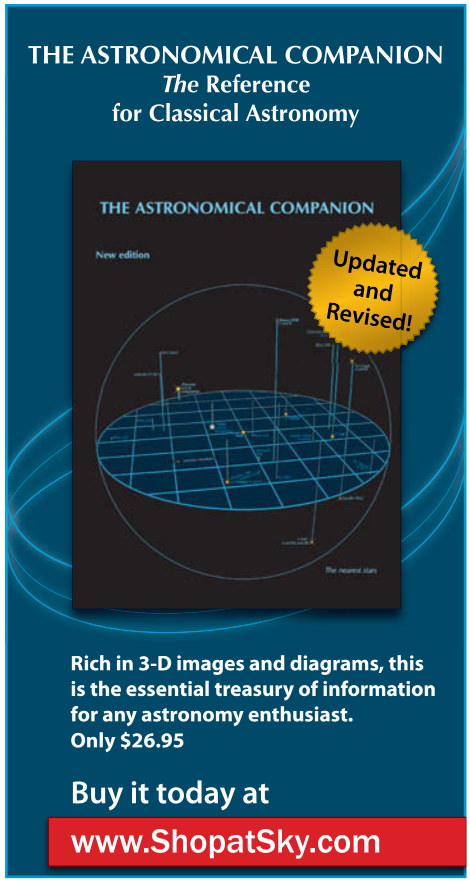
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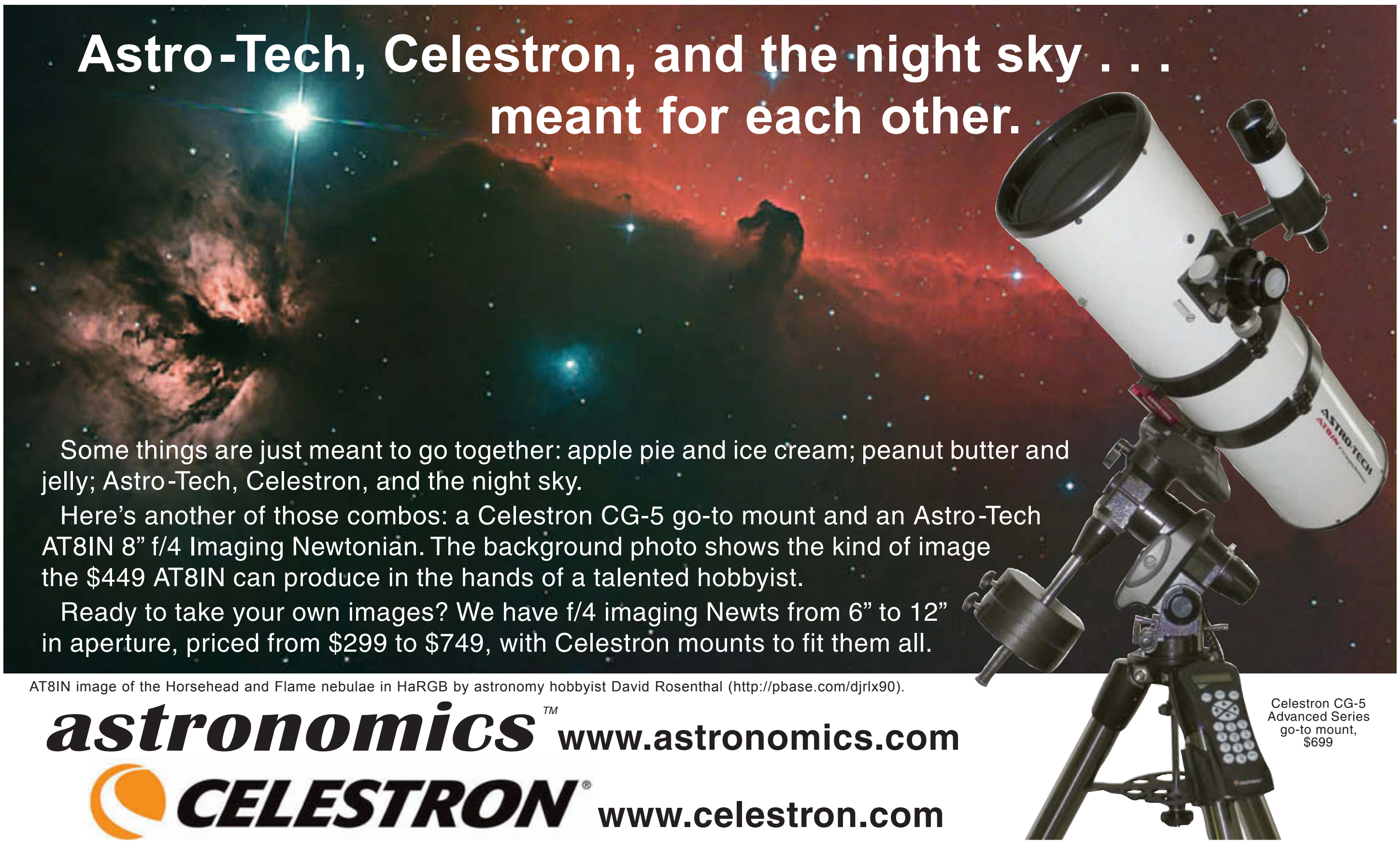
Astro-Tech, Celestron, and the night sky . . .
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Some things are just meant to go together: apple pie and ice cream; peanut butter and jelly; Astro-Tech, Celestron, and the night sky.
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Sky at a Glance

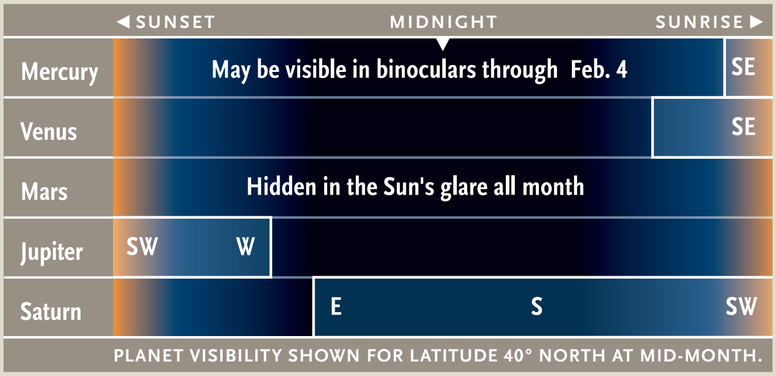
SKY & TELESCOPE

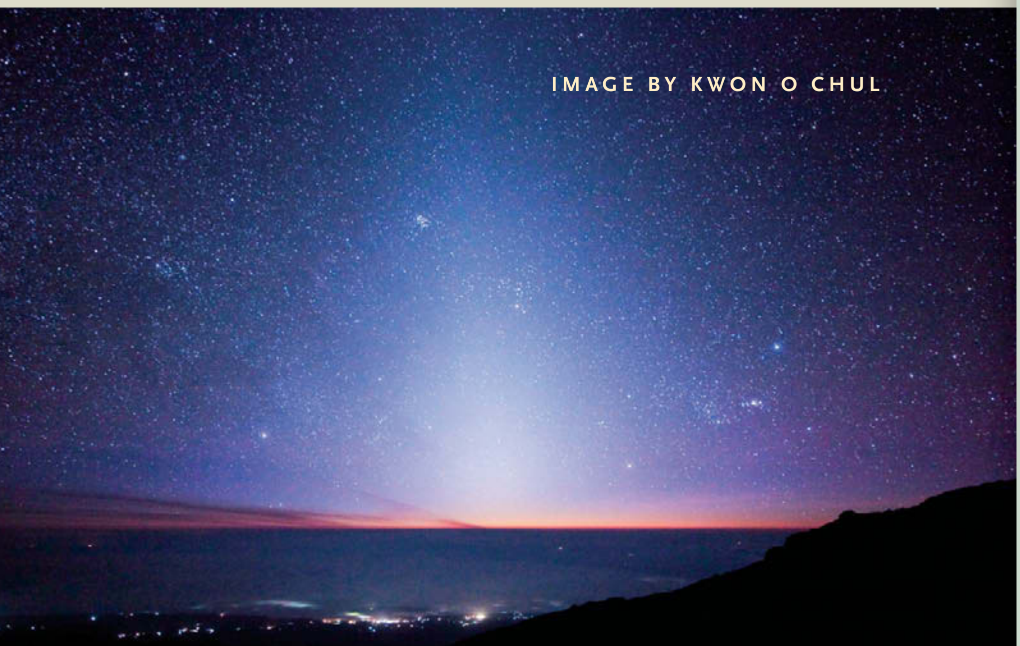
February 2011

MOON PHASES

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

PLANET VISIBILITY





The zodiacal light follows the path of the ecliptic. It appears nearly vertical from Earth's equator, as shown here. But at temperate latitudes, it's always tilted.

1 **DAWN:** About 15 minutes before sunrise, North Americans with binoculars may be able to see Mercury below a very thin crescent Moon far to Venus's lower left, as shown on page 48.

2 **NEW MOON** (9:31 p.m. EST).

3–18 **PREDAWN:** Venus passes through northern Sagittarius, experiencing close encounters with several bright stars and deep-sky objects — and with the asteroid Vesta, dim at magnitude 7.8. See page 57.

3 **EVENING:** Europa transits Jupiter's face from 5:28 to 8:12 p.m. PST (8:28 to 11:12 p.m. EST), and its shadow follows almost exactly two hours behind. See page 58 for other Jupiter satellite events.

6 **EVENING:** Jupiter is about 6° left or upper left of the crescent Moon — a lovely sight!

NIGHT: Algol is at minimum brightness for roughly 2 hours centered on 10:28 p.m. PST (1:28 a.m. EST on the 7th); see page 58.

9 **EVENING OR NIGHT:** Algol is at minimum brightness for roughly 2 hours centered on 10:18 p.m. EST (7:18 p.m. PST).

11 **FIRST-QUARTER MOON** (2:18 a.m. EST).

12 **EVENING:** Algol is at minimum brightness for roughly 2 hours centered on 7:07 p.m. EST (6:07 p.m. CST, 5:07 p.m. MST).

18 **FULL MOON** (3:36 a.m. EST).

Feb. 19 – Mar 6 **EVENING:** This is a great time to view the zodiacal light from mid-northern latitudes. Find a dark location with a good western horizon, and start looking about 80 minutes after sunset for a vague but huge, tall pyramid of pearly light. It slopes to the left, following the path of the ecliptic, with Jupiter near its base.

20–21 **NIGHT THROUGH DAWN:** Saturn and slightly fainter Spica form an almost equilateral triangle with the Moon, as shown on page 48.

24 **LAST-QUARTER MOON** (6:26 p.m. EST).

25 **DAWN:** Bright, ruddy Antares is a few degrees to the right of the Moon.

28 **DAWN:** Venus is lower left of the Moon; see page 49.

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

Facing North
Facing NE
Facing East
Facing SE
Facing South
DRACO
URSA MINOR
Little Dipper
Polaris
Thuban
URSA MAJOR
Big Dipper
Mizar & Alcor
M51
M81
M82
CANES VENATICI
CEPHEUS
CYGNUS
Deneb
M39
LACERTA
CASSIOPEIA
M52
CAMELOPARDALIS
Double Cluster
LYNX
LEO MINOR
LEO
Sickle
Regulus
Moon Feb 17
SEXTANS
HYDRA
Alphard
CANCER
M44
M67
M48
GEMINI
Castor
Pollux
Moon Feb 14
AURIGA
Capella
Zenith
M37
M36
M38
M35
PERSEUS
Algol
M34
ANDROMEDA
M31
TRIANGULUM
M33
ARIES
PISCES
Pleiades
Moon Feb 10
ECLIPTIC
Aldebaran
Hyades
TAURUS
CANIS MINOR
Procyon
Betelgeuse
Bellatrix
ORION
M42
Rigel
Saiph
EQUATOR
Mira
MONOCEROS
M50
M47
M46
Sirius
CANIS MAJOR
M41
M93
LEPUS
ERIDANUS
FORNAX
PUPPIS
COLUMBA
CAELUM
Star magnitudes
–1
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3
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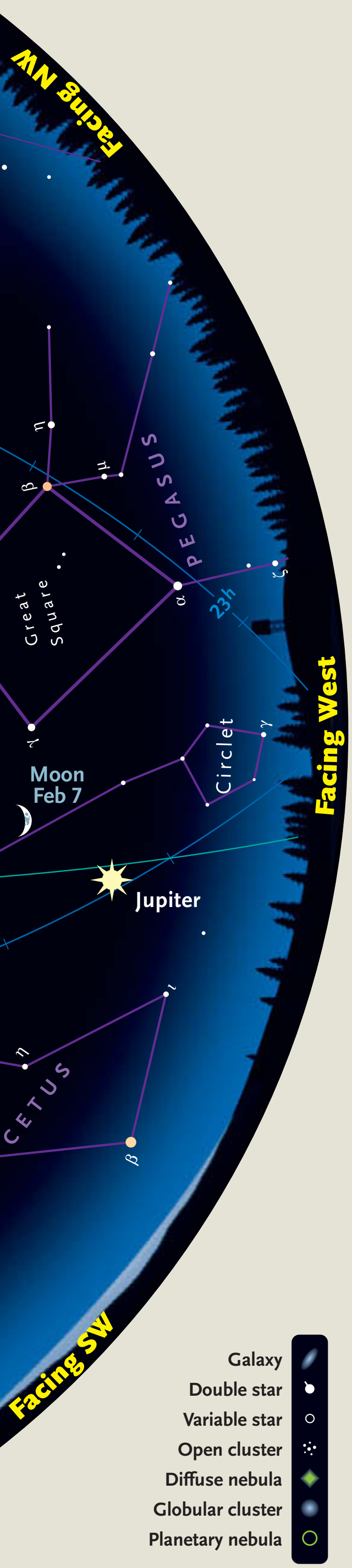


Using the Map

WHEN

Late December	11 p.m.
Early January	10 p.m.
Late January	9 p.m.
Early February	8 p.m.
Late February	7 p.m.

These are standard times.

HOW

Go outside within an hour or so of a time listed above. Hold the map out in front of you and turn it around so the yellow label for the direction you're facing (such as west or southeast) is at the bottom, right-side up. The curved edge is the horizon, and the stars above it on the map now match the stars in front of you in the sky. The map's center is the zenith, the point overhead. Ignore all parts of the map over horizons you're not facing.

Example: Rotate the map a little so that "Facing East" is right-side up. Two-thirds of the way from there to the map's center are the twin stars Castor and Pollux. Go out, face east, and look two-thirds of the way up the sky. There are the Twins!

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

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

Binocular Highlight:
M50 in Monoceros

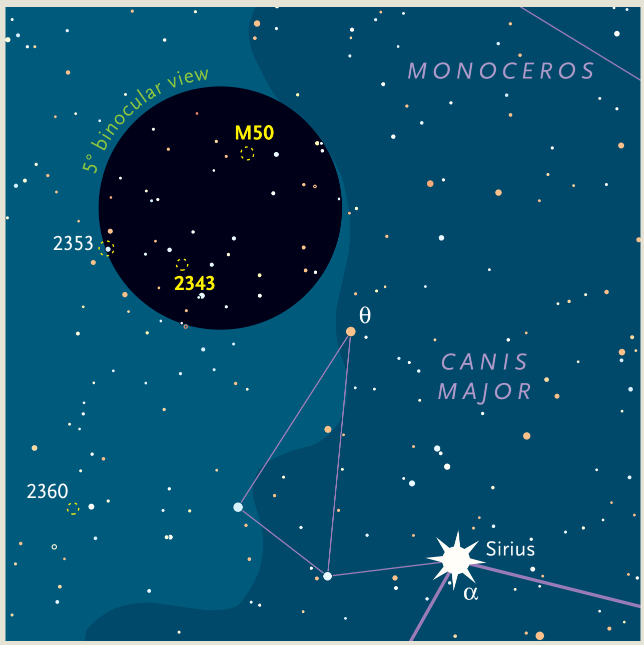
If you live under light-polluted skies, the dim hazy band of the winter Milky Way might be *caelum incognitum* to you. Sure, you may not be able to see the much brighter summer Milky Way either, but at least the warm days and mild nights of that season can be enjoyed while camping under dark country skies. Only the hardiest of souls camp in the dead of winter. And though it generally doesn't get as much attention as its summer counterpart, the winter Milky Way is similarly rich with binocular targets, including the open cluster **M50**.

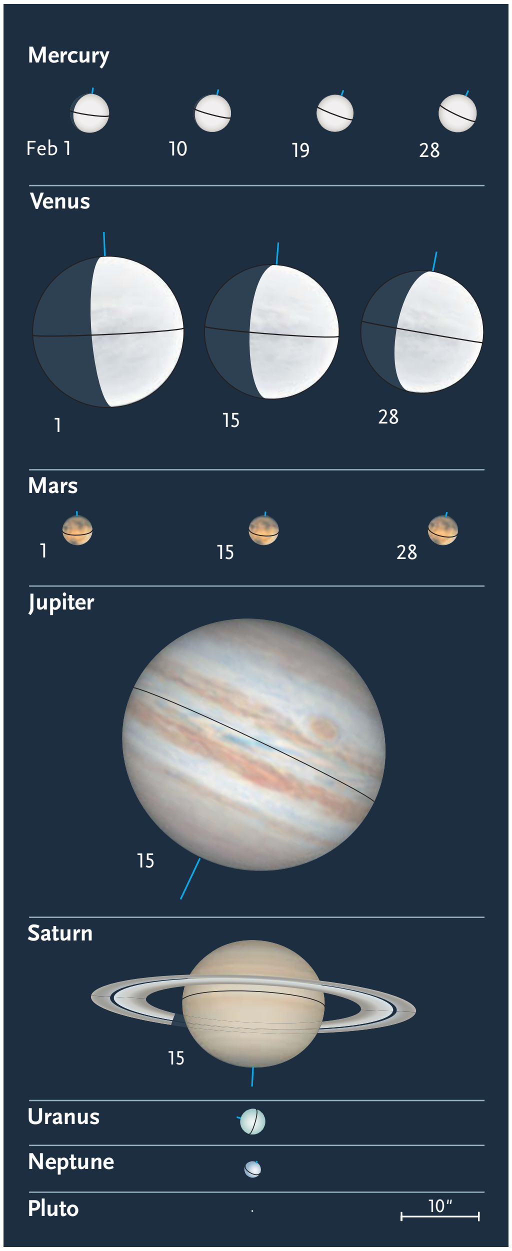
One of the best stretches of the winter Milky Way for binocular observers runs through Puppis, alongside Canis Major, and up into Monoceros. The region is peppered with lovely open clusters, including a clutch of Messier objects: M46, M47, M93, and M50, which marks the northern tip of this rich swath.

The easiest way to locate M50 is to follow a line from Sirius through Theta (θ) Canis Majoris, and extended one binocular field beyond Theta. The cluster glows at magnitude 5.9, so you can see it with very modest binoculars — I have no trouble hauling it in with my 10×30 image-stabilized binos. With these optics I see a compact grouping with a half-dozen individual stars popping in and out of view. My 10×50s are able to show these stars more steadily, along with a background glow from faint, unresolved cluster members.

If M50 proves easy, try for neighboring open cluster **NGC 2343**. Listed at magnitude 6.7, this tight knot of starlight is visible in less-than-pristine skies, though seeing more than a couple individual cluster stars nestled in a little luminous patch will be challenging even in the best of conditions. ✦

— *Gary Seronik*



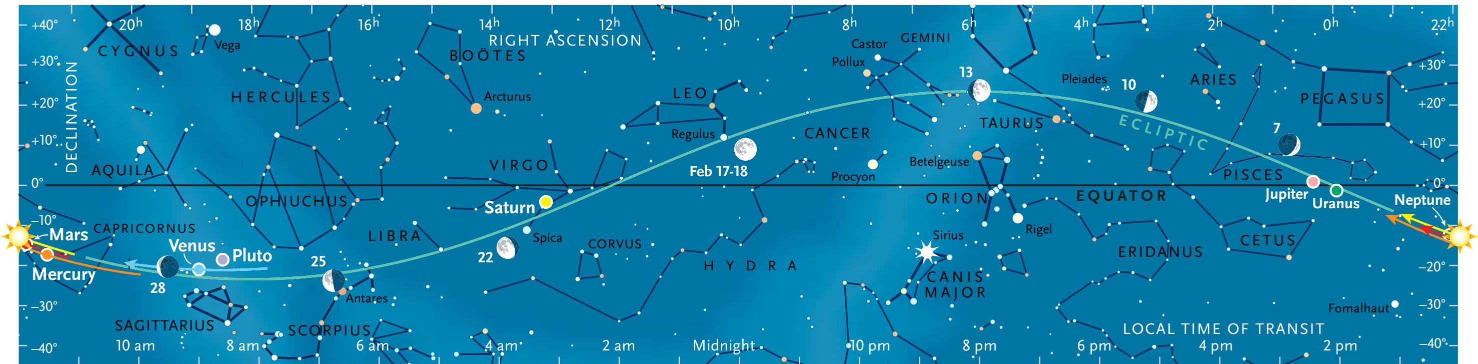


Sun and Planets, February 2011

	February	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$20^h\ 56.3^m$	–17° 18′	—	–26.8	32′ 28″	—	0.985
	28	$22^h\ 42.0^m$	–8° 14′	—	–26.8	32′ 18″	—	0.990
Mercury	1	$19^h\ 50.2^m$	–22° 19′	16° Mo	–0.3	5.1″	90%	1.322
	10	$20^h\ 49.9^m$	–19° 43′	11° Mo	–0.6	4.9″	95%	1.377
	19	$21^h\ 51.0^m$	–15° 15′	5° Mo	–1.2	4.8″	99%	1.393
	28	$22^h\ 53.1^m$	–8° 55′	3° Ev	–1.7	5.0″	100%	1.357
Venus	1	$17^h\ 43.7^m$	–20° 43′	45° Mo	–4.3	19.6″	61%	0.851
	10	$18^h\ 27.5^m$	–21° 09′	44° Mo	–4.3	18.2″	65%	0.917
	19	$19^h\ 12.1^m$	–20° 50′	43° Mo	–4.2	17.0″	68%	0.983
	28	$19^h\ 56.9^m$	–19° 44′	42° Mo	–4.1	15.9″	71%	1.046
Mars	1	$21^h\ 00.9^m$	–18° 06′	1° Ev	+1.1	3.9″	100%	2.376
	15	$21^h\ 44.7^m$	–14° 42′	3° Mo	+1.1	3.9″	100%	2.371
	28	$22^h\ 24.2^m$	–11° 07′	5° Mo	+1.1	4.0″	100%	2.365
Jupiter	1	$0^h\ 07.7^m$	–0° 26′	50° Ev	–2.2	35.7″	99%	5.524
	28	$0^h\ 28.8^m$	+1° 54′	29° Ev	–2.1	34.0″	100%	5.796
Saturn	1	$13^h\ 06.7^m$	–4° 20′	115° Mo	+0.7	18.2″	100%	9.143
	28	$13^h\ 03.6^m$	–3° 53′	143° Mo	+0.5	18.9″	100%	8.796
Uranus	15	$23^h\ 55.6^m$	–1° 15′	33° Ev	+5.9	3.4″	100%	20.912
Neptune	15	$22^h\ 01.9^m$	–12° 35′	2° Ev	+8.0	2.2″	100%	30.999
Pluto	15	$18^h\ 27.9^m$	–18° 48′	49° Mo	+14.1	0.1″	100%	32.615

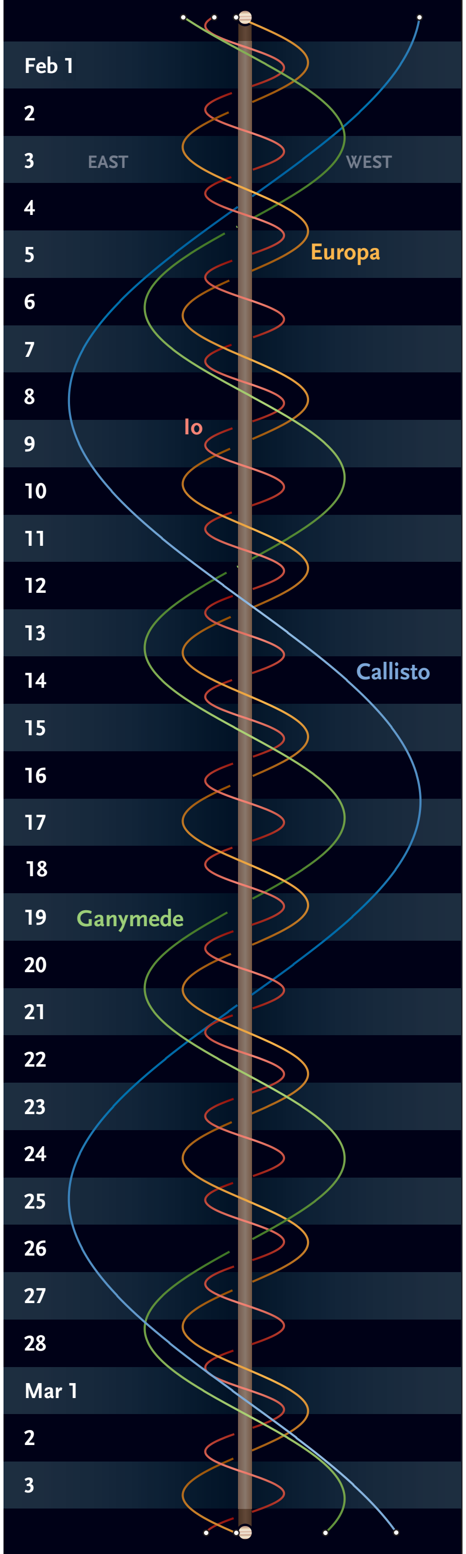
The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial 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-February; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). All Moon dates are in February. "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

Jupiter's Moons



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

A Three-Planet Month

Jupiter, Saturn, and Venus are the only planets visible to the unaided eye in February.

As evening twilight fades after February days, the sole bright planet visible is Jupiter, prominent in the southwest. It sets a couple hours later, leaving the sky empty of any planets — bright or dim — for a little while. Then Saturn rises in the east, and it in turn is the only planet visible until blazing Venus rises 2 or 3 hours before sunrise.

DUSK

Jupiter comes into view at dusk less than halfway up the southwest sky (for observers around 40° north latitude). It dims slightly in February, to magnitude –2.1, and its apparent diameter dwindles a bit to 34″. There's still much to check on its globe, however, including the status of the South Equatorial Belt and the Great Red Spot (SkyandTelescope.com/redspot). This is the last month until July when Jupiter will be high enough for good telescopic observations.

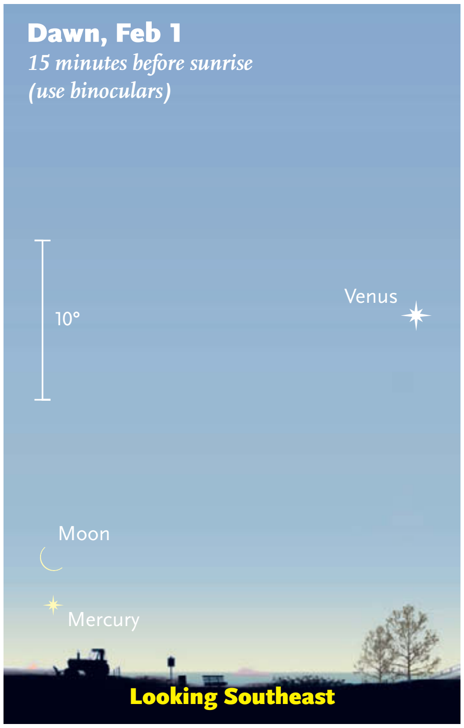
Jupiter crosses into the north celestial hemisphere on February 5th, and late in the month it leaves Pisces for a brief journey through the northwest corner of Cetus. Jupiter sets around 9:30 p.m. as February opens but around 8 p.m. as the month ends.

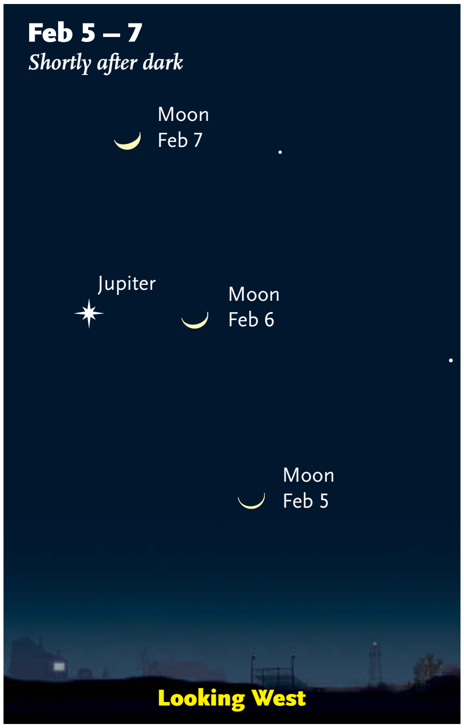
Uranus, faint at magnitude 6, had a close conjunction with Jupiter in early January, but it begins February almost 4° to Jupiter's lower right. Jupiter's swifter motion carries it to 6° from Uranus on February 14th and almost 8½° by month's end.

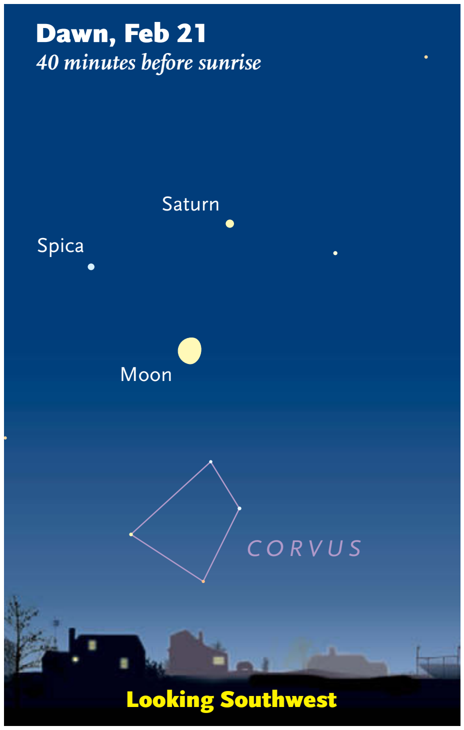
NIGHT

Saturn rises in the east in Virgo around 10:30 p.m. on February 1st and two hours earlier on February 28th. The former is an hour after Jupiter sets, the latter only a half hour. The ringed world brightens a little, from magnitude +0.7 at the beginning of February to +0.5 at month's end.

Saturn was less than 8° from Spica in late January, but now the planet is moving westward (retrograding) away from Spica.



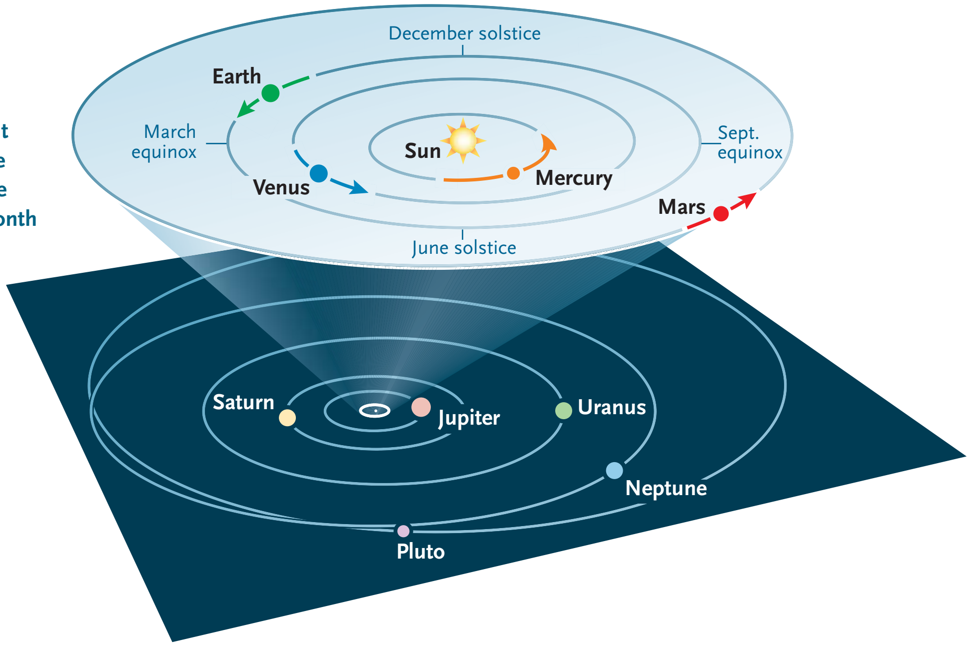




These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist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

ORBITS OF THE PLANETS

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



Saturn culminates (is highest in the south) around 4:30 a.m. at the start of February and 2:30 a.m. at month's end. The rings are getting a bit narrower during February, but they're still close to 10° from edge-on.

DAWN

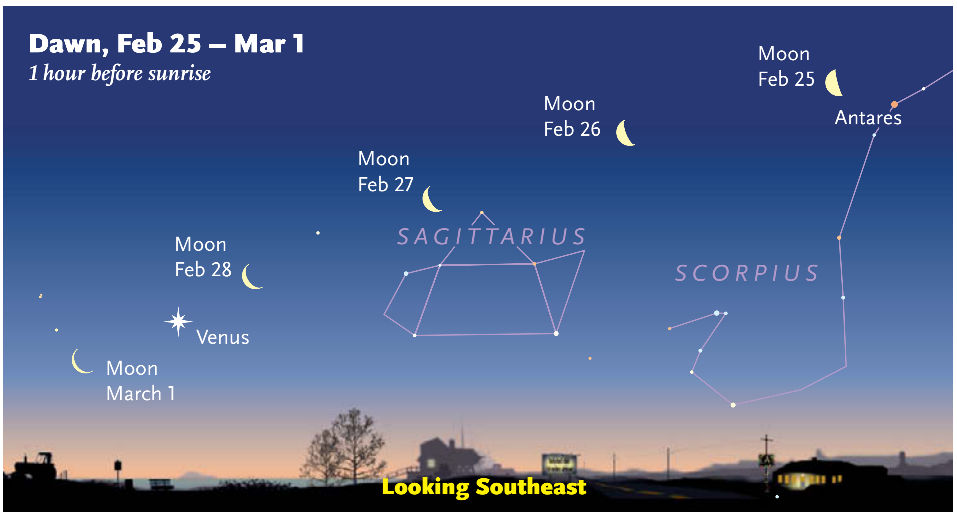
Venus rises while the sky is still fully dark throughout February, but the interval between Venus-rise and sunrise shrinks from 3 to 2 hours. Venus loses a bit of its tremendous luster this month, fading from magnitude –4.3 to –4.1. Its disk shrinks to less than 16″ in February, while its phase grows to more than 70% lit.

Venus glides eastward across Sagittarius this month, passing several stars and deep-sky objects as described on page 57.

Pluto is also in Sagittarius, but it's too faint to view when it's so low in the sky. Interestingly, however, Pluto is only 2.3° north of Venus on February 9th. Pluto is usually far in the sky from the major planets, but it has been approaching the ecliptic in recent years and will cross it in 2018. So for the next decade, Pluto will have many encounters with planets. The closest will be one I found three decades ago while perusing printouts of Steve Albers' conjunction program (*S&T*: March 1979, page 220): Mars will pass less than 1′ south of Pluto on March 23, 2020 — when they will be tightly clustered with Jupiter and Saturn, and far enough from the Sun to be readily observable!

Mercury, coming off a fine morning apparition in early January, rises only about 45 minutes before the Sun on February 1st (for viewers around 40° north). On that date, can you detect the planet with binoculars just below the crescent Moon very low in the southeast about 25 to 15 minutes before sunrise? Mercury is completely lost in the dawn glow a few dawns later. It reaches superior conjunction with the Sun on February 25th.

Mars and **Neptune** also reach conjunction with the Sun this month, on February 4th and 17th, respectively. So both are unobservable.



MOON PASSAGES

The **Moon** is a very slender crescent a few degrees above Mercury at dawn on February 1st, as shown on the facing page. A waxing crescent Moon shines to the right of Jupiter on the evening of February 6th and above it on the 7th. The Moon is waning gibbous and rising in the late evening when it forms a triangle with Saturn and Spica on February 20th, and a vertical line with them on February 21st.

The last-quarter Moon hangs to the left of Antares at dawn on February 25th. The waning lunar crescent is upper right of Venus at dawn on February 28th and lower left of Venus on March 1st. ✦

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

The Moon on Earth: Volcanism

A virtual hike on the Moon is within the reach of amateur astronomers.

WHILE ONLY 17% of the Moon's surface is covered by volcanic rocks, it includes some of the most fascinating features on our neighbor world. Many of the dark mare splotches we see are vast piles of lava flows hundreds of miles wide. Sinuous rilles, collapse pits, volcanic cones, and domes are associated with these flows. Lunar volcanic material also erupted explosively to make dark halo craters — volcanic pits ringed with ash.

Fortunately, these lunar volcanic features have analogs on Earth, allowing scientists to understand their formation processes and how they might differ on the two bodies. One of the best places on Earth to find these lunar analogs is the Craters of the Moon National Monument & Preserve (CoM) in the Snake River Plain of Idaho. NASA even took astronauts there to train for the Apollo 14 mission. The CoM lava field is the largest young basalt eruption in the contiguous 48 states, with 60 individual lava flows and 25 ash cones having formed as recently as 2,000 years ago. These lavas are similar to those that formed the lunar maria about 3 billion years ago. The entire CoM is only about 40 miles (65 km) long and would be a very minor flow on the Moon. But it is here on Earth and you can hike over it.

This Landsat 7 satellite image of Craters of the Moon National Monument & Preserve in Idaho reveals miles of basalt lava flows similar to many lunar maria.

NASA / GODDARD SPACE FLIGHT CENTER

The first things you see when visiting CoM are dark lava flows that probably look very much like lunar lavas did when they erupted. The surfaces of young lava flows are very rough, with edges so sharp they could cut into a hiker's boots or an astronaut's spacesuit. Most Apollo landings were on maria, and the astronauts walked on lava flows. Fortunately, 3 billion years of micrometeorite bombardments have eroded the rough flows into smooth rolling plains.

Lava often flows through a central channel constrained within lava levees. These narrow features commonly originate from small collapsed vents, where the magma reaches the surface and then winds its way downslope. Frequently the channel roof cools and crusts over, and lava continues to flow within the insulated enclosure — a lava tube. Channels and tubes such as Indian Tunnel at CoM are excellent analogs to sinuous lunar rilles. Occasionally, the channel is open the entire length of the flow, but often there are closed parts too. Some lava flows have completely hidden lava tubes whose presence is only revealed when part of the roof collapses, forming a skylight. A camera on NASA's Lunar Reconnaissance Orbiter has recently imaged skylights in the lunar maria.

Domes are another volcanic landform found on both worlds. In fact, the Eastern Snake River Plain in Idaho is made up of thousands of small, overlapping dome-shaped volcanoes called shield volcanoes. These formed when a vent erupts fluid lavas that flow away in all directions, building a gentle-sided cone. In Idaho the small shields are typically about 1 to 10 miles wide and up to 500 feet high, similar to their lunar counterparts.

U. S. GEOLOGICAL SURVEY

Although rare, versions of volcanic cinder cones like Sunset Crater in Arizona (above) do exist on the Moon; the easiest to spot are located on the floor of the crater Alphonsus.

The Snake River Plain also contains a few steep-sided volcanic hills made of more silica-rich lavas. Big Southern Butte is a 300,000-year-old mound of rhyolite lava that erupted like stiff toothpaste, building up an isolated mountain that is 2,300 feet (700 meters) high and 4 miles (6.4 kilometers) wide. This is similar in shape and probable mode of formation as the famous steep Gruithuisen Domes on the Moon.

Perhaps the most common type of volcanic landform on Earth is the cinder cone. These structures form when erupting magma contains enough gas to shred into small blobs called cinders, which build up a cone around the eruption vent. Cinder cones are typically about 1 kilometer wide and 200 meters high, with slopes as steep as 30°. There are only a few cinder cones on the Moon. This is exactly what is predicted when taking into account the Moon's one-sixth gravity and lack of atmosphere, both of which would allow cinders to travel far beyond their vents. Lunar cinder cones should be very wide with low rings of cinders. Features like this occur on the floor of Alphonsus and other craters — we call them dark halo craters.

Backyard observers of the Moon can increase their understanding of the volcanic processes that shaped the lunar surface by following the example of Apollo astronauts and visiting the scenic volcanic parks. It's not too early to start planning a lunar analog field trip for this summer. ✦

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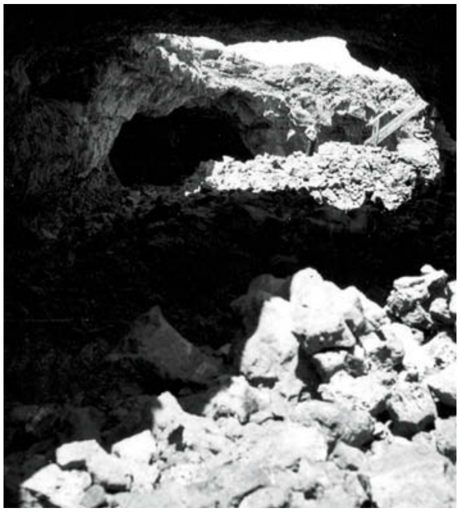
*For a daily lunar fix, visit contributing editor **Charles Wood's** website: lpod.wikispaces.com.*



U. S. GEOLOGICAL SURVEY

Indian Tunnel in Idaho is a lava tube with numerous collapsed roofs known as skylights. Scientists have discovered similar features on the Moon from Lunar Reconnaissance Orbiter images.

The Moon • February 2011

Phases

New Moon	February 3, 2:31 UT
First quarter	February 11, 7:18 UT
Full Moon	February 18, 8:36 UT
Last quarter	February 24, 23:26 UT

Distances

Perigee 220,002 miles	February 19, 7^h UT diam. 33′ 45″
Apogee 250,404 miles	February 6, 23^h UT diam. 29′ 39″

Librations

Boussingault (crater)	February 7
Demonax (crater)	February 14
Pascal (crater)	February 17
de Sitter (crater)	February 27

Dennis di Cicco

Celestron's 14-inch EdgeHD

A 21st-century update transforms Celestron's legendary telescope.

A new optical design for Celestron's 14-inch Schmidt-Cassegrain telescope (pictured in the author's observatory) delivers excellent results on Kodak's large-format KAF-16803 CCD, as seen in this view of the Veil Nebula (NGC 6992) recorded through Astrodon red, green, and blue filters.

ALL PHOTOS BY THE AUTHOR / PROCESSING BY SEAN WALKER

Celestron EdgeHD 14 OTA

U.S. price: $5,799 (OTA only)

www.celestron.com

WITH APOLOGIES TO younger readers, I have a quiz for those of us old enough to have watched the Apollo 11 Moon landing and who also have been amateur astronomers for, say, at least a dozen years (I know this "club" isn't hurting for members). Think back to your earliest days in the hobby, and name the telescope you dreamed about owning. I'll bet most of you answered Celestron's C14 Schmidt-Cassegrain.

Introduced in 1972, the C14 was truly in a class by itself — a portable 14-inch telescope that was as close to being ready-made for astrophotography as any commercial instrument then available. While the C14's optical tube assembly (OTA) has been offered with different mounts over the years, the fact that the OTA has remained in continuous production for nearly four decades speaks volumes about its optical success.

Celestron recently introduced a new version of the C14, billing the new OTA the EdgeHD 14. The revamped optical design (and this goes for the 8-, 9¼-, and 11-inch EdgeHD scopes as well) includes a two-element corrector lens located inside the primary mirror's baffle tube. The end result is a very flat, well-corrected focal plane, which delivers nice round stars across a large field of view.

I'll skip the suspense and go right to the punch line. The EdgeHD 14 offers the best-ever optics in a C14. Refinements to the OTA also make it mechanically Celestron's best 14-inch ever. And since the new design remains HyperStar compatible (more about this in a moment), the EdgeHD 14 is a remarkably versatile instrument. It is, however, no longer in a class by itself. Observers and astrophotographers today can choose from a variety of 14-inch telescopes, especially if cost is not a factor. So let's look at what makes the EdgeHD 14 special.

Some Things Change and Some Don't

I spent several months last summer and fall testing an EdgeHD 14 that we borrowed from Celestron for this review. It was housed in my suburban-Boston backyard observatory on a CGE Pro German equatorial mount (reviewed in our November 2009 issue, page 50). Celestron sells the scope and mount together as the CGE Pro 1400 HD for $9,999.

I'm not going to dwell on the scope's visual performance, since the C14 has amassed countless testimonials over the years. Nevertheless, suffice it to say that the EdgeHD 14 not only lives up its predecessor's reputation as a visual telescope, but on critical examination surpasses it because of improved star images at the edge of the field. I had particularly memorable views of Jupiter while waiting for the return of the South Equatorial Belt. And the scope was noteworthy for pulling faint stars out of my suburban sky, making it ideal for hunting down some of the lesser-known open and globular star clusters.

The well-designed mirror locks have a pin (arrowed) that presses on a wire rod (attached to the mirror support) when a conical sleeve in the hand knob is tightened. This allows the locks to be engaged without upsetting the scope's focus.

Since the EdgeHD optics retain the same front Schmidt corrector and primary mirror as the original C14, the new OTA still works with the HyperStar system (reviewed in the February 2010 issue, page 34), allowing astrophotography at an astounding f/1.9 focal ratio.

Where the EdgeHD optics differ from the original is the secondary mirror's figure and, of course, the addition of the rear corrector lens. And it's the latter that most concerns users, since it places restrictions on where cameras must be located for optimum optical performance. In the case of the EdgeHD 14, the critical spacing is 5.75 inches between the camera's detector and the mounting flange on the scope's rear cell. As in the past, when you turn the scope's focus knob, the focal point moves back and forth relative to the rear flange, but the "luxury" of slapping on any old camera adapter and bringing the focus to the camera is gone.

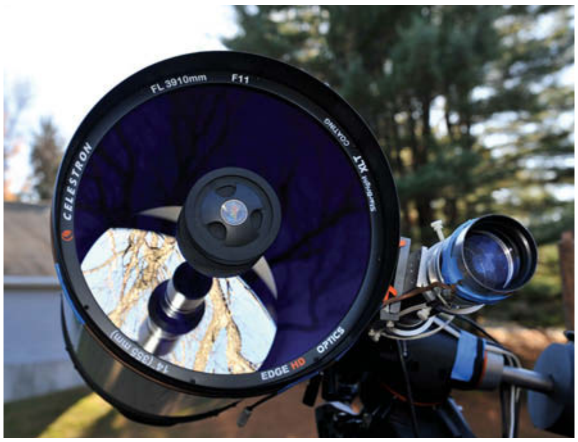
At present Celestron makes only one camera adapter for the 14-inch EdgeHD, and it's based on the well-established

WHAT WE LIKE:

- Best C14 optics ever
- Remains HyperStar compatible
- Effective mirror-locking system

WHAT WE DON'T LIKE:

- Can't use existing focal reducers
- Only camera adapter available uses T-threads



As detailed in the text, Celestron's camera adapter (*far left*) is based on the photographic T system. Also explained in the text, the new EdgeHD optics have a removable secondary mirror, and they remain compatible with Starizona's HyperStar f/1.9 imaging system.

The EdgeHD 14's long (3,910 mm) focal length is great for shooting galaxies. This full-frame view of M33 was made with a KAF-16803 CCD and, as with the Veil picture on page 52, a total exposure of 150 minutes through Astrodon filters.

To see these and more deep-sky images made during the course of this review, visit **SkyandTelescope.com/EdgeHD**.

photographic T system. In other words, the length of the adapter combined with the additional 55-millimeter back spacing dictated by the T system puts cameras at the correct 5.75-inch setback.

That's great for anyone shooting with DSLR cameras, but astronomical CCD cameras have no industry standard for back focus, and thus will usually require custom spacers when used with Celestron's camera adapter. And anyone with a camera that needs a larger opening than that afforded by T threads will have to start from scratch. I own a lathe (that's my adapter seen in the picture on page 52), but those who don't can contact PreciseParts (www.preciseparts.com), a company that specializes in making custom telescope adapters.

Celestron says the EdgeHD 14 is designed to cover the format of a 35-mm camera (image circle 42 mm in diameter), but I was very satisfied with star images across the larger field of a 38-mm-square Kodak KAF-16803 CCD (52-mm image circle). Stars appeared round and of uniform diameter in all but the extreme corners of this chip. The illumination was also very even across the central half of the field, and then dropped off smoothly by about 15% at the edges of the CCD. My images were easily corrected with routine flat-field processing.

One caveat for the EdgeHD optics is that they don't work with the current breed of focal reducers that are intended to correct off-axis aberrations in the original Schmidt-Cassegrain optics. Celestron does say, however, that it is working on a new focal reducer for the EdgeHD scopes.

Celestron's engineers deserve kudos for their elegant solution to a long-standing problem with Schmidt-Cassegrains that focus by moving their primary mirrors. Because of inevitable mechanical play in the mirror support, the primary tends to shift slightly as the scope tracks across the sky, causing the image to shift at the focal plane. This is especially true of larger instruments with heavier mirrors, and it's a curse for those of us doing long-exposure astrophotography.

The EdgeHD scopes have a nicely designed pair of mirror locks that eliminate this mirror "flop." The challenge was creating a locking system that secures the primary without disrupting, even minutely, the scope's focus when the lock is engaged. Celestron succeeded!

Quick Look *by Sean Walker*

"Double-Stacked" P.S.T.

U.S. price: $999.95
Meade Instruments
27 Hubble, Irvine, CA 92618
800-626-3233; www.meade.com

Probably no telescope since the 8-inch Schmidt-Cassegrains of the 1970s has created such an observing revolution as Coronado's Personal Solar Telescope (P.S.T.). Introduced in 2004, the P.S.T. made hydrogen-alpha solar observing affordable. Coronado is now owned by Meade, and the company is offering a "double-stacking" option that sweetens the view. Since I was enamored of the original P.S.T. (my review appears in the February 2005 issue, page 96), I was eager to see how Meade improved this already excellent instrument.

The basic P.S.T. is guaranteed to pass less than 1 angstrom of the Hα wavelength (in this case, less is better), allowing dynamic solar features to be safely visible to the eye. Shortly after the original P.S.T.'s debut, Coronado offered a second filter option to further narrow the telescope's passband, allowing greater visual contrast of subtle solar features. The caveat was that you had to send the telescope back to Coronado to have the second filter matched to your scope.

Meade has redesigned the double-stack filter, eliminating the need for matching. The new front filter has a T-Max tip-tilt mechanism and a twist adjustment dubbed the "RichView" tuner. A double-stacked P.S.T. (the scope's official name is the "<0.5 Personal Solar Telescope") takes slightly longer to tune than the basic model. I

While Schmidt-Cassegrains do not cause diffraction spikes on bright stars, reflections from the corrector plate can cause halos, as seen in this view of 52 Cygni and the Veil Nebula, NGC 6990 (*far left*). The EdgeHD 14 covers just a ½° field on a KAF-16803 CCD, which is large enough to fit the Moon.

Pleasant Surprise

Traditional Schmidt-Cassegrain telescopes with aluminum tubes are well known for drifting out of focus as the ambient temperature drops and the OTA contracts, decreasing the separation between the primary and secondary mirrors. Past solutions have included carbon-fiber tubes (which don't contract as much as aluminum) and temperature-compensating focusers that automatically make small adjustments to a camera's position as the temperature changes.

Although Celestron made no mention of the EdgeHD 14's focus being unusually resistant to temperature changes, early in my testing I became aware that the focus was much more stable than I expected. Eventually I set up a rig to accurately track the scope's focus as the tube's temperature dropped during the night.

Several nights of data confirm that each degree centigrade of temperature drop causes the EdgeHD 14's focus to move outward from the tube by slightly less than 0.01 mm. This is only about one-third of the shift I was expecting. While I and others (including engineers at Celestron) aren't exactly sure why the scope performs better than expected, it's most likely a combination of subtle effects, not the least of which involve the corrector lens. Regardless, the EdgeHD 14's focus stability is good news.

Considering its longevity in a highly volatile telescope market, it's pretty much a given that Celestron's 14-inch Schmidt-Cassegrain has been a remarkable success story. And since the new OTA offers the best performance yet, I'm confidant that the legend will live on. This is especially true in the world of astrophotography, since the EdgeHD 14's image quality compares well with much more expensive instruments. It may seem contradictory to call a $5,800 OTA a bargain, but when it comes down to versatility and performance, that's exactly what the EdgeHD 14 is. ✦

Senior editor ***Dennis di Cicco*** *has been observing with Schmidt-Cassegrain telescopes since 1972.*

WHAT WE LIKE:

Ultra-portable solar Hα package

Still affordable

WHAT WE DON'T LIKE:

Small "sweet spot" in the field of view

Second filter makes scope front heavy

found it best to start without the front filter, and tune the internal etalon until I had the best views of solar prominences. Then I'd add the front filter, adjust the T-Max to eliminate any secondary reflection, and finally adjust the RichView tuner.

As soon as the RichView was tweaked, filaments that were barely visible before adding the second filter became dramatic, dark, sinuous features set against the solar disk. Bright areas around sunspots were much more apparent, too. Overall, the Sun looks more interesting with the double-stacked P.S.T. — something that even those new to observing the Sun in Hα light will surely enjoy.

While we borrowed a double-stacked P.S.T. from Meade for this review, I also tried the scope's second filter (sold separately for $599) on my 6-year-old P.S.T., and it worked equally well.

The only downside to the double-stacked P.S.T. is that its views are dimmer than those with a single filter. Faint prominences that were visible at the Sun's limb with the single filter disappear when I added the second filter. This isn't a huge problem, as the filter goes on and off in seconds, but I found it a bit disconcerting to constantly handle the delicate filter to get the best of both views. The double-stacked P.S.T. is also front heavy and can't be balanced on a tripod using either of the ¼-20 threaded holes on the bottom of the scope.

As with the original, the double-stacked P.S.T. represents a great value for observers wanting to expand their astronomy endeavors into daylight hours. But be warned: it will quickly make you long for a larger solar telescope!

Imaging editor ***Sean Walker*** *has managed to resist aperture fever and still uses his P.S.T. every clear day at the S&T offices.*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Venus Passages

In the winter dawn, Venus crosses the riches of summery Sagittarius.

WHEN WAS THE LAST TIME you set the alarm and snuck outside into the pre-dawn dark for a look at out-of-season celestial spectacles? Yes, February may be cold, but the memories can be magical.

This winter Venus blazes low in the southeast while the morning sky is still pitch dark, and it spends the first half of February (moonless before dawn) cruising by famous Messier objects in Sagittarius — normally a scene for warm evenings in summer. In addition the asteroid 4 Vesta, now magnitude 7.8, creeps along in Venus's background three times farther away. The two appear closest, 0.4° apart, on the morning of Wednesday, February 9th.

When does dawn's first light begin at your site? To find out, use the *Skygazer's Almanac* that came with the January issue, or put your location into SkyandTelescope.com/almanac (and make sure the daylight-saving time box is unchecked).

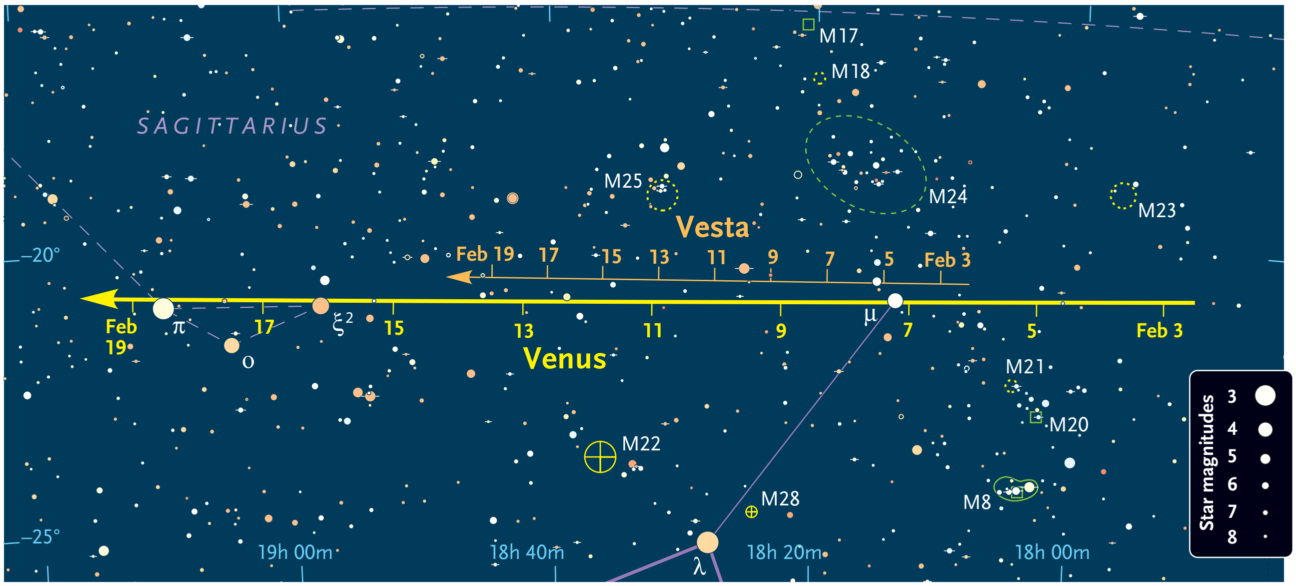
The ticks on the tracks below show where Venus and Vesta are at 0^h Universal Time on the dates indicated (which is 7 p.m. on the previous date EST). Put a pencil dot on the position of each object for the date and time you'll observe, aim your finderscope at Venus, and use the chart to work your way out from there. Note how big 5° appears on the blue degree scale on the left edge. That's about the size of a typical good finderscope's field of view.

Venus is more than 600 times brighter than the brightest star plotted. Try not to blind your night vision!

Lunar Occultation

Among the stars repeatedly occulted by the Moon in 2011 is yellow Zeta Geminorum, magnitude 3.7. On the **morning of February 15th**, use a telescope to watch it disappear on the dark limb of the waxing gibbous Moon for much of North America. Some times: Toronto, 3:54 a.m. EST; Washington DC, 4:00 EST; Atlanta, 4:11 EST; Chicago, 2:50 CST; Kansas City, 3:04 CST; Denver, 2:04 MST. The Moon will be getting low in the west.

For a much larger timetable and a map, see www.lunar-occultations.com/iota/iotandx.htm; scroll down to "Upcoming Occultation Events." There you'll find all the brightest occultations worldwide for the year.



Asteroid Occultations

QUITE DIFFERENT from lunar occultations are star coverups by tiny, distant asteroids — which, very unlike the Moon, are often completely invisible in a telescope. You just watch a lone star in the dark — and suddenly it winks out, if you're lucky. The star usually reappears in just a few seconds, whereas lunar occultations can last for more than an hour.

Late on the night of **February 1–2**, the faint asteroid 419 Aurelia should occult the 8.8-magnitude star SAO 94620 in Taurus as seen from a narrow track probably running from Delaware to southeastern Alaska. The asteroid will be near one of the stationary points in its loops on the sky, so the occultation may last for up to 22 seconds — unusually long.

On the night of **February 3–4**, faint 773 Irmintraud occults 9.4-magnitude SAO 59192 in Auriga for up to 9 seconds as seen from central Florida through central Mexico.

On the **morning of February 27th**, 38 Leda — another slow mover — occults 8.7-magnitude SAO 182321 at the Virgo-Centaurus border for up to 31 seconds as seen from southern Mexico through Texas to Montana.

For finder charts and more details, and for hundreds of other asteroid occultations predicted worldwide all year, see www.asteroidoccultation.com/IndexAll.htm.

For lots more about how to observe and time them, see www.asteroidoccultation.com/asteroid_help.htm. ✦

Minima of Algol

Jan.	UT	Feb.	UT
3	20:36	1	12:50
6	17:26	4	9:39
9	14:15	7	6:28
12	11:04	10	3:18
15	7:53	13	0:07
18	4:43	15	20:57
21	1:32	18	17:46
23	22:22	21	14:35
26	19:11	24	11:25
29	16:00	27	8:14

These geocentric predictions are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy AAVSO. The star's period seems to have lengthened slightly in early 2000.

Phenomena of Jupiter's Moons, February 2011

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

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)**. **JUPITER'S GREAT RED SPOT:** For a timetable of when Jupiter's Great Red Spot is predicted to cross the planet's central meridian, see SkyandTelescope.com/redspot.

Taking the Bull by the Horns

Each horn tip is adorned with a supernova remnant.

I mark, stern Taurus, through the twilight gray
The glinting of thy horn,
And sullen front, uprising large and dim,
Bent to the starry hunter's sword, at bay.
— Bayard Taylor, *Taurus,* 1849

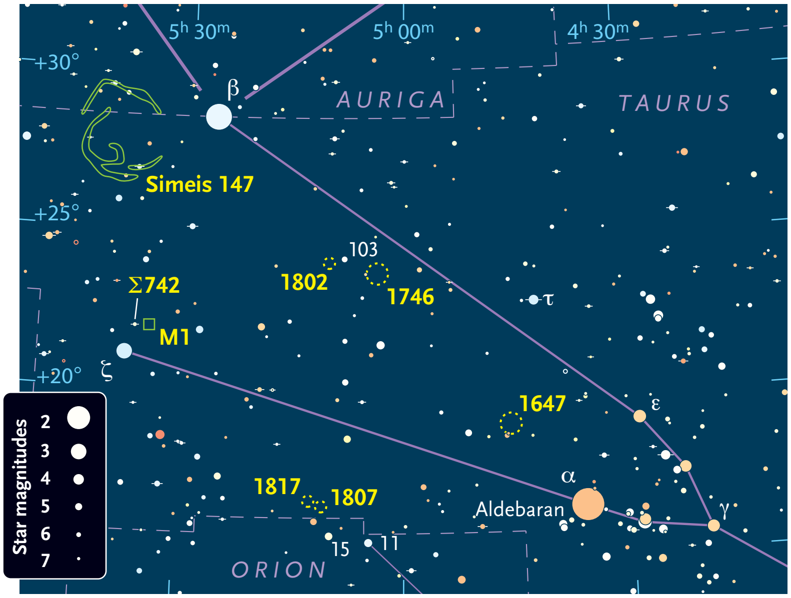
TAURUS, THE BULL, is one of the few constellations that truly resembles its namesake, with star-tipped horns and a face strikingly illumed by the Hyades and fiery orange Aldebaran. In *Astronomy with the Naked Eye,* Garrett P. Serviss remarks that the faint stars between the horns and in the top of the Bull's head "impart a glimmering beauty to the scene." The region also gleams with intriguing deep-sky wonders.

The lovely open cluster **NGC 1647** rests atop the Bull's head. My 130-mm (5.1-inch) refractor at 37× shows a 40′ group of 55 loosely scattered stars, magnitude 8.4 and fainter. The 9th-magnitude pair northeast of center is the wide double **AG 311**, whose companion star lies 33″ east-southeast of its primary. Two bright, golden field stars prop up the cluster's southern edge.

NGC 1647 was the first object discovered by William Herschel while trying out a new speculum-metal mirror for his 18.7-inch telescope on February 15, 1784. Herschel noted, "It is very bright but not quite so distinct as my first, I shall however use it all the night." The mirror was put back into play just four days later, after repolishing, whereupon Herschel pronounced it "much superior to my first."

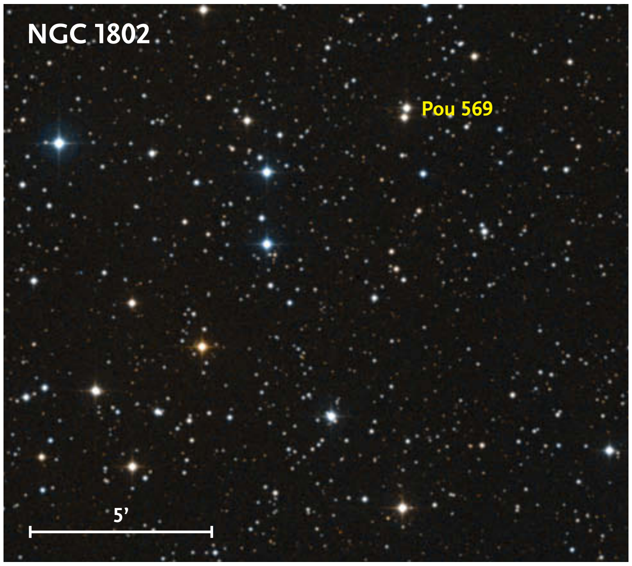
Between the Bull's horns, we find the clusters confusingly denoted as **NGC 1746**, NGC 1750, and NGC 1758. The latter two were discovered together in 1785 by William Herschel, while NGC 1746 was found 78 years later by Heinrich d'Arrest. Visually, d'Arrest's cluster has been variously identified as being a faint group 10′ north of NGC 1750, the same as NGC 1750, or a large group that includes Herschel's clusters as prominent condensations. A 2003 article in the journal *Baltic Astronomy* only recognizes the physical reality of overlapping NGC 1750 and NGC 1758, placing them at distances of 2,400 and 2,600 light-years, respectively. Although there's enough uncertainty in the distance measurements that their stars might commingle, NGC 1750 and NGC 1758 are distinguished as separate clusters by their somewhat different motions through space.

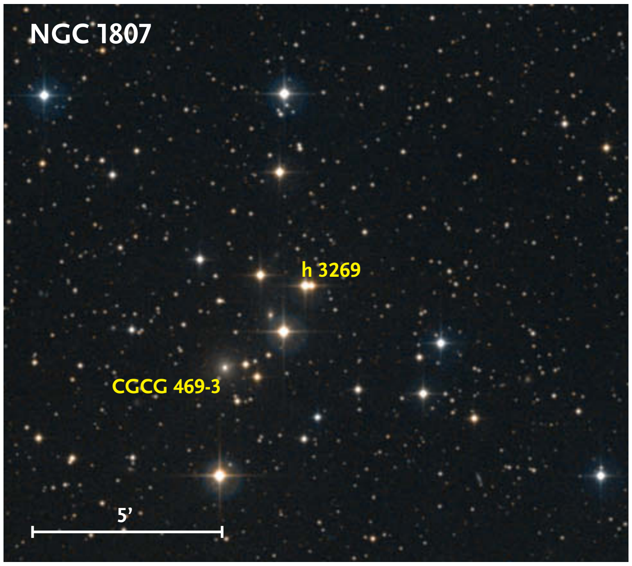
Let's simply call the whole agglomeration NGC 1746, as on many star charts, and explore what we can see. This



Messier 1 looks more spectacular in this false-color image from the Very Large Telescope than it ever does to the human eye. But it is possible to make out many of the tendrils with a filter.

ESO





POSS-II / CALTECH / PALOMAR OBSERVATORY (2)

starry jumble is very pretty through my 130-mm (5.1-inch) refractor at 37×. In the east there's a hockey stick of four gold stars, magnitudes 7.2 to 7.8. The crook of the stick cradles a dense, 10′ bunch of faint to extremely faint stars fading to a misty backdrop. Several dim stars trail 5′ south-southwest from there. To their west is a coarse, 11′ group of about 25 stars, magnitude 9 and fainter, the brightest in a pair of back-to-back arcs. The northeastern group roughly corresponds to Herschel's NGC 1758, and the southwestern one to NGC 1750. A 10-inch scope bares more than 100 stars in the area generally allotted to NGC 1746.

The blue-white, 5½-magnitude star 103 Tauri sits about 1° east-northeast of NGC 1746, and from there it's just a ½° hop east-southeast to **NGC 1802**. My 130-mm scope at 37× shows 11 faint stars fashioning a cute little leaping man, his head to the north and his upraised leg east. At 102×, 20 more stars fill out a 20′ group. The fellow's western hand is the double star **Pou 569**, the companion 15″ south-southeast of its primary. The pair's name indicates its place in a 1933 catalog by Paris Observatory's Abel Pourteau.

Although NGC 1802 looks cluster-like, only 7 of 63 stars studied in the area have a high probability of being physically related. Their derived distance is 1,300 light-years.

A nice double cluster dangles beneath the Bull's horns, 1° north-northeast of 15 Orionis. In my 105-mm refractor at 68×, **NGC 1807** is a splash of nine 9th- and 10th-magnitude stars plus as many faint ones stretched across 16′. Six bright stars form a north-south band, the bottom one golden. The northwestern star in the trio at the center of the band is the double **h3268**, the companion 10″ west of its primary. Slightly larger **NGC 1817** shares the field and boasts many very faint stars overlaid by three brighter ones in the west. Outshining all, **h3269** pins the cluster's west-northwestern edge, its yellow primary guarding a companion 20″ east-northeast.

NGC 1807 reveals two dozen stars through my 10-inch reflector at 171×, but one "star" is really the 14th-magnitude galaxy **CGCG 469-3**. It makes a squat triangle with 12th-magnitude stars roughly ½′ west and 1′ west-southwest, which lie between NGC 1807's two brightest stars.

A 2010 study of NGC 1817 places the cluster 1,600 light-years away, with an age of 1.3 billion years. Although showier, NGC 1807 isn't a true cluster, but outlying members of NGC 1817 may overlap its position.

Although there are many more clusters in Taurus, let's turn our attention to supernova remnants instead. Our celestial Bull is home to **Messier 1**, also called the Crab Nebula, the only supernova remnant in Charles Messier's 18th-century catalog.

In a dark sky, M1 is tiny but faintly visible in 7×50 binoculars. My 130-mm refractor at 23× displays an obvious

On the Horns of the Bull

Object	Type	Mag(v)	Size/Sep	RA	Dec.
NGC 1647	Open cluster	6.4	40′	$4^h\ 45.7^m$	+19° 07′
NGC 1746	Open cluster	6.1	40′	$5^h\ 03.6^m$	+23° 49′
NGC 1802	Open cluster	7.7	20′	$5^h\ 10.2^m$	+24° 08′
NGC 1807	Asterism	7.0	16′	$5^h\ 10.8^m$	+16° 31′
NGC 1817	Open cluster	7.7	20′	$5^h\ 12.5^m$	+16° 41′
CGCG 469-3	Galaxy	14.3	0.4′	$5^h\ 10.8^m$	+16° 29′
M1	Supernova remnant	8.4	6′ × 4′	$5^h\ 34.5^m$	+22° 01′
Σ742	Double star	7.1, 7.5	4.1″	$5^h\ 36.4^m$	+22° 00′
Simeis 147	Supernova remnant	—	3½°	$5^h\ 39.1^m$	+28° 00′

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.

oval about 1° northwest of Zeta (ζ) Tauri, the tip of the Bull's southern horn. The nebula appears fainter around the edges and narrower at its southeastern end. At 102× M1's interior is mottled, while its edges look subtly frilly. The double **Σ742**, ½° west of M1, can share the field. Its 7th-magnitude components shine yellow-white, with the attendant 4″ west of its primary. At 164× the Crab's interior is strongly patterned. Many dim stars surround the nebula, including a very faint one at the edge south of center and an extremely faint pair at the opposite edge.

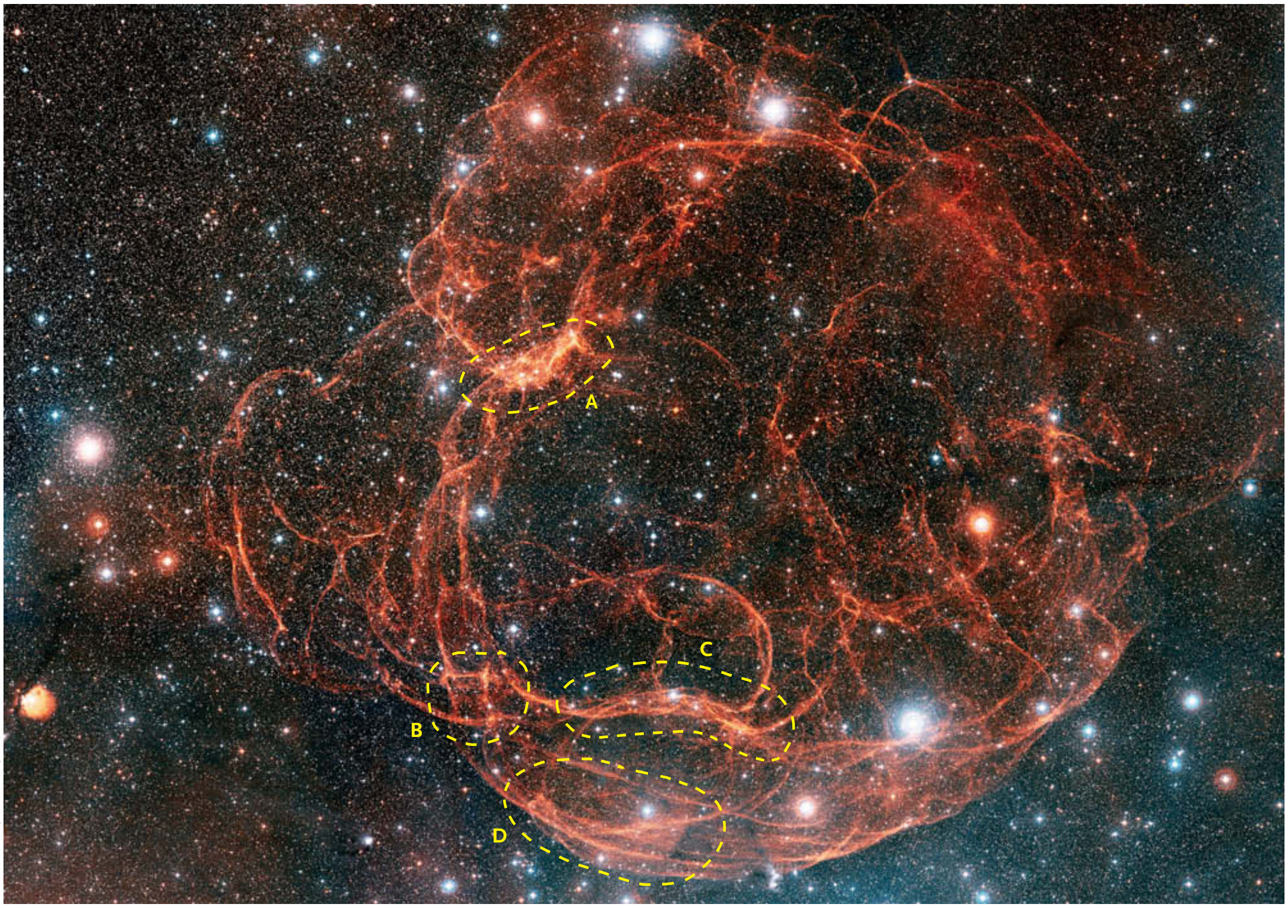
The Crab Nebula shines largely by synchrotron radiation, which doesn't respond favorably to a nebula filter. Yet a wonderful thing occurs when one is used. It dampens the general glow of the nebula, while leaving the Crab's namesake filaments relatively unscathed. Traces of them can be seen with the aid of an O III filter through my 130-mm refractor at 102×, and a narrowband filter also hints at strands. Magnifications of 115× and 166× with my 10-inch reflector and an O III filter make it considerably easier to distinguish this delicate lacework.

While the Crab Nebula is eventually visited by almost everyone with a telescope, Taurus' other supernova remnant has been seen by few. **Simeis 147** is an intricate web of filaments spanning more than 3°. I had little luck with it over the years, even though skilled observers under dark skies have seen it in scopes as small as 120 mm in aperture. Armed with a good chart, I decided to conduct a dedicated search for the most promising shreds of its tattered ribbons.

Since it's easy to imagine nebulous tendrils in the densely populated starfield interwoven with Simeis 147, I only logged regions that were enhanced with a nebula filter. Using my 10-inch scope and a narrowband filter at 70×, I could faintly see the area marked A on the image below. Three additional patches (B, C, and D) became visible with my 15-inch reflector at 49× and 79×. A narrowband filter yielded a starry view with nebula fragments that seemed a bit more structured. An O III view was darker, but with careful study, the boundaries of the pieces were better defined. I found region B rather interesting as a vaguely rectilinear nebula with a dark center.

See if you can hunt down bits of Simeis 147 and add a supernova remnant to your collection that very few observers have gazed upon. ✦

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

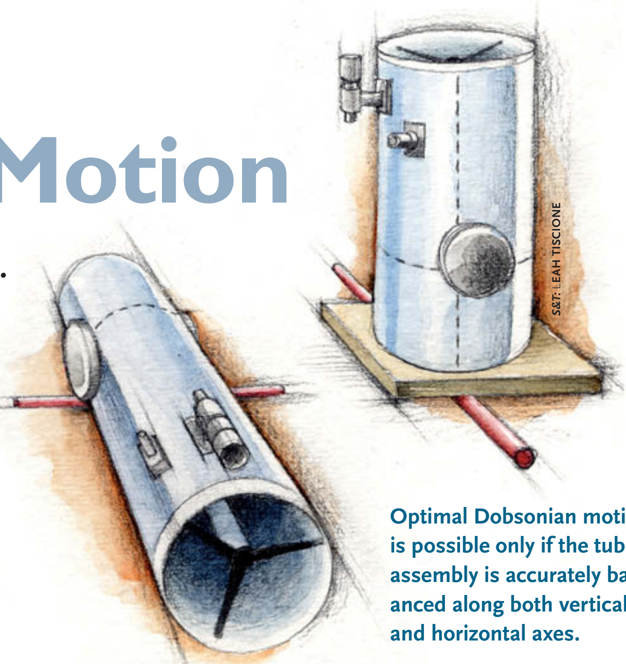


DATA: POSS-II / CALTECH / PALOMAR OBSERVATORY; PROCESSING: DAVIDE DE MARTIN

Simeis 147 is as elusive through the eyepiece as it is spectacular to the camera. Nonetheless, the author was able to sight the areas circled here with the aid of a narrowband filter.

Poetry in the Motion

Good balance is key to smooth moves.

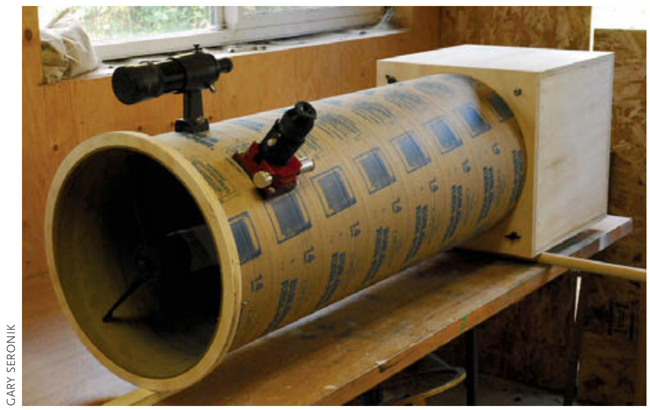


Optimal Dobsonian motion is possible only if the tube assembly is accurately balanced along both vertical and horizontal axes.

A WELL-MADE Dobsonian telescope is a thing of beauty. Readers old enough to vividly recall the pre-Dobsonian era have a deeper appreciation than most for the sheer pleasure these instruments bring to navigating the sky with a large-aperture scope. Smooth Dobsonian motions require good bearings (textured Ebony Star Formica riding on real Teflon pads is the tried-and-true recipe) and a properly balanced optical tube assembly (OTA). A balanced OTA has its center of mass positioned exactly at the center of the scope's side bearings. Achieving that state of affairs is quite simple, but there are important subtleties to take into account.

To balance your scope for the way you use it, make sure the finder is attached and your most-often-used eyepiece is loaded into the focuser (and don't forget to remove any dust caps). Lay the tube on a length of wood doweling (a broom handle works well) and roll it back and forth until you find the position where the scope teeters. Measure this balance point from the dowel's center to the back of the tube. But here's subtlety #1: make this measurement on both sides of the tube and average the results. This removes any error that might creep in because the dowel isn't exactly perpendicular to the OTA. This balance point is where the scope's side bearings belong.

Now for subtlety #2 — one that well-known Ohio ATM Ed Jones pointed out to me. If you perform the steps described above, your scope will be perfectly balanced when it's aimed at the horizon, but not necessarily at the zenith. This is because the vertical balance is likely offset from the tube's center of mass (as viewed from the front) because of the finder, eyepiece, and focuser.



The author's scope rests on a hardwood dowel so that its horizontal balance point can be determined. The square tube section makes it easy to position side bearings at the balance points.

Checking the vertical balance is simply a variation of the method discussed above. Place the tube's mirror end at the center of a piece of plywood. Position the dowel under the plywood, oriented so that it is parallel with a line passing through the centers of the side bearings. Shift the setup back and forth until you find the balance point (an assistant is very handy for this step).

I was surprised to find that my 12¾-inch Dob needed its side bearings displaced ½ inch from the OTA's centerline to achieve vertical balance. And the more lightweight the OTA, the more important it is to get this balance right, since the weight of the finder and focuser are proportionally greater. If your scope's design prevents offsetting the side bearings, you can use counterweights to achieve vertical balance.

Once everything is correctly balanced, the scope will resist drifting up or down regardless of where it's aimed in the sky. Furthermore, an optimally balanced scope is less inclined to drift when you use eyepieces of different weights — the friction in the altitude bearings is normally sufficient to overcome minor imbalances. It's a real joy to use a Dobsonian that stays where you point it. And unlike your check book, you should only have to balance your scope once. ✦

*Contributing editor **Gary Seronik** has built numerous telescopes, several of which are featured on his website, www.garyseronik.com.*

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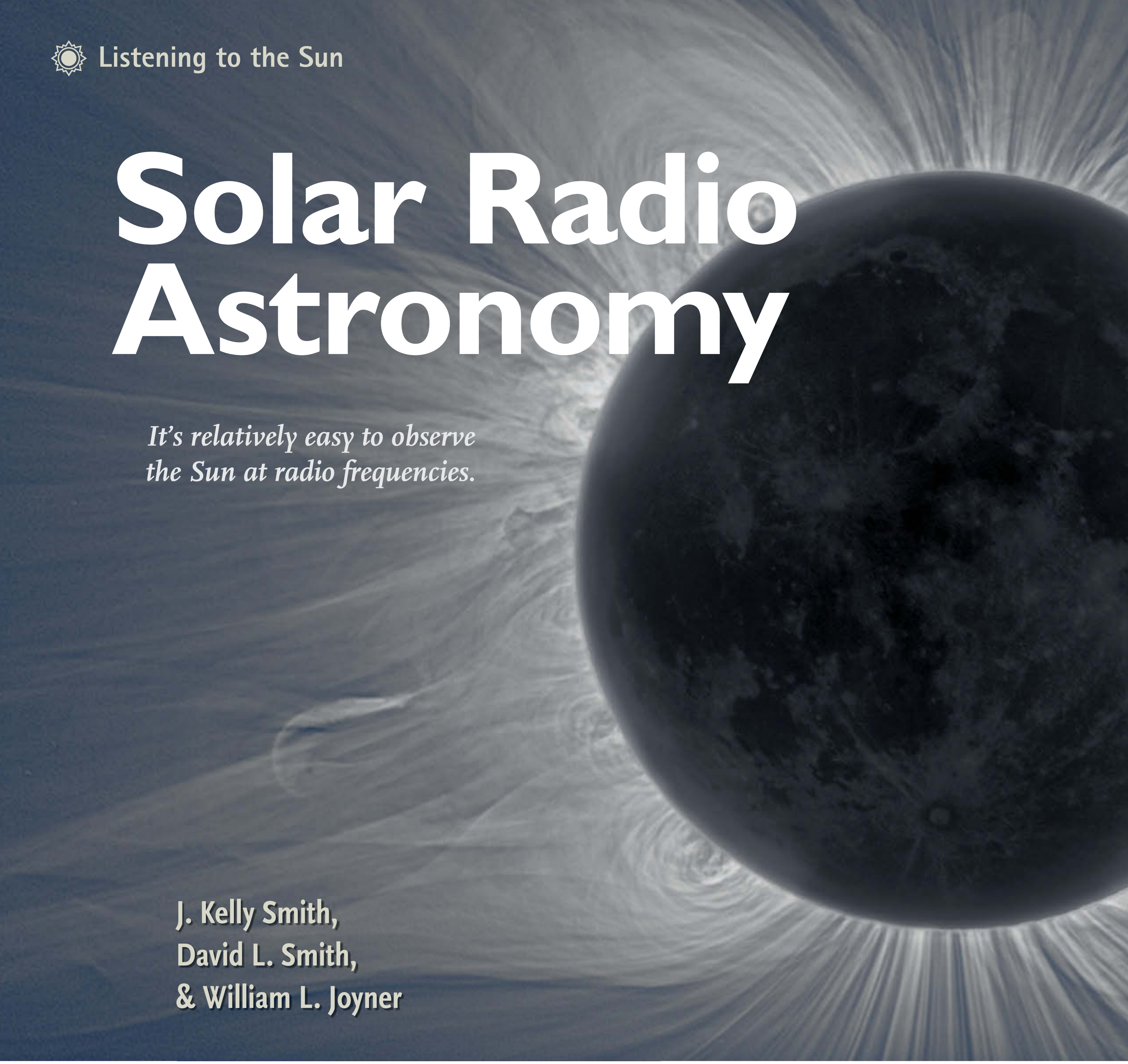


Solar Radio Astronomy

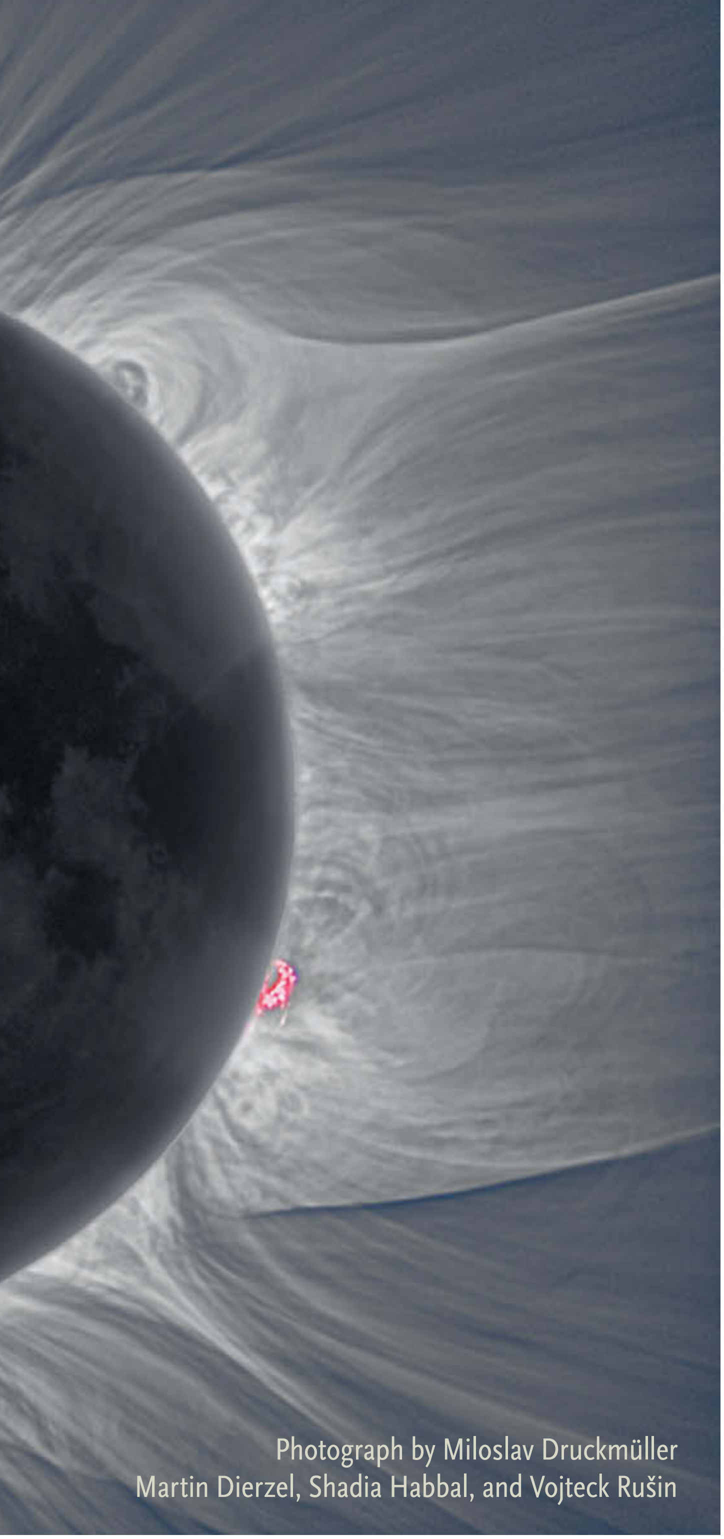
It's relatively easy to observe the Sun at radio frequencies.

J. Kelly Smith,
David L. Smith,
& William L. Joyner

The science of solar radio astronomy is nearly 70 years old, and, like so many things of scientific importance, it was discovered quite by accident.

During World War II, the British relied heavily on radar to monitor enemy activity. Much to their dismay, on February 12, 1942, two German warships, the *Scharnhorst* and *Gneisenau*, managed to slip through the English Channel unnoticed because surveillance radar had been rendered useless by a loud static noise coming from the direction of the French coast. The British War Office knew that the Germans were developing radar-jamming systems and asked that the Army Operational Research Group, which included the young civilian physicist Stanley Hey, to analyze the problem and suggest countermeasures. Hey set up a monitoring station on the cliffs at Dover, which funneled reports of jamming to the research group.

On February 27th and 28th, he was deluged by reports that daytime antiaircraft radar was rendered useless by



Photograph by Miloslav Druckmüller
Martin Dierzel, Shadia Habbal, and Vojteck Rušin

an unusually loud static noise coming from the east, raising concerns in the War Office that the Germans were planning a major air raid. Recognizing that the directions of maximum interference followed the Sun, Hey called the Royal Greenwich Observatory and learned that an exceptionally active sunspot was in transit across the solar disk. Despite skepticism on the part of his colleagues, he correctly surmised that the radar jamming was not man made but rather emanated from the Sun.

The solar corona, seen here during the July 11, 2010, total eclipse, is a tenuous atmosphere consisting of an electrically conducting gas-like mixture of highly agitated electrons and ions known as plasma. Much of the corona's structure is influenced by magnetic fields of varying strength. Because the concentration of electrons and ions and the strength of magnetic fields decrease with increasing distance above the Sun's surface, the radio emissions from within the corona change with height.

Hey had serendipitously discovered solar radio emissions while investigating the source of radar static, much as Karl Jansky a decade earlier discovered radio emissions from our galaxy while studying the source of atmospheric static in ship-to-shore and transatlantic communications.

Fortunately, it no longer requires a declaration of war to study radio emissions from the Sun. The availability of comparatively inexpensive but high-quality equipment allows amateurs to assemble their own radio telescopes for observing the Sun at centimeter, decimeter, and meter wavelengths. And, thanks to the internet, they can compare their results with real-time data acquired by ground-based stations and satellites that continually monitor the Sun for flares, coronal mass ejections (CMEs), and a broad range of electromagnetic emissions.

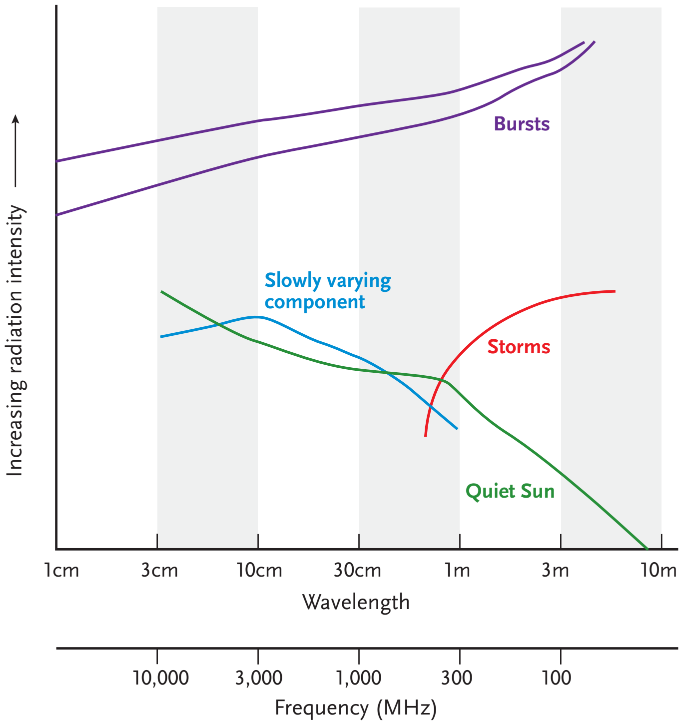
Why Now?

For an unexpectedly long time the Sun has been hovering near its minimum activity level, with its disk nearly free of sunspots and plages. But on January 19, 2010, the otherwise quiet Sun produced an M-class solar flare, the most powerful observed in nearly two years. And during the second half of 2010 our star produced more than 16 M-class and 391 C-class flares. Much to the excitement of radio astronomers, this increase in flare activity has been accompanied by the emission of as many as 137 radio bursts per week.

Solar Cycle 24 is finally underway, with solar maximum predicted to occur in the summer of 2013. Since many of the most intense radio bursts occur on the ascending side of the solar cycle, telescopes are already buzzing. So now is a good time to tool up and prepare for the fireworks.

Bursting with Excitement

Radio emissions from the Sun at solar minimum consist of two components — a steady background emission that remains at a constant level for periods of months or years, and a slowly varying component (called the S-component) that changes from day to day and has a period of about 27 days. The background emissions are generated in the Sun's atmosphere by thermally energized electrons whose velocities increase when they encounter positively charged ions. The process is referred to as free-free transition, or thermal bremsstrahlung. The S-component is generated above active areas in the Sun's chromosphere (most notably plages and sunspots) by bremsstrahlung emis-



This graph shows the spectrum of the various components of solar radio emission. Radiation intensity (flux density) from the quiet Sun and the slowly varying component is greatest in centimeter and decimeter wavelengths. On the other hand, radiation intensity from radio storms and bursts, which are currently on the increase, is greatest in meter and decameter wavelengths.

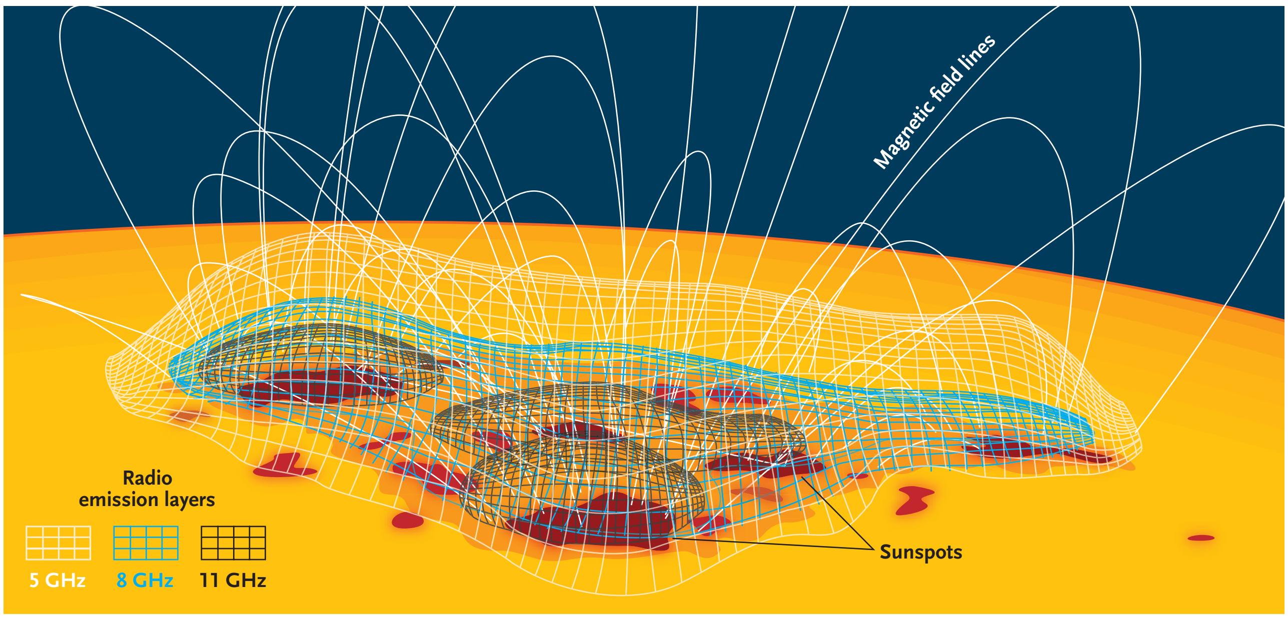
sion, and by gyromagnetic radiation — a process in which energized electrons release photons as they spiral around strong magnetic fields. It was almost certainly an increase in radio emissions above several large sunspots that caused the loud static noise heard by Hey in 1942, prompting the discovery of our radio Sun.

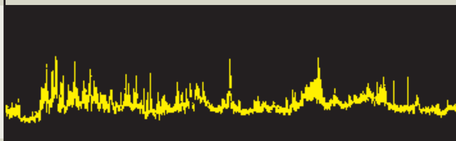
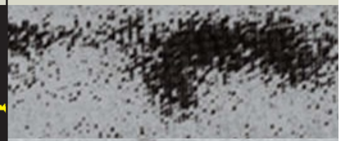
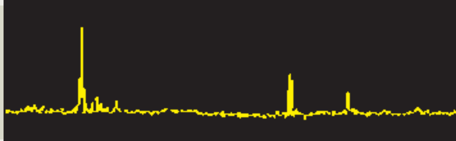
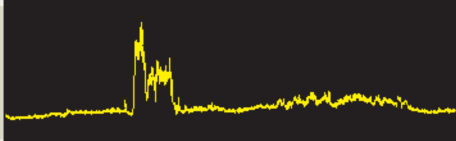
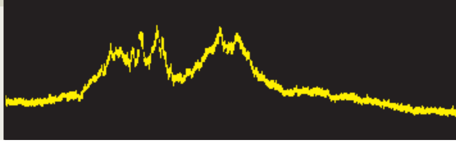
Solar flares and CMEs are the most violent phenomena in the solar system. A large flare can accelerate 30 trillion electrons per second to relativistic speeds for periods of tens of seconds. And an average CME can eject up to 10 trillion kilograms of material into the heliosphere at speeds ranging from 100 to 3,000 km per second. These events produce radio waves covering a frequency range of more than seven orders of magnitude, from a few tens of kilohertz to a few tens or hundreds of gigahertz. Fortunately for radio astronomy, two of the natural frequencies of the solar atmosphere — the electron plasma frequency and the electron gyrofrequency — are in the radio band.

Within seconds of the explosive hydrogen-alpha phase of a solar flare, streams of electrons are ejected into the corona at up to 80% of the speed of light. This energizing stream interacts with electrons and ions (the plasma) of the corona, amplifying plasma waves that are then partially transformed into narrow-bandwidth electromagnetic waves audible on radio receivers. These radio emissions, referred to as Type III bursts, "drift" to lower frequencies at about 20 MHz per second as the electron stream rises in the progressively rarefied solar atmosphere.

In extremely powerful flares, CME-associated shock

Gyration of hot electrons around the strong magnetic fields of sunspots can produce different layers of radio emission in the overlying corona. The lowest layers have high electron densities and strong magnetic fields, and emit the most energetic (highest) frequencies, whereas higher coronal layers have lower electron density and weaker magnetic fields, and emit progressively less energetic (lower frequency) radio waves.



Source	Type	Duration	Monograph	Spectrograph
S-component, late phase of flare	I (storm)	Hours, days		
Impulsive phase of flare	III	Seconds		
Impulsive phase of flare	III U	Minutes		
Late phase of flare	II	Minutes		
Late phase of flare	IV	Minutes, hours		

Most radio amateurs record emissions on a single frequency, plotting the intensity of the emission against time, thus producing a graph with a single line (a monograph). A fortunate few have the ability to plot a spectrum of frequencies against time, producing a complex pattern that permits further interpretation of received signals (a spectrograph). Real-time spectrographs can be downloaded from the internet for comparison with monographs.

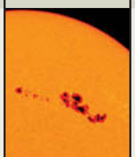
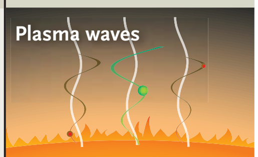
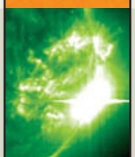
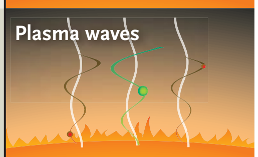
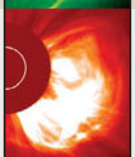
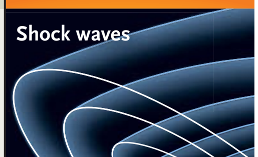
fronts can force overlying ions and magnetic fields to oscillate in traveling waves (magnetohydrodynamic or Alfvén waves) that reach supersonic velocities and trigger similar but slower-drifting and longer-lasting radio emissions from coronal plasma waves (Type II bursts).

In powerful flares, broad bandwidth "continuum" radio emissions can occur when relativistic electrons become trapped inside ejected plasma clouds in which there is intense magnetism. The electrons spin around the magnetic field lines, emitting radio waves both on the electron's gyrofrequency and on many of its harmonic frequencies. These emissions, called Type IV bursts, are audible on radio receivers tuned to millimeter, centimeter, decimeter, and meter wavelengths. Similar magnetic trapping of less-energetic electrons above large sunspots generates the kind of noise storms observed by Hey (Type I storms). These are best heard on meter and decameter wavelengths.

Whereas the forces that generate radio emissions from the quiet Sun are largely thermal, in the active Sun they are thermal, gyromagnetic, and magnetohydrodynamic.

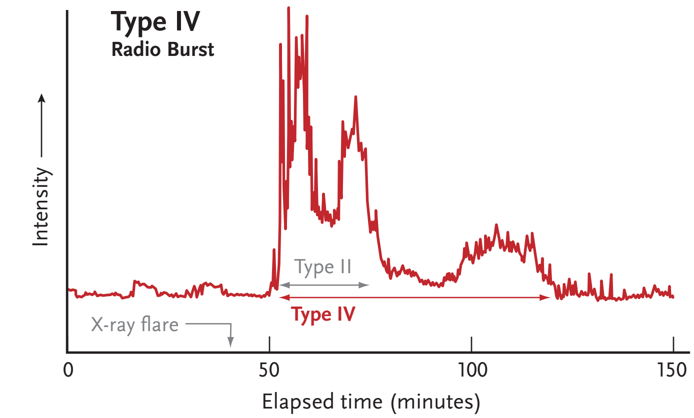
Location, Location, Location

Visual astronomers are all too familiar with the frustrating consequences of light pollution. In radio astronomy, the equivalent problem is noise pollution. If you are extremely lucky, you live in (or have access to) a radio-quiet area with a panoramic view of the horizon unobstructed by protective, yet distant, mountains. Most of us aren't so lucky. Fortunately, frequencies have been allocated to radio astronomy that are protected from harmful interference by international law. When building or purchasing a radio

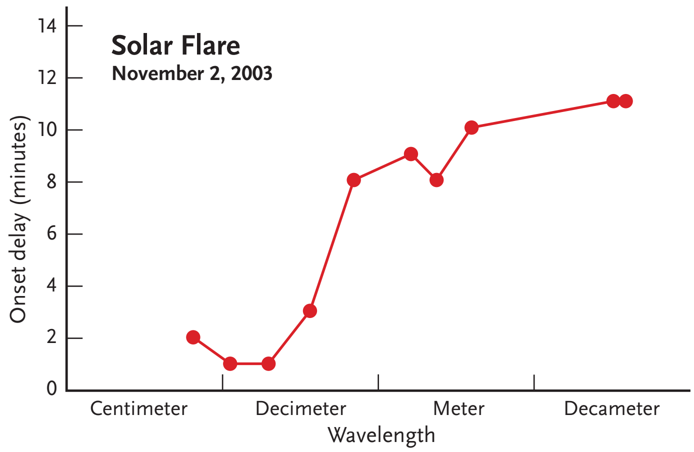
Type	Optical Association	Example	Optimal Recording Frequencies	Primary Mechanism
I (storm)	Large sunspots		3–400 MHz	
III	Flare onset		3–300 MHz	
II	CME		3–500 MHz	
IV	Flare covering umbra		All frequencies	

S&T: GREGG DINDERMAN, SOURCE: AUTHORS / SOHO / ESA / NASA (2)

Noting optical features on the Sun can help the amateur radio astronomer anticipate different types of radio bursts, and tune to optimal recording frequencies. The erudite astronomer will also be aware of the primary mechanism responsible for these storms or bursts.



The authors recorded this monograph of a Type IV radio burst that occurred on November 2, 2003, 11 minutes after the GOES 12 satellite detected a powerful X-ray flare. The radio telescope's receiver was tuned to 420 MHz at the time. The horizontal arrows indicate the intervals that Earth-bound spectrographs recorded Type II and Type IV bursts.



This graph shows the time intervals between the November 2, 2003, flare and the detection of radio emissions by the National Oceanic and Atmospheric Administration Space Environment Center's telescopes. The time gap between the flare and the detection of emissions increases with increasing wavelength, which is an important point when interpreting reception data.

S&T: LEAH TISCIONE, SOURCE: AUTHORS (2)

Useful Websites

Frequencies allocated to radio astronomy
http://www.vla.nrao.edu/astro/rfi/alloc/

Radio fundamentals, design, and equipment resources
http://www.arrl.org/catalog/

Space weather data
http://www.swpc.noaa.gov/Data/

Solar data and images
http://www.lmsal.com/solarsoft/latest_events/

Solar Dynamics Observatory
http://sdo.gsfc.nasa.gov/data/

Real time spectrographs
http://www.ips.gov.au/Solar

Radio Jove Project
http://radiojove.gsfc.nasa.gov/

Haystack Observatory's small radio telescope kit
http://www.cassicorp.com/

receiver for astronomy, it's important to select one that can listen at one or more of these frequencies. Also, if you wish to accurately categorize radio bursts, you'll need to monitor several frequencies simultaneously.

When selecting a radio frequency, you are, in effect, choosing a location in the Sun's atmosphere to listen to. An area of particular interest to space weather agencies is the transitional region — the major source of S-component radio emissions, and the region in which solar flares and CMEs are initiated. Activity in this region is best monitored using telescopes listening at centimeter and decimeter wavelengths.

Detection of radio emissions from celestial objects has been likened to receiving ripples, on the top of waves, on top of an entire sea of noise. Your challenge as a radio astronomer is to select a system capable of amplifying extraordinarily faint signals (which includes those from the Sun) while at the same time minimizing undesirable noise generated locally, in the atmosphere, and in the radio telescope itself.

For amateurs wishing to listen at meter wavelengths, NASA has designed a telescope for its Radio Jove Project. This is an educational outreach program that encourages students and the public to participate in solar and planetary radio astronomy. The project makes available a 20.1-MHz (15-meter band) receiver that can be purchased pre-assembled or as a kit for less than the cost of a typical DVD player. An antenna kit and necessary software are also available at minimal cost. The telescope is a reasonable choice for the beginner and has the added advantage of being able to detect radio emissions from Jupiter during the night.

For solar observations, a radio-quiet area measuring 10 by 32 feet (3 by 10 meters) is needed to assemble a single-dipole antenna. For more sensitive solar reception and for the ability to listen to Jupiter, a 30-by-40-foot area is required to assemble a two-element dipole antenna. Construction time for the radio receiver and antenna kits is estimated to be about 11 and 3 to 5½ hours, respectively. Solar activity can be continuously monitored by feeding the receiver's output into your computer using the radio kit's software program.

Receivers monitoring the Sun at decimeter and centimeter frequencies have the advantage of using parabolic dishes or Yagi antennas. Unlike fixed-wire antennas, these can be directed in altitude and azimuth using rotators and software programs and can track the Sun throughout the day. Local interference and sky noise is also less on these bands, several of which are protected from military and civilian transmissions by U.S. and international law.

Since doubling the frequency of observation increases the resolution by a factor of two, resolution at these higher frequencies is vastly improved over meter wavelengths. The use of off-the-shelf assemblies developed for a mass market (TV, ham, and satellite communications) enables

	Decameter	Meter	Decimeter	Centimeter
Frequency	3-30 MHz	30-300 MHz	300-3,000 MHz	3-30 GHz
Band	HF	VHF	UHF	SHF

WAVELENGTHS USED IN AMATEUR RADIO ASTRONOMY

As a rule, the quiet Sun is loudest in the UHF and SHF bands, whereas the active Sun also radiates heavily in the HF and VHF bands. Earth's atmosphere is opaque to frequencies below 5 MHz and above 600 GHz.

observers to assemble radio telescopes very close to state of the art, at minimal cost.

Telescopes designed for high-frequency listening are also available in kit form. The Massachusetts Institute of Technology's Haystack Observatory has developed a small radio telescope (SRT) capable of observations at centimeter- and millimeter-frequency ranges. The kit includes a 2.1- or 3-meter parabolic dish, a fully steerable altazimuth mount, a digital receiver, a controller, and software for computer control. The cost of the telescope, which was designed to introduce students and amateur astronomers to the field of radio astronomy, compares favorably with that of a 14-inch reflector. In addition to broadband emissions, the SRT can monitor spectral emissions of molecular hydrogen, making it a perfect companion for optical solar telescopes.

Regardless of the frequency chosen, it's important to recognize that all observations must be done in AM, preferably with the receiver's automatic gain control (AGC) defeated. The normal function of AGC is to prevent volume overload — an undesirable feature in radio telescopes that use receiver volume as a measure of radiation intensity.

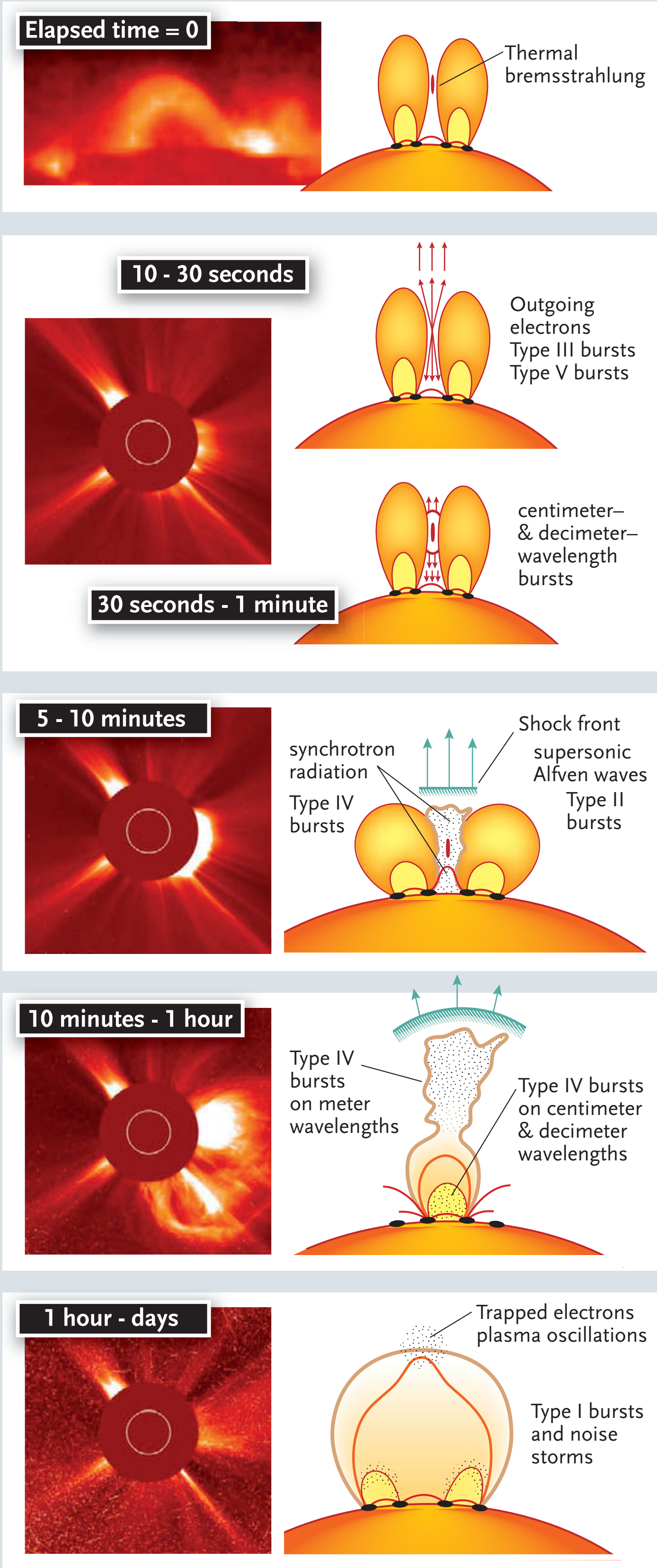
SARA

The Society of Amateur Radio Astronomers (SARA) is an international society of dedicated enthusiasts who teach, learn, trade technical information, and do their own observations of the radio sky. The group consists of optical astronomers, ham-radio operators, engineers, teachers, and nontechnical persons. Many of SARA's members are new to the field, and membership is extended to all who have an interest in radio astronomy. The society provides an opportunity for members to publish their results in their online journal or present them at the society's annual meeting.

These are but a few of the resources available to the amateur, who, like Stanley Hey, may someday discover something new about our 4.5-billion-year-old Sun. ✦

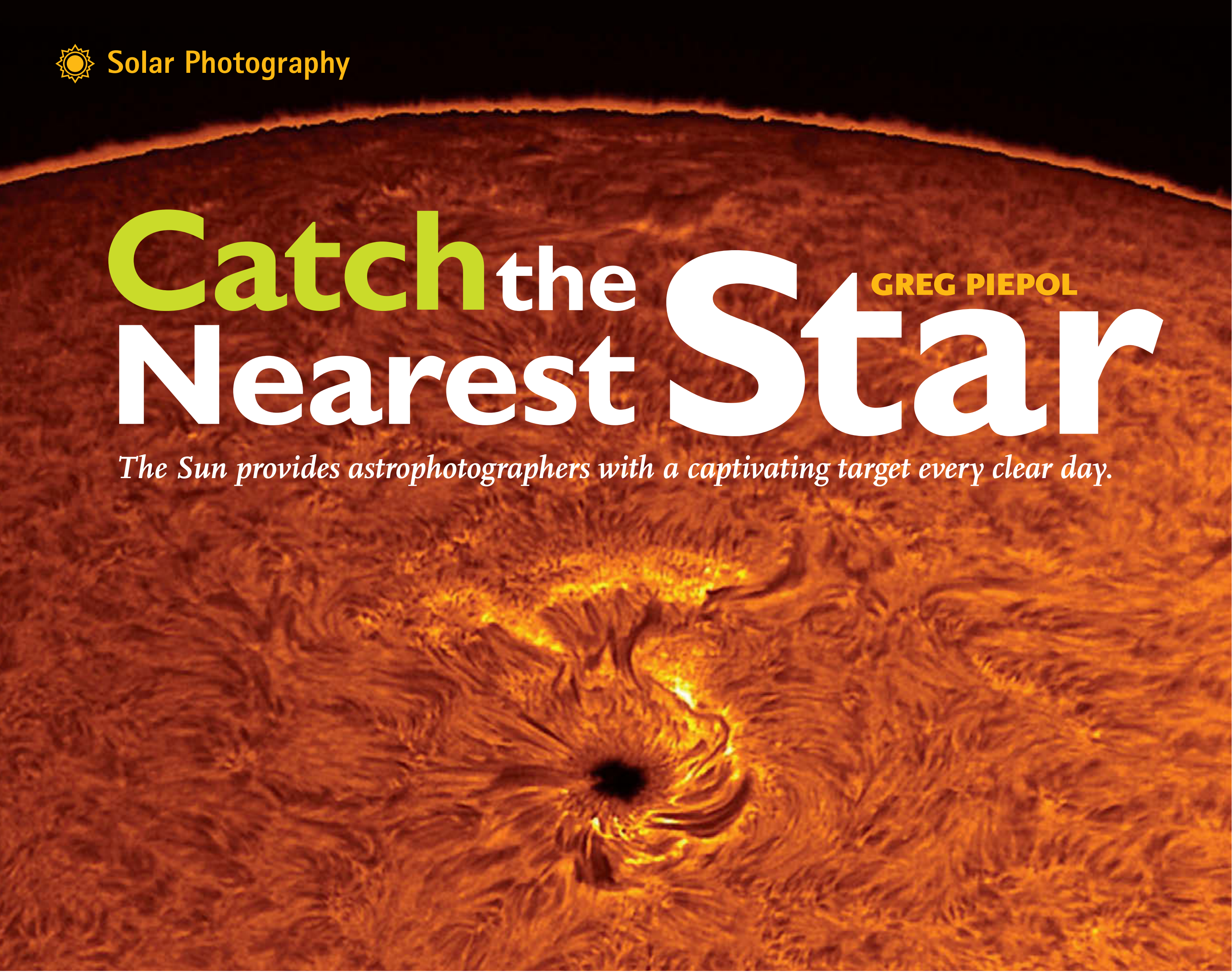
__J. Kelly Smith__ is an Emeritus Professor of Medicine at the James H. Quillen College of Medicine at East Tennessee State University. __David L. Smith__ is an experienced naturalist and avid meteorite collector. __William L. Joyner__ is Professor and Chairman of the Department of Physiology at the James H. Quillen College of Medicine.

Evolution of an Hα Flare



S&T: LEAH TISCIONE, SOURCE: JOHN WILEY & SONS, INC.

An evolutionary model of radio emissions occurring during a major solar flare.



Catch the Nearest Star

GREG PIEPOL

The Sun provides astrophotographers with a captivating target every clear day.

With solar activity on the rise, now is the perfect time to focus your attention on the Sun. Specialized solar filters reveal features normally invisible to the eye. This image, recorded through a solar hydrogen-alpha (Hα) filter, captures a sunspot surrounded by magnetic filaments and bright plage. Imaging these rapidly changing features with most cameras is easy, as the author explains.

ARE YOU LOOKING FOR an exciting, dynamic imaging target that's easy to find, loaded with fascinating details, and changes by the minute? Then consider focusing your attention on our closest star, the Sun. As it slowly starts to awaken from a long solar minimum, the Sun is providing us with an exciting subject to shoot and enjoy. The variety of tools available to safely observe the Sun, including solar filters, dedicated solar telescopes, and astronomical cameras, gives us a winning combination that entertains and amazes both the novice and seasoned astrophotographer alike.

Solar Filters

In the past decade solar observing has expanded from viewing solely in white light. Amateurs are now routinely monitoring the Sun in exotic spectral regions such as hydrogen-alpha (Hα) and calcium K (CaK), where particularly exciting features become visible.

Traditional white-light filters transmit less than 0.0032% of the Sun's energy, revealing in great detail dark sunspots and their surrounding penumbras as well as bright faculae in the photosphere. The addition of a continuum filter (which blocks blue and red light) will enhance the visibility of surface granulation and tiny sunspot details when skies are steady.

The next popular wavelength to observe the Sun (and arguably the most interesting) is the narrow region of the red spectrum known as hydrogen-alpha. When limiting the visible light passing through your telescope to a single angstrom or less centered at 656.28 nanometers, the layer of the Sun's atmosphere known as the chromosphere becomes visible. At this wavelength, magnetic fields that penetrate the photosphere carry ionized gas to form massive prominences, filaments, and other details that can change appearance literally within minutes. Sunspots, embedded in the relatively small jets of gas called spicules, appear with amazing detail against the solar disk.

Another interesting spectral region on our Sun resides in the violet at the wavelength of 393.3 nm, known as calcium K. This view gives you another option to view deeper into the solar chromosphere. The incandescent glow at this wavelength shows primarily supergranule cells. Seeing this violet network in the eyepiece can be difficult for some observers, but it's easy to record with most cameras.

Sharing the View

Capturing the Sun at any of these wavelengths can be easy. The simplest method requires nothing more than an inexpensive point-and-shoot camera. Simply hold your camera up to the eyepiece and snap away. Known as afocal photography, your pictures will come out best using this technique if you can mechanically couple your camera directly to the eyepiece, or place it on a tripod and aim it into the eyepiece. Manual override settings, such as exposure, focus, and particularly a black-and-white setting, will greatly aid in your success rate with this method. The black-and-white setting gives you added contrast to assist in focusing, allowing you to see sunspots or small details better.

A step up from point-and-shoot cameras, DSLR cameras and T-adapters let you directly couple your camera to your scope and shoot the Sun at prime focus. A major benefit to this method is that you'll have less optical elements in your imaging train to deal with, and T-adapters for DSLRs are an easy-to-acquire accessory. Again, shoot in black-and-white mode, choose a small feature to focus on, and snap away. Experiment with different exposure settings; short exposures will reveal details across the solar disk, such as sunspots, filaments, or faculae, depending on the solar filter you're using. Longer exposures will reveal prominences on the edge of the Sun through Hα and CaK filters, at the expense of overexposing the solar disk.

While your pocket digital camera or DSLR can take nice solar images, the best results are often recorded with dedicated equipment designed specifically for use on a telescope. Astronomical CCD cameras are well known for capturing stunning solar photos. With their electronic shutters, large detectors, and multifaceted control software, these cameras consistently produce excellent results. Avoid one-shot color cameras when selecting a model for your narrowband solar imagery; you can easily colorize your images later if you so desire. If you find your CCD camera overexposes the Sun even while using your fastest shutter speed, a neutral-density filter put in front of the camera will reduce incoming light to acceptable levels. As with other cameras, short exposures will capture disk details, while longer ones will adequately expose for prominences.

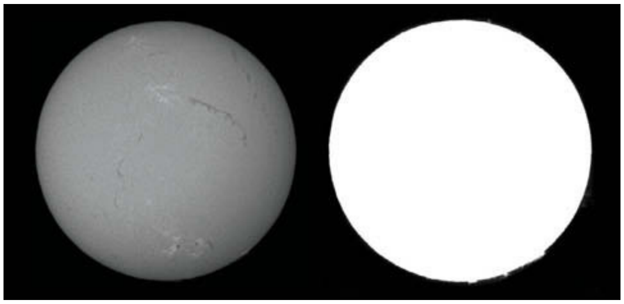
The most common technique for capturing jaw-dropping solar images today uses live-feed video cameras that record movie files directly to your computer. These devices are surprisingly small and lightweight. Advanced models, such as those manufactured by Lumenera (www.lumenera.com) or the Imaging Source (www.astronomycameras.com) work exceptionally well with solar filters. These cameras allow you to record up to 60 frames per second, providing you with a better chance of capturing sharp images during those fleeting moments of steady seeing. Using video stacking software, you can select only the clearest frames for further processing.

Processing Your Images

Once you've captured your images, it's time to adjust them to your liking. If you intend on combining multiple frames, *RegiStax* (www.astronomie.be/registax) or *AviStack* (www.avistack.de) both allow you to stack your individual frames from a variety of formats into a single image. Because the Sun will encompass most of your frame, using the multi-point alignment functions of these programs ensures your best result. Sunspots, filaments, or structures within a prominence work well as consistent alignment features. Once the selected frames are stacked, you can then use the wavelet sharpening in either program to really make the details in your image "pop." Moving one or two wavelet sliders may be all you need, but experiment to find your own preferred result.

SUSAN PIEPOL, ALL OTHER IMAGES: GREG PIEPOL

Maryland amateur astronomer Greg Piepol poses with two of his solar telescopes. The upper scope is a Coronado SolarMax 90 Hα telescope, while the other is a similar model that passes the calcium K (CaK) line of the spectrum.



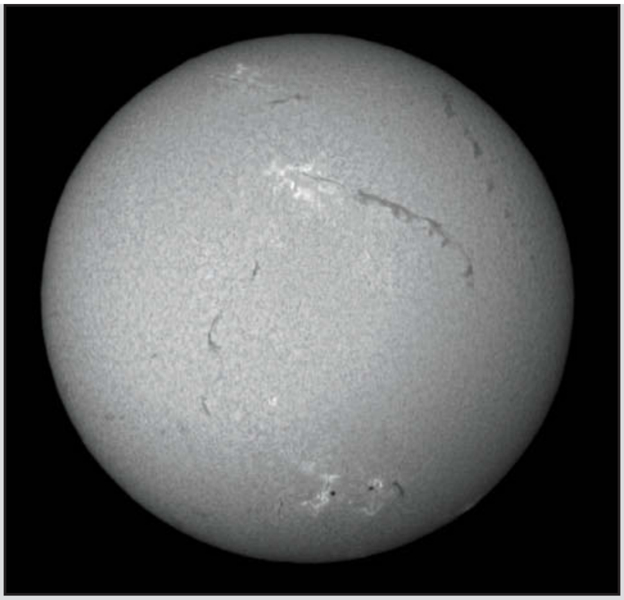
The easiest route to recording details through Hα or CaK solar filters, regardless of the camera you use, is to capture two exposures; one that records features across the solar disk *(left)*, and another that overexposes the disk to reveal faint prominences dancing along the edge (limb) of the Sun *(right)*.

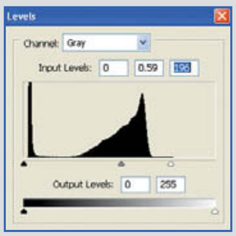
After stacking, a few additional steps can make your images stand out. Though your camera-capture software may provide some brightness and pre-sharpening capabilities, advanced programs such as *Adobe Photoshop* or the freeware *Gimp* (www.gimp.org) offer a large selection of powerful processing tools.

I like to combine two exposures recorded through my Hα or CaK scopes with *Adobe Photoshop* to create one image that showcases both disk details and prominences. I begin by adjusting the white and black points of the disk photo. The Levels tool (Adjust > Levels) has three sliders below a histogram display to accomplish this: black point slider at left, mid-tone (gray) in the center, and white point at the far right. I first move the white-point slider toward the left to highlight the brightest part of the image. Next, I move the mid-tone slider to increase the subtle contrasts on the disk without dimming the brightest areas.

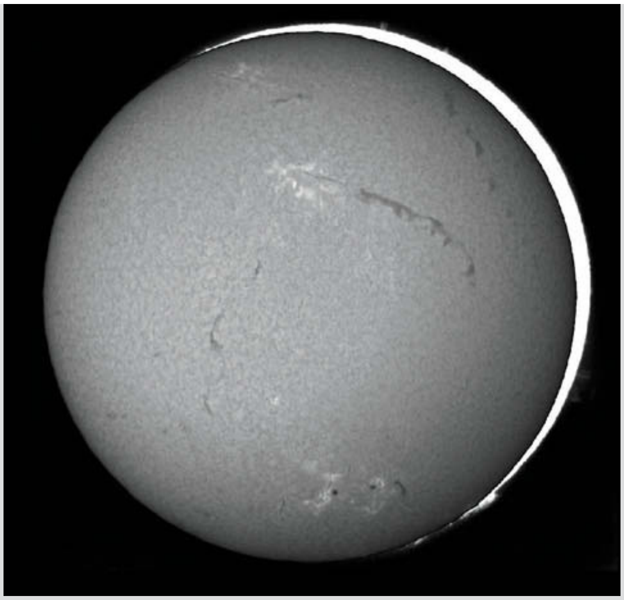
Once finished, I use the magic wand from the tools palette to select the background, then invert the selection (Select > Inverse) and copy the area using Edit > Copy to cut out the disk image. Next, I'll open my prominence photo and paste the selected disk image on top of it. I align the disk and prominence images together by using the Move Tool from the tools palette. When I'm satisfied with the alignment of the two layers, I'll flatten them into a single image using the pulldown command Layer > Flatten Image.

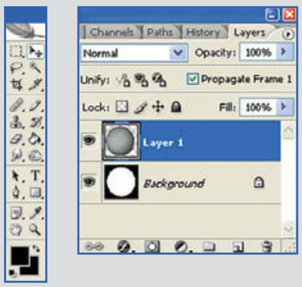
My next step is to sharpen the result a tiny bit using





Before combining a solar-disk image with one exposed to reveal prominences, use the Levels function in *Adobe Photoshop*, shown at left, to stretch the contrast of the disk photo to better reveal bright active regions.



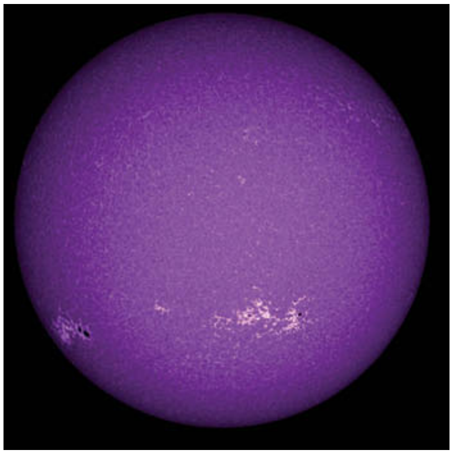


Next, paste the solar-disk image onto a prominence shot. The images will be misaligned, as shown here. Align the two layers using the Move tool from the tool palette until the overexposed area on your prominence shot is completely hidden by the disk layer.

the Unsharp Mask filter (Filter > Sharpen > Unsharp Mask). I use just a small radius of two or three pixels with this filter to clear up the details in an image without introducing artifacts. No amount of sharpening, however, can substitute for a steady sky.

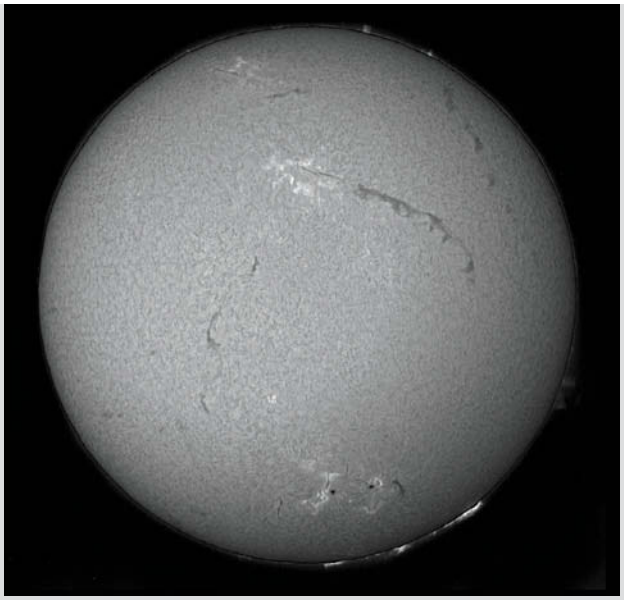
Now I'm left with a sharp black-and-white photo of the Sun. Because I prefer color images, I "colorize" my photos in *Photoshop*. I start by converting my image to RGB color (if it's in grayscale) using Image > Mode > RGB Color. Next, using the Curves function (Image > Adjust > Curves), I select the red channel only and click in the middle of the diagonal line to apply an anchor point and drag it slightly upward. Now I choose the green channel and drag its mid-point slightly downward. Finally, I select the top-right point of the blue curve and drag it to the bottom of the dialog box. This produces a golden-orange version of the Sun. If I desire a purplish Sun for shots taken through a CaK scope, I'll simply boost the red and blue curve mid-point while lowering the green-channel curve.

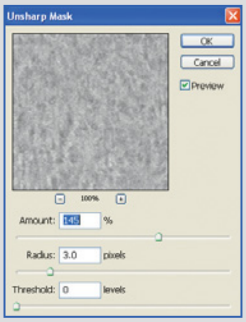
Look for great things to come in the future of solar observing. Solar-equipment manufacturers are constantly innovating and producing new designs, and the price of introductory solar filters has never been lower. Combining these with the latest cameras makes the future of solar photography look brighter than ever! ✦



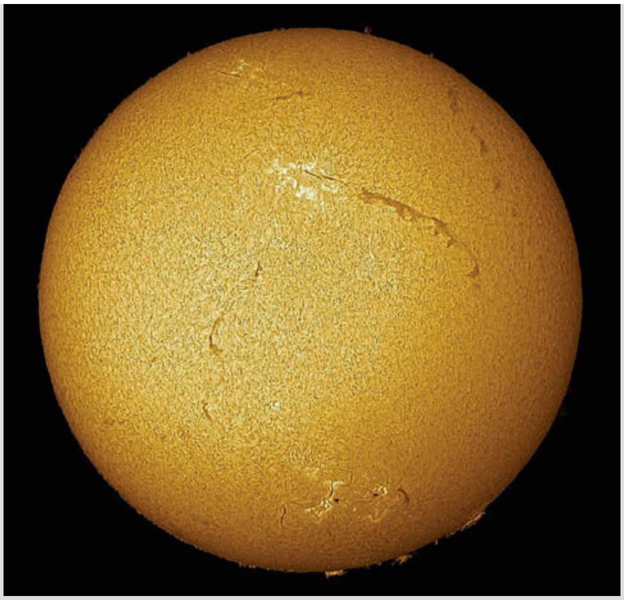
This view through a CaK filter reveals the Sun at the violet region of the spectrum and offers radically different views than possible through a white-light solar filter. CaK filters can also reveal prominences along the limb of the Sun.

NASA/JPL Solar System Ambassador ***Greg Piepol****'s most frequently used "solar filter" is rated SPF 50. View more tips and images at his website: www.sungazer.net.*



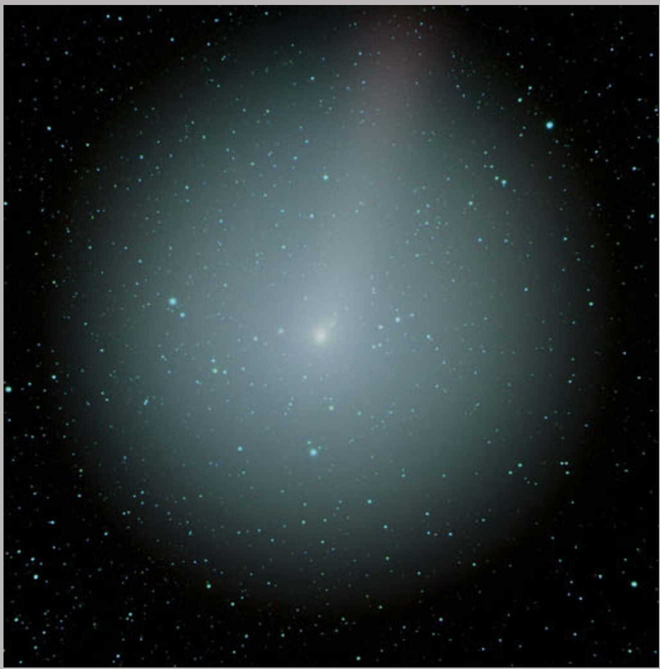


Using the Unsharp Mask filter *(left)* can clear up any residual "fuzziness" in your images. Often it's only necessary to sharpen slightly using a radius of a few pixels. Lowering the Amount slider will also reduce the filter's aggressiveness.



Photographers who prefer a color image can use the Curves function in *Photoshop* to colorize their results. While Hydrogen-alpha resides deep in the red end of the spectrum, imagers often depict the Sun as an orange or yellow-orange because it's much more difficult to see details in a red-colored picture.

Visit SkyandTelescope.com/howto/astrophotography for more information on astrophotography.



◀ **HARTLEY 2 ON APPROACH**

Nick Howes

This deep exposure of Comet 103P/Hartley 2 was captured on October 13, 2010, using narrowband filters to reveal a faint reddish dust tail.

Details: *TMB 105 f/6.2 refractor with an Atik 4000 CCD camera. Total exposure was 85 minutes through Astronomik narrowband and clear filters.*

▼ **EARLY TO RISE**

Doug Zubenel

On the morning of October 20, 2010, Comet 103P/Hartley 2 was closest to Earth, situated in Auriga between the open clusters M37 and M38 at left and the bright star Capella at right.

Details: *Canon EOS Digital Rebel XTi DSLR with 85-mm lens. Total exposure was 254 seconds at ISO 800.*

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▲ **DUSTY CORNER OF ARIES**

Eric Zbinden

Far from being the bland patch of nondescript sky suggested by most star charts, Aries is rife with faint streams of dust. Among the brightest are the twisted knots of LBN 762 (lower middle of this 2°-wide image) and LBN 753 (top right). Catalogs of little-known celestial objects such as B. T. Lynds's *Catalogue of Bright Nebulae* offer modern astrophotographers a rich assortment of targets that have been rarely photographed in the past.

Details: *Astro-Physics AP155EDF refractor with an FLI PL16803 CCD camera. Total exposure is 16 hours through Baader Planetarium color filters.*

A YOUNG CLUSTER BURSTS FORTH

Neil Fleming

The molecular cloud Cederblad 214 in Cepheus takes on a three-dimensional appearance in this narrowband image. The young open cluster NGC 7822 is the primary source of hot stellar winds that is carving out the large hollow at the center of the nebula.

Details: *TMB 203-mm f/7 refractor with SBIG STL-6303 CCD camera. Two-panel mosaic totaling an unusually long 68¼ hours of exposure through Astrodon narrowband and color filters.* ✦

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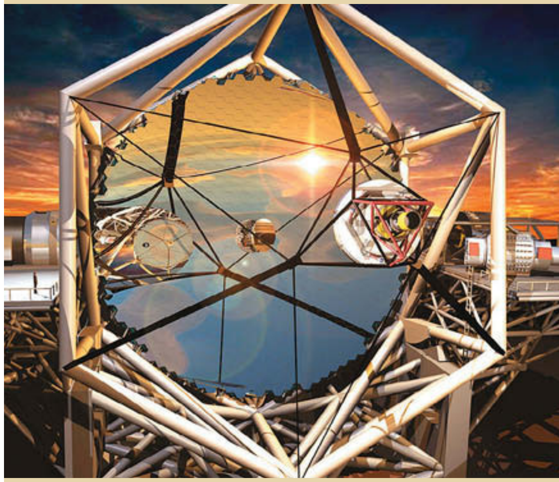

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Giving An Astronomy Show

Share your love and knowledge of the sky with park visitors.

One of the most enjoyable aspects of astronomy is showing the wonders of the universe to other people. I do this by giving frequent astronomy shows at state parks and churches. Perhaps you can join the fun.

I give shows in two ways. One happens when I visit a park and the night sky is clear. I simply ask park staffers if I can present an astronomy show. Usually they are delighted, so I put up my big sign saying, "Astronomy Show Here, 8 p.m." near the office and set up my telescope in a nearby field. Often 15 to 20 people show up.

But other times a park staffer asks me to give a show. State parks love astronomy shows because they are always searching for additional activities for campers. The problem is that park staffers often want to book a show a month in advance so they can publicize it, but I can't promise the sky will be clear that night.

S&T: LEAH TISCIONE

To solve this problem, I developed an indoor astronomy presentation that consists of a 30-minute talk and a 30-minute slide show of mostly pictures from the Hubble Space Telescope. I recommend using 35-mm slides because it's simple and easy (but Powerpoint or Keynote is also an option). You can deliver it anywhere (even outdoors) and it involves nothing but a 35-mm projector and a screen. I always take a backup projector and bulbs.

A park will love hearing that you can present an outdoor and indoor show. If the staff books a show a month in advance, they have to know that you'll be there. If clouds cancel your telescope show, just go to the slide presentation. No matter what the weather, you can present a great show.

You don't need a large telescope to do these shows. My 144-mm Go To reflector is perfect. Your audience will not consist of astronomy buffs, so don't blow them away with a huge telescope.

Your main targets should be the planets, the Moon, and a couple of bright galaxies or star clusters. I like to show at least one globular cluster and one spiral galaxy if I can. If sky conditions won't allow you to show at least two good deep-sky objects, then give your indoor presentation.

A Go To telescope is very helpful because it slews right to the objects and it tracks them while people are standing in line. Often I have 20 people in line to see Saturn, and it's very helpful if the telescope remains on target.

Your qualifications don't matter. Park officials won't care if you don't have an astronomy degree. Just be dependable and give an entertaining talk. The group will enjoy your talk if it's quick, uncomplicated, and has no math.

One of my greatest joys is to have people look in my telescope and say, "Oh wow, look at that!" If you've been reading *S&T* for awhile, you have enough knowledge to put together an hour-long talk. It's really a lot of fun, and I hope you get into it like I did 20 years ago. ✦

***Chris Miller** is an amateur astronomer from Marietta, Georgia who is active in motorcycles, jet skis, hunting, fishing, target shooting, camping, traveling, photography, writing, reading, and leading large church groups.*